

01/14/03  
1105 U.S. PTO

01-16-03

10342576 0114A

Please type a plus sign (+) inside this box → +

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PTO/SB/05 (03-01)

Approved for use through 10/31/2002. OMB 0651-0032

U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

**UTILITY  
PATENT APPLICATION  
TRANSMITTAL**

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 3771P004  
First Inventor Daniel E. Grupp, et al.  
Title Insulated Gate Field Effect Transistor Having Passivated Schottky Barriers To  
Express Mail Label No. EV261812635US

**APPLICATION ELEMENTS**

See MPEP chapter 600 concerning utility patent application contents

ADDRESS TO:

Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

1. ☒ Fee Transmittal Form (e.g., PTO/SB/17)  
(Submit an original and a duplicate for fee processing)
2. ☒ Applicant claims small entity status.  
See 37 CFR 1.27.
3. ☒ Specification [Total Pages 34]  
(preferred arrangement set forth below)  
- Descriptive title of the Invention  
- Cross References to Related Applications  
- Statement Regarding Fed sponsored R & D  
- Reference to sequence listing, a table,  
or a computer program listing appendix  
- Background of the Invention  
- Brief Summary of the Invention  
- Brief Description of the Drawings (if filed)  
- Detailed Description  
- Claim(s)  
- Abstract of the Disclosure
4. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 2]
5. Oath or Declaration (signed) [Total Pages 5]  
a. ☒ Newly executed (original or copy)  
b. ☐ Copy from a prior application (37 C.F.R. § 1.63(d))  
(for continuation/divisional with Box 18 completed)  
i. ☐ DELETION OF INVENTOR(S)  
Signed statement attached deleting inventor(s)  
named in the prior application, see 37 CFR  
1.63(d)(2) and 1.33(b).
6. ☐ Application Data Sheet. See 37 CFR 1.76

7. ☐ CD-ROM or CD-R in duplicate, large table or  
Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission  
(if applicable, all of the following are necessary)
- a. ☐ Computer Readable Form (CRF)
- b. Specification Sequence Listing on:  
i. ☐ CD-ROM or CD-R (2 copies); or  
ii. ☐ paper
- c. ☐ Statements verifying identity of above copies

9. ☒ Assignment Papers (cover sheet & document(s))
10. ☐ 37 C.F.R. § 3.73(b) Statement ☒ Power of Attorney  
(when there is an assignee)
11. ☐ English Translation Document (if applicable)
12. ☐ Information Disclosure ☐ Copies of IDS  
Statement (IDS)/PTO-1449 Citations
13. ☐ Preliminary Amendment ☐ Application Amended  
to Reflect Claim of Priority
14. ☒ Return Receipt Postcard (MPEP 503)  
(Should be specifically itemized)
15. ☐ Certified Copy of Priority Document(s)  
(if foreign priority is claimed)
16. ☒ Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i).  
Applicant must attach form PTO/SB/35 or its equivalent.
17. ☐ Other:

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP)

of prior application No:

Prior application Information: Examiner

Group/Art Unit:

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

**18. CORRESPONDENCE ADDRESS**

☒ Customer Number or Bar Code Label



\*08791\*

or ☒ Correspondence address below

|         |                                         |           |                |          |                |
|---------|-----------------------------------------|-----------|----------------|----------|----------------|
| Name    | Tarek N. Fahmi                          |           |                |          |                |
|         | Blakely, Sokoloff, Taylor & Zafman LLP  |           |                |          |                |
| Address | 12400 Wilshire Boulevard, Seventh Floor |           |                |          |                |
| City    | Los Angeles                             | State     | California     | Zip Code | 90025-1030     |
| Country | USA                                     | Telephone | (408) 947-8200 | Fax      | (408) 947-8280 |

|                   |                |                                   |          |
|-------------------|----------------|-----------------------------------|----------|
| Name (Print/Type) | Tarek N. Fahmi | Registration No. (Attorney/Agent) | 41,402   |
| Signature         | Date           |                                   | 01/14/03 |

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231.

|                                                                                                                            |  |                                             |  |
|----------------------------------------------------------------------------------------------------------------------------|--|---------------------------------------------|--|
| <b>FEE TRANSMITTAL<br/>for FY 2003</b><br><small>Effective 01/01/2003. Patent fees are subject to annual revision.</small> |  | <b>Complete if Known</b>                    |  |
| <input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27.                                 |  | Application Number                          |  |
|                                                                                                                            |  | Filing Date                                 |  |
|                                                                                                                            |  | First Named Inventor <b>Daniel E. Grupp</b> |  |
|                                                                                                                            |  | Examiner Name                               |  |
|                                                                                                                            |  | Group/Art Unit                              |  |
| TOTAL AMOUNT OF PAYMENT (\$)                                                                                               |  | 640.00                                      |  |
| Attorney Docket No.                                                                                                        |  | 3771P004                                    |  |

| <b>METHOD OF PAYMENT (check one)</b><br><input checked="" type="checkbox"/> Check <input type="checkbox"/> Credit card <input type="checkbox"/> Money Order <input type="checkbox"/> Other <input type="checkbox"/> None<br><input type="checkbox"/> Deposit Account<br>Deposit Account Number: <b>02-2666</b><br>Deposit Account Name: <b>Blakely, Sokoloff, Taylor &amp; Zafman LLP</b><br>The Commissioner is authorized to: (check all that apply)<br><input type="checkbox"/> Charge fee(s) indicated below <input type="checkbox"/> Credit any overpayments<br><input checked="" type="checkbox"/> Charge any additional fee(s) required under 37 CFR §§ 1.16, 1.17, 1.18 and 1.20.<br><input type="checkbox"/> Charge fee(s) indicated below, except for the filing fee to the above-identified deposit account | <b>FEE CALCULATION (continued)</b><br><b>3. ADDITIONAL FEES</b><br><table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2">Large Entity</th> <th colspan="2">Small Entity</th> <th rowspan="2">Fee Description</th> <th rowspan="2">Fee Paid</th> </tr> <tr> <th>Fee Code</th> <th>Fee (\$)</th> <th>Fee Code</th> <th>Fee (\$)</th> </tr> </thead> <tbody> <tr> <td>1051</td> <td>130</td> <td>2051</td> <td>65</td> <td>Surcharge - late filing fee or oath</td> <td></td> </tr> <tr> <td>1052</td> <td>50</td> <td>2052</td> <td>25</td> <td>Surcharge - late provisional filing fee or cover sheet.</td> <td></td> </tr> <tr> <td>2053</td> <td>130</td> <td>2053</td> <td>130</td> <td>Non-English specification</td> <td></td> </tr> <tr> <td>1812</td> <td>2,520</td> <td>1812</td> <td>2,520</td> <td>For filing a request for <i>ex parte</i> reexamination</td> <td></td> </tr> <tr> <td>1804</td> <td>920 *</td> <td>1804</td> <td>920 *</td> <td>Requesting publication of SIR prior to Examiner action</td> <td></td> </tr> <tr> <td>1805</td> <td>1,840 *</td> <td>1805</td> <td>1,840 *</td> <td>Requesting publication of SIR after Examiner action</td> <td></td> </tr> <tr> <td>1251</td> <td>110</td> <td>2251</td> <td>55</td> <td>Extension for reply within first month</td> <td></td> </tr> <tr> <td>1252</td> <td>410</td> <td>2252</td> <td>205</td> <td>Extension for reply within second month</td> <td></td> </tr> <tr> <td>1253</td> <td>930</td> <td>2253</td> <td>465</td> <td>Extension for reply within third month</td> <td></td> </tr> <tr> <td>1254</td> <td>1,450</td> <td>2254</td> <td>725</td> <td>Extension for reply within fourth month</td> <td></td> </tr> <tr> <td>1255</td> <td>1,970</td> <td>2255</td> <td>985</td> <td>Extension for reply within fifth month</td> <td></td> </tr> <tr> <td>1404</td> <td>320</td> <td>2401</td> <td>160</td> <td>Notice of Appeal</td> <td></td> </tr> <tr> <td>1402</td> <td>320</td> <td>2402</td> <td>160</td> <td>Filing a brief in support of an appeal</td> <td></td> </tr> <tr> <td>1403</td> <td>280</td> <td>2403</td> <td>140</td> <td>Request for oral hearing</td> <td></td> </tr> <tr> <td>1451</td> <td>1,510</td> <td>2451</td> <td>1,510</td> <td>Petition to institute a public use proceeding</td> <td></td> </tr> <tr> <td>1452</td> <td>110</td> <td>2452</td> <td>55</td> <td>Petition to revive - unavoidable</td> <td></td> </tr> <tr> <td>1453</td> <td>1,300</td> <td>2453</td> <td>650</td> <td>Petition to revive - unintentional</td> <td></td> </tr> <tr> <td>1501</td> <td>1,300</td> <td>2501</td> <td>650</td> <td>Utility issue fee (or reissue)</td> <td></td> </tr> <tr> <td>1502</td> <td>470</td> <td>2502</td> <td>235</td> <td>Design issue fee</td> <td></td> </tr> <tr> <td>1503</td> <td>630</td> <td>2503</td> <td>315</td> <td>Plant issue fee</td> <td></td> </tr> <tr> <td>1460</td> <td>130</td> <td>2460</td> <td>130</td> <td>Petitions to the Commissioner</td> <td></td> </tr> <tr> <td>1807</td> <td>50</td> <td>1807</td> <td>50</td> <td>Processing fee under 37 CFR 1.17(q)</td> <td></td> </tr> <tr> <td>1806</td> <td>180</td> <td>1806</td> <td>180</td> <td>Submission of Information Disclosure Stmt</td> <td></td> </tr> <tr> <td>8021</td> <td>40</td> <td>8021</td> <td>40</td> <td>Recording each patent assignment per property (times number of properties)</td> <td>40.00</td> </tr> <tr> <td>1809</td> <td>750</td> <td>1809</td> <td>375</td> <td>Filing a submission after final rejection (37 CFR § 1.129(a))</td> <td></td> </tr> <tr> <td>1810</td> <td>750</td> <td>2810</td> <td>375</td> <td>For each additional invention to be examined (37 CFR § 1.129(b))</td> <td></td> </tr> <tr> <td>1801</td> <td>750</td> <td>2801</td> <td>375</td> <td>Request for Continued Examination (RCE)</td> <td></td> </tr> <tr> <td>1802</td> <td>900</td> <td>1802</td> <td>900</td> <td>Request for expedited examination of a design application</td> <td></td> </tr> </tbody> </table> Other fee (specify) _____<br>*Reduced by Basic Filing Fee Paid | Large Entity |          | Small Entity                                                               |          | Fee Description | Fee Paid | Fee Code | Fee (\$) | Fee Code | Fee (\$) | 1051 | 130 | 2051 | 65 | Surcharge - late filing fee or oath |  | 1052 | 50 | 2052 | 25 | Surcharge - late provisional filing fee or cover sheet. |  | 2053 | 130 | 2053 | 130 | Non-English specification |  | 1812 | 2,520 | 1812 | 2,520 | For filing a request for <i>ex parte</i> reexamination |  | 1804 | 920 * | 1804 | 920 * | Requesting publication of SIR prior to Examiner action |  | 1805 | 1,840 * | 1805 | 1,840 * | Requesting publication of SIR after Examiner action |  | 1251 | 110 | 2251 | 55 | Extension for reply within first month |  | 1252 | 410 | 2252 | 205 | Extension for reply within second month |  | 1253 | 930 | 2253 | 465 | Extension for reply within third month |  | 1254 | 1,450 | 2254 | 725 | Extension for reply within fourth month |  | 1255 | 1,970 | 2255 | 985 | Extension for reply within fifth month |  | 1404 | 320 | 2401 | 160 | Notice of Appeal |  | 1402 | 320 | 2402 | 160 | Filing a brief in support of an appeal |  | 1403 | 280 | 2403 | 140 | Request for oral hearing |  | 1451 | 1,510 | 2451 | 1,510 | Petition to institute a public use proceeding |  | 1452 | 110 | 2452 | 55 | Petition to revive - unavoidable |  | 1453 | 1,300 | 2453 | 650 | Petition to revive - unintentional |  | 1501 | 1,300 | 2501 | 650 | Utility issue fee (or reissue) |  | 1502 | 470 | 2502 | 235 | Design issue fee |  | 1503 | 630 | 2503 | 315 | Plant issue fee |  | 1460 | 130 | 2460 | 130 | Petitions to the Commissioner |  | 1807 | 50 | 1807 | 50 | Processing fee under 37 CFR 1.17(q) |  | 1806 | 180 | 1806 | 180 | Submission of Information Disclosure Stmt |  | 8021 | 40 | 8021 | 40 | Recording each patent assignment per property (times number of properties) | 40.00 | 1809 | 750 | 1809 | 375 | Filing a submission after final rejection (37 CFR § 1.129(a)) |  | 1810 | 750 | 2810 | 375 | For each additional invention to be examined (37 CFR § 1.129(b)) |  | 1801 | 750 | 2801 | 375 | Request for Continued Examination (RCE) |  | 1802 | 900 | 1802 | 900 | Request for expedited examination of a design application |  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|----------|----------------------------------------------------------------------------|----------|-----------------|----------|----------|----------|----------|----------|------|-----|------|----|-------------------------------------|--|------|----|------|----|---------------------------------------------------------|--|------|-----|------|-----|---------------------------|--|------|-------|------|-------|--------------------------------------------------------|--|------|-------|------|-------|--------------------------------------------------------|--|------|---------|------|---------|-----------------------------------------------------|--|------|-----|------|----|----------------------------------------|--|------|-----|------|-----|-----------------------------------------|--|------|-----|------|-----|----------------------------------------|--|------|-------|------|-----|-----------------------------------------|--|------|-------|------|-----|----------------------------------------|--|------|-----|------|-----|------------------|--|------|-----|------|-----|----------------------------------------|--|------|-----|------|-----|--------------------------|--|------|-------|------|-------|-----------------------------------------------|--|------|-----|------|----|----------------------------------|--|------|-------|------|-----|------------------------------------|--|------|-------|------|-----|--------------------------------|--|------|-----|------|-----|------------------|--|------|-----|------|-----|-----------------|--|------|-----|------|-----|-------------------------------|--|------|----|------|----|-------------------------------------|--|------|-----|------|-----|-------------------------------------------|--|------|----|------|----|----------------------------------------------------------------------------|-------|------|-----|------|-----|---------------------------------------------------------------|--|------|-----|------|-----|------------------------------------------------------------------|--|------|-----|------|-----|-----------------------------------------|--|------|-----|------|-----|-----------------------------------------------------------|--|
| Large Entity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Small Entity |          | Fee Description                                                            | Fee Paid |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| Fee Code                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Fee (\$)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Fee Code     | Fee (\$) |                                                                            |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1051                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 130                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2051         | 65       | Surcharge - late filing fee or oath                                        |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1052                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 50                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2052         | 25       | Surcharge - late provisional filing fee or cover sheet.                    |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 2053                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 130                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2053         | 130      | Non-English specification                                                  |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1812                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2,520                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1812         | 2,520    | For filing a request for <i>ex parte</i> reexamination                     |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1804                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 920 *                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 1804         | 920 *    | Requesting publication of SIR prior to Examiner action                     |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1805                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1,840 *                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 1805         | 1,840 *  | Requesting publication of SIR after Examiner action                        |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1251                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 110                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2251         | 55       | Extension for reply within first month                                     |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1252                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 410                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2252         | 205      | Extension for reply within second month                                    |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1253                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 930                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2253         | 465      | Extension for reply within third month                                     |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1254                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1,450                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2254         | 725      | Extension for reply within fourth month                                    |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1255                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1,970                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2255         | 985      | Extension for reply within fifth month                                     |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1404                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 320                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2401         | 160      | Notice of Appeal                                                           |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1402                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 320                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2402         | 160      | Filing a brief in support of an appeal                                     |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1403                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 280                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2403         | 140      | Request for oral hearing                                                   |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1451                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1,510                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2451         | 1,510    | Petition to institute a public use proceeding                              |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1452                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 110                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2452         | 55       | Petition to revive - unavoidable                                           |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1453                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1,300                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2453         | 650      | Petition to revive - unintentional                                         |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1501                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1,300                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2501         | 650      | Utility issue fee (or reissue)                                             |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1502                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 470                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2502         | 235      | Design issue fee                                                           |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1503                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 630                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2503         | 315      | Plant issue fee                                                            |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1460                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 130                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2460         | 130      | Petitions to the Commissioner                                              |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1807                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 50                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1807         | 50       | Processing fee under 37 CFR 1.17(q)                                        |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1806                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 180                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1806         | 180      | Submission of Information Disclosure Stmt                                  |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 8021                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 40                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 8021         | 40       | Recording each patent assignment per property (times number of properties) | 40.00    |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1809                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 750                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1809         | 375      | Filing a submission after final rejection (37 CFR § 1.129(a))              |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1810                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 750                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2810         | 375      | For each additional invention to be examined (37 CFR § 1.129(b))           |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1801                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 750                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 2801         | 375      | Request for Continued Examination (RCE)                                    |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |
| 1802                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 900                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 1802         | 900      | Request for expedited examination of a design application                  |          |                 |          |          |          |          |          |      |     |      |    |                                     |  |      |    |      |    |                                                         |  |      |     |      |     |                           |  |      |       |      |       |                                                        |  |      |       |      |       |                                                        |  |      |         |      |         |                                                     |  |      |     |      |    |                                        |  |      |     |      |     |                                         |  |      |     |      |     |                                        |  |      |       |      |     |                                         |  |      |       |      |     |                                        |  |      |     |      |     |                  |  |      |     |      |     |                                        |  |      |     |      |     |                          |  |      |       |      |       |                                               |  |      |     |      |    |                                  |  |      |       |      |     |                                    |  |      |       |      |     |                                |  |      |     |      |     |                  |  |      |     |      |     |                 |  |      |     |      |     |                               |  |      |    |      |    |                                     |  |      |     |      |     |                                           |  |      |    |      |    |                                                                            |       |      |     |      |     |                                                               |  |      |     |      |     |                                                                  |  |      |     |      |     |                                         |  |      |     |      |     |                                                           |  |

| <b>1. BASIC FILING FEE</b><br><table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2">Large Entity</th> <th colspan="2">Small Entity</th> <th rowspan="2">Fee Description</th> <th rowspan="2">Fee Paid</th> </tr> <tr> <th>Fee Code</th> <th>Fee (\$)</th> <th>Fee Code</th> <th>Fee (\$)</th> </tr> </thead> <tbody> <tr> <td>1001</td> <td>750</td> <td>2001</td> <td>375</td> <td>Utility filing fee</td> <td>375.00</td> </tr> <tr> <td>1002</td> <td>330</td> <td>2002</td> <td>165</td> <td>Design filing fee</td> <td></td> </tr> <tr> <td>1003</td> <td>520</td> <td>2003</td> <td>260</td> <td>Plant filing fee</td> <td></td> </tr> <tr> <td>1004</td> <td>750</td> <td>2004</td> <td>375</td> <td>Reissue filing fee</td> <td></td> </tr> <tr> <td>1005</td> <td>160</td> <td>2005</td> <td>80</td> <td>Provisional filing fee</td> <td></td> </tr> <tr> <td colspan="5" style="text-align: right;">SUBTOTAL (1)</td> <td>(\$) 375.00</td> </tr> </tbody> </table> |          | Large Entity |          | Small Entity                                              |             | Fee Description | Fee Paid | Fee Code | Fee (\$) | Fee Code | Fee (\$) | 1001 | 750 | 2001 | 375 | Utility filing fee | 375.00 | 1002 | 330 | 2002 | 165 | Design filing fee |  | 1003 | 520 | 2003 | 260 | Plant filing fee |  | 1004 | 750 | 2004 | 375 | Reissue filing fee |  | 1005 | 160 | 2005 | 80 | Provisional filing fee |  | SUBTOTAL (1) |  |  |  |  | (\$) 375.00 | <b>2. EXTRA CLAIM FEES</b><br>Total Claims: 45 - 20* = 25 X 9.00 = \$225.00<br>Independent Claims: 3 - 3* = 0 X 42.00 = \$0.00<br>Multiple Dependent: _____<br><table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2">Large Entity</th> <th colspan="2">Small Entity</th> <th rowspan="2">Fee Description</th> <th rowspan="2">Fee Paid</th> </tr> <tr> <th>Fee Code</th> <th>Fee (\$)</th> <th>Fee Code</th> <th>Fee (\$)</th> </tr> </thead> <tbody> <tr> <td>1202</td> <td>18</td> <td>2202</td> <td>9</td> <td>Claims in excess of 20</td> <td></td> </tr> <tr> <td>1201</td> <td>84</td> <td>2201</td> <td>42</td> <td>Independent claims in excess of 3</td> <td></td> </tr> <tr> <td>1203</td> <td>280</td> <td>2203</td> <td>140</td> <td>Multiple Dependent claim, if not paid</td> <td></td> </tr> <tr> <td>1204</td> <td>84</td> <td>2204</td> <td>42</td> <td>**Reissue independent claims over original patent</td> <td></td> </tr> <tr> <td>1205</td> <td>18</td> <td>2205</td> <td>9</td> <td>**Reissue claims in excess of 20 and over original patent</td> <td></td> </tr> <tr> <td colspan="5" style="text-align: right;">SUBTOTAL (2)</td> <td>(\$) 225.00</td> </tr> </tbody> </table> |  | Large Entity |  | Small Entity |  | Fee Description | Fee Paid | Fee Code | Fee (\$) | Fee Code | Fee (\$) | 1202 | 18 | 2202 | 9 | Claims in excess of 20 |  | 1201 | 84 | 2201 | 42 | Independent claims in excess of 3 |  | 1203 | 280 | 2203 | 140 | Multiple Dependent claim, if not paid |  | 1204 | 84 | 2204 | 42 | **Reissue independent claims over original patent |  | 1205 | 18 | 2205 | 9 | **Reissue claims in excess of 20 and over original patent |  | SUBTOTAL (2) |  |  |  |  | (\$) 225.00 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------------|----------|-----------------------------------------------------------|-------------|-----------------|----------|----------|----------|----------|----------|------|-----|------|-----|--------------------|--------|------|-----|------|-----|-------------------|--|------|-----|------|-----|------------------|--|------|-----|------|-----|--------------------|--|------|-----|------|----|------------------------|--|--------------|--|--|--|--|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--------------|--|--------------|--|-----------------|----------|----------|----------|----------|----------|------|----|------|---|------------------------|--|------|----|------|----|-----------------------------------|--|------|-----|------|-----|---------------------------------------|--|------|----|------|----|---------------------------------------------------|--|------|----|------|---|-----------------------------------------------------------|--|--------------|--|--|--|--|-------------|
| Large Entity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |          | Small Entity |          | Fee Description                                           | Fee Paid    |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| Fee Code                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Fee (\$) | Fee Code     | Fee (\$) |                                                           |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1001                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 750      | 2001         | 375      | Utility filing fee                                        | 375.00      |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1002                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 330      | 2002         | 165      | Design filing fee                                         |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1003                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 520      | 2003         | 260      | Plant filing fee                                          |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1004                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 750      | 2004         | 375      | Reissue filing fee                                        |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1005                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 160      | 2005         | 80       | Provisional filing fee                                    |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| SUBTOTAL (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |          |              |          |                                                           | (\$) 375.00 |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| Large Entity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |          | Small Entity |          | Fee Description                                           | Fee Paid    |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| Fee Code                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Fee (\$) | Fee Code     | Fee (\$) |                                                           |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1202                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 18       | 2202         | 9        | Claims in excess of 20                                    |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1201                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 84       | 2201         | 42       | Independent claims in excess of 3                         |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1203                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 280      | 2203         | 140      | Multiple Dependent claim, if not paid                     |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1204                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 84       | 2204         | 42       | **Reissue independent claims over original patent         |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| 1205                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 18       | 2205         | 9        | **Reissue claims in excess of 20 and over original patent |             |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |
| SUBTOTAL (2)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |          |              |          |                                                           | (\$) 225.00 |                 |          |          |          |          |          |      |     |      |     |                    |        |      |     |      |     |                   |  |      |     |      |     |                  |  |      |     |      |     |                    |  |      |     |      |    |                        |  |              |  |  |  |  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |  |              |  |              |  |                 |          |          |          |          |          |      |    |      |   |                        |  |      |    |      |    |                                   |  |      |     |      |     |                                       |  |      |    |      |    |                                                   |  |      |    |      |   |                                                           |  |              |  |  |  |  |             |

\*or number previously paid, if greater, For Reissues, see below

SUBTOTAL (3) (\$) 40.00

This collection of information is required by 37 CFR 1.17 and 1.27. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application to the USPTO. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Washington, DC 20231.

10542576, 011403

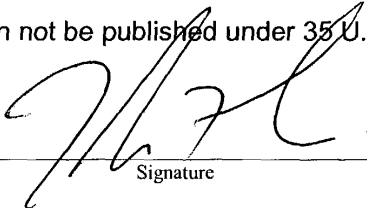
PTO/SB/35 (11-00)  
Approved for use through 10/31/2002. OMB 0651-0031  
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE  
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

|                                                                       |                        |                                                                                              |
|-----------------------------------------------------------------------|------------------------|----------------------------------------------------------------------------------------------|
| <b>NONPUBLICATION REQUEST<br/>UNDER<br/>35 U.S.C. 122(b)(2)(B)(i)</b> | First Named Inventor   | Daniel E. Grupp                                                                              |
|                                                                       | Title                  | Insulated Gate Field Effect Transistor Having<br>Passivated Schottky Barriers To The Channel |
|                                                                       | Attorney Docket Number | 3771P004                                                                                     |

I hereby certify that the invention disclosed in the attached application **has not and will not be** the subject of an application filed in another country, or under a multilateral agreement, that requires publication at eighteen months after filing.

I hereby request that the attached application not be published under 35 U.S.C. 122(b).

01/14/03  
Date

  
Signature  
Tarek N. Fahmi, Reg. No. 41,402  
Typed or printed name

This request must be signed in compliance with 37 CFR 1.33(b) and submitted with the application **upon filing**.

Applicant may rescind this nonpublication request at any time. If applicant rescinds a request that an application not be published under 35 U.S.C. 122(b), the application will be scheduled for publication at eighteen months from the earliest claimed filing date for which a benefit is claimed.

If applicant subsequently files an application directed to the invention disclosed in the attached application in another country, or under a multilateral international agreement, that requires publication of applications eighteen months after filing, the applicant **must** notify the United States Patent and Trademark Office of such filing within forty-five (45) days after the date of the filing of such foreign or international application. **Failure to do so will result in abandonment of this application (35 U.S.C. 112(b)(2)(B)(iii)).**

Burden Hour Statement: This collection of information is required by 37 CFR 1.213(a). This information is used by the public to request that an application not be published under 35 U.S.C. 122(b) and the PTO to process that request. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This form is estimated to take 6 minutes to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

Attorney Docket No.: 3771P004

Patent Application

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

TITLE OF THE INVENTION

**INSULATED GATE FIELD EFFECT TRANSISTOR HAVING PASSIVATED SCHOTTKY BARRIERS TO THE CHANNEL**

INVENTORS:

**DANIEL E. GRUPP  
DANIEL J. CONNELLY**

Prepared by

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP  
12400 WILSHIRE BOULEVARD  
SEVENTH FLOOR  
LOS ANGELES, CA 90025-1026  
(408) 947-8200

**EXPRESS MAIL CERTIFICATE OF MAILING**

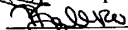
"Express Mail" mailing label number: EV261812635US

Date of Deposit: January 14, 2003

I hereby certify that I am causing this paper or fee to be deposited with the United States Postal Service "Express Mail Post Office to Addressee" service on the date indicated above and that this paper or fee has been addressed to the Commissioner of Patents and Trademarks, Washington, D. C. 20231

Patricia A. Balero

(Typed or printed name of person mailing paper or fee)



(Signature of person mailing paper or fee)

# **INSULATED GATE FIELD EFFECT TRANSISTOR HAVING PASSIVATED SCHOTTKY BARRIERS TO THE CHANNEL**

## **RELATED APPLICATIONS**

[0001] The present application is a continuation-in-part of co-pending U.S. Patent Application No.10/217,758, entitled "Method for Depinning the Fermi Level of a Semiconductor at an Electrical Junction and Devices Incorporating Such Junctions", by Daniel Grupp and Daniel J. Connelly, filed on August 12, 2002, and assigned to the same assignee as the present application. This patent application is hereby incorporated by reference in its entirety.

## **FIELD OF THE INVENTION**

[0002] The invention relates generally to solid-state switching and amplification devices. More particularly, the invention relates to a transistor having passivated metal-semiconductor junctions from the source to the channel and/or from the channel to the drain and at which the Fermi level of a semiconductor which comprises the channel is depinned.

## **BACKGROUND**

[0003] One of the most basic electrical junctions used in modern devices is the metal-semiconductor junction. In these junctions, a metal (such as aluminum) is brought into contact with a semiconductor (such as silicon). This forms a device (a diode) which can be inherently rectifying; that is, the junction will tend to conduct current in one direction more favorably than in the other direction. In other cases, depending on the materials used, the junction may be ohmic in nature (i.e., the contact may have negligible resistance regardless of the direction of current flow). In addition to diodes, such metal –

semiconductor junctions are also present at source/drain – channel interfaces within a class of transistors known as MOSFETs (metal oxide semiconductor field effect transistors).

**[0004]** As explained in the above-cited patent application, there exists at a metal-semiconductor contact a so-called Schottky barrier. The Schottky barrier at a conventional metal – semiconductor junction is characterized by Fermi level pinning of the semiconductor, due to both extrinsic and intrinsic surface states. The extrinsic states may arise from defects in the crystal structure of the interface. The intrinsic states arise from the quantum-mechanical penetration of the electrons in the metal into the bandgap of the semiconductor. These so-called metal-induced gap states (MIGS) appear to be of fundamental importance in explaining the physics of such junctions. See J. Tersoff, “Schottky Barrier Heights and the Continuum of Gap States,” Phys. Rev. Lett. 52 (6), Feb. 6, 1984.

**[0005]** The Schottky barrier height at a metal–semiconductor interface determines the electrical properties of the junction. Thus, if it were possible to control or adjust the barrier height of a metal – semiconductor junction, electrical devices of desired characteristics could be produced. To tune the barrier height, the Fermi level of the semiconductor must be depinned. As discussed in detail in the above-cited patent application, the present inventors have achieved this goal in a device that still permits substantial current flow between the metal and the semiconductor. Below, the inventors present an application of this technology to MOSFET devices.

**[0006]** MOSFETs which incorporate Schottky junctions have a long—and largely unfruitful—history. In 1966, Lepselter and Kahng were investigating Schottky diodes. In that year they received U.S. Patent 3,290,127 directed to a device with a PtSi/Si interface. Use of the silicide was found to be an improvement over previous metal/Si contacts. The diodes were reproducible and stable, in part because the interface was sealed, as noted by the inventors at the time. The silicide also may reduce the extrinsic surface states (defects). The remaining pinning is most likely due to intrinsic surface states (MIGS), although this was not recognized at the time. Shortly thereafter, Lepselter and Sze incorporated the Schottky barrier into a MOSFET (see M. P. Lepselter and S. M. Sze, “SB-IGFET: An insulated-gate

field-effect transistor using Schottky barrier contacts as source and drain”, Proc. IEEE 56, 1088 (1968)). U.S. Patent 3,590,471 to Lepselter discussed the incorporation of the Schottky barriers, but the channel was still essentially isolated by implanted regions. The first patent for a channel isolated by Schottky barriers (U.S. Patent 3,708,360) was issued to Wakefield and Cunningham in 1973. This device also utilized silicided junctions.

**[0007]** In U.S. Patent 4,300,152, Lepselter described a Schottky barrier MOSFET. By eliminating the pn-junction in the source-substrate region, Lepselter showed that the parasitic pnpn structure responsible for latch-up could be eliminated. The proposed devices still utilized PtSi for the source and drain metal, however.

**[0008]** An extension of Lepselter's early work is found in U.S. Patent 4,485,550 to Koenke et al. In these devices, an extra implant is added to extend beyond the source metal. This is similar to modern CMOS halo implants. The extra implant improves the drive current capabilities of the transistor by bringing the channel edge under the gate. The channel isolation in this device is from a pn-junction, not the PtSi source metal. An attempt to bring the source under the gate was investigated by recessing the source/drain contacts by etching (see C.J. Koenke et al., “Schottky MOSFET for VLSI”, IEDM, 367 (1981)). Sidewall spacers were still a limiting factor, however. This was improved by Snyder as described in US Patent 6,303,479, which also disclosed the ability to control vertical doping profiles without regard to horizontal profile control. The contacts were again made from PtSi.

**[0009]** U.S. Patent 6,096,590 to Chan et al. describes a device in which the PtSi/Si junctions are not recessed. This yields a poor sub-threshold slope from reduced coupling of the gate at the edge of the channel. Exponential turn-on, indicative of the Schottky barrier being too high, is seen in measurements presented in the patent. Further, the gate-source capacitance will be high.

**[0010]** Recently, MOSFET devices having metal – semiconductor junctions between a source/drain and a channel have been demonstrated with sub-50 nm channel-lengths, using PtSi<sub>2</sub> (see, e.g., C. Wang et al., “Sub-40 nm PtSi Schottky source/drain metal-oxide field-effect transistors”, Appl. Phys. Lett. 74, 1174

(1999); and A. Itoh et al., "A 25-nm-long channel metal-gate p-type Schottky source/drain metal-oxide-semiconductor field-effect transistor on separation-by-implanted-oxygen substrate", J. Journal Appl. Phys. Part 1 39, 4757 (2000)), ErSi<sub>2</sub> (see, e.g., J. Kedzierski et al., "Complementary silicide source/drain thin-body MOSFETs for the 20 nm gate length regime", IEDM Tech. Dig., International Electron Devices Meeting 2000, San Francisco, CA, p. 00-57 (2000); and W. Saitoh et al., "Analysis of short-channel Schottky source/drain metal-oxide-semiconductor field-effect transistor on silicon-on-insulator substrate and demonstration of sub-50-nm n-type devices with metal gate", J. Journal Appl. Phys. Part 1 38, 6226 (1999)), and CoSi<sub>2</sub> (see, e.g., U. K. Matsuzawa et al., "Enhancement of hot-electron generation rate in Schottky source metal-oxide-semiconductor field-effect transistors", Appl. Phys. Lett. 76, 3992 (2000)) for the source/drain metal. Also, simulations have been performed all the way down to channel lengths of 10 nm (see, e.g., C. K. Huang et al., "Two-dimensional numerical simulation of Schottky barrier MOSFET with channel length to 10 nm", IEEE Trans. on Elect. Dev. 45, 842 (1998)), although a poor choice of device parameters limited the performance results, e.g., a large  $\Phi_B$ . The performance of all of these devices is limited in part by the inability to control, and especially to lower, the height of the Schottky barrier at the source and drain interfaces to the channel.

**[0011]** Only two disclosures of a non-silicide pure-metal/Si contact embodiment of a Schottky-barrier MOSFET have been found by the present inventors. Welch, U.S. Patent 5,663,584, seems to describe Schottky barrier MOSFET systems and fabrication thereof; however, a contact of "metal or metal silicide" is mentioned. This is inappropriate for fabrication of a device with a controlled barrier height. That is, there is no surface treatment or interface dielectric disclosed.

**[0012]** The disclosure by Hebiguchi in U.S. Patent 5,801,398 is perhaps more practical, and a method for manufacturing a thin-film transistor such as for use in displays is presented. In this device (which is a field effect transistor or FET), the source/drain contacts to the Si channel are metal (a list of possibilities is presented), but again, no surface preparation is mentioned.

[0013] Figure 1 shows the FET 100 that was discussed by Hebiguchi. The transistor contains a glass substrate 110, a gate electrode 120, a gate insulating film 130, a drain electrode 140, a source electrode 150, and a semiconductor active film 160. During operation, voltage is applied to the source electrode 150 and to the gate electrode 120. The voltage applied to the gate electrode 120 changes the electrical properties of the semiconductor active film 160 allowing current to flow from the source electrode 150 to the drain electrode 140. In particular, the voltage applied to the gate electrode 120 creates a channel-generating region 170, in the semiconductor active film 160 a short distance from the gate insulating film 130, through which current may flow.

[0014] Hebiguchi describes the semiconductor active film 160 as being hydrogenated amorphous silicon, the drain and source electrodes 140 and 150 are formed of conductive materials (metals) such as chromium (Cr), aluminum (Al), tantalum (Ta), platinum (Pt), gold (Au), tungsten (W), nickel (Ni), molybdenum (Mo), or certain mixtures of these materials, and the junctions between the semiconductor active film 160 and the source and drain electrodes 150 and 140 are insulating Schottky barriers. The metal selected for an n-channel thin film transistor is chosen on the basis of having a workfunction that is smaller than that of silicon and the metal selected for a p-channel thin film transistor has a workfunction that is larger than that of silicon.

[0015] A significant limitation with the transistor discussed in Hebiguchi, is the generally poor control over the Schottky barrier height. As is well known, use of different metals with widely varying work functions tends to result in Schottky barriers which vary in height over a dramatically reduced range. Further, no special effort is made in Hebiguchi to control or reduce extrinsic surface states.

[0016] Another type of junction to the channel is introduced by Yoshimura in U.S. Patent 6,037,605, with the stated goal being to reduce short-channel effects. An oxide or nitride is disposed between Si source and drain contacts and a Si channel. The oxide is thicker farther away from the channel (down into the Si) to reduce currents not controlled by the gate. The thickness of the oxide is "sufficiently thin to permit charge tunneling", and is disclosed to be 0.5 to 2.0 nm. This differs from the present invention, which is

described in detail below, in several ways, for example the use of Si as a source/drain, as opposed to a metal.



## BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The present invention is illustrated by way of example, and not limitation, in the figures of the accompanying drawings, in which like reference numerals refer to similar elements.

[0019] **Figure 1** shows a conventional FET having metal – semiconductor Schottky junctions between the source and the channel and the channel and the drain.

[0020] **Figure 2** shows a FET having passivated metal – semiconductor junctions from the source to the channel and from the channel to the drain, according to one embodiment of the present invention.

[0021] **Figure 3** shows a method for fabricating a transistor having passivated metal – semiconductor junctions from the source to the channel and from the channel to the drain, according to one embodiment of the present invention.

[0022] **Figures 4A-4I** show intermediate substrates representing fabrication of a transistor having passivated aluminum-silicon junctions formed from an aluminum source to a silicon channel and from the silicon channel to an aluminum drain, according to one embodiment of the present invention.

[0023] **Figure 5A** illustrates portions of a conventional FinFET device.

[0024] **Figure 5B** illustrates portions of a FinFET device having interface layers between the source/drain and the channel in accordance with an embodiment of the present invention.

[0025] **Figure 6A** illustrates portions of a conventional vertical MOSFET device.

[0026] **Figure 6B** illustrates portions of a vertical MOSFET device having interface layers between the source/drain and the channel in accordance with an embodiment of the present invention.

[0027] **Figure 7A** illustrates portions of a conventional MESFET device.

[0028] **Figure 7B** illustrates portions of a MESFET device having an interface layer between the gate and the channel in accordance with an embodiment of the present invention.

[0029] **Figure 8** illustrates the operation of different n-type devices having tunnel barriers in accordance with an embodiment of the present invention under various gate voltage conditions.

## DETAILED DESCRIPTION OF THE INVENTION

[0030] The above-cited co-pending patent application describes processes for depinning the Fermi level of a silicon-based or germanium semiconductor (e.g., Si, SiC, SiGe, SiGeC, or Ge) at a metal-semiconductor junction as well as devices that use such a junction. As more fully discussed in that application, an interface layer is introduced between the semiconductor and the metal. The interface layer functions to passivate the semiconductor surface (that is, terminate dangling bonds that may otherwise be present at the semiconductor surface so as to assure chemical stability of the surface) and to displace the semiconductor from the metal so as to reduce the effect of MIGS.

[0031] As discussed more fully below, the present inventors have determined that for thin interface layers disposed between a metal and a silicon-based or germanium semiconductor (e.g., Si, SiC, SiGe, SiGeC, or Ge), so as to form a metal – interface layer – semiconductor junction, there exist corresponding minimum specific contact resistances. Indeed, minimum specific contact resistances of less than or equal to approximately  $1000 \, \Omega - \mu m^2$  or less than or equal to approximately  $100 \, \Omega - \mu m^2$  or less than or equal to approximately  $50 \, \Omega - \mu m^2$  or less than or equal to approximately  $10 \, \Omega - \mu m^2$  or even less than or equal to approximately  $1 \, \Omega - \mu m^2$  may be achieved for such junctions in accordance with the present invention. To achieve such low contact resistances, a metal that has a work function near the conduction band of the semiconductor for n-type semiconductors, or a work function that is near the valence band for p-type semiconductors, is selected.

[0032] The effect of (and reason for) using such metals may be understood with reference to **Figure 8**. Shown in the illustration is a 2x2 grid of band diagrams. The upper two diagrams illustrate the operation of an n-type device having tunnel barriers (in the form of an interface layer configured in accordance with the present invention) and a metal source/drain in which the workfunction is aligned to the semiconductor channel conduction band under different gate voltages. Notice that the device is OFF (i.e., not conducting current) when the gate-to-source voltage ( $V_{GS}$ ) is 0. The device is ON (i.e., conducting current) when  $V_{GS} > 0$ . The lower two diagrams illustrate the operation of the n-type device having a metal source/drain in which the workfunction is aligned to the semiconductor channel mid-gap. Notice that even in the ON

state ON (i.e.,  $V_{GS} > 0$ ) a barrier to current flow exists due to band bending. This results in a higher contact resistance.

[0033] The interface layers described in the above-cited patent application may be used in connection with a semiconductor surface of a channel in a FET, as discussed below. That is, an interface layer may be disposed between a source and a channel, a channel and a drain, or both of an insulated gate field effect transistor. Such use of an interface layer is described in detail herein. The present invention provides a source – channel and/or channel – drain contact wherein the Fermi level of the source and/or drain metal is aligned (or approximately aligned) with the conduction or valence band of the semiconductor, depending on the type of semiconductor material and metals used.

[0034] In addition, the junction of the present invention can be used in making contacts to source or drain implanted wells and will have the advantage of reducing the need for high doping levels (which are now reaching their limits of solid solubility). The high doping profiles were required in the past in order to keep the junction depletion layer relatively thin, so as to increase the tunneling current, thus reducing the junction resistance. However, it is becoming increasingly difficult to increase doping profiles in order to provide low resistance junctions. It may be possible to reach the same level of resistance with a lower doping concentration using the present invention. It may further be possible to achieve much lower resistance even with lower doping concentration. When the present invention is used with high doping levels, the resistance will be further reduced.

[0035] To aid in the understanding of the present invention, the following description provides specific details of presently preferred embodiments of the invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without some of these specific details, for example by substituting well-known equivalent materials in place of those described herein for semiconductors, passivation layers and/or conductors. Where the discussion refers to well-known structures and devices, block diagrams are used, in part to demonstrate the broad applicability of the present invention to a wide range of such structures and devices.

[0036] The present inventors have devised a scheme to passivate a semiconductor surface such as a channel surface within a Schottky barrier transistor. The scheme involves forming a passivation layer which is a nitride, hydride, oxide, arsenide and/or fluoride of the semiconductor that makes up the channel. In some cases (e.g., when the passivating layer is a hydride or fluoride of the semiconductor of the channel), it may be necessary to include a separation layer between the semiconductor and the metal source/drain to reduce or eliminate the effect of intrinsic surface states in the semiconductor channel. The term interface layer will be used in connection with the present invention to include passivation layers alone and passivation layers in combination with separation layers, where such separation layers are appropriate.

[0037] The interface layer chemically neutralizes and physically protects the semiconductor channel surface. The interface layer also allows for a tunable Schottky barrier, having a height that depends on bulk characteristics of the channel semiconductor and the source/drain metal, rather than on surface properties. This allows greater control over the barrier height to meet the operational characteristics that are desired for the transistor. This scheme differs from past attempts by others to insulate channel surfaces and provide adjustable Schottky barriers in that the passivation materials used for the interface layer are not limited to metals that readily form silicides with the semiconductor channel. In other words, the present invention decouples the need for semiconductor passivation from other considerations used to select the source/drain metal, such as the desirability of a particular workfunction. It further provides for greater control of the Schottky-barrier height than previously possible.

#### I. An Exemplary Transistor

[0038] **Figure 2** shows a transistor 200 formed on a substrate 210 (e.g., a semiconductor substrate such as Si or a compound substrate such as SOI) and configured in accordance with an embodiment of the present invention. The transistor 200 contains a channel 220 that is separated from a source 250 and a drain 260 by interface layers 230 and 240, respectively, each of which form passivated Schottky barriers.

The particular transistor 200 shown, which is one example of a switching device, is an Insulated Gate FET. The interface layers 230 and 240 passivate the surfaces of channel 220 in the regions of the source/drain – channel junctions by chemically stabilizing the channel surface. The interface layers 230 and 240 also reduce or eliminate the effect of MIGS in the region of the source/drain – channel junctions by displacing the source/drain (250/260) away from the channel 220. The result of introducing the interface layers 230 and 240 between the semiconductor channel 220 and the metal source/drain 250/260 is a depinning of the Fermi level of the semiconductor that makes up channel 220. When the Fermi level of the semiconductor is depinned, the height of the Schottky barrier will depend only on the difference of the bulk workfunctions of the metal and the semiconductor in contact at the junction, and will not be dependent upon the interface. The reduction in the effectiveness of the MIGS to pin the Fermi level depends on the choice of interface dielectric. There will be MIGS at the interface between the metal and the dielectric. In general, dielectrics have much weaker MIGS than semiconductors, primarily due to larger bandgaps. Thus the choice of dielectric is important in determining the final electrical characteristics of the Schottky barrier junction.

[0039] The transistor 200 also includes a gate 270 surrounded by an insulator 280. The terms gate, source and drain each refer to terminals of a three terminal Insulated Gate FET. The source 250 and drain 260 are the terminals between which conduction occurs under the influence of an electric field resulting from a voltage applied to the gate 270. The source 250 and the drain 260 are provided at opposite ends of the channel 220 so that the channel 220 is disposed between the source 250 and the drain 260. Often, though it is not a requirement of the present invention, the source 250 and drain 260 are fabricated such that they are geometrically symmetrical. Symmetrical source and drain terminals may be referred to as source/drain terminals. A particular terminal may be designated a source or a drain on the basis of the voltage to be applied to that terminal when the FET is operated in an electrical circuit. In the particular transistor 200 shown, the source 250 is provided at a left-hand side of the channel 220 and the drain 260 is provided at a right-hand side of the channel 220, although another embodiment is contemplated wherein the source 250 and the drain 260 are interchanged.

[0040] The source 250 and the drain 260 may each contain a conductor, preferably a metal. Examples of metals that may be used include pure metals, alloys, refractory metals, metals that do not form silicides, and metals having a predetermined work function. The gate 270, which may also preferably contain a conductor, such as a metal, is located above the channel 220 and is capacitively coupled to the channel 220 through the insulator 280. Note, in other embodiments the transistor's three terminals may be coplanar or the gate 270 may be disposed below the level of the source 250 and/or the drain 260 in the substrate 210.

[0041] The insulator 280 (which may be made of a dielectric such as an oxide of the metal gate or an oxide of a semiconductor) surrounds the gate 270 and separates the gate 270 from the source 250, the drain 260, the channel 220, and the interface layers 230 and 240. The insulator 280 is of a sufficient thickness to provide a high resistance between the gate 270 and the channel 220 such that essentially no current flows between the gate 270 and the channel 220. For example, the resistance may be between about  $10^8$  Ohms and about  $10^{12}$  Ohms, or greater. Such a resistance may allow the gate 270 and the channel 220 to be capacitively coupled, while preventing current from flowing between the gate 270 and the channel 220.

[0042] The insulator 280 may also or alternatively contain a high-k dielectric material that has a higher dielectric constant than that of silicon dioxide (i.e., higher than about 4.0). The high-k material may allow the same charge induced in the channel 220 under the gate 270 to be achieved at the same gate voltage in a thicker layer. That is, the higher dielectric constant may allow the insulator 280 to have a greater layer thickness than a corresponding layer of silicon dioxide that provides the same amount of insulation. The increased thickness may simplify fabrication of the transistor 200. The thicker layer may also have less leakage current than a thinner  $\text{SiO}_2$  layer. Exemplary high-k dielectric materials that are contemplated include materials having a dielectric constant greater than about 4 (e.g., zinc oxide,  $\text{ZnO}$ ), greater than about 10 (e.g., aluminum oxide,  $\text{Al}_2\text{O}_3$ ), greater than about 20 (e.g., zirconium oxide,  $\text{ZrO}_2$ ), and greater than about 40 (e.g., hafnium oxide,  $\text{HfO}$ ).

[0043] As discussed above, the channel 220 contains a semiconductor material. The term semiconductor is used to refer to a material having a bandgap that is greater than about 0.1 electron volts and less than about 4 electron volts. Exemplary semiconductors that are contemplated include Si, Ge, SiGe or SiC. The semiconductor material may have a wide range of doping levels including no doping at all. The interface layers 230 and 240 each contain a passivation material that provides passivation to the channel 220 by covalently bonding with a dangling bond of a surface semiconductor atom to fully coordinate the semiconductor atom and thereby help passivate the semiconductor atom. The passivation material is preferably selected from the group consisting of a hydride, a nitride, an arsenide, an oxide and a fluoride of the semiconductor channel 220. Depending on the passivation material selected (e.g., where H, As or F are used as passivation materials), a separation layer in addition to a passivation layer within the interface layers 230 and 240 may be needed. Of course, the combination of the passivation layer and the separation layer must be sufficiently thin to permit the low specific contact resistances described in the above-cited patent application. Further details regarding the formation of an interface layer may be found in the above-cited patent application and will not be repeated herein.

## II. Fabricating a Transistor Having Passivated Schottky Barriers to the Channel

[0044] **Figure 3** shows a method 300 for fabricating a transistor having passivated metal – semiconductor junctions from the source to the channel and from the channel to the drain, according to one embodiment of the present invention. The method starts at block 301 and then proceeds to block 310 where a substrate is provided. At block 320 an insulated gate structure is formed on the substrate. The insulated gate structure may contain a gate having a conductive material (e.g., a metal) and a gate insulator having an insulating material beneath the conductive material. Then at block 330 a channel is formed under the insulated gate. The channel may include undercut void regions subjacent the gate dielectric and extending into the channel on both ends of the insulated gate structure. The method advances to block 340 where an interface layer is formed on the channel sides. Forming the interface

layer may include creating a passivating layer and (where necessary) a separation layer using one or more of the materials discussed above. The method then advances to block 350 where a source and drain are formed on opposite sides of the channel, including on the interface layer, and within any undercut regions. Depending upon the interface layer thickness and robustness, the source and drain may be formed by substantially non-invasive approaches. The method terminates at block 360.

[0045] An alternative procedure does not use the undercut described above. Instead, there is an “underlap”. That is, in the alternative process the width of the gate is intentionally made less than the width of the channel so that the gate underlaps the channel.

### III. Exemplary Process For Fabricating a Transistor

[0046] **Figures 4A-I** show intermediate substrates, representing fabrication of the transistor shown in Figure 4I, according to one embodiment of the present invention. The particular transistor shown in Figure 4I contains passivated aluminum-silicon junctions 482I and 484I formed from the aluminum source 492I to the silicon channel 430I and from the silicon channel 430I to the aluminum drain 494I. However, this is merely one example of a transistor configured in accordance with the present invention. For example, planar devices, wherein the gate, source and drain are co-planar in or above the substrate are also within the scope of the present invention, as are embodiments where the gate is disposed in a plane below the source and/or drain. Likewise, embodiments wherein the width of the gate is less than the width of the channel are included within the present invention.

[0047] **Figures 4A-I** therefore show one embodiment of fabricating a transistor, according to the method 300. **Figures 4A-4C** show providing a substrate and forming an insulated gate on the substrate. **Figures 4D-4E** show forming a channel beneath the insulated gate, such that the channel and the insulated gate define a first and a second undercut void region that extend underneath the insulated gate toward the channel from a first and a second side of the insulated gate. **Figure 4G** shows forming an interface layer

on exposed sidewall surfaces of the channel. Finally, **Figures 4F, 4G, and 4H** show forming a source and a drain terminal on a first and a second side of the channel including on the interface layers, and forming extension tips within the undercut voids beneath the insulated gate.

**[0048]** **Figure 4A** shows a first intermediate substrate 400A containing a silicon substrate 410A, a layer of buried oxide of silicon 420A, a layer of silicon on insulator 430A, a layer of an oxide of silicon 440A, and an aluminum gate 450A. The layers 410A-430A represent a conventional Silicon On Insulator (SOI) substrate. The SOI substrate includes the buried layer 440A to help isolate proximate semiconductor devices formed in the layer of silicon on insulator. This isolation may help reduce short-channel effects, as compared to semiconductor devices formed in a bulk wafer. The buried oxide layer may have a thickness that is effective to isolate the silicon on insulator, preferably greater than about 10 nm. The layer of silicon on insulator may have a thickness of about 20 nm, or slightly less.

**[0049]** As will be understood by a person having an ordinary level of skill in the art and the benefit of the present disclosure, the SOI substrate is not a limitation of the present invention. Other substrates are contemplated to replace the SOI substrate. For example, the SOI substrate may be replaced by a Silicon-On-Sapphire substrate, although this may increase the cost of fabrication, or the SOI substrate may be replaced by a plain silicon wafer, although this may provide inferior electrical isolation of semiconductor devices and poor short-channel characteristics.

**[0050]** The layer of oxide of silicon 440A, in one embodiment silicon dioxide ( $\text{SiO}_2$ ), may be formed by wet or dry oxidation of the silicon on insulator, as is common in the semiconductor processing arts. The layer may be sufficiently thin to serve as a gate oxide and have a thickness between about 1 nm and about 10 nm.

**[0051]** The aluminum gate 450A is formed on the oxide 440A. The aluminum gate has a width 451A that is about equal to, or slightly larger than the intended channel length, which in one embodiment is less than about 50 nm and in another embodiment is less than about 20 nm. More than slight increases of the width over the channel length may increase the extent and angle of a subsequent undercut etch, which

may complicate fabrication. The gate 450A may be formed by depositing a layer of aluminum on the oxide 440A, depositing a photoresist layer on the deposited aluminum layer, exposing a pattern including the width 451A in the photoresist using conventional high-resolution lithography, removing a portion of the photoresist according to the exposed pattern, wet or dry etching a portion of the deposited layer of aluminum according to the patterned photoresist, and removing the remaining photoresist.

[0052] **Figure 4B** shows a second intermediate substrate 400B containing an oxide of aluminum insulator 460B formed on exposed portions, including the top and sides, of the aluminum gate 450B. The oxide of aluminum layer 460B may have a thickness between about 1 nm and about 20 nm. The thickness may be about equivalent to the thickness of the layer 440B, or slightly larger. Larger thickness may improve performance by reducing capacitance between the gate and the source, however the additional thickness may also increase fabrication complexity by increasing undercut. Forming the oxide of aluminum layer 460B may include oxidizing the aluminum gate 450A in an oxygen plasma etcher that provides a suitable oxidizing atmosphere, or by other methods known in the semiconductor processing arts.

[0053] **Figure 4C** shows a third intermediate substrate 400C containing a gate oxide 440C formed by removing a portion of the layer 440B that is not beneath aluminum gate 450B or aluminum oxide 460B. The removal may include using the oxidized aluminum gate 450B-460B as a mask for the layer 440B and etching portions of the layer 440B that are not subjacent to and concealed by the oxidized aluminum gate 450B-460B. This removal leaves a portion of the silicon on insulator layer 430C that is not subjacent to the gate oxide 440C, aluminum gate 450C, or oxide 460C exposed. Etching may include Reactive Ion Etching (RIE) to encourage etching preferentially in the direction normal or perpendicular to the surface of the layer 440B. RIE is a dry-etch process wherein the intermediate substrate 400B is placed on a radio frequency powered electrode and provided with a potential that helps ionize and accelerate ion bombardment of etching species extracted from plasma toward the etched surface.

[0054] **Figure 4D** shows a fourth intermediate substrate 400D containing a silicon channel 430D formed by removing a portion of the silicon on insulator layer 430C that is substantially not subjacent and concealed by the gate oxide 440C. Removal may include etching silicon on insulator that has a standard Si-100 orientation with tetramethylammonium hydroxide (TMAH) to form angled sidewalls that slope inward toward the gate 450D, as shown. Alternatively, comparatively straight sidewalls aligned with the gate oxide 440D may be formed by a self-limiting etch in TMAH if the silicon on insulator has a Si-110 orientation. Such comparatively straight sidewalls may also be formed by RIE.

[0055] **Figure 4E** shows a fifth intermediate substrate 400E containing an undercut silicon channel 430E formed by removing a portion of the channel 430D that is subjacent and aligned with the gate oxide 440D. The undercut silicon channel 430E contains an undercut region wherein the silicon is removed from the channel 430D at a left and right-hand edge of the gate oxide 440D to allow a subsequent formation of source and drain material vertically under the gate oxide 440E. Removal may be by a non-directional or isotropic wet silicon etch with TMAH wherein etching takes place in substantial uniform amounts along the sidewall. If the crystal axis of the silicon on insulator are not aligned precisely with the lithography, the TMAH etch may not be completely self-limiting and may form an undercut due to the vertical ridges or stair steps of crystal structure. Alternatively, removal may be by an isotropic RIE.

[0056] **Figure 4F** shows a sixth intermediate substrate 400F containing a seed layer 476F, 472F, and 474F formed respectively on a top surface of the insulated gate and on a left and right-hand side of the insulated gate. The seed layer facilitates subsequent formation of a metal source and drain. The seed layer may be deposited anisotropically so that no significant seed layer material is deposited on the vertical sidewalls of the aluminum oxide 460F, gate oxide 440F, or channel 430F and essentially no metal is deposited on the underside of the undercut overhang of the gate oxide 440F. This is desired to electrically isolate the seed layer portion 476F from the seed layer portion 472F and 474F. In one embodiment, the seed layer contains chromium deposited from a thermal source. Chromium provides desirable electrochemistry and is well suited for formation of ultra-thin films.

[0057] **Figure 4G** shows a seventh intermediate substrate 400G containing a modified seed layer 472G-474G formed by selectively removing the layer portion 476F from the top surface of the insulated gate. Removal of the portion 476F is desirable to allow depositing the source and drain materials superjacent the layer portions 472G and 476G without depositing the source and drain materials atop the oxidized aluminum gate structure. Since the seed layer portion 476F is electrically isolated from the seed layer portions 472F and 474F, the portion 476F may be removed electrochemically by a Ceric Ammonium Nitrate (CAN) chrome etch. For example, the seed layer portions 472F and 474F but not the seed layer portion 476F may be electrically coupled with a copper electrical probe at the edge of the substrate to etch the seed layer portion 476F but not the portions 472F-474F. It should be noted however, that another embodiment is contemplated wherein patterning may be used to form chromium layers 472F and 474F without forming chromium layer 476F. This may avoid a subsequent removal of the chromium layer 476F.

[0058] **Figure 4H** shows an eighth intermediate substrate 400H containing interface layers 482H and 484H formed on the sidewall surfaces of the channel 430H. The interface layers may be a monolayer, slightly more than a monolayer, less than about 0.3 nm, less than about 0.5 nm or less than about 1 nm (depending upon the desired Schottky barrier characteristics). That is, in some cases an amount of passivation material sufficient to terminate all or a sufficient number of dangling bonds of the semiconductor channel to achieve chemical stability of the surface may be used. The interface layers may be grown in accordance with the techniques discussed in the above-cited patent application. Passivation materials that are contemplated include arsenic, hydrogen, fluorine, oxygen, and nitrogen, as discussed above, and the interface layers 482H and 484H may be made up of both a passivation layer and a separation layer.

[0059] **Figure 4I** shows a ninth intermediate substrate 400I containing a source 492I formed superjacent upon the seed material 472H and beneath the left undercut overhang and a drain 494I formed superjacent upon the seed material 474H and beneath the right undercut overhang. The source and drain have a thickness that extends above the gate insulator 440I. Desirably, the thickness may be precisely controlled.

Forming may include plating the potentially different source/drain materials on the seed layers 472H and 474H. This may include depositing a photoresist, irradiating the photoresist to expose a channel width pattern, removing a portion of the photoresist to expose the seed layers 472H and 474H, plating the source/drain materials on the seed layers 472H and 474H, and removing the remainder of the photoresist. According to one embodiment, the source and drain materials are aluminum. Alternatively, the source and drain materials may be another desired and potentially different metal or alloy.

[0060] The transistor shown in **Figure 4I** has a number of advantages. In general, the transistor provides a simple construction. This may allow extending transistor fabrication below 50 nm channel lengths, below 20 nm channel lengths, or even below 10 nm channel lengths. Another advantage is greater control over the Schottky barrier height provided by the interface layers. The barrier height may be controlled by the properties of the interface layer such as passivation material, layer thickness, and layer formation conditions, in addition to difference in workfunctions between the source/drain and the channel. This ability to control the barrier height is further increased by greater flexibility in selecting source/drain materials, since, due to the interface layers, the source/drain materials do not have to readily form silicides with the silicon channel. Yet another advantage is low resistance in the source due to the use of a high conductivity metal rather than doped silicon. Removal of dopants in the junctions in general may be attractive from an Ultra-Large-Scale-Integration (ULSI) manufacturing perspective, since application of such dopants is posing a limit to process controllability.

[0061] The channel – interface layer – source/drain junction(s) of the transistor shown in **Figure 4I** are unique in that the Fermi level of the semiconductor channel is depinned in a region near the junction and the junction has a specific contact resistance of less than approximately  $1000 \Omega\text{-}\mu\text{m}^2$ . This is true of all transistors configured in accordance with the present invention. Indeed, minimum specific contact resistances of less than or equal to approximately  $10 \Omega\text{-}\mu\text{m}^2$  or even less than or equal to approximately  $1 \Omega\text{-}\mu\text{m}^2$  may be achieved for such junctions in accordance with the present invention. To achieve such low contact resistances, a source/drain metal that has a work function near the conduction band of the semiconductor for n-type semiconductors, or a work function that is near the

valence band for p-type semiconductors, is selected. The depinning role played by the interface layer in tuning, adjusting, or controlling the height of the barrier between the source/drain and the semiconductor channel involves both a reduction in surface states of the channel, by bonding to the semiconductor material to consume dangling bonds, a reduction in the formation of MIGS in the semiconductor channel, by providing a thickness and bandgap that prevent the electron wave function (of the source/drain metal) from penetrating into the semiconductor channel. The electron wave function may instead penetrate into the interface layer and form MIGS within the interface layer at an energy related to the states of the interface layer material. As desired, the density of the MIGS and the depth of MIGS penetration into the interface layer may be reduced by choosing an interface layer material or materials having a larger bandgap or higher effective mass than the semiconductor of the channel. The interface layer is operable to pass current to/from the semiconductor channel during device operation.

**[0062]** In some embodiments, it may be desirable to use an interface layer having a thickness of a monolayer, or, for example between about 0.1 nm and about 0.3 nm, and also having a wide bandgap (as compared to that of the semiconductor of the channel) so that the interface layer both depins the Fermi level (so that the barrier height depends predominantly on bulk properties of the junction materials) and allows sufficient current transfer across it. In some cases the interface layer may include only an amount of passivation material sufficient to terminate all or a sufficient number of dangling bonds of the semiconductor channel to achieve chemical stability of the surface. Advantageously, such interface layers may be sufficiently thin to provide low impedance to current flow (due to the exponential dependence of direct tunneling on barrier thickness), which is desirable for many semiconductor devices, while also providing sufficient semiconductor surface passivation to allow an adjustable barrier height. That is, the interface layer may allow passivation of surface states and reduction (or elimination) of MIGS in the semiconductor to allow for an adjustable barrier height with a substantially thin layer that allows sufficient current to be transferred across the interface layer.

**[0063]** As explained in the above-cited patent application, there are several methods by which the barrier height can be made adjustable. For example, adjustment may be made by tuning the degree of Fermi

level pinning. In other words, some embodiments may allow for a sufficiently thin interface layer so that not all of the effects of MIGS in the semiconductor channel are eliminated. Further, the pinning may be varied by combinations of thickness of the interface layer and the choice of interface material. The metal in contact with the interface layer may be pinned by MIGS at different levels in different materials. Conversely, or in addition, the semiconductor channel passivation may be left incomplete to allow for an effective level of unpassivated states. Complete depinning of the Fermi level (that is removal of all surface states in the semiconductor channel including MIGS) is another option, in which case one could tune the barrier height simply by choosing a pure metal or an alloy that possesses the desired workfunction.

[0064] In summary then, one embodiment for fabricating a transistor on a semiconductor substrate includes: (1) forming a semiconductor oxide dielectric layer on a semiconductor substrate by oxidizing the semiconductor substrate; (2) forming a metal gate on the semiconductor oxide layer by depositing a layer of metal on the semiconductor oxide and removing a portion of the deposited layer of metal based on a lithographic exposure; (3) forming a metal oxide dielectric layer on exposed portions of the metal gate by oxidizing the metal gate; (4) forming a gate oxide dielectric by removing a portion of the semiconductor oxide layer that is protected by the metal oxide formed on the metal gate; (5) forming a semiconductor channel structure by removing a portion of the semiconductor substrate that is not protected by the metal oxide formed on the metal gate; (6) forming an undercut semiconductor channel containing a source undercut region for a source tip and a drain undercut region for a drain tip by removing a source tip portion of the semiconductor channel structure that is subjacent to a left-hand end of the gate oxide and extends underneath the gate oxide toward the channel top interior and removing a drain tip portion of the semiconductor channel structure that is subjacent to a right-hand end of the gate oxide and extends underneath the gate oxide toward the channel top interior; (7) forming a source seed layer on a left-hand side of the undercut semiconductor channel and forming a drain seed layer on a right-hand side of the undercut semiconductor channel by anisotropically depositing seed layer material so that seed layer material is not deposited on exposed sidewall surfaces of the undercut semiconductor channel

and removing a portion of deposited seed layer material that is above the undercut semiconductor channel; (8) forming an interface layer on the exposed sidewall surfaces of the undercut semiconductor channel by covalently bonding at least a monolayer (or less) of passivation material to semiconductor atoms of the exposed sidewall surfaces of the undercut semiconductor channel; and (9) forming a source on a first side of the channel including on the passivation layer and within a first undercut corresponding to the removal of the first portion of the semiconductor channel structure and forming a drain on a second side of the channel including on the interface layer and within a second undercut corresponding to the removal of the second portion of the semiconductor channel structure.

#### IV. Alternative Arrangements

[0065] The transistor illustrated in Figure 4I is but one example of the types of FETs that can benefit from the present invention. Other FETs known in the art may also realize such benefits by incorporating the present interface layers into source/drain – channel junctions. For example, so-called FinFETs may incorporate such interface layers. A FinFET is an example of a thin-body SOI device and is the name given to a class of FETs developed by researchers at the University of California, Berkely. Conventional FinFETs are described in detail in Yang-Kyu Choi et al., “Nanoscale CMOS Spacer FinFET for the Terabit Era”, IEEE Electron Device Letters, vol. 25, no. 1 (Jan. 2002), incorporated herein by reference, and an example of such a device 500 is illustrated in **Figure 5A**. As shown, the channel of a finFET is formed by spacer-defined semiconductor fins.

[0066] **Figure 5B** shows a Fin-FET 520 modified to incorporate interface layers 522 in accordance with an embodiment of the present invention. In this embodiment, the semiconductor source and/or drain are replaced with a metal source and/or drain. The semiconductor fins (i.e., the channel) contact these source/drain regions through an interface layer.

**[0068] Figure 6B** shows a vertical MOSFET 620 modified to incorporate interface layers in accordance with an embodiment of the present invention. This transistor is similar to the MOSFET illustrated in Figure 6A but the upper Si n-region (the drain in this example) has been replaced with a metal drain and contact to the channel is through an interface layer 622. Thus, such devices may be asymmetric, having a passivated Si/metal tunnel junction at the top contact, and a Si p-n junction at the bottom of the device on the substrate side. Complementary devices may be fabricated on the same substrate by first implanting p and n regions for the bottom contacts, and then employing two different metals, each with work functions chosen to yield p-type or n-type devices, as the top contacts to the channel.

**[0069]** Figure 7A illustrates yet another type of transistor 700, the MESFET. A MESFET (Metal Semiconductor FET) replaces the gate/insulator/semiconductor stack adjacent to the channel with a metal/semiconductor contact, intentionally forming a Schottky barrier. The conductance of the channel is modulated when an applied gate voltage results in a change in the depletion width of the Schottky barrier into the channel. The channel as shown may be a thin Si layer, as in an SOI substrate.

**[0070]** For optimizing the utility of a particular MESFET application, it may be desirable to either raise or lower the Schottky barrier. This may be achieved as shown in **Figure 7B** by implementation of the present invention in a transistor 720 wherein a particular interface dielectric and contact metal may be appropriately chosen. The interface dielectric forms an interface layer 722 between the gate and the channel. In other embodiments, the gate may be poly Si instead of a metal.

## V. Use of Transistor In Electrical Systems

[0071] Transistors such as those described herein may be used in chips, integrated circuits, monolithic devices, semiconductor devices, microelectronic devices, and the like within a number of electrical systems. Electrical systems that are contemplated include computer systems (e.g., portable, laptop, desktop, server, mainframe, etc.), hard copy equipment (e.g., printer, plotter, fax machine, etc.), and other electrical systems. For example, in one embodiment a computer system may comprise a microprocessor having such a transistor to help execute instructions. The computer system may contain other conventional components including but not limited to a bus or other communication means to communicate information, a memory to store information (e.g., a dynamic memory such as RAM or a static memory such as ROM), a display device, a data input device, and a communication device such as a modem, as will be appreciated by a person having an ordinary level of skill in the art and the benefit of the present disclosure. Any or all of these devices may include transistors configured in accordance with the present invention.

[0072] Thus, a transistor having passivated junctions from the source to the channel and/or from the channel to the drain, and a method for forming such a transistor have been described. Although described with reference to specific embodiments it should be remembered that various modifications and changes may be made to the techniques described herein without departing from the broader spirit and scope of the invention. For example, metals other than aluminum may be used in transistors configured in accordance with the present invention. Low work function metals that may be so used include Er, Eu, Ba, Cs, Ca, Ce, Rb, Sm, Y, and Yb. All have workfunctions less than 3 eV. High work function metals (for aligning to valence bands) which may be used include Pt, Ir, Pd, Re, Ni, Co, and Au. The specification and drawings are accordingly to be regarded in an illustrative rather than a restrictive sense and the invention measured only in terms of the claims, which follow.

## CLAIMS

What is claimed is:

1. A transistor, comprising a semiconductor channel disposed (i) nearby a gate configured to control conductance within the channel and (ii) in an electrical path between a source and a drain, at least one of which is made of a metal, wherein the channel and whichever of the source and/or the drain is/are made of the metal is/are separated by an interface layer so as to form a channel – interface layer – source/drain junction in which a Fermi level of the semiconductor channel is depinned in a region near the junction and the junction has a specific contact resistance of less than approximately  $1000 \Omega\text{-}\mu\text{m}^2$ .
2. The transistor of claim 1 wherein the semiconductor channel is made of one of Si, Ge, SiGe, SiGeC, or SiC.
3. The transistor of claim 1 wherein the metal comprises one of a pure metal, an alloy, or a refractory metal.
4. The transistor of claim 1 wherein the metal comprises aluminum.
5. The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $100 \Omega\text{-}\mu\text{m}^2$ .
6. The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $50 \Omega\text{-}\mu\text{m}^2$ .

7. The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $10 \Omega\text{-}\mu\text{m}^2$ .
8. The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $1 \Omega\text{-}\mu\text{m}^2$ .
9. The transistor of claim 1 wherein the interface layer includes a passivating material.
10. The transistor of claim 9 wherein the passivating material comprises one or more of a nitride of the semiconductor of the channel, a fluoride of the semiconductor of the channel, an oxide of the semiconductor of the channel, an oxynitride of the semiconductor of the channel, a hydride of the semiconductor of the channel and/or an arsenide of the semiconductor of the channel.
11. The transistor of claim 10 wherein the interface layer consists essentially of an amount of passivating material sufficient to terminate enough dangling bonds of a surface of the semiconductor channel so as to achieve chemical stability of the surface.
12. The transistor of claim 10 wherein the interface layer consists essentially of a monolayer configured to depin the Fermi level of the semiconductor of the channel.
13. The transistor of claim 12 wherein the interface layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.
14. The transistor of claim 9 wherein the interface layer further includes a separation layer.
15. The transistor of claim 14 wherein the separation layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.

16. The transistor of claim 1 wherein the semiconductor channel is separated from the gate by a dielectric.

17. A method , comprising:

forming, on one or more surfaces of a semiconductor channel of a transistor, an interface layer; and

forming, on one or more surfaces of the interface layer opposite the semiconductor channel, a source or drain terminal for the transistor so as to create a channel – interface layer – source/drain junction in which a Fermi level of the semiconductor channel is depinned in a region near the junction and the junction has a specific contact resistance of less than approximately  $1000 \Omega\text{-}\mu\text{m}^2$ .

18. The method of claim 17 wherein the semiconductor channel is formed by removing a portion of a semiconductor substrate that is not protected by a mask created at least in part by a gate structure formed above the semiconductor channel.

19. The method of claim 17 wherein the specific contact resistance is less than or equal to approximately  $100 \Omega\text{-}\mu\text{m}^2$ .

20. The method of claim 17 wherein the specific contact resistance is less than or equal to approximately  $50 \Omega\text{-}\mu\text{m}^2$ .

21. The method of claim 17 wherein the specific contact resistance is less than or equal to approximately  $10 \Omega\text{-}\mu\text{m}^2$ .

22. The method of claim 17 wherein the specific contact resistance is less than or equal to approximately  $1 \Omega\text{-}\mu\text{m}^2$ .
23. The method of claim 17 wherein the semiconductor channel is made of one of Si, Ge, SiGe, SiGeC, or SiC.
24. The method of claim 23 wherein the gate is formed on a oxide layer disposed over the semiconductor channel.
25. The method of claim 24 wherein the oxide layer comprises a dielectric layer sufficiently thick enough to provide only capacitive coupling between the gate and the semiconductor channel.
26. The method of claim 24 wherein the oxide layer is formed over the semiconductor substrate by oxidizing the substrate.
27. The method of claim 26 wherein the gate is formed on the oxide layer by depositing a layer of metal on the oxide layer and removing a portion of the deposited layer of metal based on a lithographic exposure.
28. The method of claim 25 wherein the source or drain terminal is formed from a seed layer created by anisotropically depositing seed layer material on the semiconductor substrate.
29. The method of claim 27 wherein the interface layer is formed by covalently bonding at least a monolayer of a passivation material to the semiconductor channel.
30. The method of claim 29 wherein the passivation material comprises one or more of a nitride of the semiconductor channel, a fluoride of the semiconductor channel, an oxide of the semiconductor channel,

Figure 1 consists of 12 histograms arranged in a single row. Each histogram represents the frequency distribution of the number of non-zero elements in the vector  $x$  for a specific value of  $n$ . The values of  $n$  are 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, and 120, labeled above each respective histogram. The x-axis for all histograms is the number of non-zero elements, ranging from 0 to approximately 120. The y-axis represents the frequency, with scales varying between histograms. As  $n$  increases, the distribution of non-zero elements shifts to the right, indicating that the vector  $x$  contains more non-zero elements as  $n$  grows.

31. The method of claim 29 wherein the interface layer includes a separation layer comprising a material different than the passivation material.

32. The method of claim 31 wherein the material that makes up the separation layer comprises an oxide of the semiconductor channel.

33. The method of claim 17 wherein the interface layer comprises an amount of a passivation material sufficient to terminate all or a sufficient number of dangling bonds of the one or more surfaces of the semiconductor channel to achieve chemical stability of the one or more surfaces.

34. An electrical system comprising a circuit coupled to a transistor having a semiconductor channel disposed nearby a gate and in an electrical path between a source and a drain, at least one of which is made of a metal, wherein the channel and whichever of the source and/or the drain is/are made of the metal is/are separated by an interface layer so as to form a channel – interface layer – source/drain junction in which a Fermi level of the semiconductor channel is depinned in a region near the junction and the junction has a specific contact resistance of less than approximately  $1000 \Omega\text{-}\mu\text{m}^2$ .

35. The electrical system of claim 34 wherein the semiconductor channel is separated from the gate by a dielectric.

36. The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately  $100 \Omega - \mu m^2$ .

37. The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately  $50 \Omega\text{-}\mu\text{m}^2$ .

38. The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately  $10 \Omega\text{-}\mu\text{m}^2$ .

39. The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately  $1\ \Omega\text{-}\mu\text{m}^2$ .

40. The electrical system of claim 35 wherein the semiconductor channel is made of one of Si, Ge, SiGe, SiGeC, or SiC.

41. The electrical system of claim 35 wherein the interface layer includes a passivating material.

42. The electrical system of claim 41 wherein the interface layer includes a separation layer comprising a material different than the passivation material.

43. The electrical system of claim 41 wherein the interface layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.

44. The electrical system of claim 41 wherein the interface layer comprises an amount of passivating material sufficient to terminate all or a sufficient number of dangling bonds of the semiconductor channel to achieve chemical stability of a surface of the semiconductor channel in the region near the junction.

45. The electrical system of claim 44 wherein amount of passivating material comprises a monolayer.

**ABSTRACT**

[0073] A transistor includes a semiconductor channel disposed nearby a gate and in an electrical path between a source and a drain, wherein the channel and at least one of the source or the drain are separated by an interface layer so as to form a channel – interface layer – source/drain junction in which a Fermi level of the semiconductor channel is depinned in a region near the junction and the junction has a specific contact resistance of less than approximately  $1000 \Omega\text{-}\mu\text{m}^2$ . The interface layer may include a passivating material such as a nitride, a fluoride, an oxide, an oxynitride, a hydride and/or an arsenide of the semiconductor of the channel. In some cases, the interface layer consists essentially of a monolayer configured to depin the Fermi level of the semiconductor of the channel, or an amount of passivation material sufficient to terminate all or a sufficient number of dangling bonds of the semiconductor channel to achieve chemical stability of the surface. Also, the interface layer may include a separation layer of a material different than the passivating material. Where used, the separation layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.

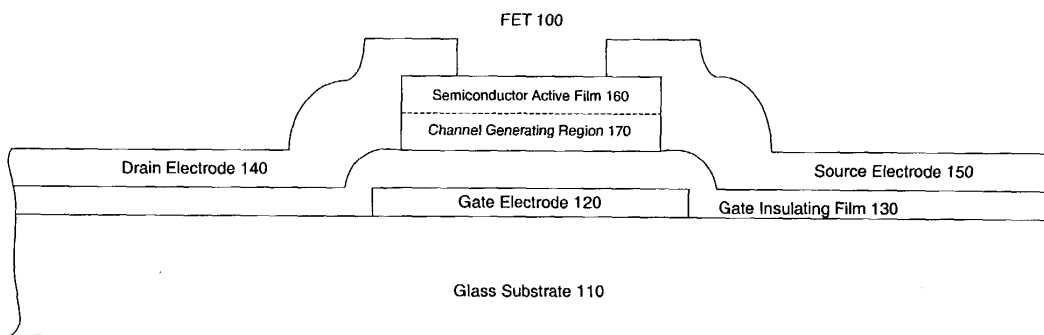


Fig. 1  
(Prior Art)

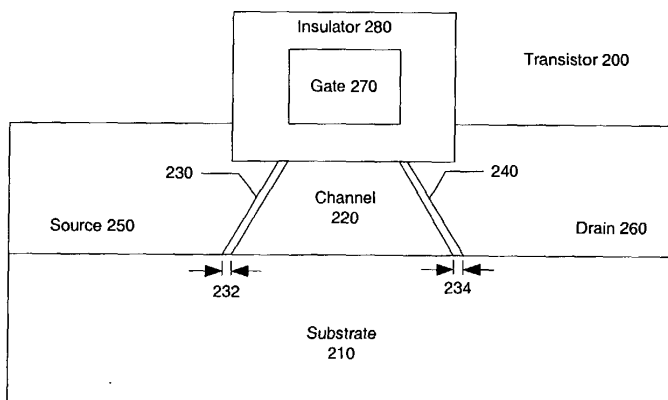


Fig. 2

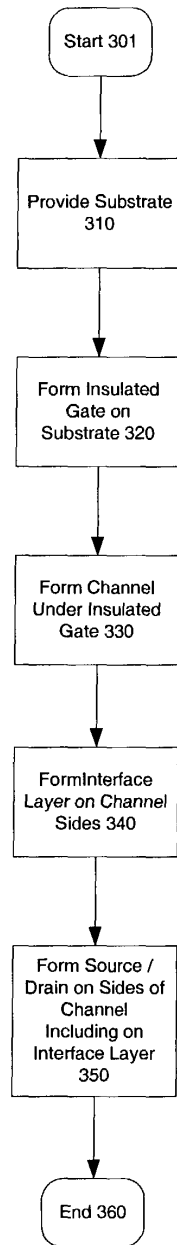


Fig. 3

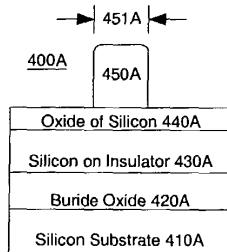


Fig. 4A

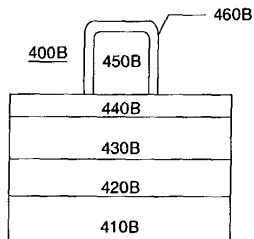


Fig. 4B

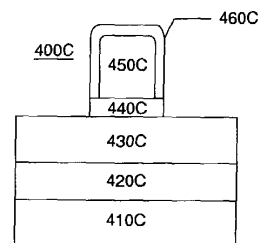


Fig. 4C

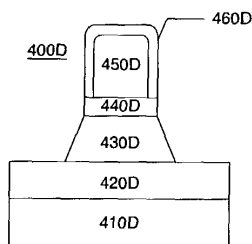


Fig. 4D

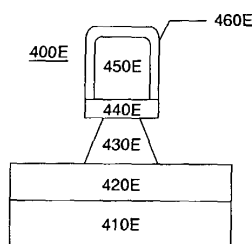


Fig. 4E

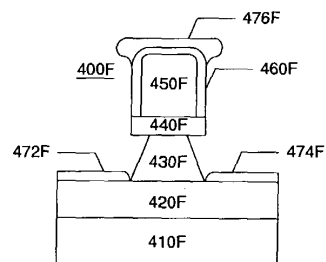


Fig. 4F

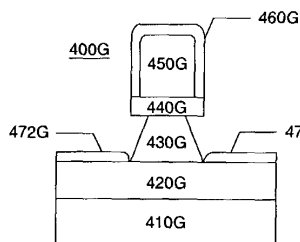


Fig. 4G

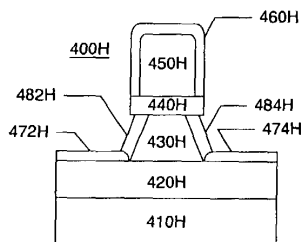


Fig. 4H

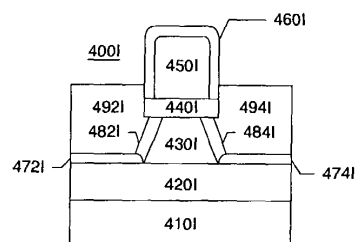


Fig. 4I

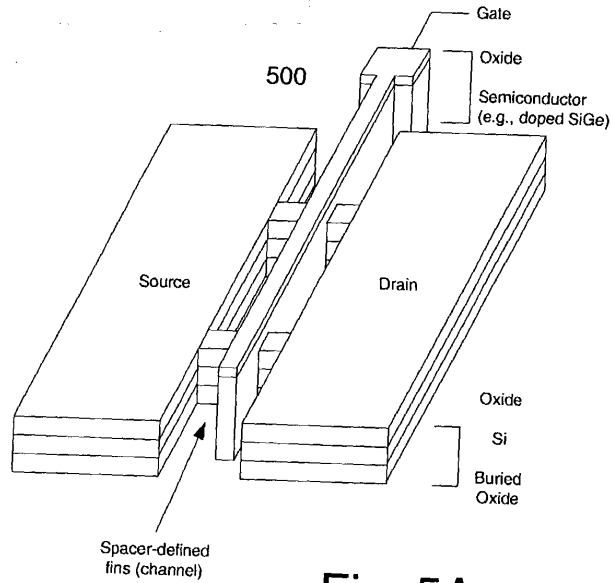


Fig. 5A

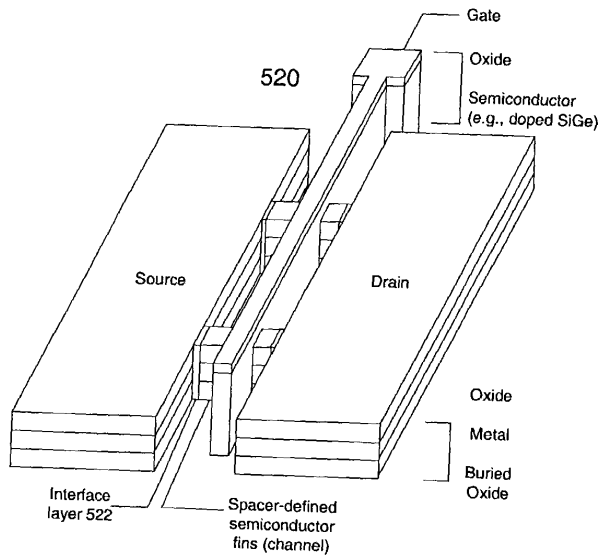


Fig. 5B

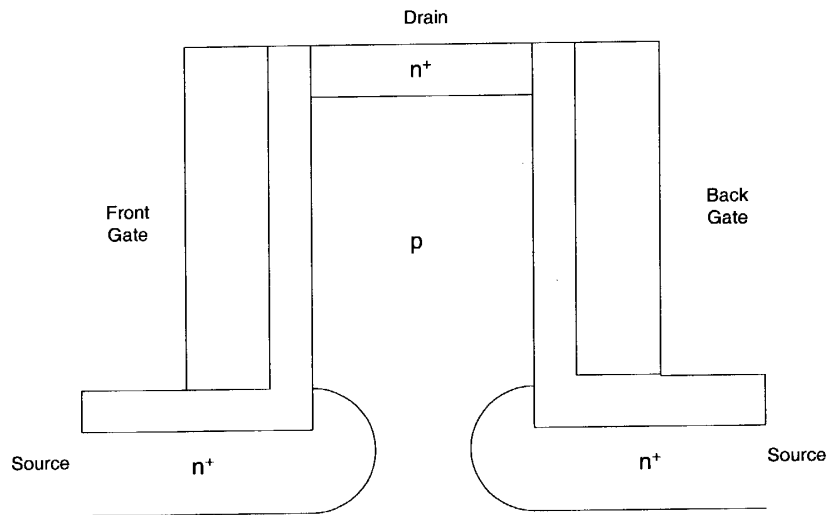


Fig. 6A

600

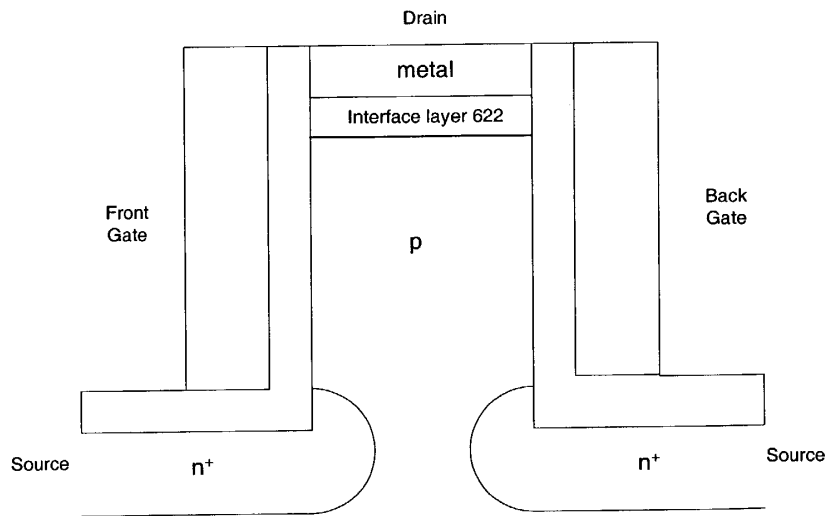


Fig. 6B

620

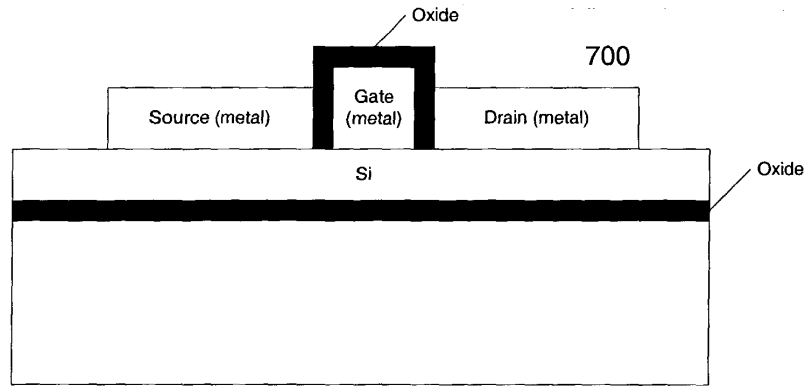


Fig. 7A

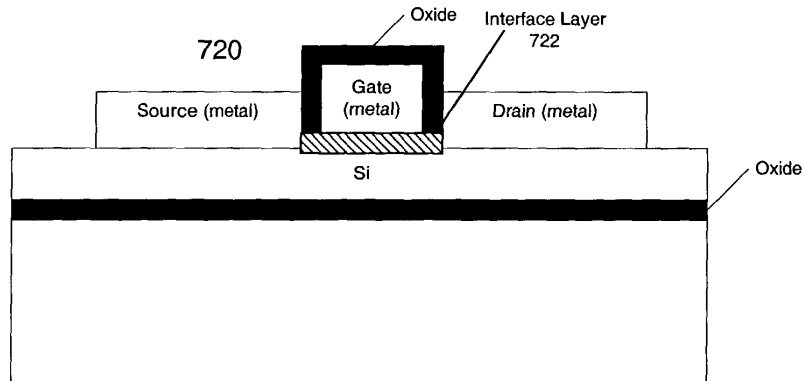


Fig. 7B

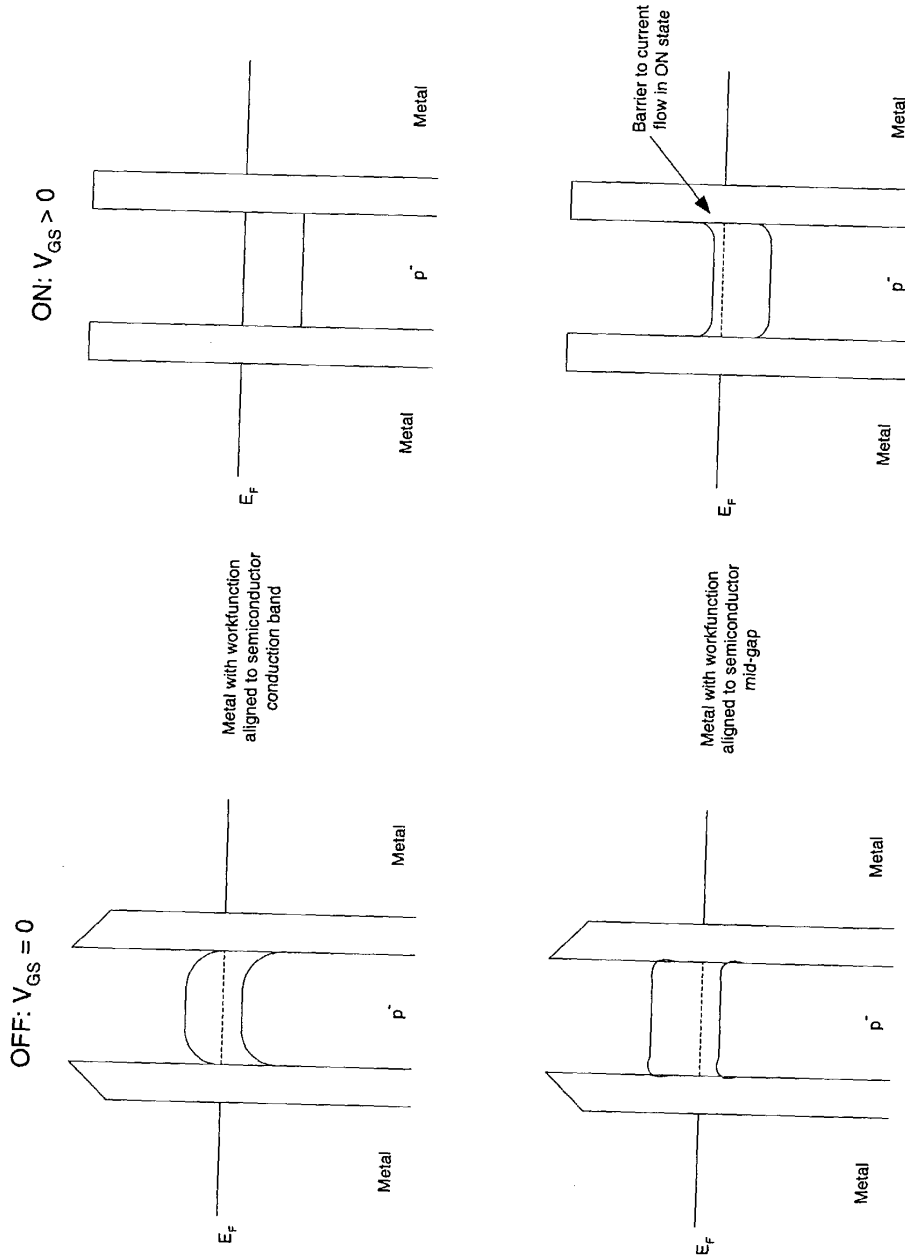


Fig. 8

Attorney's Docket No.: 3771P004

Patent

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

**INSULATED GATE FIELD EFFECT TRANSISTOR HAVING PASSIVATED SCHOTTKY BARRIERS TO THE CHANNEL**

the specification of which

  X   is attached hereto.  
       was filed on (MM/DD/YYYY) \_

\_\_\_\_\_ as  
 United States Application Number \_\_\_\_\_  
 or PCT International Application Number \_\_\_\_\_  
 and was amended on (MM/DD/YYYY) \_\_\_\_\_  
 (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application. I do not know and do not believe that the claimed invention was in public use or on sale in the United States of America more than one year prior to this application, nor do I know or believe that the invention has been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

| <u>Prior Foreign Application(s)</u> |                    |                                                | <u>Priority Claimed</u> |    |
|-------------------------------------|--------------------|------------------------------------------------|-------------------------|----|
| _____<br>(Number)                   | _____<br>(Country) | _____<br>(Foreign Filing Date -<br>MM/DD/YYYY) | Yes                     | No |
| _____<br>(Number)                   | _____<br>(Country) | _____<br>(Foreign Filing Date -<br>MM/DD/YYYY) | Yes                     | No |
| _____<br>(Number)                   | _____<br>(Country) | _____<br>(Foreign Filing Date -<br>MM/DD/YYYY) | Yes                     | No |

I hereby claim the benefit under title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below:

|                               |                                     |
|-------------------------------|-------------------------------------|
| _____<br>(Application Number) | _____<br>(Filing Date – MM/DD/YYYY) |
| _____<br>(Application Number) | _____<br>(Filing Date – MM/DD/YYYY) |

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

|                                    |                                          |                                                        |
|------------------------------------|------------------------------------------|--------------------------------------------------------|
| 10/217,758<br>(Application Number) | 08/12/2002<br>(Filing Date – MM/DD/YYYY) | Pending<br>(Status -- patented,<br>pending, abandoned) |
| _____<br>(Application Number)      | _____<br>(Filing Date – MM/DD/YYYY)      | _____<br>(Status -- patented,<br>pending, abandoned)   |

I hereby appoint the persons listed on Appendix A hereto (which is incorporated by reference and a part of this document) as my respective patent attorneys and patent agents, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

Send correspondence Tarek N. Fahmi, Reg. No. 41,402, BLAKELY,  
SOKOLOFF, TAYLOR &

(Name of Attorney or Agent)

ZAFMAN LLP, 12400 Wilshire Boulevard 7th Floor, Los Angeles, California  
90025 and direct telephone calls to Tarek N. Fahmi, (408) 720-  
8300.

(Name of Attorney or Agent)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of Sole/First Inventor DANIEL E. GRUPP

Inventor's Signature D. E. Grupp Date 1/10/03

Residence PALO ALTO, CA Citizenship USA  
(City, State) (Country)

Post Office Address 334 LELAND AVE.  
PALO ALTO, CA 94306

Full Name of Second/Joint Inventor DANIEL J. CONNELLY

Inventor's Signature Daniel Connelly Date 10 JAN 2003

Residence REDWOOD CITY, CA Citizenship USA  
(City, State) (Country)

Post Office Address 525 RUTHERFORD AVE  
REDWOOD CITY CA 94061-4215

\_\_\_\_\_

## APPENDIX B

### Title 37, Code of Federal Regulations, Section 1.56 Duty to Disclose Information Material to Patentability

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

- (1) Prior art cited in search reports of a foreign patent office in a counterpart application, and
- (2) The closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

- (1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or
- (2) It refutes, or is inconsistent with, a position the applicant takes in:
  - (i) Opposing an argument of unpatentability relied on by the Office, or
  - (ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

- (1) Each inventor named in the application;
- (2) Each attorney or agent who prepares or prosecutes the application; and
- (3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.

(e) In any continuation-in-part application, the duty under this section includes the duty to disclose to the Office all information known to the person to be material to patentability, as defined in paragraph (b) of this section, which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

371A U.S. PTO  
10/342576  
01/14/2003

N  
U.S. UTILITY Patent Application

PATENT NUMBER and  
ISSUE DATE

| APPL NUM | FILING DATE | CLASS | SUBCLASS | GAU  | EXAMINER      |
|----------|-------------|-------|----------|------|---------------|
| 10342576 | 01/14/2003  | 257   | 980      | 2811 | F. THOMAS KAW |

\*\*APPLICANTS: Grupp Daniel; Connelly Daniel;

BEST AVAILABLE COPY

\*\*CONTINUING DATA VERIFIED:

This application is a CIP of 10/217,758 08/12/2002

\*\* FOREIGN APPLICATIONS VERIFIED:

|                                                                                                   |                                                    |                                  |
|---------------------------------------------------------------------------------------------------|----------------------------------------------------|----------------------------------|
| PG-PUB                                                                                            | DO NOT PUBLISH <input checked="" type="checkbox"/> | RESCIND <input type="checkbox"/> |
| Foreign priority claimed <input type="checkbox"/> yes <input type="checkbox"/> no                 |                                                    | ATTORNEY DOCKET NO               |
| 35 USC 119 conditions met <input type="checkbox"/> yes <input type="checkbox"/> no                |                                                    | 3771P004                         |
| Verified and Acknowledged Examiners's Initials                                                    |                                                    |                                  |
| TITLE : Insulated gate field effect transistor having passivated schottky barriers to the channel |                                                    |                                  |

U.S. DEPT. OF COMM./PAT. & TM.-PTO-4361/R

|                                   |           |                                                                                                                                                                                                                                                                                         |                      |                      |
|-----------------------------------|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|----------------------|
| NOTICE OF ALLOWANCE MAILED        |           | Assistant Examiner                                                                                                                                                                                                                                                                      | CLAIMS ALLOWED       |                      |
|                                   |           |                                                                                                                                                                                                                                                                                         | Total Claims         | Print Claim for O.G. |
| ISSUE FEE                         |           | Primary Examiner                                                                                                                                                                                                                                                                        | DRAWING              |                      |
| Amount Due                        | Date Paid |                                                                                                                                                                                                                                                                                         | Sheets Drwg.         | Figs. Drwg.          |
| <input type="checkbox"/> TERMINAL |           | PREPARED F R ISSUE                                                                                                                                                                                                                                                                      | Application Examiner |                      |
| DISCLAIMER                        |           | WARNING: The information disclosed herein may be restricted. Unauthorized disclosure may be prohibited by the United States Code Title 35, Sections 122, 181 and 368, Possession outside the U.S. Patent & Trademark Office is restricted to authorized employees and contractors only. |                      |                      |

FILED WITH: ☐ DISK (CRF) ☐ CD-ROM  
(Attached in pocket on right inside flap)

## SEARCH

| Class               | Sub. | Date | Exmr. |  |  |  |  |
|---------------------|------|------|-------|--|--|--|--|
| BEST AVAILABLE COPY |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |
|                     |      |      |       |  |  |  |  |

## SEARCH NOTES

(List databases searched. Attach search strategy inside.)

|  | Date | Exmr. |  |  |
|--|------|-------|--|--|
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |
|  |      |       |  |  |

## INTERFERENCE SEARCHED

| Class | Sub. | Date | Exmr. |  |  |  |  |
|-------|------|------|-------|--|--|--|--|
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |
|       |      |      |       |  |  |  |  |

**ISSUE SLIP STAPLE AREA (for additional cross-references)**

**ISSUING CLASSIFICATION**

| ORIGINAL                     |          | CROSS REFERENCE(S) |                                   |  |  |  |  |  |  |  |
|------------------------------|----------|--------------------|-----------------------------------|--|--|--|--|--|--|--|
| CLASS                        | SUBCLASS | CLASS              | SUBCLASS (ONE SUBCLASS PER BLOCK) |  |  |  |  |  |  |  |
|                              |          |                    |                                   |  |  |  |  |  |  |  |
| INTERNATIONAL CLASSIFICATION |          |                    |                                   |  |  |  |  |  |  |  |
|                              | /        |                    |                                   |  |  |  |  |  |  |  |
|                              | /        |                    |                                   |  |  |  |  |  |  |  |
|                              | /        |                    |                                   |  |  |  |  |  |  |  |
|                              | /        |                    |                                   |  |  |  |  |  |  |  |
|                              | /        |                    |                                   |  |  |  |  |  |  |  |
|                              | /        |                    |                                   |  |  |  |  |  |  |  |

**BEST AVAILABLE COPY**

^ Continued on Issue Slip Inside File Jacket

## INDEX OF CLAIMS

|   |                |                                  |         |              |         |          |
|---|----------------|----------------------------------|---------|--------------|---------|----------|
| ✓ | ..... Rejected | - (Through numeral) ... Canceled | N ..... | Non-elected  | A ..... | Appeal   |
| = | ..... Allowed  | + ..... Restricted               | I ..... | Interference | O ..... | Objected |

| Claim | Date |
|-------|------|
| 1     |      |
| 2     |      |
| 3     |      |
| 4     |      |
| 5     |      |
| 6     |      |
| 7     |      |
| 8     |      |
| 9     |      |
| 10    |      |
| 11    |      |
| 12    |      |
| 13    |      |
| 14    |      |
| 15    |      |
| 16    |      |
| 17    |      |
| 18    |      |
| 19    |      |
| 20    |      |
| 21    |      |
| 22    |      |
| 23    |      |
| 24    |      |
| 25    |      |
| 26    |      |
| 27    |      |
| 28    |      |
| 29    |      |
| 30    |      |
| 31    |      |
| 32    |      |
| 33    |      |
| 34    |      |
| 35    |      |
| 36    |      |
| 37    |      |
| 38    |      |
| 39    |      |
| 40    |      |
| 41    |      |
| 42    |      |
| 43    |      |
| 44    |      |
| 45    |      |
| 46    |      |
| 47    |      |
| 48    |      |
| 49    |      |
| 50    |      |

| Claim |          | Date |  |
|-------|----------|------|--|
| Final | Original |      |  |
| 51    |          |      |  |
| 52    |          |      |  |
| 53    |          |      |  |
| 54    |          |      |  |
| 55    |          |      |  |
| 56    |          |      |  |
| 57    |          |      |  |
| 58    |          |      |  |
| 59    |          |      |  |
| 60    |          |      |  |
| 61    |          |      |  |
| 62    |          |      |  |
| 63    |          |      |  |
| 64    |          |      |  |
| 65    |          |      |  |
| 66    |          |      |  |
| 67    |          |      |  |
| 68    |          |      |  |
| 69    |          |      |  |
| 70    |          |      |  |
| 71    |          |      |  |
| 72    |          |      |  |
| 73    |          |      |  |
| 74    |          |      |  |
| 75    |          |      |  |
| 76    |          |      |  |
| 77    |          |      |  |
| 78    |          |      |  |
| 79    |          |      |  |
| 80    |          |      |  |
| 81    |          |      |  |
| 82    |          |      |  |
| 83    |          |      |  |
| 84    |          |      |  |
| 85    |          |      |  |
| 86    |          |      |  |
| 87    |          |      |  |
| 88    |          |      |  |
| 89    |          |      |  |
| 90    |          |      |  |
| 91    |          |      |  |
| 92    |          |      |  |
| 93    |          |      |  |
| 94    |          |      |  |
| 95    |          |      |  |
| 96    |          |      |  |
| 97    |          |      |  |
| 98    |          |      |  |
| 99    |          |      |  |
| 100   |          |      |  |

| Claim |          | Date |  |  |  |  |  |  |
|-------|----------|------|--|--|--|--|--|--|
| Final | Original |      |  |  |  |  |  |  |
|       | 101      |      |  |  |  |  |  |  |
|       | 102      |      |  |  |  |  |  |  |
|       | 103      |      |  |  |  |  |  |  |
|       | 104      |      |  |  |  |  |  |  |
|       | 105      |      |  |  |  |  |  |  |
|       | 106      |      |  |  |  |  |  |  |
|       | 107      |      |  |  |  |  |  |  |
|       | 108      |      |  |  |  |  |  |  |
|       | 109      |      |  |  |  |  |  |  |
|       | 110      |      |  |  |  |  |  |  |
|       | 111      |      |  |  |  |  |  |  |
|       | 112      |      |  |  |  |  |  |  |
|       | 113      |      |  |  |  |  |  |  |
|       | 114      |      |  |  |  |  |  |  |
|       | 115      |      |  |  |  |  |  |  |
|       | 116      |      |  |  |  |  |  |  |
|       | 117      |      |  |  |  |  |  |  |
|       | 118      |      |  |  |  |  |  |  |
|       | 119      |      |  |  |  |  |  |  |
|       | 120      |      |  |  |  |  |  |  |
|       | 121      |      |  |  |  |  |  |  |
|       | 122      |      |  |  |  |  |  |  |
|       | 123      |      |  |  |  |  |  |  |
|       | 124      |      |  |  |  |  |  |  |
|       | 125      |      |  |  |  |  |  |  |
|       | 126      |      |  |  |  |  |  |  |
|       | 127      |      |  |  |  |  |  |  |
|       | 128      |      |  |  |  |  |  |  |
|       | 129      |      |  |  |  |  |  |  |
|       | 130      |      |  |  |  |  |  |  |
|       | 131      |      |  |  |  |  |  |  |
|       | 132      |      |  |  |  |  |  |  |
|       | 133      |      |  |  |  |  |  |  |
|       | 134      |      |  |  |  |  |  |  |
|       | 135      |      |  |  |  |  |  |  |
|       | 136      |      |  |  |  |  |  |  |
|       | 137      |      |  |  |  |  |  |  |
|       | 138      |      |  |  |  |  |  |  |
|       | 139      |      |  |  |  |  |  |  |
|       | 140      |      |  |  |  |  |  |  |
|       | 141      |      |  |  |  |  |  |  |
|       | 142      |      |  |  |  |  |  |  |
|       | 143      |      |  |  |  |  |  |  |
|       | 144      |      |  |  |  |  |  |  |
|       | 145      |      |  |  |  |  |  |  |
|       | 146      |      |  |  |  |  |  |  |
|       | 147      |      |  |  |  |  |  |  |
|       | 148      |      |  |  |  |  |  |  |
|       | 149      |      |  |  |  |  |  |  |
|       | 150      |      |  |  |  |  |  |  |

If more than 150 claims or 9 actions staple additional sheet here

PATENT APPLICATION SERIAL NO. \_\_\_\_\_

U.S. DEPARTMENT OF COMMERCE  
PATENT AND TRADEMARK OFFICE  
FEE RECORD SHEET

01/17/2003 RHEBRAHT 00000014 10342576

|            |           |
|------------|-----------|
| 01 FC:2001 | 375.00 OP |
| 02 FC:2202 | 225.00 OP |

PTO-1556  
(5/87)

**PATENT APPLICATION FEE DETERMINATION RECORD**  
Effective January 1, 2003

Application or Docket Number

3771P004

**CLAIMS AS FILED - PART I**

|                                                           | (Column 1)      | (Column 2)   |
|-----------------------------------------------------------|-----------------|--------------|
| TOTAL CLAIMS                                              | 45              |              |
| FOR                                                       | NUMBER FILED    | NUMBER EXTRA |
| TOTAL CHARGEABLE CLAIMS                                   | 45 minus 20 = * | 25           |
| INDEPENDENT CLAIMS                                        | 3 minus 3 = *   | 0            |
| MULTIPLE DEPENDENT CLAIM PRESENT <input type="checkbox"/> |                 |              |

\* If the difference in column 1 is less than zero, enter "0" in column 2

**CLAIMS AS AMENDED - PART II**

|                    | (Column 1)                                                              | (Column 2)                         | (Column 3)    |
|--------------------|-------------------------------------------------------------------------|------------------------------------|---------------|
| <b>AMENDMENT A</b> | CLAIMS REMAINING AFTER AMENDMENT                                        | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA |
|                    | Total                                                                   | * Minus **                         | =             |
|                    | Independent                                                             | * Minus ***                        | =             |
|                    | FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <input type="checkbox"/> |                                    |               |

|                    | (Column 1)                                                              | (Column 2)                         | (Column 3)    |
|--------------------|-------------------------------------------------------------------------|------------------------------------|---------------|
| <b>AMENDMENT B</b> | CLAIMS REMAINING AFTER AMENDMENT                                        | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA |
|                    | Total                                                                   | * Minus **                         | =             |
|                    | Independent                                                             | * Minus ***                        | =             |
|                    | FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <input type="checkbox"/> |                                    |               |

|                    | (Column 1)                                                              | (Column 2)                         | (Column 3)    |
|--------------------|-------------------------------------------------------------------------|------------------------------------|---------------|
| <b>AMENDMENT C</b> | CLAIMS REMAINING AFTER AMENDMENT                                        | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA |
|                    | Total                                                                   | * Minus **                         | =             |
|                    | Independent                                                             | * Minus ***                        | =             |
|                    | FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <input type="checkbox"/> |                                    |               |

\* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."

\*\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

**SMALL ENTITY TYPE** ☐ OR

**OTHER THAN SMALL ENTITY**

| RATE      | FEE   |
|-----------|-------|
| BASIC FEE | \$375 |
| X\$ 9=    | 225   |
| X42=      |       |
| +140=     |       |
| TOTAL     | 600   |

| RATE      | FEE   |
|-----------|-------|
| BASIC FEE | \$750 |
| X\$18=    |       |
| X84=      |       |
| +280=     |       |
| TOTAL     |       |

**SMALL ENTITY** OR

**OTHER THAN SMALL ENTITY**

| RATE             | ADDITIONAL FEE |
|------------------|----------------|
| X\$ 9=           |                |
| X42=             |                |
| +140=            |                |
| TOTAL ADDIT. FEE |                |

| RATE             | ADDITIONAL FEE |
|------------------|----------------|
| X\$18=           |                |
| X84=             |                |
| +280=            |                |
| TOTAL ADDIT. FEE |                |

| RATE             | ADDITIONAL FEE |
|------------------|----------------|
| X\$ 9=           |                |
| X42=             |                |
| +140=            |                |
| TOTAL ADDIT. FEE |                |

| RATE             | ADDITIONAL FEE |
|------------------|----------------|
| X\$18=           |                |
| X84=             |                |
| +280=            |                |
| TOTAL ADDIT. FEE |                |

| RATE             | ADDITIONAL FEE |
|------------------|----------------|
| X\$ 9=           |                |
| X42=             |                |
| +140=            |                |
| TOTAL ADDIT. FEE |                |

| RATE             | ADDITIONAL FEE |
|------------------|----------------|
| X\$18=           |                |
| X84=             |                |
| +280=            |                |
| TOTAL ADDIT. FEE |                |

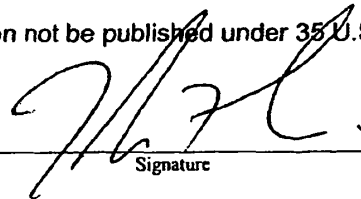
**NONPUBLICATION REQUEST  
UNDER  
35 U.S.C. 122(b)(2)(B)(i)**

|                        |                                                                                           |
|------------------------|-------------------------------------------------------------------------------------------|
| First Named Inventor   | Daniel E. Grupp                                                                           |
| Title                  | Insulated Gate Field Effect Transistor Having Passivated Schottky Barriers To The Channel |
| Attorney Docket Number | 3771P004                                                                                  |

I hereby certify that the invention disclosed in the attached application **has not and will not be** the subject of an application filed in another country, or under a multilateral agreement, that requires publication at eighteen months after filing.

I hereby request that the attached application not be published under 35 U.S.C. 122(b).

01/14/03  
Date

  
Signature

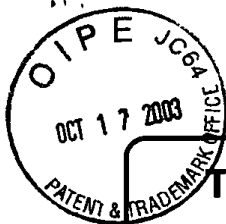
Tarek N. Fahmi, Reg. No. 41,402  
Typed or printed name

This request must be signed in compliance with 37 CFR 1.33(b) and submitted with the application **upon filing**.

Applicant may rescind this nonpublication request at any time. If applicant rescinds a request that an application not be published under 35 U.S.C. 122(b), the application will be scheduled for publication at eighteen months from the earliest claimed filing date for which a benefit is claimed.

If applicant subsequently files an application directed to the invention disclosed in the attached application in another country, or under a multilateral international agreement, that requires publication of applications eighteen months after filing, the applicant **must** notify the United States Patent and Trademark Office of such filing within forty-five (45) days after the date of the filing of such foreign or international application. **Failure to do so will result in abandonment of this application (35 U.S.C. 112(b)(2)(B)(iii)).**

Burden Hour Statement. This collection of information is required by 37 CFR 1.213(a). This information is used by the public to request that an application not be published under 35 U.S.C. 122(b) (and the PTO to process that request). Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This form is estimated to take 6 minutes to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.



RECEIVED

OCT 20 2003

OFFICE OF PETITIONS

DAB

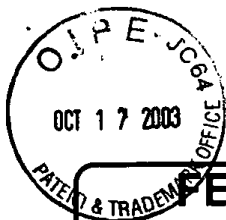
|                                                                                     |                      |                        |          |
|-------------------------------------------------------------------------------------|----------------------|------------------------|----------|
| <b>TRANSMITTAL FORM</b><br>(to be used for all correspondence after initial filing) | Application No.      | 10/342,576             |          |
|                                                                                     | Filing Date          | January 14, 2003       |          |
|                                                                                     | First Named Inventor | Daniel E. Grupp        |          |
|                                                                                     | Art Unit             | 2811                   |          |
|                                                                                     | Examiner Name        |                        |          |
| Total Number of Pages in This Submission                                            | 4                    | Attorney Docket Number | 3771P004 |

| ENCLOSURES (check all that apply)                                            |                                                                                         |                                                                                            |
|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| <input checked="" type="checkbox"/> Fee Transmittal Form                     | <input type="checkbox"/> Drawing(s)                                                     | <input type="checkbox"/> After Allowance Communication to Group                            |
| <input checked="" type="checkbox"/> Fee Attached                             | <input type="checkbox"/> Licensing-related Papers                                       | <input type="checkbox"/> Appeal Communication to Board of Appeals and Interferences        |
| <input type="checkbox"/> Amendment / Response                                | <input checked="" type="checkbox"/> Petition                                            | <input type="checkbox"/> Appeal Communication to Group (Appeal Notice, Brief, Reply Brief) |
| <input type="checkbox"/> After Final                                         | <input type="checkbox"/> Petition to Convert a Provisional Application                  | <input type="checkbox"/> Proprietary Information                                           |
| <input type="checkbox"/> Affidavits/declaration(s)                           | <input type="checkbox"/> Power of Attorney, Revocation Change of Correspondence Address | <input type="checkbox"/> Status Letter                                                     |
| <input type="checkbox"/> Extension of Time Request                           | <input type="checkbox"/> Terminal Disclaimer                                            | <input type="checkbox"/> Other Enclosure(s) (please identify below):                       |
| <input type="checkbox"/> Express Abandonment Request                         | <input type="checkbox"/> Request for Refund                                             |                                                                                            |
| <input type="checkbox"/> Information Disclosure Statement                    | <input type="checkbox"/> CD, Number of CD(s)                                            |                                                                                            |
| <input type="checkbox"/> PTO/SB/08                                           |                                                                                         |                                                                                            |
| <input type="checkbox"/> Certified Copy of Priority Document(s)              |                                                                                         |                                                                                            |
| <input type="checkbox"/> Response to Missing Parts/Incomplete Application    |                                                                                         |                                                                                            |
| <input type="checkbox"/> Basic Filing Fee                                    |                                                                                         |                                                                                            |
| <input type="checkbox"/> Declaration/POA                                     |                                                                                         |                                                                                            |
| <input type="checkbox"/> Response to Missing Parts under 37 CFR 1.52 or 1.53 |                                                                                         |                                                                                            |
| Remarks                                                                      |                                                                                         |                                                                                            |

| SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT |                                                                           |
|--------------------------------------------|---------------------------------------------------------------------------|
| Firm or Individual name                    | Tarek N. Fahmi, Reg. No. 41,402<br>BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP |
| Signature                                  |                                                                           |
| Date                                       | October 14, 2003                                                          |

| CERTIFICATE OF MAILING/TRANSMISSION                                                                                                                                                                                                                                                         |                     |      |                  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|------|------------------|
| I hereby certify that this correspondence is being deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: Mail Stop Petition, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. |                     |      |                  |
| Typed or printed name                                                                                                                                                                                                                                                                       | Jennifer L. Stewart |      |                  |
| Signature                                                                                                                                                                                                                                                                                   |                     | Date | October 14, 2003 |

Based on PTO/SB/21 (08-03) as modified by Blakely, Sokoloff, Taylor & Zafman (wir) 09/11/2003.  
SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450



# FEE TRANSMITTAL for FY 2003

Effective 01/01/2003. Patent fees are subject to annual revision.

☒ Applicant claims small entity status. See 37 CFR 1.27.

TOTAL AMOUNT OF PAYMENT (\$) 665.00

Complete if Known

Application Number 10/342,576  
Filing Date January 14, 2003  
First Named Inventor Daniel E. Grupp  
Examiner Name  
Group/Art Unit 2811  
Attorney Docket No. 3771P004

RECEIVED

OCT 20 2003

OFFICE OF PETITIONS

## METHOD OF PAYMENT (check all that apply)

☒ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None  
☒ Deposit Account

Deposit Account Number

02-2666

Deposit Account Name

Blakely, Sokoloff, Taylor & Zafman LLP

The Commissioner is authorized to: (check all that apply)

☒ Charge fee(s) indicated below ☒ Credit any overpayments  
☒ Charge any additional fee(s) required under 37 CFR §§ 1.16, 1.17, 1.18 and 1.20.  
☐ Charge fee(s) indicated below, except for the filing fee to the above-identified deposit account

## FEE CALCULATION

### 1. BASIC FILING FEE

| Large Entity |          | Small Entity |          | Fee Description        | Fee Paid |
|--------------|----------|--------------|----------|------------------------|----------|
| Fee Code     | Fee (\$) | Fee Code     | Fee (\$) |                        |          |
| 1001         | 770      | 2001         | 385      | Utility filing fee     |          |
| 1002         | 340      | 2002         | 170      | Design filing fee      |          |
| 1003         | 530      | 2003         | 265      | Plant filing fee       |          |
| 1004         | 770      | 2004         | 385      | Reissue filing fee     |          |
| 1005         | 160      | 2005         | 80       | Provisional filing fee |          |
| SUBTOTAL (1) |          |              |          | (\$)                   |          |

### 2. EXTRA CLAIM FEES

Total Claims  - 20\*\* =  X  =   
Independent Claims  - 3 =  X  =   
Multiple Dependent  =

| Large Entity |          | Small Entity |          | Fee Description                                           | Fee Paid |
|--------------|----------|--------------|----------|-----------------------------------------------------------|----------|
| Fee Code     | Fee (\$) | Fee Code     | Fee (\$) |                                                           |          |
| 1202         | 18       | 2202         | 9        | Claims in excess of 20                                    |          |
| 1201         | 86       | 2201         | 43       | Independent claims in excess of 3                         |          |
| 1203         | 290      | 2203         | 145      | Multiple Dependent claim, if not paid                     |          |
| 1204         | 86       | 2204         | 43       | **Reissue independent claims over original patent         |          |
| 1205         | 18       | 2205         | 9        | **Reissue claims in excess of 20 and over original patent |          |
| SUBTOTAL (2) |          |              |          | (\$)                                                      |          |

\*\*or number previously paid, if greater, For Reissues, see below

## FEE CALCULATION (continued)

### 3. ADDITIONAL FEES

| Large Entity              |          | Small Entity |          | Fee Description                                                            | Fee Paid |
|---------------------------|----------|--------------|----------|----------------------------------------------------------------------------|----------|
| Fee Code                  | Fee (\$) | Fee Code     | Fee (\$) |                                                                            |          |
| 1051                      | 130      | 2051         | 65       | Surcharge - late filing fee or oath                                        |          |
| 1052                      | 50       | 2052         | 25       | Surcharge - late provisional filing fee or cover sheet                     |          |
| 2053                      | 130      | 2053         | 130      | Non-English specification                                                  |          |
| 1812                      | 2,520    | 1812         | 2,520    | For filing a request for <i>ex parte</i> reexamination                     |          |
| 1804                      | 920 *    | 1804         | 920 *    | Requesting publication of SIR prior to Examiner action                     |          |
| 1805                      | 1,840 *  | 1805         | 1,840 *  | Requesting publication of SIR after Examiner action                        |          |
| 1251                      | 110      | 2251         | 55       | Extension for reply within first month                                     |          |
| 1252                      | 420      | 2252         | 210      | Extension for reply within second month                                    |          |
| 1253                      | 950      | 2253         | 475      | Extension for reply within third month                                     |          |
| 1254                      | 1,480    | 2254         | 740      | Extension for reply within fourth month                                    |          |
| 1255                      | 1,210    | 2255         | 605      | Extension for reply within fifth month                                     |          |
| 1404                      | 330      | 2401         | 165      | Notice of Appeal                                                           |          |
| 1402                      | 330      | 2402         | 165      | Filing a brief in support of an appeal                                     |          |
| 1403                      | 290      | 2403         | 145      | Request for oral hearing                                                   |          |
| 1451                      | 1,510    | 2451         | 1,510    | Petition to institute a public use proceeding                              |          |
| 1452                      | 110      | 2452         | 55       | Petition to revive - unavoidable                                           |          |
| 1453                      | 1,330    | 2453         | 665      | Petition to revive - unintentional                                         | 665.00   |
| 1501                      | 1,330    | 2501         | 665      | Utility issue fee (or reissue)                                             |          |
| 1502                      | 480      | 2502         | 240      | Design issue fee                                                           |          |
| 1503                      | 640      | 2503         | 320      | Plant issue fee                                                            |          |
| 1460                      | 130      | 2460         | 130      | Petitions to the Commissioner                                              |          |
| 1807                      | 50       | 1807         | 50       | Processing fee under 37 CFR 1.17(q)                                        |          |
| 1806                      | 180      | 1806         | 180      | Submission of Information Disclosure Stmt                                  |          |
| 8021                      | 40       | 8021         | 40       | Recording each patent assignment per property (times number of properties) |          |
| 1809                      | 770      | 1809         | 385      | Filing a submission after final rejection (37 CFR § 1.129(a))              |          |
| 1810                      | 770      | 2810         | 385      | For each additional invention to be examined (37 CFR § 1.129(b))           |          |
| 1801                      | 770      | 2801         | 385      | Request for Continued Examination (RCE)                                    |          |
| 1802                      | 900      | 1802         | 900      | Request for expedited examination of a design application                  |          |
| Other fee (specify) _____ |          |              |          |                                                                            |          |

\* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) (\$) 665.00

## SUBMITTED BY

Name (Print/Type) Tarek N. Fahmy

Signature

Registration No. (Attorney/Agent)

41,402

Complete (if applicable)

Telephone (408) 947-8200

Date

10/14/03

Based on PTO/SB/17 (08-03) as modified by Blakely, Sokoloff, Taylor & Zafman (wlr) 08/11/2003.  
SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450



RECEIVED  
OCT 20 2003  
OFFICE OF PETITIONS

# 2

|                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                |                                          |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|------------------------------------------|
| <b>PETITION FOR REVIVAL OF AN APPLICATION FOR PATENT<br/>ABANDONED FOR FAILURE TO NOTIFY THE OFFICE OF A FOREIGN OR<br/>INTERNATIONAL FILING (37 CFR 1.137(f))</b>                                                                                                                                                                                                                                                                               |                | Docket Number (Optional)<br><br>3771P004 |
| First Named Inventor: Daniel E. Grupp                                                                                                                                                                                                                                                                                                                                                                                                            |                |                                          |
| Application No.: 10/342,576                                                                                                                                                                                                                                                                                                                                                                                                                      | Art Unit: 2811 |                                          |
| Filed: January 14, 2003                                                                                                                                                                                                                                                                                                                                                                                                                          | Examiner:      |                                          |
| Title: Insulated Gate Field Effect Transistor Having Passivated Schottky Barriers To The Channel                                                                                                                                                                                                                                                                                                                                                 |                |                                          |
| Attention: Office of Petitions<br><b>Mail Stop Petition</b><br>Commissioner for Patents<br>P.O. Box 1450<br>Alexandria, VA 22313-1450<br>FAX: (703) 308-6916                                                                                                                                                                                                                                                                                     |                |                                          |
| NOTE: If information or assistance is needed in completing this form, please contact Petitions Information at (703) 305-9283                                                                                                                                                                                                                                                                                                                     |                |                                          |
| The above-identified application became abandoned pursuant to 35 U.S.C. 122(b)(2)(B)(iii) for failure to timely notify the Office of the filing of an application in a foreign country or under a multinational international treaty that requires publication of applications eighteen months after filing. The date of abandonment is the day after the expiration date of the forty-five (45) day period set in 35 U.S.C. 122(b)(2)(B)(iii) . |                |                                          |
| PURSUANT TO 37 CFR 1.137(f), APPLICANT HEREBY PETITIONS FOR REVIVAL OF THIS APPLICATION<br>UNDER 37 CFR 1.137(b)                                                                                                                                                                                                                                                                                                                                 |                |                                          |
| 1. Petition fee                                                                                                                                                                                                                                                                                                                                                                                                                                  |                |                                          |
| <input checked="" type="checkbox"/> Small entity-fee \$ <u>665.00</u> (37 CFR 1.17(m)). Applicant claims small entity status. See 37 CFR 1.27.                                                                                                                                                                                                                                                                                                   |                |                                          |
| <input type="checkbox"/> Other than small entity - fee \$_____ (37 CFR 1.17(m)).                                                                                                                                                                                                                                                                                                                                                                 |                |                                          |
| 2. Notice of Foreign or International Filing (35 U.S.C. 122(b)(2)(B)(iii) and 37 CFR 1.213(c))                                                                                                                                                                                                                                                                                                                                                   |                |                                          |
| Subsequent to the filing of the above-identified application, an application was filed in another country, or under a multinational international treaty (e.g., filed under the Patent Cooperation Treaty), that requires publication of applications eighteen months after filing. The filing date of the subsequently filed foreign or international application is <u>August 8, 2003</u> .                                                    |                |                                          |

SEND TO: Mail Stop Petition, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.  
Based on Form PTO/SB/64a (05-03) as modified by BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP on 5/13/03.

10/20/2003 AWONDAF1 00000113 10342576

[Page 1 of 2]

01 FC:2453

665.00 DP

STATEMENT: The entire delay in filing the required notice of a foreign or international filing from the due date for the required notice until the filing of a grantable petition under 37 CFR 1.137(b) was unintentional.

[NOTE: The United States Patent and Trademark Office may require additional information if there is a question as to whether either the abandonment or the delay in filing a petition under 37 CFR 1.137(b) was unintentional (MPEP 711.03(c), subsections (III)(C) and (D))].

**WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2039.**

October 14, 2003

Date

Telephone

Number: (408) 947-8200

  
Signature

Tarek N. Fahmi, Reg. No. 41,402

Typed or printed name & Registration No.

Blakely, Sokoloff, Taylor & Zafman LLP  
12400 Wilshire Boulevard, 7th Floor  
Los Angeles, CA 90025

Enclosures: ☒ Fee Payment  
☐ Additional sheets containing statements establishing unintentional delay  
☐ Other:

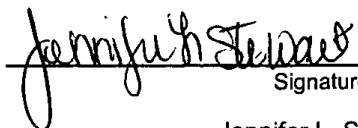
CERTIFICATE OF MAILING OR TRANSMISSION [37 CFR 1.8(a)]

I hereby certify that this correspondence is being:

- ☒ deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: Mail Stop Petition, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313.1450.
- ☐ transmitted by facsimile on the date shown below to the United States Patent and Trademark Office at (703) 308-6916.

October 14, 2003

Date

  
Signature

Jennifer L. Stewart

Typed or printed name of person signing certificate



Paper No. 3

BLAKELY SOKOLOFF TAYLOR & ZAFMAN  
12400 WILSHIRE BOULEVARD, SEVENTH FLOOR  
LOS ANGELES, CA 90025

**COPY MAILED**

**OCT 3 1 2003**

In re Application of  
Danie E. Grupp, et al.  
Application No. 10/342,576  
Filed: January 14, 2003  
Attorney Docket No. 3771P004

**OFFICE OF PETITIONS**

DECISION GRANTING PETITION  
UNDER 37 CFR 1.137(b)

This is a decision on the petition, filed October 17, 2003, which is being treated as a petition under 37 CFR 1.137(b) to revive the instant nonprovisional application for failure to timely notify the U.S. Patent and Trademark (USPTO) of the filing of an application in a foreign country, or under a multinational treaty that requires publication of applications eighteen months after filing. *See* 37 CFR 1.137(f).

The petition is **GRANTED**.

Petitioner states that the instant nonprovisional application is the subject of an application filed in an eighteen month publication country on August 8, 2003. However, the USPTO was unintentionally not notified of this filing within 45 days subsequent to the filing of the subject application in an eighteen month publication country.

In view of the above, this application became abandoned pursuant to 35 U.S.C. § 122(b)(2)(B)(iii) and 37 CFR 1.213(c) for failure to timely notify the Office of the filing of an application in a foreign country or under a multilateral international agreement that requires publication of applications 18 months after filing.

A petition to revive an application abandoned pursuant to 35 U.S.C. 122(b)(2)(B)(iii) for failure to notify the USPTO of a foreign filing must be accompanied by:

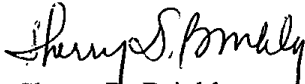
- (1) the required reply which is met by the notification of such filing in a foreign country or under a multinational treaty;
- (2) the petition fee as set forth in 37 CFR 1.17(m); and
- (3) a statement that the entire delay in filing the required reply from the due date of the reply until the filing of a grantable petition was unintentional.

The instant petition has been found to be in compliance with 37 CFR 1.137(b). Accordingly, the failure to timely notify the USPTO of a foreign or international filing within 45 days after the date of filing of such foreign or international application as provided by 35 U.S.C. § 122(b)(2)(B)(iii) and 37 CFR 1.213(c) is accepted as having been unintentionally delayed.

The previous Request and Certification under 35 U.S.C. § 122(b)(2)(B)(i) has been rescinded. A Notice Regarding Rescission of Nonpublication Request which sets forth the projected publication date of February 12, 2004 accompanies this decision on petition.

Any inquiries concerning this decision may be directed to the undersigned at (703) 305-9220.

This application is being forwarded to Technology Center Art Unit 2811 for examination in due course.



Sherry D. Brinkley  
Petitions Examiner  
Office of Petitions  
Office of the Deputy Commissioner  
for Patent Examination Policy

ATTACHMENT: Notice Regarding Rescission of Nonpublication Request



## UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
 United States Patent and Trademark Office  
 Address: COMMISSIONER FOR PATENTS  
 P.O. Box 1450  
 Alexandria, Virginia 22313-1450  
 www.uspto.gov

| APPLICATION NUMBER | FILING/RECEIPT DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO. |
|--------------------|---------------------|-----------------------|------------------|
| 10/342,576         | 01/14/2003          | Daniel E. Grupp       | 3771P004         |

CONFIRMATION NO. 9775

08791

BLAKELY SOKOLOFF TAYLOR & ZAFMAN  
 12400 WILSHIRE BOULEVARD, SEVENTH FLOOR  
 LOS ANGELES, CA 90025



\*OC000000011150420\*

Date Mailed: 10/31/2003

### Communication Regarding Rescission Of Nonpublication Request and/or Notice of Foreign Filing

Applicant's rescission of the previously-filed nonpublication request and/or notice of foreign filing is acknowledged. The paper has been reflected in the Patent and Trademark Office's (USPTO's) computer records so that the earliest possible projected publication date can be assigned.

The projected publication date is 02/12/2004.

If applicant rescinded the nonpublication request before or on the date of "foreign filing,"<sup>1</sup> then no notice of foreign filing is required.

If applicant foreign filed the application after filing the above application and before filing the rescission, and the rescission did not also include a notice of foreign filing, then a notice of foreign filing (not merely a rescission) is required to be filed within 45 days of the date of foreign filing. See 35 U.S.C. § 122(b)(2)(B)(iii), and Clarification of the United States Patent and Trademark Office's Interpretation of the Provisions of 35 U.S.C. § 122(b)(2)(B)(ii)-(iv), 1272 Off. Gaz. Pat. Office 22 (July 1, 2003).

If a notice of foreign filing is required and is not filed within 45 days of the date of foreign filing, then the application becomes abandoned pursuant to 35 U.S.C. § 122(b)(2)(B)(iii). In this situation, applicant should either file a petition to revive or notify the Office that the application is abandoned. See 37 CFR 1.137(f). Any such petition to revive will be forwarded to the Office of Petitions for a decision. Note that the filing of the petition will not operate to stay any period of reply that may be running against the application.

Questions regarding petitions to revive should be directed to the Office of Petitions at (703) 305-9282. Questions regarding publications of patent applications should be directed to the patent application publication hotline at (703) 605-4283 or by e-mail [pgpub@uspto.gov](mailto:pgpub@uspto.gov).

<sup>1</sup> Note, for purpose of this notice, that "foreign filing" means "filing an application directed to the same invention in another country, or under a multilateral international agreement, that requires publication of applications 18 months after filing".



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
| 10/342,576      | 01/14/2003  | Daniel E. Grupp      | 3771P004            | 9775             |

8791 7590 12/09/2003

BLAKELY SOKOLOFF TAYLOR & ZAFMAN  
12400 WILSHIRE BOULEVARD, SEVENTH FLOOR  
LOS ANGELES, CA 90025

EXAMINER

KANG, DONGHEE

| ART UNIT | PAPER NUMBER |
|----------|--------------|
|----------|--------------|

2811

DATE MAILED: 12/09/2003

Please find below and/or attached an Office communication concerning this application or proceeding.

22

|                              |                                      |                                     |  |
|------------------------------|--------------------------------------|-------------------------------------|--|
| <b>Office Action Summary</b> | <b>Application No.</b><br>10/342,576 | <b>Applicant(s)</b><br>GRUPP ET AL. |  |
|                              | <b>Examiner</b><br>Donghee Kang      | <b>Art Unit</b><br>2811             |  |

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 1 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

- 1) ☒ Responsive to communication(s) filed on 14 January 2003.
- 2a) ☐ This action is FINAL.                      2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

- 4) ☒ Claim(s) 1-45 is/are pending in the application.
- 4a) Of the above claim(s) \_\_\_\_\_ is/are withdrawn from consideration.
- 5) ☐ Claim(s) \_\_\_\_\_ is/are allowed.
- 6) ☐ Claim(s) \_\_\_\_\_ is/are rejected.
- 7) ☐ Claim(s) \_\_\_\_\_ is/are objected to.
- 8) ☒ Claim(s) 1-45 are subject to restriction and/or election requirement.

**Application Papers**

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☐ The drawing(s) filed on \_\_\_\_\_ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.  
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).  
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. §§ 119 and 120**

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).  
a) ☐ All   b) ☐ Some \* c) ☐ None of:  
1. ☐ Certified copies of the priority documents have been received.  
2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.  
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).  
\* See the attached detailed Office action for a list of the certified copies not received.
- 13) ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application) since a specific reference was included in the first sentence of the specification or in an Application Data Sheet. 37 CFR 1.78.  
a) ☐ The translation of the foreign language provisional application has been received.
- 14) ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121 since a specific reference was included in the first sentence of the specification or in an Application Data Sheet. 37 CFR 1.78.

**Attachment(s)**

- |                                                                                              |                                                                             |
|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| 1) <input type="checkbox"/> Notice of References Cited (PTO-892)                             | 4) <input type="checkbox"/> Interview Summary (PTO-413) Paper No(s). _____  |
| 2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948)         | 5) <input type="checkbox"/> Notice of Informal Patent Application (PTO-152) |
| 3) <input type="checkbox"/> Information Disclosure Statement(s) (PTO-1449) Paper No(s) _____ | 6) <input type="checkbox"/> Other: _____                                    |

**DETAILED ACTION**

***Election/Restrictions***

1. Restriction to one of the following inventions is required under 35 U.S.C. 121:

I. Claims 1-16 & 34-45, drawn to a semiconductor device, classified in class 257, subclass 330.

II. Claims 17-33, drawn to a method of making a semiconductor device, classified in class 438, subclass 259.

2. The inventions are distinct, each from the other because of the following reasons: Inventions II and I are related as process of making and product made. The inventions are distinct if either or both of the following can be shown: (1) that the process as claimed can be used to make other and materially different product or (2) that the product as claimed can be made by another and materially different process (MPEP § 806.05(f)). In the instant case, the product as claimed can be made by reverse order, such as forming source/drain terminal, forming interface layer and then forming channel.

3. Because these inventions are distinct for the reasons given above and have acquired a separate status in the art as shown by their different classification, the search required for Group I is not required for Group II, and separated examination would be required, restriction for examination purposes as indicated is proper.

4. Applicant is advised that the reply to this requirement to be complete must include an election of the invention to be examined even though the requirement be traversed (37 CFR 1.143).

5. Applicant is reminded that upon the cancellation of claims to a non-elected invention, the inventorship must be amended in compliance with 37 CFR 1.48(b) if one or more of the currently named inventors is no longer an inventor of at least one claim remaining in the application. Any amendment of inventorship must be accompanied by a request under 37 CFR 1.48(b) and by the fee required under 37 CFR 1.17(i).

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Donghee Kang whose telephone number is 703-305-9147. The examiner can normally be reached on Maxiflex.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Eddie C Lee can be reached on 703-308-1690. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-0956.



Donghee Kang  
Examiner  
Art Unit 2811

dhk



2811

|                                                                                     |   |                        |                  |
|-------------------------------------------------------------------------------------|---|------------------------|------------------|
| <b>TRANSMITTAL FORM</b><br>(to be used for all correspondence after initial filing) |   | Application No.        | 10/342,576       |
|                                                                                     |   | Filing Date            | January 14, 2003 |
|                                                                                     |   | First Named Inventor   | Daniel E. Grupp  |
|                                                                                     |   | Art Unit               | 2811             |
|                                                                                     |   | Examiner Name          | Kang, Donghee    |
| Total Number of Pages in This Submission                                            | 7 | Attorney Docket Number | 3771P004         |

| ENCLOSURES (check all that apply)                                            |                                                                                          |                                                                                            |
|------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Fee Transmittal Form                                | <input type="checkbox"/> Drawing(s)                                                      | <input type="checkbox"/> After Allowance Communication to Group                            |
| <input type="checkbox"/> Fee Attached                                        | <input type="checkbox"/> Licensing-related Papers                                        | <input type="checkbox"/> Appeal Communication to Board of Appeals and Interferences        |
| <input checked="" type="checkbox"/> Amendment / Response                     | <input type="checkbox"/> Petition                                                        | <input type="checkbox"/> Appeal Communication to Group (Appeal Notice, Brief, Reply Brief) |
| <input type="checkbox"/> After Final                                         | <input type="checkbox"/> Petition to Convert a Provisional Application                   | <input type="checkbox"/> Proprietary Information                                           |
| <input type="checkbox"/> Affidavits/declaration(s)                           | <input type="checkbox"/> Power of Attorney, Revocation, Change of Correspondence Address | <input type="checkbox"/> Status Letter                                                     |
| <input type="checkbox"/> Extension of Time Request                           | <input type="checkbox"/> Terminal Disclaimer                                             | <input type="checkbox"/> Other Enclosure(s) (please identify below):                       |
| <input type="checkbox"/> Express Abandonment Request                         | <input type="checkbox"/> Request for Refund                                              |                                                                                            |
| <input type="checkbox"/> Information Disclosure Statement                    | <input type="checkbox"/> CD, Number of CD(s)                                             |                                                                                            |
| <input type="checkbox"/> PTO/SB/08                                           |                                                                                          |                                                                                            |
| <input type="checkbox"/> Certified Copy of Priority Document(s)              |                                                                                          |                                                                                            |
| <input type="checkbox"/> Response to Missing Parts/Incomplete Application    | Remarks                                                                                  |                                                                                            |
| <input type="checkbox"/> Basic Filing Fee                                    |                                                                                          |                                                                                            |
| <input type="checkbox"/> Declaration/POA                                     |                                                                                          |                                                                                            |
| <input type="checkbox"/> Response to Missing Parts under 37 CFR 1.52 or 1.53 |                                                                                          |                                                                                            |

| SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT |                                                                            |
|--------------------------------------------|----------------------------------------------------------------------------|
| Firm or Individual name                    | Tarek N. Fahmi / Reg. No. 41,402<br>BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP |
| Signature                                  |                                                                            |
| Date                                       | January 9, 2004                                                            |

| CERTIFICATE OF MAILING/TRANSMISSION                                                                                                                                                                                                                                                                  |                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| I hereby certify that this correspondence is being deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: Mail Stop Non-Fee Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. |                    |
| Typed or printed name                                                                                                                                                                                                                                                                                | Patricia A. Balero |
| Signature                                                                                                                                                                                                                                                                                            |                    |
| Date                                                                                                                                                                                                                                                                                                 | January 9, 2004    |

Based on PTO/SB/21 (08-03) as modified by Blakely, Sokoloff, Taylor & Zafman (wtr) 09/11/2003.  
SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450

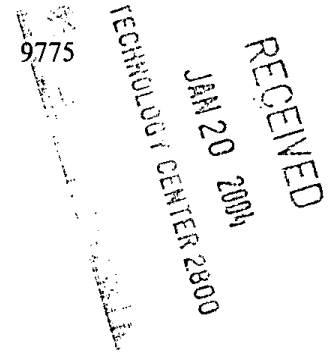


IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No. : 10/342,576  
Applicant : Daniel E. Grupp  
Filed : January 14, 2003  
TC/A.U. : 2811  
Examiner : Kang, Donghee

Confirmation No.: 9775

Docket No. : 3771P004  
Customer No. : 08791



Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

RESPONSE TO RESTRICTION REQUIREMENT

Sir:

In response to the restriction requirement mailed December 9, 2003, please amend the above-identified application as follows:

**Amendment to the Claims** are reflected in the listing of claims which begins on page 2 of this paper.

**Remarks/Arguments** begin on page 6 of this paper.

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail with sufficient postage in an envelope addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231

on January 9, 2004  
Date of Deposit  
Patricia A. Balero  
Name of Person Mailing Correspondence  
[Signature] 1/9/04  
Signature Date

1. (Original) A transistor, comprising a semiconductor channel disposed (i) nearby a gate configured to control conductance within the channel and (ii) in an electrical path between a source and a drain, at least one of which is made of a metal, wherein the channel and whichever of the source and/or the drain is/are made of the metal is/are separated by an interface layer so as to form a channel – interface layer – source/drain junction in which a Fermi level of the semiconductor channel is depinned in a region near the junction and the junction has a specific contact resistance of less than approximately  $1000 \Omega\text{-}\mu\text{m}^2$ .
2. (Original) The transistor of claim 1 wherein the semiconductor channel is made of one of Si, Ge, SiGe, SiGeC, or SiC.
3. (Original) The transistor of claim 1 wherein the metal comprises one of a pure metal, an alloy, or a refractory metal.
4. (Original) The transistor of claim 1 wherein the metal comprises aluminum.
5. (Original) The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $100 \Omega\text{-}\mu\text{m}^2$ .
6. (Original) The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $50 \Omega\text{-}\mu\text{m}^2$ .
7. (Original) The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $10 \Omega\text{-}\mu\text{m}^2$ .
8. (Original) The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $1 \Omega\text{-}\mu\text{m}^2$ .

9. (Original) The transistor of claim 1 wherein the interface layer includes a passivating material.

10. (Original) The transistor of claim 9 wherein the passivating material comprises one or more of a nitride of the semiconductor of the channel, a fluoride of the semiconductor of the channel, an oxide of the semiconductor of the channel, an oxynitride of the semiconductor of the channel, a hydride of the semiconductor of the channel and/or an arsenide of the semiconductor of the channel.

11. (Original) The transistor of claim 10 wherein the interface layer consists essentially of an amount of passivating material sufficient to terminate enough dangling bonds of a surface of the semiconductor channel so as to achieve chemical stability of the surface.

12. (Original) The transistor of claim 10 wherein the interface layer consists essentially of a monolayer configured to depin the Fermi level of the semiconductor of the channel.

13. (Original) The transistor of claim 12 wherein the interface layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.

14. (Original) The transistor of claim 9 wherein the interface layer further includes a separation layer.

15. (Original) The transistor of claim 14 wherein the separation layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.

16. The transistor of claim 1 wherein the semiconductor channel is separated from the gate by a dielectric.

17 – 33 (Cancelled)

34. (Original) An electrical system comprising a circuit coupled to a transistor having a semiconductor channel disposed nearby a gate and in an electrical path between a source and a drain, at least one of which is made of a metal, wherein the channel and whichever of the source and/or the drain is/are made of the metal is/are separated by an interface layer so as to form a channel – interface layer – source/drain junction in which a Fermi level of the semiconductor channel is depinned in a region near the junction and the junction has a specific contact resistance of less than approximately  $1000 \Omega\text{-}\mu\text{m}^2$ .

35. (Original) The electrical system of claim 34 wherein the semiconductor channel is separated from the gate by a dielectric.

36. (Original) The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately  $100 \Omega\text{-}\mu\text{m}^2$ .

37. (Original) The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately  $50 \Omega\text{-}\mu\text{m}^2$ .

38. (Original) The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately  $10 \Omega\text{-}\mu\text{m}^2$ .

39. (Original) The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately  $1 \Omega\text{-}\mu\text{m}^2$ .

40. (Original) The electrical system of claim 35 wherein the semiconductor channel is made of one of Si, Ge, SiGe, SiGeC, or SiC.

41. The electrical system of claim 35 wherein the interface layer includes a passivating material.

42. (Original) The electrical system of claim 41 wherein the interface layer includes a separation layer comprising a material different than the passivation material.

43. (Original) The electrical system of claim 41 wherein the interface layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.

44. (Original) The electrical system of claim 41 wherein the interface layer comprises an amount of passivating material sufficient to terminate all or a sufficient number of dangling bonds of the semiconductor channel to achieve chemical stability of a surface of the semiconductor channel in the region near the junction.

45. (Original) The electrical system of claim 44 wherein amount of passivating material comprises a monolayer.

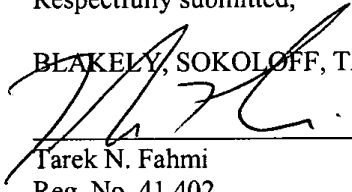
Applicant hereby elects claims 1-16 and 34-45 (Group 1) for prosecution in this application. Please cancel claims 17-33 without prejudice.

If there are any additional charges, please charge Deposit Account No. 02-2666.

Respectfully submitted,

BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP

Date: 1/9, 2004

  
Tarek N. Fahmi  
Reg. No. 41,402

12400 Wilshire Blvd.  
Seventh Floor  
Los Angeles, CA 90025-1026  
(408) 947.8200

| L<br>Number | Hits | Search Text                                                                                                                                                                                                                                                                                                                                                                                                                                                           | DB                                                      | Time stamp          |
|-------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|---------------------|
| 1           | 30   | ((("3116427") or ("4631352") or ("4675711") or ("4751563") or ("4837604") or ("4935804") or ("5019530") or ("5258625") or ("5291274") or ("5401980") or ("5422496") or ("5475341") or ("5589692") or ("5596206") or ("5604154") or ("5608231") or ("5612233") or ("5646420") or ("5646559") or ("5665979") or ("5677637") or ("5705827") or ("5710051") or ("5731598") or ("5754077") or ("5834793") or ("5844279") or ("5877511") or ("5963471") or ("5972744")).PN. | USPAT                                                   | 2004/02/03<br>12:23 |
| 2           | 674  | 257/25,27,104.ccls.                                                                                                                                                                                                                                                                                                                                                                                                                                                   | USPAT;<br>US-PGPUB;<br>EPO; JPO;<br>DERWENT;<br>IBM_TDB | 2004/02/03<br>12:24 |
| -           | 1067 | 257/330,332.ccls.                                                                                                                                                                                                                                                                                                                                                                                                                                                     | USPAT;<br>US-PGPUB;<br>EPO; JPO;<br>DERWENT;<br>IBM_TDB | 2004/02/03<br>10:13 |
| -           | 21   | ((("3590471") or ("3708360") or ("4300152") or ("4485550") or ("5399206") or ("5612567") or ("5663584") or ("5801398") or ("5888891") or ("5939763") or ("6037605") or ("6096590") or ("6150286") or ("6198113") or ("6207976") or ("6261932") or ("6291866") or ("6291867") or ("6303479") or ("5596218") or ("5578848")).PN.                                                                                                                                        | USPAT                                                   | 2004/02/03<br>10:19 |
| -           | 1550 | transistor and fermi adj1 level                                                                                                                                                                                                                                                                                                                                                                                                                                       | USPAT;<br>US-PGPUB;<br>EPO; JPO;<br>DERWENT;<br>IBM_TDB | 2004/02/03<br>10:22 |
| -           | 30   | ((transistor and fermi adj1 level) and metal) and interface adj1 layer                                                                                                                                                                                                                                                                                                                                                                                                | USPAT;<br>US-PGPUB;<br>EPO; JPO;<br>DERWENT;<br>IBM_TDB | 2004/02/03<br>10:22 |
| -           | 1187 | (transistor and fermi adj1 level) and metal                                                                                                                                                                                                                                                                                                                                                                                                                           | USPAT;<br>US-PGPUB;<br>EPO; JPO;<br>DERWENT;<br>IBM_TDB | 2004/02/03<br>11:15 |
| -           | 12   | depinned                                                                                                                                                                                                                                                                                                                                                                                                                                                              | USPAT;<br>US-PGPUB;<br>EPO; JPO;<br>DERWENT;<br>IBM_TDB | 2004/02/03<br>11:16 |
| -           | 1195 | 257/24,30,37,38,39.ccls.                                                                                                                                                                                                                                                                                                                                                                                                                                              | USPAT;<br>US-PGPUB;<br>EPO; JPO;<br>DERWENT;<br>IBM_TDB | 2004/02/03<br>12:19 |



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NO.                                                                                      | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|------------------------------------------------------------------------------------------------------|-------------|----------------------|---------------------|------------------|
| 10/342,576                                                                                           | 01/14/2003  | Daniel E. Grupp      | 3771P004            | 9775             |
| 8791                                                                                                 | 7590        | 02/13/2004           | EXAMINER            |                  |
| BLAKELY SOKOLOFF TAYLOR & ZAFMAN<br>12400 WILSHIRE BOULEVARD, SEVENTH FLOOR<br>LOS ANGELES, CA 90025 |             |                      | KANG, DONGHEE       |                  |
|                                                                                                      |             |                      | ART UNIT            | PAPER NUMBER     |
|                                                                                                      |             |                      | 2811                |                  |
| DATE MAILED: 02/13/2004                                                                              |             |                      |                     |                  |

Please find below and/or attached an Office communication concerning this application or proceeding.

AKC

|                              |                               |                              |  |
|------------------------------|-------------------------------|------------------------------|--|
| <b>Office Action Summary</b> | Application No.<br>10/342,576 | Applicant(s)<br>GRUPP ET AL. |  |
|                              | Examiner<br>Donghee Kang      | Art Unit<br>2811             |  |

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

- 1) ☒ Responsive to communication(s) filed on 12 January 2004.
- 2a) ☐ This action is **FINAL**.                      2b) ☒ This action is non-final.
- 3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

- 4) ☒ Claim(s) 1-16 and 34-42 is/are pending in the application.
- 4a) Of the above claim(s) \_\_\_\_\_ is/are withdrawn from consideration.
- 5) ☐ Claim(s) \_\_\_\_\_ is/are allowed.
- 6) ☒ Claim(s) 1-13, 16, 34-41 and 43-45 is/are rejected.
- 7) ☒ Claim(s) 14, 15 and 42 is/are objected to.
- 8) ☐ Claim(s) \_\_\_\_\_ are subject to restriction and/or election requirement.

**Application Papers**

- 9) ☐ The specification is objected to by the Examiner.
- 10) ☒ The drawing(s) filed on 14 January 2003 is/are: a) ☐ accepted or b) ☒ objected to by the Examiner.  
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).  
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
- 11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All    b) ☐ Some \*    c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).
- \* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

- |                                                                                                                        |                                                                                         |
|------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| 1) <input checked="" type="checkbox"/> Notice of References Cited (PTO-892)                                            | 4) <input type="checkbox"/> Interview Summary (PTO-413)<br>Paper No(s)/Mail Date. _____ |
| 2) <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948)                                   | 5) <input type="checkbox"/> Notice of Informal Patent Application (PTO-152)             |
| 3) <input type="checkbox"/> Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08)<br>Paper No(s)/Mail Date _____ | 6) <input type="checkbox"/> Other: _____                                                |

## **DETAILED ACTION**

### ***Continuing Domestic Data***

1. Acknowledgment is made that this application is a continuation-in-part of Application Serial No. 10/217,758, filed 12 August 2002.

### ***Election/Restrictions***

2. Applicant's election without traverse of Group I (Claims 1-16 & 34-45) filed January 12, 2004 is acknowledged. Claims 17-33 are cancelled.

### ***Drawings***

3. The drawings are objected to under 37 CFR 1.83(a). The drawings must show every feature of the invention specified in the claims. Therefore, the limitation "the interface layer further includes a separation layer" in claims 14 & 42 must be shown or the feature(s) canceled from the claim(s). No new matter should be entered.

A proposed drawing correction or corrected drawings are required in reply to the Office action to avoid abandonment of the application. The objection to the drawings will not be held in abeyance.

### ***Claim Rejections - 35 USC § 102***

4. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

5. Claims 1-13, 16, 34-41 & 43-45 are rejected under 35 U.S.C. 102(b) as being anticipated by Grupp (US 6,198,113).

Re claims 1, 5-8, 34 & 36-39, Grupp teaches a transistor (Fig.1), comprising a semiconductor channel (26) disposed nearby a gate (24) configured to control conductance within the channel and in an electrical path between a source (28) and a drain (30), at least one of which is made of a metal, where the channel and whichever of the source and the drain are made of the metal are separated by an interface layer (34 & 36) so as to form a channel-interface layer-source/drain junction in which a Fermi level of the semiconductor channel is depinned in a region near the junction and the junction has a specific contact resistance of less than approximately 1000  $\Omega$ . Col.4, line 61 – Col.6, line 58.

Re claims 2 & 40, Grupp teaches the semiconductor channel is made of Si.

Re claim 3, Grupp teaches the metal comprises metal.

Re claim 4, Grupp teaches the metal comprises aluminum.

Re claims 9-13, 41 & 43-45, Grupp teaches the interface layer comprises an oxide of the semiconductor of the channel.

Re claims 16 & 35, Grupp teaches the semiconductor channel is separated from the gate by a dielectric (22).

***Allowable Subject Matter***

6. Claims 14-15 & 42 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Grupp fails to teach or suggest the interface layer includes a separation layer comprising a material different than the passivation material.

**Conclusion**

7. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Donghee Kang whose telephone number is 571-272-1656. The examiner can normally be reached on Maxiflex.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Eddie C Lee can be reached on 703-308-1690. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

  
Donghee Kang  
Examiner  
Art Unit 2811

dhk

|                                   |                                       |  |                                                            |             |
|-----------------------------------|---------------------------------------|--|------------------------------------------------------------|-------------|
| <b>Notice of References Cited</b> | Application/Control No.<br>10/342,576 |  | Applicant(s)/Patent Under<br>Reexamination<br>GRUPP ET AL. |             |
|                                   | Examiner<br>Donghee Kang              |  | Art Unit<br>2811                                           | Page 1 of 1 |

**U.S. PATENT DOCUMENTS**

| * |   | Document Number<br>Country Code-Number-Kind Code | Date<br>MM-YYYY | Name             | Classification |
|---|---|--------------------------------------------------|-----------------|------------------|----------------|
|   | A | US-6,198,113                                     | 03-2001         | Grupp, Daniel E. | 257/39         |
|   | B | US-                                              |                 |                  |                |
|   | C | US-                                              |                 |                  |                |
|   | D | US-                                              |                 |                  |                |
|   | E | US-                                              |                 |                  |                |
|   | F | US-                                              |                 |                  |                |
|   | G | US-                                              |                 |                  |                |
|   | H | US-                                              |                 |                  |                |
|   | I | US-                                              |                 |                  |                |
|   | J | US-                                              |                 |                  |                |
|   | K | US-                                              |                 |                  |                |
|   | L | US-                                              |                 |                  |                |
|   | M | US-                                              |                 |                  |                |

**FOREIGN PATENT DOCUMENTS**

| * |   | Document Number<br>Country Code-Number-Kind Code | Date<br>MM-YYYY | Country | Name | Classification |
|---|---|--------------------------------------------------|-----------------|---------|------|----------------|
|   | N |                                                  |                 |         |      |                |
|   | O |                                                  |                 |         |      |                |
|   | P |                                                  |                 |         |      |                |
|   | Q |                                                  |                 |         |      |                |
|   | R |                                                  |                 |         |      |                |
|   | S |                                                  |                 |         |      |                |
|   | T |                                                  |                 |         |      |                |

**NON-PATENT DOCUMENTS**

| * |   | Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages) |
|---|---|-------------------------------------------------------------------------------------------|
|   | U |                                                                                           |
|   | V |                                                                                           |
|   | W |                                                                                           |
|   | X |                                                                                           |

\*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)  
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

1  
 2  
 3  
 4  
 5  
 6  
 7  
 8  
 9  
 10  
 11  
 12  
 13  
 14  
 15  
 16  
 17  
 18  
 19  
 20  
 21  
 22  
 23  
 24  
 25  
 26  
 27  
 28  
 29  
 30  
 31  
 32  
 33  
 34  
 35  
 36  
 37  
 38  
 39  
 40  
 41  
 42  
 43  
 44  
 45  
 46  
 47  
 48  
 49  
 50  
 51  
 52  
 53  
 54  
 55  
 56  
 57  
 58  
 59  
 60  
 61  
 62  
 63  
 64  
 65  
 66  
 67  
 68  
 69  
 70  
 71  
 72  
 73  
 74  
 75  
 76  
 77  
 78  
 79  
 80  
 81  
 82  
 83  
 84  
 85  
 86  
 87  
 88  
 89  
 90  
 91  
 92  
 93  
 94  
 95  
 96  
 97  
 98  
 99  
 100  
 101  
 102  
 103  
 104  
 105  
 106  
 107  
 108  
 109  
 110  
 111  
 112  
 113  
 114  
 115  
 116  
 117  
 118  
 119  
 120  
 121  
 122  
 123  
 124  
 125  
 126  
 127  
 128  
 129  
 130  
 131  
 132  
 133  
 134  
 135  
 136  
 137  
 138  
 139  
 140  
 141  
 142  
 143  
 144  
 145  
 146  
 147  
 148  
 149  
 150  
 151  
 152  
 153  
 154  
 155  
 156  
 157  
 158  
 159  
 160  
 161  
 162  
 163  
 164  
 165  
 166  
 167  
 168  
 169  
 170  
 171  
 172  
 173  
 174  
 175  
 176  
 177  
 178  
 179  
 180  
 181  
 182  
 183  
 184  
 185  
 186  
 187  
 188  
 189  
 190  
 191  
 192  
 193  
 194  
 195  
 196  
 197  
 198  
 199  
 200  
 201  
 202  
 203  
 204  
 205  
 206  
 207  
 208  
 209  
 210  
 211  
 212  
 213  
 214  
 215  
 216  
 217  
 218  
 219  
 220  
 221  
 222  
 223  
 224  
 225  
 226  
 227  
 228  
 229  
 230  
 231  
 232  
 233  
 234  
 235  
 236  
 237  
 238  
 239  
 240  
 241  
 242  
 243  
 244  
 245  
 246  
 247  
 248  
 249  
 250  
 251  
 252  
 253  
 254  
 255  
 256  
 257  
 258  
 259  
 260  
 261  
 262  
 263  
 264  
 265  
 266  
 267  
 268  
 269  
 270  
 271  
 272  
 273  
 274  
 275  
 276  
 277  
 278  
 279  
 280  
 281  
 282  
 283  
 284  
 285  
 286  
 287  
 288  
 289  
 290  
 291  
 292  
 293  
 294  
 295  
 296  
 297  
 298  
 299  
 300  
 301  
 302  
 303  
 304  
 305  
 306  
 307  
 308  
 309  
 310  
 311  
 312  
 313  
 314  
 315  
 316  
 317  
 318  
 319  
 320  
 321  
 322  
 323  
 324  
 325  
 326  
 327  
 328  
 329  
 330  
 331  
 332  
 333  
 334  
 335  
 336  
 337  
 338  
 339  
 340  
 341  
 342  
 343  
 344  
 345  
 346  
 347  
 348  
 349  
 350  
 351  
 352  
 353  
 354  
 355  
 356  
 357  
 358  
 359  
 360  
 361  
 362  
 363  
 364  
 365  
 366  
 367  
 368  
 369  
 370  
 371  
 372  
 373  
 374  
 375  
 376  
 377  
 378  
 379  
 380  
 381  
 382  
 383  
 384  
 385  
 386  
 387  
 388  
 389  
 390  
 391  
 392  
 393  
 394  
 395  
 396  
 397  
 398  
 399  
 400  
 401  
 402  
 403  
 404  
 405  
 406  
 407  
 408  
 409  
 410  
 411  
 412  
 413  
 414  
 415  
 416  
 417  
 418  
 419  
 420  
 421  
 422  
 423  
 424  
 425  
 426  
 427  
 428  
 429  
 430  
 431  
 432  
 433  
 434  
 435  
 436  
 437  
 438  
 439  
 440  
 441  
 442  
 443  
 444  
 445  
 446  
 447  
 448  
 449  
 450  
 451  
 452  
 453  
 454  
 455  
 456  
 457  
 458  
 459  
 460  
 461  
 462  
 463  
 464  
 465  
 466  
 467  
 468  
 469  
 470  
 471  
 472  
 473  
 474  
 475  
 476  
 477  
 478  
 479  
 480  
 481  
 482  
 483  
 484  
 485  
 486  
 487  
 488  
 489  
 490  
 491  
 492  
 493  
 494  
 495  
 496  
 497  
 498  
 499  
 500  
 501  
 502  
 503  
 504  
 505  
 506  
 507  
 508  
 509  
 510  
 511  
 512  
 513  
 514  
 515  
 516  
 517  
 518  
 519  
 520  
 521  
 522  
 523  
 524  
 525

10/342,576

**Donghee Kang**

GRUPP ET AL.

2811

[illegible]

| Class | Subclass | Date | Examiner |
|-------|----------|------|----------|
|       |          |      |          |
|       |          |      |          |
|       |          |      |          |
|       |          |      |          |

[illegible]

# Index of Claims



Applicati n No.

10/342,576

Examin r

Donghee Kang

Applicant(s)

GRUPP ET AL.

Art Unit

2811

|   |          |
|---|----------|
| ✓ | Reject d |
| = | Allowed  |

|   |                                |
|---|--------------------------------|
| — | (Through num ral)<br>Cancelled |
| + | Restricted                     |

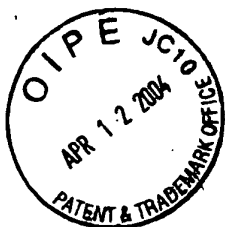
|   |              |
|---|--------------|
| N | Non-Elected  |
| I | Interference |

|   |          |
|---|----------|
| A | App al   |
| O | Objected |

| Claim | Final | Original | Date |
|-------|-------|----------|------|
| 1     | ✓     | ✓        |      |
| 2     |       |          |      |
| 3     |       |          |      |
| 4     |       |          |      |
| 5     |       |          |      |
| 6     |       |          |      |
| 7     |       |          |      |
| 8     |       |          |      |
| 9     |       |          |      |
| 10    |       |          |      |
| 11    |       |          |      |
| 12    |       |          |      |
| 13    | ✓     |          |      |
| 14    | 0     |          |      |
| 15    | 0     |          |      |
| 16    | ✓     |          |      |
| 17    |       |          |      |
| 18    |       |          |      |
| 19    |       |          |      |
| 20    |       |          |      |
| 21    |       |          |      |
| 22    |       |          |      |
| 23    |       |          |      |
| 24    |       |          |      |
| 25    |       |          |      |
| 26    |       |          |      |
| 27    |       |          |      |
| 28    |       |          |      |
| 29    |       |          |      |
| 30    |       |          |      |
| 31    |       |          |      |
| 32    |       |          |      |
| 33    |       |          |      |
| 34    | ✓     |          |      |
| 35    |       |          |      |
| 36    |       |          |      |
| 37    |       |          |      |
| 38    |       |          |      |
| 39    |       |          |      |
| 40    |       |          |      |
| 41    | ✓     |          |      |
| 42    | 0     |          |      |
| 43    | ✓     |          |      |
| 44    | ✓     |          |      |
| 45    | ✓     |          |      |
| 46    |       |          |      |
| 47    |       |          |      |
| 48    |       |          |      |
| 49    |       |          |      |
| 50    |       |          |      |

| Claim | Final | Original | Date |
|-------|-------|----------|------|
| 51    |       |          |      |
| 52    |       |          |      |
| 53    |       |          |      |
| 54    |       |          |      |
| 55    |       |          |      |
| 56    |       |          |      |
| 57    |       |          |      |
| 58    |       |          |      |
| 59    |       |          |      |
| 60    |       |          |      |
| 61    |       |          |      |
| 62    |       |          |      |
| 63    |       |          |      |
| 64    |       |          |      |
| 65    |       |          |      |
| 66    |       |          |      |
| 67    |       |          |      |
| 68    |       |          |      |
| 69    |       |          |      |
| 70    |       |          |      |
| 71    |       |          |      |
| 72    |       |          |      |
| 73    |       |          |      |
| 74    |       |          |      |
| 75    |       |          |      |
| 76    |       |          |      |
| 77    |       |          |      |
| 78    |       |          |      |
| 79    |       |          |      |
| 80    |       |          |      |
| 81    |       |          |      |
| 82    |       |          |      |
| 83    |       |          |      |
| 84    |       |          |      |
| 85    |       |          |      |
| 86    |       |          |      |
| 87    |       |          |      |
| 88    |       |          |      |
| 89    |       |          |      |
| 90    |       |          |      |
| 91    |       |          |      |
| 92    |       |          |      |
| 93    |       |          |      |
| 94    |       |          |      |
| 95    |       |          |      |
| 96    |       |          |      |
| 97    |       |          |      |
| 98    |       |          |      |
| 99    |       |          |      |
| 100   |       |          |      |

| Claim | Final | Original | Date |
|-------|-------|----------|------|
| 101   |       |          |      |
| 102   |       |          |      |
| 103   |       |          |      |
| 104   |       |          |      |
| 105   |       |          |      |
| 106   |       |          |      |
| 107   |       |          |      |
| 108   |       |          |      |
| 109   |       |          |      |
| 110   |       |          |      |
| 111   |       |          |      |
| 112   |       |          |      |
| 113   |       |          |      |
| 114   |       |          |      |
| 115   |       |          |      |
| 116   |       |          |      |
| 117   |       |          |      |
| 118   |       |          |      |
| 119   |       |          |      |
| 120   |       |          |      |
| 121   |       |          |      |
| 122   |       |          |      |
| 123   |       |          |      |
| 124   |       |          |      |
| 125   |       |          |      |
| 126   |       |          |      |
| 127   |       |          |      |
| 128   |       |          |      |
| 129   |       |          |      |
| 130   |       |          |      |
| 131   |       |          |      |
| 132   |       |          |      |
| 133   |       |          |      |
| 134   |       |          |      |
| 135   |       |          |      |
| 136   |       |          |      |
| 137   |       |          |      |
| 138   |       |          |      |
| 139   |       |          |      |
| 140   |       |          |      |
| 141   |       |          |      |
| 142   |       |          |      |
| 143   |       |          |      |
| 144   |       |          |      |
| 145   |       |          |      |
| 146   |       |          |      |
| 147   |       |          |      |
| 148   |       |          |      |
| 149   |       |          |      |
| 150   |       |          |      |



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.: 10/342,576

Inventors: Daniel E. Grupp et al.

Filed: January 14, 2003

TC/A.U.: 2811

Examiner: Kang, Donghee

Docket No.:

Customer No.: 08791

Confirmation No.: 2811

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail with sufficient postage in an envelope addressed to the Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

on April 8, 2004  
Date of Deposit

Patricia A. Balero

Name of Person Mailing Correspondence

[Signature]  
Signature

4/8/04  
Date

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450.

**AMENDMENT**

Sir:

In response to the Office action of February 13, 2004, please amend the above-identified application as follow:

**Amendments to the Specification** begin on page 2 of this paper.

**Amendments to the Claims** are reflected in the listing of claims which begins on page 3 of this paper.

**Amendments to the Drawings** begin on page 8 of this paper.

**Remarks/Arguments** begin on page 9 of this paper.

An **Appendix** including amended drawing figures is attached following page 10 of this paper.

### **Amendments to the Specification**

Please replace paragraph [0043] with the following amended paragraph:

[0043] As discussed above, the channel 220 contains a semiconductor material. The term semiconductor is used to refer to a material having a bandgap that is greater than about 0.1 electron volts and less than about 4 electron volts. Exemplary semiconductors that are contemplated include Si, Ge, SiGe or SiC. The semiconductor material may have a wide range of doping levels including no doping at all. The interface layers 230 and 240 each contain a passivation material that provides passivation to the channel 220 by covalently bonding with a dangling bond of a surface semiconductor atom to fully coordinate the semiconductor atom and thereby help passivate the semiconductor atom. The passivation material is preferably selected from the group consisting of a hydride, a nitride, an arsenide, an oxide and a fluoride of the semiconductor channel 220. Depending on the passivation material selected (e.g., where H, As or F are used as passivation materials), a separation layer 242 in addition to a passivation layer 244 within the interface layers ~~230 and 240~~ may be needed. Of course, the combination of the passivation layer and the separation layer must be sufficiently thin to permit the low specific contact resistances described in the above-cited patent application. Further details regarding the formation of an interface layer may be found in the above-cited patent application and will not be repeated herein.

**Amendments to the Claims:**

This listing of claims will replace all prior versions, and listings, of the claims in the application:

1. (Amended) A transistor, comprising a semiconductor channel disposed (i) nearby a gate configured to control conductance within the channel and (ii) in an electrical path between a source and a drain, at least one of which is made of a metal, wherein the channel and whichever of the source and/or the drain is/are made of the metal is/are separated by an interface layer so as to form a channel – interface layer – source/drain junction in which a Fermi level of the semiconductor channel is depinned in a region near the junction, and the junction including a passivated semiconductor surface ~~has~~ and having a specific contact resistance of less than approximately  $1000\ \Omega\text{-}\mu\text{m}^2$ .
2. (Original) The transistor of claim 1 wherein the semiconductor channel is made of one of Si, Ge, SiGe, SiGeC, or SiC.
3. (Original) The transistor of claim 1 wherein the metal comprises one of a pure metal, an alloy, or a refractory metal.
4. (Original) The transistor of claim 1 wherein the metal comprises aluminum.
5. (Original) The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $100\ \Omega\text{-}\mu\text{m}^2$ .
6. (Original) The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $50\ \Omega\text{-}\mu\text{m}^2$ .
7. (Original) The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $10\ \Omega\text{-}\mu\text{m}^2$ .

8. (Original) The transistor of claim 1 wherein the specific contact resistance is less than or equal to approximately  $1\ \Omega\text{-}\mu\text{m}^2$ .
9. (Original) The transistor of claim 1 wherein the interface layer includes a passivating material.
10. (Original) The transistor of claim 9 wherein the passivating material comprises one or more of a nitride of the semiconductor of the channel, a fluoride of the semiconductor of the channel, an oxide of the semiconductor of the channel, an oxynitride of the semiconductor of the channel, a hydride of the semiconductor of the channel and/or an arsenide of the semiconductor of the channel.
11. (Original) The transistor of claim 10 wherein the interface layer consists essentially of an amount of passivating material sufficient to terminate enough dangling bonds of a surface of the semiconductor channel so as to achieve chemical stability of the surface.
12. (Original) The transistor of claim 10 wherein the interface layer consists essentially of a monolayer configured to depin the Fermi level of the semiconductor of the channel.
13. (Original) The transistor of claim 12 wherein the interface layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.
14. (Original) The transistor of claim 9 wherein the interface layer further includes a separation layer.
15. (Original) The transistor of claim 14 wherein the separation layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.
16. (Original) The transistor of claim 1 wherein the semiconductor channel is separated from the gate by a dielectric.

17 – 33 (Cancelled)

34. (Amended) An electrical system comprising a circuit coupled to a transistor having a semiconductor channel disposed nearby a gate and in an electrical path between a source and a drain, at least one of which is made of a metal, wherein the channel and whichever of the source and/or the drain is/are made of the metal is/are separated by an interface layer so as to form a channel – interface layer – source/drain junction in which a Fermi level of the semiconductor channel is depinned in a region near the junction, ~~and the junction has~~ including a passivated semiconductor surface and having a specific contact resistance of less than approximately 1000  $\Omega\text{-}\mu\text{m}^2$ .

35. (Original) The electrical system of claim 34 wherein the semiconductor channel is separated from the gate by a dielectric.

36. (Original) The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately 100  $\Omega\text{-}\mu\text{m}^2$ .

37. (Original) The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately 50  $\Omega\text{-}\mu\text{m}^2$ .

38. (Original) The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately 10  $\Omega\text{-}\mu\text{m}^2$ .

39. (Original) The electrical system of claim 35 wherein the specific contact resistance is less than or equal to approximately 1  $\Omega\text{-}\mu\text{m}^2$ .

40. (Original) The electrical system of claim 35 wherein the semiconductor channel is made of one of Si, Ge, SiGe, SiGeC, or SiC.

41. (Original) The electrical system of claim 35 wherein the interface layer includes a passivating material.

42. (Original) The electrical system of claim 41 wherein the interface layer includes a separation layer comprising a material different than the passivation material.

43. (Original) The electrical system of claim 41 wherein the interface layer has a thickness sufficient to reduce effects of metal-induced gap states in the semiconductor channel.

44. (Original) The electrical system of claim 41 wherein the interface layer comprises an amount of passivating material sufficient to terminate all or a sufficient number of dangling bonds of the semiconductor channel to achieve chemical stability of a surface of the semiconductor channel in the region near the junction.

45. (Original) The electrical system of claim 44 wherein amount of passivating material comprises a monolayer.

46. (New) The transistor of claim 1 wherein the metal in the source and/or the drain has a workfunction near a conduction band of the semiconductor channel.

47. (New) The transistor of claim 1 wherein the metal in the source and/or the drain has a workfunction near a valence band of the semiconductor channel.

48. (New) The electrical system of claim 34 wherein the metal in the source and/or the drain has a workfunction near a conduction band of the semiconductor channel.

49. (New) The transistor of claim 34 wherein the metal in the source and/or the drain has a workfunction near a conduction band of the semiconductor channel.

**Amendments to the Drawings:**

The attached sheet of drawings includes changes to Fig. 2. This sheet, which includes Figs. 1 and 2, replaces the original sheet including Figs. 1 and 2. In Figure 2, previously omitted elements 242 and 244 have been added.

Attachment: Replacement Sheet

### REMARKS

Reconsideration of this application, as amended, is respectfully requested. New claims 46 – 49 are supported by the specification as originally filed, for example in paragraph 31. Likewise, the amendments to claims 1 and 34 are supported by the specification as originally filed, for example at paragraphs 30, etc. No new matter is added by these amendments.

On April 7, 2004, during a telephone interview with Examiner Kang, the undersigned and the inventors discussed the distinctions between the present invention and the cited art of record.

As indicated above, Figure 2 has been amended to show separation layer 242 and passivation layer 244, which make up interface layer 240 (for example), as requested in the Office Action. Paragraph 43 of the specification has been amended to correspond to these changes in the drawing. Because the subject matter now reflected in figure 2 was explicitly described in the specification as originally filed, these amendments do not introduce new matter and are being made simply for convenience and to comply with the request set forth in the Office Action.

Claims 1-13, 16, 34-41 and 43-45 have been rejected under 35 USC 102(b) as being anticipated by Grupp, US Patent 6,198,113. However, to anticipate a claim, the reference must teach every element of the claim. Stated differently, “A claim is anticipated only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single prior art reference.” Verdegaal Bros. v. Union Oil Co. of California, 814 F.2d 628, 631, 2 USPQ2d 1051, 1053 (Fed. Cir. 1987). In the present case, independent claims 1 and 34 each recite subject matter that is not found (either explicitly or inherently) in Grupp.

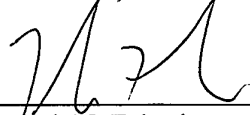
Specifically, claims 1 and 34, as amended, each recite depinning of the Fermi level of a semiconductor channel in a region near a junction that includes a passivated semiconductor surface. On the other hand, Grupp describes a device having a metal source/drain separated from a semiconductor island by tunnel junctions. These are not inherently the same thing. As explained in the present application, Fermi level depinning involves, in part, passivation of a

material surface by satisfying “dangling bonds”. Grupp’s tunnel junctions do not inherently provide such passivation, and there is no teaching or suggestion in the reference to indicate otherwise. All that is required is that the tunnel junctions ohmically isolate the semiconductor island. Consequently, because the cited reference does not specifically teach depinning of the Fermi level at least in part by passivation of surface states and because such a condition is not inherent in the structure described in the reference, the claims are patentable over the reference.

In addition, each of claims 1 and 34 recites a junction having a specific contact resistance of less than approximately  $1000 \Omega \cdot \mu\text{m}^2$ . On the other hand, Grupp describes a device having a resistance of, in some cases, less than  $1000 \Omega$ . See, e.g., Grupp at col. 6, ll. 30-32. The quantities of resistance and specific contact resistance are mutually independent as is evident by the fact that each recites different units of measure compelled by different physical phenomena. Accordingly, Grupp does not anticipate the present claims.

If there are any additional fees associated with this communication, please charge our Deposit Account No. 02-2666.

Respectfully submitted,  
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP



Tarek N. Fahmi  
Reg. No. 41,402

Dated: April 8, 2004

12400 Wilshire Blvd.  
Seventh Floor  
Los Angeles, CA 90025-1026  
(408) 947-8200

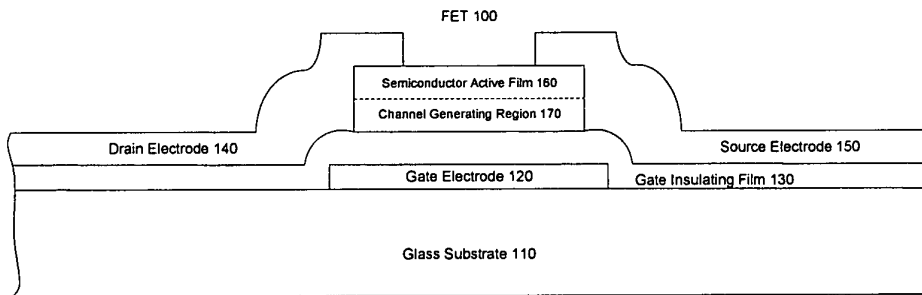
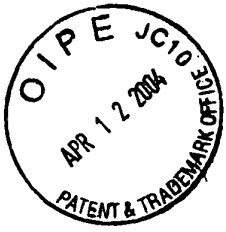


Fig. 1  
(Prior Art)

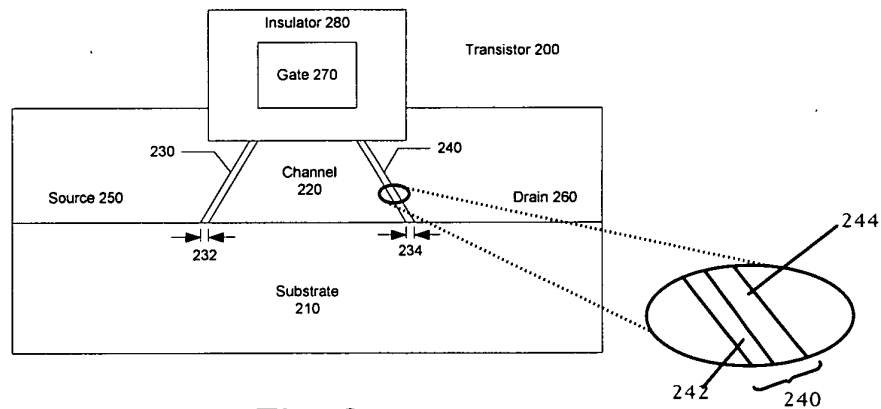
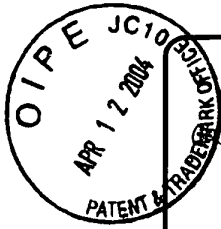


Fig. 2

Image

2811B

**TRANSMITTAL FORM***to be used for all correspondence after initial filing*

|                                          |                  |
|------------------------------------------|------------------|
| Application No.                          | 10/342,576       |
| Filing Date                              | January 14, 2003 |
| First Named Inventor                     | Daniel E. Grupp  |
| Art Unit                                 | 2811             |
| Examiner Name                            | Kang, Donghee    |
| Attorney Docket Number                   | 3771P004         |
| Total Number of Pages in This Submission | 17               |

**ENCLOSURES (check all that apply)**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input checked="" type="checkbox"/> Fee Transmittal Form<br><input checked="" type="checkbox"/> Fee Attached<br><input checked="" type="checkbox"/> Amendment / Response<br><input type="checkbox"/> After Final<br><input type="checkbox"/> Affidavits/declaration(s)<br><input type="checkbox"/> Extension of Time Request<br><input type="checkbox"/> Express Abandonment Request<br><input checked="" type="checkbox"/> Information Disclosure Statement<br><input checked="" type="checkbox"/> PTO/SB/08<br><input type="checkbox"/> Certified Copy of Priority Document(s)<br><input type="checkbox"/> Response to Missing Parts/Incomplete Application<br><input type="checkbox"/> Basic Filing Fee<br><input type="checkbox"/> Declaration/POA<br><input type="checkbox"/> Response to Missing Parts under 37 CFR 1.52 or 1.53 | <input checked="" type="checkbox"/> Drawing(s)<br><input type="checkbox"/> Licensing-related Papers<br><input type="checkbox"/> Petition<br><input type="checkbox"/> Petition to Convert a Provisional Application<br><input type="checkbox"/> Power of Attorney, Revocation Change of Correspondence Address<br><input type="checkbox"/> Terminal Disclaimer<br><input type="checkbox"/> Request for Refund<br><input type="checkbox"/> CD, Number of CD(s) | <input type="checkbox"/> After Allowance Communication to Group<br><input type="checkbox"/> Appeal Communication to Board of Appeals and Interferences<br><input type="checkbox"/> Appeal Communication to Group (Appeal Notice, Brief, Reply Brief)<br><input type="checkbox"/> Proprietary Information<br><input type="checkbox"/> Status Letter<br><input type="checkbox"/> Other Enclosure(s) (please identify below):<br><div style="border: 1px solid black; height: 60px; width: 150px; margin-top: 10px;"></div> |
| <b>Remarks</b><br><div style="border: 1px solid black; height: 40px; width: 100%;"></div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

**SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT**

|                         |                                                                                      |
|-------------------------|--------------------------------------------------------------------------------------|
| Firm or Individual name | Tarek N. Fahmi, Reg. No. 41,402<br><b>BLAKELY, SOKOLOFF, TAYLOR &amp; ZAFMAN LLP</b> |
| Signature               |                                                                                      |
| Date                    | April 8, 2004                                                                        |

**CERTIFICATE OF MAILING/TRANSMISSION**

I hereby certify that this correspondence is being deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: Mail Stop Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

|                       |                    |      |               |
|-----------------------|--------------------|------|---------------|
| Typed or printed name | Patricia A. Balero |      |               |
| Signature             |                    | Date | April 8, 2004 |

Based on PTO/SB/21 (02-04) as modified by Blakely, Sokoloff, Taylor & Zafman (wlr) 02/10/2004.  
SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450



# FEE TRANSMITTAL for FY 2004

Effective 01/01/2004. Patent fees are subject to annual revision.

☒ Applicant claims small entity status. See 37 CFR 1.27.

TOTAL AMOUNT OF PAYMENT (\$) 180.00

## Complete if Known

Application Number 10/342,576  
Filing Date January 14, 2003  
First Named Inventor Daniel E. Grupp  
Examiner Name Kang, Donghee  
Art Unit 2811  
Attorney Docket No. 3771P004

## METHOD OF PAYMENT (check all that apply)

☒ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None  
☒ Deposit Account

Deposit Account Number 02-2666  
Deposit Account Name Blakely, Sokoloff, Taylor & Zafman LLP

The Commissioner is authorized to: (check all that apply)

☐ Charge fee(s) indicated below ☒ Credit any overpayments  
☒ Charge any additional fee(s) or underpayment of fees as required under 37 CFR §§ 1.16, 1.17, 1.18 and 1.20.  
☐ Charge fee(s) indicated below, except for the filing fee to the above-identified deposit account

## FEE CALCULATION

### 1. BASIC FILING FEE

| Large Entity |          | Small Entity |          | Fee Description        | Fee Paid |
|--------------|----------|--------------|----------|------------------------|----------|
| Fee Code     | Fee (\$) | Fee Code     | Fee (\$) |                        |          |
| *1001        | 770      | 2001         | 385      | Utility filing fee     |          |
| 1002         | 340      | 2002         | 170      | Design filing fee      |          |
| 1003         | 530      | 2003         | 265      | Plant filing fee       |          |
| 1004         | 770      | 2004         | 385      | Reissue filing fee     |          |
| 1005         | 160      | 2005         | 80       | Provisional filing fee |          |
| SUBTOTAL (1) |          |              |          |                        | (\$)     |

### 2. EXTRA CLAIM FEES

Total Claims 45\* =  X  =   
Independent Claims 3 =  X  =   
Multiple Dependent

| Large Entity |          | Small Entity |          | Fee Description                                           | Fee Paid |
|--------------|----------|--------------|----------|-----------------------------------------------------------|----------|
| Fee Code     | Fee (\$) | Fee Code     | Fee (\$) |                                                           |          |
| -1202        | 18       | 2202         | 9        | Claims in excess of 20                                    |          |
| 1201         | 86       | 2201         | 43       | Independent claims in excess of 3                         |          |
| 1203         | 290      | 2203         | 145      | Multiple Dependent claim, if not paid                     |          |
| 1204         | 86       | 2204         | 43       | **Reissue independent claims over original patent         |          |
| 1205         | 18       | 2205         | 9        | **Reissue claims in excess of 20 and over original patent |          |
| SUBTOTAL (2) |          |              |          |                                                           | (\$)     |

\*or number previously paid, if greater, For Reissues, see below

## FEE CALCULATION (continued)

### 3. ADDITIONAL FEES

| Large Entity        |          | Small Entity |          | Fee Description                                                            | Fee Paid |
|---------------------|----------|--------------|----------|----------------------------------------------------------------------------|----------|
| Fee Code            | Fee (\$) | Fee Code     | Fee (\$) |                                                                            |          |
| 1051                | 130      | 2051         | 65       | Surcharge - late filing fee or oath                                        |          |
| 1052                | 50       | 2052         | 25       | Surcharge - late provisional filing fee or cover sheet                     |          |
| 2053                | 130      | 2053         | 130      | Non-English specification                                                  |          |
| 1812                | 2,520    | 1812         | 2,520    | For filing a request for <i>ex parte</i> reexamination                     |          |
| 1804                | 920*     | 1804         | 920*     | Requesting publication of SIR prior to Examiner action                     |          |
| 1805                | 1,840*   | 1805         | 1,840*   | Requesting publication of SIR after Examiner action                        |          |
| 1251                | 110      | 2251         | 55       | Extension for reply within first month                                     |          |
| 1252                | 420      | 2252         | 210      | Extension for reply within second month                                    |          |
| 1253                | 950      | 2253         | 475      | Extension for reply within third month                                     |          |
| 1254                | 1,480    | 2254         | 740      | Extension for reply within fourth month                                    |          |
| 1255                | 1,210    | 2255         | 605      | Extension for reply within fifth month                                     |          |
| 1404                | 330      | 2401         | 165      | Notice of Appeal                                                           |          |
| 1402                | 330      | 2402         | 165      | Filing a brief in support of an appeal                                     |          |
| 1403                | 290      | 2403         | 145      | Request for oral hearing                                                   |          |
| 1451                | 1,510    | 2451         | 1,510    | Petition to institute a public use proceeding                              |          |
| 1452                | 110      | 2452         | 55       | Petition to revive - unavoidable                                           |          |
| 1453                | 1,330    | 2453         | 665      | Petition to revive - unintentional                                         |          |
| 1501                | 1,330    | 2501         | 665      | Utility issue fee (or reissue)                                             |          |
| 1502                | 480      | 2502         | 240      | Design issue fee                                                           |          |
| 1503                | 640      | 2503         | 320      | Plant issue fee                                                            |          |
| 1460                | 130      | 2460         | 130      | Petitions to the Commissioner                                              |          |
| 1807                | 50       | 1807         | 50       | Processing fee under 37 CFR 1.17(q)                                        |          |
| 1806                | 180      | 1806         | 180      | Submission of Information Disclosure Stmt                                  | 180.00   |
| 8021                | 40       | 8021         | 40       | Recording each patent assignment per property (times number of properties) |          |
| 1809                | 770      | 1809         | 385      | Filing a submission after final rejection (37 CFR § 1.129(a))              |          |
| 1810                | 770      | 2810         | 385      | For each additional invention to be examined (37 CFR § 1.129(b))           |          |
| 1801                | 770      | 2801         | 385      | Request for Continued Examination (RCE)                                    |          |
| 1802                | 900      | 1802         | 900      | Request for expedited examination of a design application                  |          |
| Other fee (specify) |          |              |          |                                                                            |          |

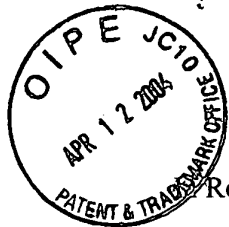
\* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) (\$) 180.00

## SUBMITTED BY

Name (Print/Type) Tarek N. Rahmi Registration No. 41,402 Telephone (408) 947-8200  
Signature [Signature] Date 04/08/04

Based on PTO/SB/17 (10-03) as modified by Blakely, Sokoloff, Taylor & Zafman (wlr) 02/10/2004.  
SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450



Docket No.: 3771P004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Re the Application of:

DANIEL E. GRUPP, ET AL.

Application No.: 10/342,576

Filed: January 14, 2003

For: **Insulated Gate Field Effect Transistor  
Having Passivated Schottky Barriers To  
The Channel**

Art Group: 2811

Examiner: Kang, Donghee

INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §1.97

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

In accordance with the duty of disclosure, enclosed is a copy of IDS Citation Form PTO/SB/08 or PTO-1449, together with copies of the documents cited on that form, except for copies not required to be submitted (e.g., copies of U.S. patents and U.S. published patent applications need not be enclosed for applications filed after June 30, 2003). This IDS and IDS Citation Form are being submitted before the mailing of a final Office Action. It is respectfully requested that the cited references be considered and that the enclosed copy of PTO/SB/08 be initialed by the Examiner to indicate such consideration and a copy thereof returned to applicant(s).

The references were cited in a Search Report dated December 18, 2003 (copy enclosed herewith) in a counterpart PCT application.

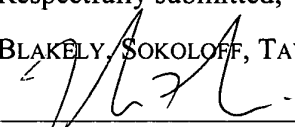
The submission of this Information Disclosure Statement is not to be construed as a representation that a search has been made in the subject application and is not to be construed as an admission that the information cited in this statement is material to patentability.

The fee set in the amount of \$180.00 for submission of the Information Disclosure Statement is enclosed herewith. Please charge any additional fees due to Deposit Account 02-2666. A duplicate copy of the Fee Transmittal (PTO/SB/17) is enclosed for this purpose.

Respectfully submitted,

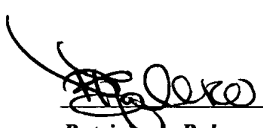
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP

Date: April 08, 2004

  
Tarek N. Fahmi, Reg. No. 41,402

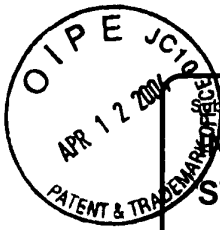
12400 Wilshire Boulevard, 7th Floor  
Los Angeles, CA 90025  
Telephone: (408) 947-8200

I hereby certify that this correspondence is being deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: Mail Stop Non-Fee Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

  
Patricia A. Balero

04-08-04

Date



|                                                                                               |   |    |   |                          |                  |
|-----------------------------------------------------------------------------------------------|---|----|---|--------------------------|------------------|
| Substitute for form 1449A/PTO                                                                 |   |    |   | <b>Complete if Known</b> |                  |
| <b>INFORMATION DISCLOSURE<br/>STATEMENT BY APPLICANT</b><br>(use as many sheets as necessary) |   |    |   | Application Number       | 10/342,576       |
|                                                                                               |   |    |   | Filing Date              | January 14, 2003 |
|                                                                                               |   |    |   | First Named Inventor     | Daniel E. Grupp  |
|                                                                                               |   |    |   | Art Unit                 | 2811             |
|                                                                                               |   |    |   | Examiner Name            | Kang, Donghee    |
|                                                                                               |   |    |   | Attorney Docket Number   | 3771P004         |
| Sheet                                                                                         | 1 | of | 2 |                          |                  |

| U.S. PATENT DOCUMENTS |           |                                |                                              |                                                    |                                                                                 |
|-----------------------|-----------|--------------------------------|----------------------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------|
| Examiner Initials*    | Cite No.¹ | Document Number                | Publication Date<br>Issue Date<br>MM-DD-YYYY | Name of Patentee or Applicant<br>of Cited Document | Pages, Columns, Lines, Where<br>Relevant Passages or Relevant<br>Figures Appear |
|                       |           | Number - Kind Code² (if known) |                                              |                                                    |                                                                                 |
|                       |           | US- 3,983,264                  | 09-28-1976                                   | Schroen et al.                                     |                                                                                 |
|                       |           | US- 5,021,365                  | 04-04-1991                                   | Kirchner et al.                                    |                                                                                 |
|                       |           | US- 5,801,398                  | 09-01-1998                                   | Hebiguchi                                          |                                                                                 |
|                       |           | US- 200/0061646 A1             | 05-23-2002                                   | Kan et al.                                         |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |
|                       |           | US-                            |                                              |                                                    |                                                                                 |

| FOREIGN PATENT DOCUMENTS |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|--------------------------|-----------------------|-------------------------------------------------------------------------------------|--------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------|----|
| Examiner Initials*       | Cite No. <sup>1</sup> | Foreign Patent Document                                                             | Publication Date<br>MM-DD-YYYY | Name of Patentee or<br>Applicant of Cited Document | Pages, Columns, Lines,<br>Where Relevant Passages<br>or Relevant Figures Appear | T* |
|                          |                       | Country Code <sup>2</sup> - Number <sup>1</sup> - Kind Code <sup>2</sup> (if known) |                                |                                                    |                                                                                 |    |
|                          |                       | EP 0 295 490 A1                                                                     | 12-21-2088                     | IBM                                                |                                                                                 |    |
|                          |                       | EP 0 789 388 A2                                                                     | 08-13-1997                     | Agency IND Science Techn.                          |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    |                                                                                 |    |
|                          |                       |                                                                                     |                                |                                                    | </                                                                              |    |

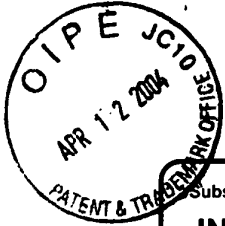
|                    |                 |
|--------------------|-----------------|
| Examiner Signature | Date Considered |
|--------------------|-----------------|

\*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication.

¹Applicant's unique citation designation number (optional). ²See Kinds Codes of USPTO Patent Documents at [www.uspto.gov](http://www.uspto.gov) or MPEP 901.04. ³Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). ⁴For Japanese patent documents, the indication of the year of reign of the Emperor must precede the serial number of the patent document. ⁵Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. ⁶Applicant is to place a check mark here if English language Translation is attached.

Based on PTO/SB/08A (08-03) as modified by Blakely, Solokoff, Taylor & Zafman (wlr) 08/11/2003.

Send To: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450



|                                                          |   |    |   |                          |                  |
|----------------------------------------------------------|---|----|---|--------------------------|------------------|
| Substitute for form 1449A/PTO                            |   |    |   | <b>Complete if Known</b> |                  |
| <b>INFORMATION DISCLOSURE<br/>STATEMENT BY APPLICANT</b> |   |    |   | Application Number       | 10/342,576       |
|                                                          |   |    |   | Filing Date              | January 14, 2003 |
|                                                          |   |    |   | First Named Inventor     | Daniel E. Grupp  |
|                                                          |   |    |   | Art Unit                 | 2811             |
|                                                          |   |    |   | Examiner Name            | Kang, Donghee    |
| Sheet                                                    | 2 | of | 2 | Attorney Docket Number   | 3771P004         |

| NON PATENT LITERATURE DOCUMENTS |                          |                                                                                                                                                                                                                                                                                                         |                |
|---------------------------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Examiner<br>Initials*           | Cite<br>No. <sup>1</sup> | Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.                                         | T <sup>2</sup> |
|                                 |                          | International Search Report, PCT/US03/25057, Mailing Date December 18, 2003                                                                                                                                                                                                                             |                |
|                                 |                          | S. M., SZE, "Metal-Semiconductor Contacts", Physics of Semiconductor Devices, New Your, John Wiley & Sons, US, 1981 Pgs. 245-311, XP002068071                                                                                                                                                           |                |
|                                 |                          | T, TERAJI et al., "Ohmic Contacts To N. Type 6H.SIC Without Post-Annealing", Materials Research Society Symposium Proceedings, Materials Research Society, Pittsburg, PA, US, April 8, 1996, Pgs. 149-154, XP002068069                                                                                  |                |
|                                 |                          | V.S. BANNIKOV et al., "Field-Effect Transistor With Metal-(Tunneling-Insulator)-Semiconductor Contacts and A Gate Insulator Made of A Langmuir-Blodgett Film", Soviet Technoical Physics Letters, American Institute of Physics, New York, US, Vol. 15, No. 3, March 1, 1989, Pgs. 211-212, XP000102701 |                |
|                                 |                          | L.M. PORTER et al., "A Critical Review of Ohmic and Rectifying Contacts For Silicon Carbide", Materials Science and Engineering, Vol. 34, No. 2, November 1, 1995, Pgs. 83-105, XP004000935                                                                                                             |                |
|                                 |                          | S. HARA et al., "Pinning-Controlled Metal/Semiconductor Interfaces", Proceedings of the Spie, Bellingham, VA, US, Vol. 2779, June 3, 1996, Pgs. 802-806, XP002068070                                                                                                                                    |                |
|                                 |                          |                                                                                                                                                                                                                                                                                                         |                |

|                       |                    |
|-----------------------|--------------------|
| Examiner<br>Signature | Date<br>Considered |
|-----------------------|--------------------|

\*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication.

<sup>1</sup>Applicant's unique citation designation number. <sup>2</sup>Applicant is to place a check mark here if English language Translation is attached.

Based on PTO/SB/08B (08-03) as modified by Blakely, Solokoff, Taylor & Zafman (wlr) 08/11/2003.  
Send To: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450

(19)



Europäisches Patentamt  
European Patent Office  
Office européen des brevets

(11) Publication number:

**0 295 490  
A1**

(12)

## EUROPEAN PATENT APPLICATION

(21) Application number: 88108684.7

(51) Int. Cl.<sup>4</sup>: **H01L 21/314 , H01L 29/40 ,  
H01L 21/285**

(22) Date of filing: 31.05.88

(30) Priority: 18.06.87 US 64414

(43) Date of publication of application:  
21.12.88 Bulletin 88/51

(84) Designated Contracting States:  
**DE FR GB**

(71) Applicant: International Business Machines  
Corporation  
Old Orchard Road  
Armonk, N.Y. 10504(US)

(72) Inventor: Fowler, Alan B.  
3511 Kamhi Drive  
Yorktown Heights New York 10598(US)  
Inventor: Freeouf, John L.  
East Mountain, Lake Katonah, Route 3  
Katonah New York 10536(US)  
Inventor: Kirchner, Peter D.  
RR1, Box 156A  
Putnam Valley New York 10579(US)  
Inventor: Warren, Alan C.  
150 Overlook Avenue, Apt. 7A  
Peekskill New York 10566(US)  
Inventor: Woodall, Jerry M.  
336 Cherry Street  
Katonah New York 10507(US)

(74) Representative: Kreidler, Eva-Maria, Dr. rer.  
nat.  
IBM Deutschland GmbH Patentwesen und  
Urheberrecht Schönaicher Strasse 220  
D-7030 Böblingen(DE)

(54) **Compound semiconductor surface termination.**

**EP 0 295 490 A1**

(57) A surface termination of a compound semiconductor is provided wherein conditions are provided for a pristine surface to be retained in an unpinned condition and a surface layer of a non-metallic material is provided. A GaAs substrate is heated in an oxygen-free atmosphere at high temperature with hydrogen sulfide, producing a pristine surface with a coating of gallium sulfide covered with a 1,000 nanometer covering of low temperature plasma enhanced chemical vapor deposited silicon dioxide.

## COMPOUND SEMICONDUCTOR SURFACE TERMINATION

The invention relates to semiconductor devices fabricated of compound semiconductor materials and to the surfaces of those semiconductor materials that influence the fabrication of devices.

The design and operation of compound semiconductor devices are influenced by a number of factors, a principal one being the properties of the exposed semiconductor surface and of interfaces between the semiconductor crystal and metals or insulators.

In such compound semiconductor devices, on the surface of the semiconductor crystal, the Fermi level is pinned at some characteristic energy and this produces the undesirable effect of both carrier recombination at the surface and an inherent barrier. The development of a number of otherwise possible and useful devices and device structures have been prevented by these conditions and a more nearly ideal interface, that is one whose Fermi level may be moved freely and has low recombination velocity is required.

There has been effort directed to the problem. The effort usually is called passivation and the result is the providing of a covering member over the compound semiconductor crystal surface.

The work in the art indicates responsiveness to the presence of the element sulfur.

In U.S. Patent 4,354,198, it is taught that on a Group III-V compound semiconductor, such as GaAs, a Group II-VI semiconductor operates to passivate the surface, with the preferred Group II-VI compound being ZnS.

Further work indicates a need for care in the field. In an article in the Journal of Vacuum Science & Technology, Volume 17, No. 5, p.1134, Sept./Oct. 1980, there is described the fact that exposure of GaAs to H<sub>2</sub>S in vacuum unpins the Fermi level and that this effect persists after the adding of Al. In another article in the Journal of Vacuum Science & Technology, Vol. B3, No. 4, July/Aug. 1985, p.1197, studies and data indicate the fact that for GaAs, arsenic must be removed or the results become unpredictable. In yet another article, in the Journal of Vacuum Science and Technology, Vol. 19, 1981, p.794, it is shown that native oxides of Ga and As which form in the presence of O are associated with Fermi level pinning. Thus, O behaves in a detrimental way.

The use of sulfur compounds to passivate Group III-V compound semiconductors has been reported Applied Physics Letters, July 1987, wherein data is advanced that lithium sulfide, ammonium sulfide and sodium sulfide provide improvement in the GaAs surface recombination property.

The sulfur compound type further passivation work is reported in Applied Physics Letters, July 1987, describing the use of sodium sulfide in an aqueous solution applied at surface electrode locations to provide passivation.

FIG. 1 is a schematic view of a compound semiconductor crystal illustrating a surface with the elements of the invention.

FIG. 2 is an illustration of a band diagram of a tunneling type contact achievable with the invention.

FIG. 3 is an illustration of a variable barrier height contact achievable with the invention.

FIG. 4 is an illustration of passivation in a planar structure where a p-n junction is at the surface.

FIG. 5 is a schematic illustration of the application of the invention to a metal oxide semiconductor field effect transistor.

FIG. 6 is a schematic illustration of the application of the invention to the passivation of a bipolar transistor.

FIG. 7 is a schematic illustration of the application of the invention to the passivation of a light emitting device.

FIG. 8 is a schematic illustration of the application of the invention to the passivation of a semiconductor structure employing a small dimension, quantum wire type feature.

The invention provides a surface termination capability for a variety of compound semiconductor device structures in which there is recognized that there are several interdependent factors that are responsible and that useful termination properties include compatibility with the device being fabricated.

The invention structurally employs a very thin Fermi level pinning control layer of a material that unpins the Fermi level of the compound semiconductor material at the surface. This layer should be on the order of a monolayer in thickness. A monolayer layer of a material may be defined as one surface atom for each surface atom of the material on which it is positioned. The quantity needed for coverage is sensitive to crystallographic orientation. For compatibility with device fabricating the pinning control layer would preferably be thin enough not to attenuate light and permit tunneling for ohmic contact performance. A quantum mechanical tunneling thickness of the order of 2 nm would be satisfactory. The term pristine crystal surface refers to a damage-free uncontaminated crystal surface. The layer of unpinning material is covered with a second layer of a non-metallic material. The non-metallic material is selected for dielectric, ambient

reaction inertness and translucence properties.

The resulting compound semiconductor crystal with the surface termination structure of the invention can serve as an intermediate manufacturing product in the fabrication of compound semiconductor devices.

The factors influencing the surface problem may be viewed in the light of the following principles. In order to facilitate communication, the III-V compound GaAs has been selected for illustration although in the light of the principles involved, translation to other semiconductor materials will be readily apparent.

The first factor is that there exists at a compound semiconductor surface an agent responsible for moving the Fermi level away from the normal which is the position in the absence of any surface charge and producing the phenomenon in the art known as Fermi level pinning. In the case of GaAs, this agent appears to be an excess of one or more of the components of the compound semiconductor crystal. In view of this, surface termination for practical device purposes will require the removal of any such agent at that surface. The semiconductor surface is to be pristine.

A second factor is that the compound semiconductor surface will react with the ambient and become contaminated unless steps are taken by protecting with a coating of material that insures that the Fermi level remain in an unpinned condition both on the shelf and in conditions of use, such as in the presence of the materials at the device interface.

The third factor is that generally materials that will control the pinning condition must be able to be compatible with other functional purposes in device fabrication and there may be conditions of material properties and layer thickness incompatibility. In accordance with the invention where such conditions are encountered, a layer is applied to provide the required properties.

The resulting multilayer termination structure of the invention is capable of being employed in a variety of compound semiconductor device structures because the elimination of the Fermi level pinning condition enables the formation of ideal interfaces where barrier height to conduction is no longer constant but depends on the relative work functions of the materials. This in turn provides the ability to selectably form such interfaces as ohmic contacts, selectable barrier height rectifying contacts, and selectable threshold inversion channel carrier control in devices.

Referring to FIG. 1, on a compound semiconductor substrate 1, at a pristine surface 2, that is at a surface 2 where there is essentially no damage and essentially no extraneous material, there will be no pinning agent species, a layer of material

that retains the Fermi level in the normal position is applied. The layer for device fabrication and performance compatibility is a very thin, of the order of a monolayer in thickness layer of a material 3 for coverage and is preferably for tunneling purposes of less than tunneling thickness.

Over the layer 3, a layer 4 is provided. The layer 4 is selected to provide dielectric, ambient reaction inertness and translucence properties. It is non-metallic and may be a semiconductor or an insulator.

In accordance with the invention, the compound semiconductor may be a compound of Ga, Al or In with As or Sb or ternary and quaternary alloys thereof.

The layer 3 is a compound of a cation ingredient with respect to the compound semiconductor together with one of S, Se and Te. In a compound semiconductor, the element of the lower group of the periodic table is the cationic ingredient. For one example, a compound of Ga with S. For another example, the layer 3 can be a cation oxide such as  $Ga_2O_3$  for a GaAs crystal, if the anion oxide which for GaAs would be  $As_2O_3$  plus any excess anion such as As are removed before or during formation of the unpinning layer.

The layer 4 is non-metallic and may be such materials as low temperature plasma enhanced  $SiO_2$ ,  $CaF_2$ , NaS, ZnS, GaP, GaSe and polyimides.

In the fabrication of the invention, the substrate 1 may be rendered pristine and free of the pinning producing species in, as examples, the following ways, using GaAs as the example:

- by heating the crystal with an arsenic coating at about  $400^\circ C$  for about 10 seconds in vacuum. This procedure produces a surface reconstruction such that the surface unit cell is equivalent to the bulk unit cell and removes the cause of the Fermi level pinning;
- by treatment with zinc selenide in a beam that tends to strip the arsenic from the surface;
- by exposure to an ambient of hydrogen sulfide at high temperatures;
- by the etching of the surface with acids and bases; and
- by photo-washing under conditions where the crystal surface is subjected to water in the presence of light.

All of these operations provide a compound semiconductor crystal with pristine surface that does not have any of the pinning causing species thereon. Such a surface requires protection so that in accordance with the invention a very thin material that will retain the Fermi level in the free

position is applied. This material is a compound of the cation of the compound semiconductor crystal and is a member taken from the group of S, Se and Te, which for GaAs is gallium sulfide, gallium selenide and gallium telluride.

Th application of the layer 4 may employ such techniques as exposing the crystal 1 in FIG. 1 with the layer 3 in place to an ambient of H<sub>2</sub>S, to an evaporation of sodium sulfide, gallium sulfide or gallium selenide, and by the technique of photo-washing.

The technique of photo-washing is described in European patent application Serial No. 87 107 476.1. The surface produced by that technique may be used as the structure of Fig. 1 on which the layer 4 is to be applied.

The layer 4 is then applied in a thickness of up to approximately 1,000 nanometers.

The surface termination of the invention is useful in a variety of device structures.

Referring next to FIG. 2, there is shown a band energy diagram illustrating an interface suitable for ohmic contact performance where the layer 3 at the pristine surface 2 results in the Fermi level  $E_f$  being unpinned at the surface 2 and the dielectric layer 4 is made sufficiently thin to permit quantum mechanical tunneling so that a contact through a low work function metal, such as In for the metal 5 will demonstrate on a GaAs crystal essentially ohmic conduction performance. The layer 3 being of a monolayer order is thin enough not to interfere with the tunneling mechanism and the layer 4 is of the proper thickness which for most applications is of the order of 2 nm generally achieved in connection with the positioning of the metal contact 5.

In the fabricating of different types of device structures, it is desirable to have a barrier to electrical conduction that is selectable. The selectability provides controllable performance rectifying contacts and the ability to control carrier flow in an inversion channel in a device.

Referring next to FIG. 3, a band energy diagram is shown where the layer 4 is sufficiently thin to permit quantum mechanical tunneling so that when a higher work function metal, such as Au is used for the metal 5, the performance is that of a selectable Schottky barrier height. This is useful in threshold control of field effect transistors.

In FIGS. 4 through 8, the application of the invention to various types of semiconductor structures is illustrated.

Referring next to FIG. 4, there is illustrated a device wherein there is a p-n junction 6 that terminates at the surface. Where such a structural condition occurs, the carrier recombination is aggravated by the presence of very high fields illustrated at one intersection as element 7. In accordance with the invention, the layers 3 and 4 under these

conditions operate to prevent both carrier recombination and the effects of the field.

In FIG. 5, a field effect transistor semiconductor device known as a Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is illustrated wherein the semiconductor substrate 1 has positioned thereon source and drain ohmic contacts 8 and 9 that go through the layer 3 on the surface 2 and dielectric layer 4 is in a shape modified to accommodate the other requirements of the device. The thin essentially monolayer thickness of the layer 3 permits the ohmic contacts 8 and 9 to be merely positioned on the layer 3 which in turn doesn't interfere with their electrical performance. The layer 4 serves as the insulator of gate 10 with the layer 4 being provided with appropriate thickness and dielectric strength to have the threshold properties for the inversion of a channel between contacts 8 and 9 at the interface of the crystal 1.

With the structural principles of the invention, it will be readily apparent that the type of selectability of the barrier shown in FIG. 3 provides flexibility in imparting characteristics to a device being fabricated.

Referring next to FIG. 6, a bipolar transistor type structure is illustrated vertically oriented with respect to the substrate wherein the substrate 1, appropriately doped, serves as the collector, with an opposite conductivity type appropriately doped base region 11 positioned adjacent the interface 2. On the layer 3 at interface 2, a circular ohmic electrode 12 is positioned separated from and surrounding a mesa semiconductor region 13 epitaxially joined at the interface 2 serving as the emitter which in turn has a contact facilitating semiconductor region 14 serving as the interface to the metal emitter contact 15.

The features of the invention are employed in this type of structure to facilitate prevention of leakage problems that occur with respect to closely positioned contacts, interfaces terminating at the surface, and ohmic performance. The two layer termination structure on pristine surface of the invention is applied around the emitter 13 shown as element 16. The layer 4 is removed in the positioning of ohmic contact 12 and the layer 3 due to the thin dimension thereof does not affect the ohmic performance of contact 12.

The principles of the invention are further applicable to facilitate construction of electro-optical conversion devices.

Referring next to FIG. 7, one of the serious problems in the electro-optical conversion field has been the translucent passivation of pn junctions that radiate light.

Referring to FIG. 7, a light emitting diode type device is shown wherein on a substrate 1, there is a high conductivity extrinsic n+ layer 18, an n-type

layer 19 and a p-type layer 20 in a mesa type configuration, with the pn junction between elements 19 and 20 serving as the light emitting source in a mesa type configuration. The light emitting junction at the surface is indicated as having a field with the circle at 21. The termination structure of the invention is shown as element 22 applied over the mesa. The ohmic contacts 23 to the n+ region 18 and 24 to the p region 20 are made by removing the layer 4, the ohmic performance being unaffected by the thin layer 3.

In this type of structure, the layers 3 and 4 in the termination of the invention are sufficiently thin not to attenuate the emitted light, yet they serve in passivation and facilitate contacting.

Referring to FIG. 8, a typical, very small, of the order of 5 to 10nm dimension active region device is shown. Such a device has come to be known in the art as a quantum wire structure. In FIG. 8, on the substrate 25 of a first band gap semiconductor material, such as GaAs, a region 26 of an atomically compatible different band gap high mobility semiconductor, such as InGaAs, is sandwiched between another layer 27 of a different band gap lower mobility semiconductor material such as GaAs in a mesa configuration. In accordance with the invention, the surface at both sides of the mesa and the substrate is coated with the termination structure comprising layer 3 on a pristine surface covered by layer 4.

The termination operates to passivate the surfaces including the hetero-interfaces between different semiconductor materials. Ohmic contacts 28 and 29 are illustrated showing the presence of the layer 3 which due to thickness does not affect ohmic contact performance. The structure of FIG. 8 would have a contact to the quantum wire region 26, not shown.

The preferred embodiment for fabrication of the structure of FIG. 1 would employ a GaAs crystal 1 which is heated with surface 2 exposed in an oxygen-free atmosphere in H<sub>2</sub>S at 700° C for 30 seconds to render the surface 2 pristine and forms a thin, of the order of a monolayer, coating 3 of gallium sulfide. The GaS coated structure is then provided with a 1-1,000 nanometer dielectric coating 4 of low temperature plasma enhanced chemical vapor deposited silicon dioxide.

What has been described is the fact that surface termination of compound semiconductor material for device use involves insuring the absence of an agent that causes the pinning, the presence of a material that prevents the pinning, and the protection of that material with a non-metallic layer that provides capability for dielectric, ambient reaction inertness and translucence properties.

## Claims

1. Compound semiconductor crystal intermediate manufacturing product comprising in combination on a pristine crystal interface of a monocrystalline compound semiconductor material taken from the group of Ga or Al or In and As or Sb and monocrystalline ternary and quaternary alloys thereof,

a Fermi level pinning control layer of a compound of a cation ingredient of said compound semiconductor and a member taken from the group of S, Se and Te in a thickness compatible with electrical current conduction through said layer, and a surface layer of a non-metallic material.

2. Intermediate manufacturing product of claim 1 wherein said compound semiconductor crystal is GaAs and said Fermi level pinning control layer is a Ga compound.

3. Intermediate manufacturing product of claim 1 wherein said non-metallic material is taken from the group of SiO<sub>2</sub>, CaF<sub>2</sub>, NaS, ZnS, GaP, GaSe and polyimides.

4. Intermediate manufacturing product of claim 1 wherein said Fermi level pinning layer thickness is in a range of one monolayer to approximately 2 nm.

5. Intermediate manufacturing product of claim 1 where the surface layer is in the range of 1 to 1000 nanometers thick.

6. In the fabrication of compound semiconductor device structures, the improvement in providing a compound semiconductor crystal with a device fabrication compatible surface termination, the intermediate manufacturing product comprising on a pristine crystal interface of a monocrystalline compound semiconductor material taken from the group of Ga or Al or In and As or Sb and monocrystalline ternary and quaternary alloys thereof, a Fermi level pinning control layer of a compound of a cation ingredient of said compound semiconductor and a member taken from the group of S, Se and Te in a thickness compatible with electrical current conduction through said layer, and a surface layer of a non-metallic material.

7. Intermediate manufacturing product of claim 6 wherein said compound semiconductor crystal is GaAs and said Fermi level pinning control layer is a Ga compound.

8. Intermediate manufacturing product of claim 6 wherein said non-metallic material is taken from the group of SiO<sub>2</sub>, CaF<sub>2</sub>, NaS, ZnS, GaP, GaSe and polyimides.

9. Intermediate manufacturing product of claim 6 wherein said Fermi level pinning layer thickness is in a range of the order of one monolayer to approximately 2 nm.

10. Intermediate manufacturing product of claim 6 where the surface layer is in the range of 1 to 1000 nanometers thick.

5

10

15

20

25

30

35

40

45

50

55

6

FIG. 1

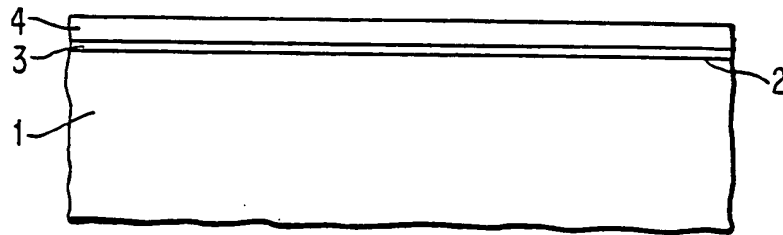


FIG. 2

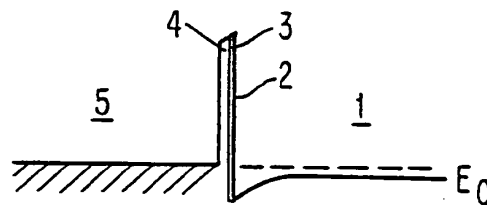


FIG. 3

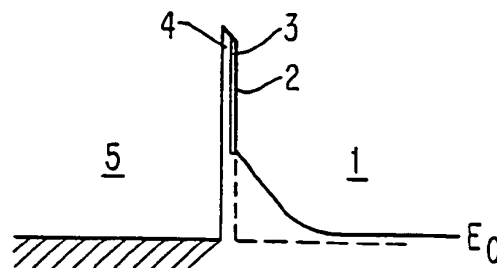


FIG. 4

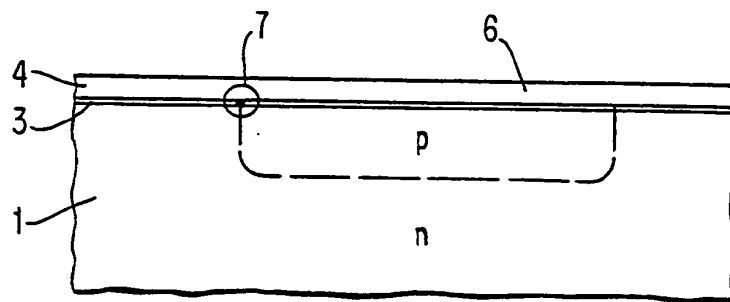


FIG. 5

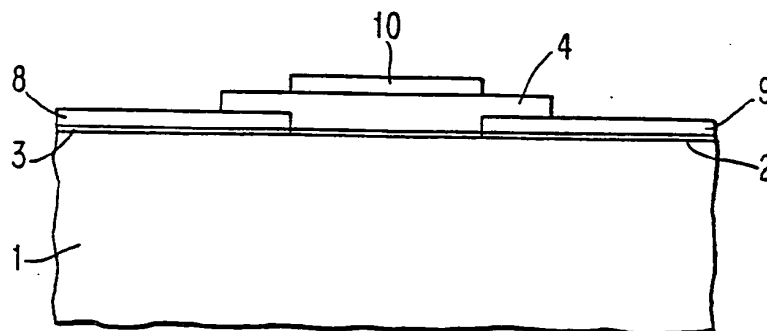


FIG. 6

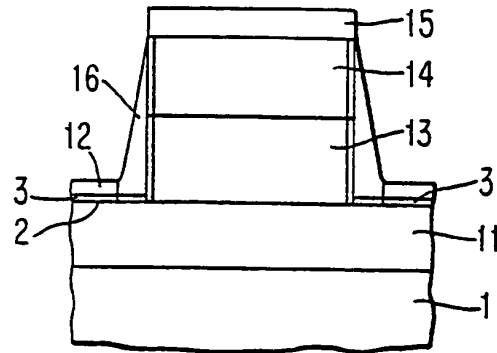


FIG. 7

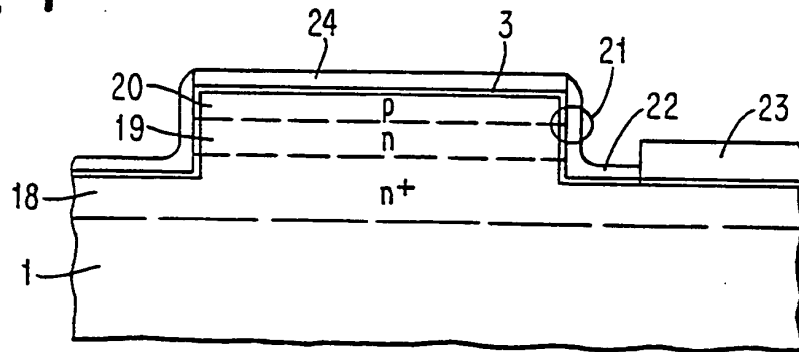
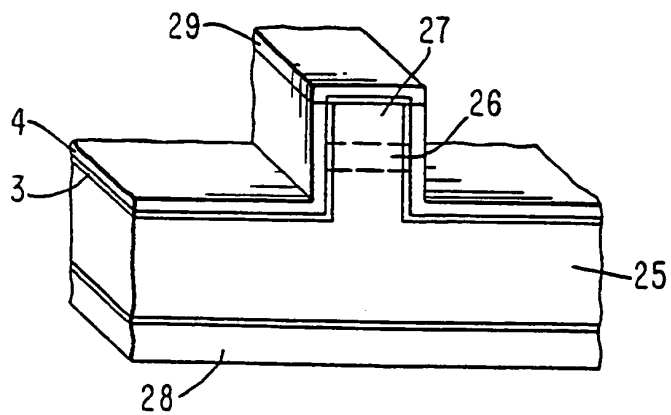


FIG. 8





European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number

EP 88 10 8684

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                 |                                                |                                                |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|------------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Citation of document with indication, where appropriate, of relevant passages                                                                                                                                                                                                                                                                   | Relevant to claim                              | CLASSIFICATION OF THE APPLICATION (Int. Cl. 4) |
| P,X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | EP-A-0 265 314 (CNET/CNRS)<br>* Page 2, line 37 - page 3, line 36 *<br>---                                                                                                                                                                                                                                                                      | 1-3                                            | H 01 L 21/314<br>H 01 L 29/40<br>H 01 L 21/285 |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | APPLIED PHYSICS LETTERS, vol. 38, no. 9, 1st May 1981, pages 693-695, American Institute of Physics, New York, US; J. MASSIES et al.: "Monocrystalline aluminium ohmic contact to n-GaAs by H <sub>2</sub> S adsorption"<br>* Abstract; page 695 *<br>---                                                                                       | 6,7,9                                          |                                                |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | IDEM<br>---                                                                                                                                                                                                                                                                                                                                     | 1,2,4                                          |                                                |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | WO-A-8 304 420 (HUGHES AIRCRAFT CO.)<br>* Page 12, line 24; page 15, lines 26-34; page 24, line 4 - page 26, line 30; page 27, line 1 - page 28, line 1 *<br>---                                                                                                                                                                                | 1,2,4                                          |                                                |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | ---                                                                                                                                                                                                                                                                                                                                             | 6,7,9                                          |                                                |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | US-A-3 983 264 (TEXAS INSTRUMENTS INC.)<br>* Page 3, lines 1-39 *<br>---                                                                                                                                                                                                                                                                        | 1,2,4,6,7,9                                    | TECHNICAL FIELDS SEARCHED (Int. Cl. 4)         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | GB-A-2 046 994 (D. CHEMLA et al.)<br>* Abstract *<br>---                                                                                                                                                                                                                                                                                        | 1,2,6,7                                        | H 01 L                                         |
| D,A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | JOURNAL OF VACUUM SCIENCE & TECHNOLOGY, vol. B3, no. 4, July/August 1985, pages 1197-1201, American Vacuum Society, New York, US; J.R. WALDROP: "Influence of S and Se on the schottky-barrier height and interface chemistry of Au contacts to GaAs"<br>* Abstract; page 1197, right-hand column - page 1198, left-hand column *<br>---<br>-/- | 1,6                                            |                                                |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                 |                                                |                                                |
| Place of search<br>THE HAGUE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                 | Date of completion of the search<br>30-09-1988 | Examiner<br>GELEBART J. F. M.                  |
| <b>CATEGORY OF CITED DOCUMENTS</b><br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br><br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br><br>& : member of the same patent family, corresponding document |                                                                                                                                                                                                                                                                                                                                                 |                                                |                                                |

EPO FORM 1503 03.82 (P0401)



European Patent  
Office

# EUROPEAN SEARCH REPORT

Page 2

Application Number

EP 88 10 8684

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                         |                                                |                                                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|------------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Citation of document with indication, where appropriate, of relevant passages                                                                                                                                                                                                           | Relevant to claim                              | CLASSIFICATION OF THE APPLICATION (Int. Cl. 4) |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | JOURNAL OF THE ELECTROCHEMICAL SOCIETY, vol. 134, no. 2, February 1987, pages 437-439, Manchester, NH, US; T. NARUSAWA et al.: "Structural study of GaAs-dielectric film (CaF <sub>2</sub> , Al <sub>2</sub> O <sub>3</sub> ) interfaces by high-energy ion scattering"<br>* Abstract * | 3,8                                            |                                                |
| D,A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | JOURNAL OF VACUUM SCIENCE & TECHNOLOGY, vol. 17, no. 5, September/October 1980, pages 1134-1140, American Vacuum Society; J. MASSIES et al.: "Effects of H <sub>2</sub> S adsorption on surface properties of GaAs (100) grown in situ by MBE"                                          |                                                |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                         |                                                | TECHNICAL FIELDS SEARCHED (Int. Cl. 4)         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                         |                                                |                                                |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                         |                                                |                                                |
| Place of search<br>THE HAGUE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                         | Date of completion of the search<br>30-09-1988 | Examiner<br>GELEBART J. F. M.                  |
| <b>CATEGORY OF CITED DOCUMENTS</b><br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                                                                                                                                                         |                                                |                                                |

EPO FORM 1503 03 82 (P0401)



(19)



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11)

EP 0 789 388 A2

(12)

## EUROPEAN PATENT APPLICATION

(43) Date of publication:  
13.08.1997 Bulletin 1997/33

(51) Int Cl.<sup>6</sup>: H01L 21/285

(21) Application number: 96306139.5

(22) Date of filing: 22.08.1996

(84) Designated Contracting States:  
DE FR GB

(30) Priority: 25.08.1995 JP 216935/95  
25.03.1996 JP 68018/96

(71) Applicant: AGENCY OF INDUSTRIAL SCIENCE  
AND TECHNOLOGY  
Chiyoda-ku Tokyo (JP)

(72) Inventors:  
• Hara, Shiro  
Tsukuba-shi, Ibaraki (JP)

• Kajimura, Koji  
Tsukuba-shi, Ibaraki (JP)  
• Okushi, Hideyo  
Tsukuba-shi, Ibaraki (JP)  
• Teraji, Tokuyuki  
Tsukuba-shi, Ibaraki (JP)

(74) Representative: Beresford, Keith Denis Lewis  
BERESFORD & Co.  
2-5 Warwick Court  
High Holborn  
London WC1R 5DJ (GB)

(54) Structure and fabrication method for schottky and ohmic electrodes onto semiconductor devices

(57) A novel electrode structure for Schottky electrodes and Ohmic electrodes and novel methods of fabricating electrodes by freely controlling electric characteristics of electrodes on semiconductors. Interface states density of a semiconductor (11) after deposition of an electrode metal (13, 14) is decreased by flattening the surface of the semiconductor on an atomic level to freely control the Schottky barrier height. The method can realize an ideal Ohmic electrode having a Schottky barrier height of substantially zero. The Schottky barrier height is varied freely by decreasing the interface level density and selecting work function of the electrode metal. The method can provide stable Schottky and Ohmic electrodes (13, 14) without need of heat treatment. Further, the method can provide Ohmic electrodes without high concentration doping.

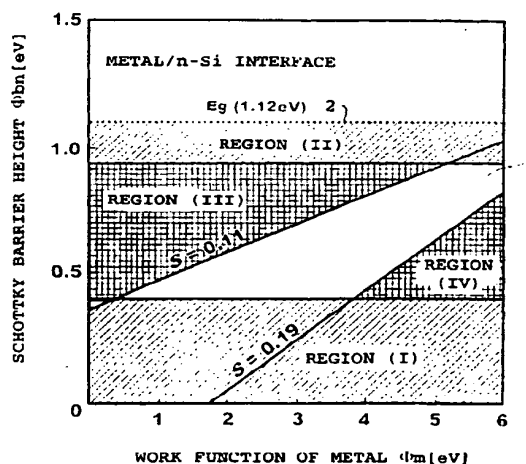


FIG. 2

EP 0 789 388 A2

## Description

The present invention relates to an electrode provided on a semiconductor and a method for fabricating an electrode on a semiconductor. The present invention is applicable to various fields of industry which involve fabrication of electrodes on semiconductors. For example, the present invention can be applied to various semiconductor devices such as microprocessors, memories, power devices and the like.

In conventional fabrication methods of electrodes on semiconductors, rectifying potential barriers, i.e., Schottky barriers, which will appear on the interfaces between electrode metals and semiconductors, have been impossible to control their magnitude. Hence, it has been impossible to artificially control the rectifying properties and conductivities of all the electrodes including not only those semiconductor devices whose performance depends directly on the heights of Schottky barriers, such as Schottky diodes as typical examples, but also those electrodes in the semiconductor devices thus far fabricated. The Schottky barrier height and leakage current, which is an indicator of important performance of interface on the device, inconveniently vary to a greater extent depending on combination of metals and semiconductors as well as on the process in which the interface is formed. Conventionally, this problem has been solved empirically. That is, when a new semiconductor has been developed, a method for fabricating an electrode on the semiconductor has been investigated and developed for each metal one after another until a suitable one is obtained. In other words, going into detail, there have conventionally been developed unique fabrication methods for fabricating electrodes adapted for respective combinations of semiconductors and electrode metal materials. Because of having had to resort to empirical rule, methods for fabricating electrodes differ from institution to institution or from manufacturer to manufacturer. There has been established no fabrication method for fabricating electrodes which method can be uniformly applied to any or most of electrode metal/semiconductor combinations. Under the circumstances, development of electrodes has needed much human and monetary resources for investigation. In all the semiconductor device fabrication technology inclusive of technologies for fabricating integrated semiconductor devices such as VLSIs and the like, only the technology for forming electrodes has remained as a unit technology that is out of reach of successful efforts for free designing.

More specific explanation will be made as to how to fabricate electrodes for Schottky electrodes and Ohmic electrodes, respectively.

First, in the case of Schottky electrodes, it was almost impossible to control their Schottky barrier height and, hence there was no other way than accept such non-controlled values as they are. For example, silicon Schottky diodes have almost fixed barrier heights on the order of about 0.5 to about 0.7 eV. While use of different metals or application of heat to cause interface reaction will vary barrier height to some extent, the width of change in barrier height is at most about 0.2 eV. Thus, in Schottky devices, the Schottky barrier height, which is the most important indicator for the device characteristics, cannot be controlled freely.

In the case of Ohmic electrodes, a severer problem arises. That is, electrode fabrication inevitably results in the formation of a Schottky barrier whose interface usually shows rectifying resistance. As a result, formation of a conductive Ohmic electrode, which is contrary to the fabrication of an electrode having a rectifying resistance, requires in principle a very difficult technique. Practically, in fabrication of almost all of the Ohmic electrodes fabricators have presupposed presence of a Schottky barrier in the interface between the electrode metal and semiconductor and then taken a measure to allow a leakage current to flow in the barrier.

There have been known several methods for increasing a leakage current. For example, a method for fabricating a device in which impurity ions are doped to extremely increase the concentration of electrons or holes which contribute to conductivity in the vicinity of the surface of the semiconductor (cf., e.g., E.H. Rhoderick and R.H. Williams: "Metal-Semiconductor Contacts, 2nd Ed.," Oxford Science Publications, 1988, M.Murakami: Materials Science Reports, 5, 273 (1990), P.A. Barnes and A.Y. Cho, Appl. Phys. Lett., 33, 651 (1978), and T. Uemoto: Jpn. J. Appl. Phys., 34, L7 (1995)). This reduces the width of the Schottky barrier, i.e., decreases the thickness of the depletion layer and, hence, a leakage current in the form of tunneling current, can be flown in the thin depletion layer. However, in the case of SiC, GaN and the like new semiconductor materials that are under development are usually difficult to dope with impurities at high concentrations so that electrodes having sufficiently low resistance cannot be obtained in most cases. The above-described method is not simple nor convenient in some cases since it requires an ion implanting apparatus or an electric oven for diffusing impurities in gaseous phases. Furthermore, the concentration of impurities has an upper limit at about  $10^{20}\text{cm}^{-3}$ . This automatically determines the minimum width of the depletion layer and, hence, sets technical limits to the interface resistance of an Ohmic electrode to be realized. Theoretically, this approach is unsuccessful in making the interface resistance of the Ohmic electrode to be zero. In addition, there may occur reflection of electrons or holes between the high concentration doped region and the low concentration doped substrate. This reflection of carriers increases the resistance of the electrode. From these, the interface resistance of an Ohmic electrode fabricated on a silicon substrate is limited to about  $10^{-8}\ \Omega\text{cm}^2$  based on the technical restrictions as described above.

Another method for fabricating an Ohmic electrode is to heat the electrode to decrease its resistance (cf., e.g., E. H. Rhoderick and R.H. Williams: "Metal-Semiconductor Contacts, 2nd Ed.," Oxford Science Publications, 1988, M.

Murakami: Materials Science Reports, 5, 273 (1990), H.C. Card: IEEE Trans. Electron Devices, ED-23, 538 (1976), T.C. Shen, G.B. Gao, and H. Morkoç: J. Vac. Sci. Technol., B10, 2113 (1992), N. Braslau, J.B. Gunn, and J.L. Staples: Solid-State Electronics, 10, 381 (1967), J. Appl. Phys., 77, 1317 (1967), and J. Crofton, P.G. McMullin, J.R. Williams, and M.J. Bozack: J. Appl. Phys., 77, 1317 (1995)). In this method, after the electrode metal is deposited, heat treatment is carried out so that there occurs interface chemical reaction between the metal and the semiconductor and metallization of the semiconductor proceeds in the vicinity of the interface. This induces impurity level or defect level in the depletion layer of the Schottky barrier. These levels generate leakage current. This method is simple and can be used in combination with high concentration doping. Because of the advantages, the method is used without fail in the conventional process of fabricating electrodes. However, interface reaction is complicated since it differs from a metal/semiconductor system to another and the mode of reaction varies widely depending on temperature and time of heat treatment. In some reaction systems, it is often the case that heating results in the formation of good Schottky barrier, which means heating does not always enhance Ohmicity (cf., e.g., S. Zaima, T. Yamauchi, Y. Koide, and Y. Yasuda: Appl. Surf. Sci., 70, 624 (1993)). This is a decisive defect of the above-described heating method.

Still another approach is to grow on a first semiconductor a crystal of a second semiconductor having a bandgap smaller than that of the first semiconductor so that the highest possible Schottky barrier height can be decreased to facilitate the formation of Ohmic contact (cf., e.g., E.H. Rhoderick and R.H. Williams: "Metal-Semiconductor Contacts, 2nd Ed.," Oxford Science Publications, 1988; M. Murakami: Materials Science Reports, 5, 273 (1990), and T.C. Shen, G.B. Gao, and H. Morkoç: J. Vac. Sci. Technol., B10, 2113 (1992)). This method involves heteroepitaxy of a semiconductor and, hence, its application is limited to semiconductor systems which allow heteroepitaxy.

Further, heteroepitaxy itself is a high technology which requires a complicated manufacturing process, which increases production costs. Therefore, the method is suited to a very limited range of semiconductor materials, more particularly, new semiconductor materials having wide bandgaps, such as GaN and the like, which are difficult to dope with impurities with high concentration doping of impurities.

The above-described three methods use large process apparatus suitable for fabricating devices and thus are not simple. Accordingly, in early stages of research and development for evaluating electric properties of materials or developing various devices, simpler means such as scratching of semiconductor or the like is used (here, by the term "scratching" is meant to hurt the surface of a semiconductor with a diamond needle or the like to coarsen it (cf., e.g., E.H. Rhoderick and R.H. Williams: "Metal-Semiconductor Contacts, 2nd Ed.," Oxford Science Publications, 1988)). On a coarse surface, a lot of structural defects are induced which increase leakage current. This method is quite inconvenient for making fine structures in the fabrication of semiconductor devices. In most cases, no good interface resistance can be obtained.

As described above, electrodes have been fabricated based on empirical rules. The primary reason for this is a lack of common or uniform understanding of the mechanism in forming a metal/semiconductor interface potential barrier. Uncontrollability of Schottky barriers and complexity of the mechanism of Ohmic contact formation which is attributable thereto would be due to the fact that Schottky barrier height is by nature fixed to a certain level. Fixation of Schottky barrier height of a semiconductor is equivalent to the fact that the Fermi level is fixed in the bandgap of the semiconductor on the metal/semiconductor interface. The fixation of Fermi level is usually referred to pinning of the Fermi level. The pinning of the Fermi level occurs as a result of generation of electron level in the bandgap of a semiconductor on the interface between the metal and the semiconductor. Carriers flow from bulk to the interface, i.e., electrons in the case of n-type semiconductor or holes in the case of p-type semiconductor flow from the bulk semiconductor to the interface and the carriers are trapped therein to create an electric double layer of the semiconductor bulk and the interface, i.e., a potential barrier or Schottky barrier.

Reviewing the development of Schottky barrier, in 1947, J. Bardeen stated that the interface level is caused by electronic level due to dangling bonds and the like existing on the surface of the semiconductor (cf. J. Bardeen: Phys. Rev., 71, 717 (1947)). Thereafter, however, in view of the impossibility of controlling the surface level density accurately by the technology available at that time, the leading view was that surface level density was uncontrollable and intrinsic to the material concerned, and interface electron level embedded in a solid should be an essential electron level that was more difficult to control than the surface level. The belief that pinning was intrinsic to materials and cannot be controlled artificially has led to a theory of MIGS (Metal-induced Gap States) which explains a cause of generation of interface levels (cf. V. Heine: Phys. Rev., 138, A1689 (1965)). According to this theory, interface levels are induced when a metal approaches toward the semiconductor. Since 1965 when V. Heine proposed it, the MIGS theory has been leading to date. The MIGS theory has inhibited research of a technology which controls the height of Schottky barrier. In fact, regardless of theories, there have been unavailable high technologies that can control interface level density in actual semiconductor devices.

Concerning numerical consideration of pinning, the work which referred to Schottky barrier for the first time was by W. Schottky (cf. W. Schottky: Naturwissenschaften, 26, 843 (1938) and N.F. Mott: Proc. Camb. Philos. Soc., 34, 568 (1938)). According to Schottky, the Schottky barrier height,  $\phi_{bn}$ , of a n-type semiconductor is given by the following equation (1):

EP 0 789 388 A2

$$\phi_{bn} = \phi_m - \chi S + C \quad (1)$$

wherein  $\phi_m$  is a work function of the metal,  $\chi S$  is electron affinity of the semiconductor, C is a constant no greater than several meV. On the other hand, the Schottky barrier height of a p-type semiconductor in a pinning-free state is given by the following equation (2):

$$\phi_{bp} = E_g - (\phi_m - \chi S + C) \quad (2)$$

wherein  $E_g$  is a bandgap.

The equations (1) and (2) are called Schottky models. However, no interface has been realized that meets these equations. The actual interface is expressed by the following equation (3):

$$\phi_{bn} = S (\phi_m - \chi S) + C \quad (3)$$

wherein S is a coefficient which indicates a dependence of  $\phi_{bn}$  on  $\phi_m$  and  $0 \leq S \leq 1$ .

When  $S=0$ ,  $\phi_{bn}$  is constant and the interface is pinned strongly. This state is called a Bardeen barrier. On the contrary, when  $S=1$ , the equation (3) is the same as the equation (1) and represents a pinning-free interface according to the Schottky-Mott model. Actual interfaces fall between the both states. Heretofore, the S factor has been believed to be a physical property specific to the material concerned and, hence, beyond control.

Table 1 below summarizes values of S factor and maximum and minimum values of Schottky barrier height of representative semiconductors.

Table 1  
PINNING RATIOS S OF VARIOUS KNOWN SEMICONDUCTORS AND RANGE OF SCHOTTKY BARRIER HEIGHT

| SEMI-<br>CONDUCTOR | S FACTOR                     | INTERCEPT<br>PARAMETER        | MINIMUM SCHOTTKY<br>BARRIER HEIGHT<br>[eV] | MAXIMUM SCHOTTKY<br>BARRIER HEIGHT<br>[eV] |
|--------------------|------------------------------|-------------------------------|--------------------------------------------|--------------------------------------------|
| Ge                 | $0.182 \leq S \leq 0.051$    | $-0.23 \leq C_2 \leq 0.111$   |                                            |                                            |
| Si(001)            | $0.192 \leq S \leq 0.111$    | $-0.34 \leq C_2 \leq 0.351$   | $0.37 (\text{GdSi}_2/\text{HoSi}_2)^2$     | $0.94 (\text{IrSi}_3)^3$                   |
| GaAs(001)          | $0.222 \leq S \leq 0.061$    | $-0.40 \leq C_2 \leq 0.0751$  | $0.62 (\text{Mg})^4$                       | $0.96 (\text{Cu})^4$                       |
| GaP                | $0.212 \leq S \leq 0.071$    | $0.45 \leq C_2 \leq 0.801$    |                                            |                                            |
| InP                | $0.372 \leq S \leq 0.241$    | $-1.00 \leq C_2 \leq 0.811$   |                                            |                                            |
| ZnS                | $0.662 \leq S \leq 0.211$    | $-1.63 \leq C_2 \leq 0.911$   |                                            |                                            |
| ZnSe               | $0.242 \leq S \leq 0.171$    | $-0.25 \leq C_2 \leq 0.571$   |                                            |                                            |
| 6H-SiC(0001)       | $0.252 \leq S \leq 0.235-10$ | $-3.5 \leq C_2 \leq 0.155-10$ | $0.73 (\text{Ti})^6$                       | $1.37 (\text{Au})^5$                       |

1. B.L. Sharma and S.C. Gupta, Solid State Technology, **23**(6), 90 (1980).
2. K.N. Tu, R.D. Thompson, and B.Y. Tsaur, Appl. Phys. Lett. **38**, 626(1981).
3. C.S. Petersson, et al., J. Appl. Phys., **50**, 3357 (1979).
4. J.R. Waldrop, J. Vac. Sci. Technol., **B2**, 445 (1984).
5. J.R. Waldrop, et al., J. Appl. Phys., **72**, 4757 (1992).
6. J.R. Waldrop, et al., Appl. Phys. Lett., **62**, 2685 (1993).
7. L.M. Porter, et al., Mat. Res. Soc. Symp. Proc., **287**, 471 (1993).
8. L.M. Porter, et al., J. Mat. Res., **10**, 26 (1995).
9. L.M. Porter, et al., J. Mat. Res., **10**, 668 (1995).
10. L.M. Porter, et al., M. Mat. Res. **10**, 2336 (1995).

Fig. 1 is a graphical presentation of the data in Table 1, plotting Schottky barrier height ( $\phi_{bn}$  [eV]) against work function of a metal ( $\phi_m$  [eV]) taking as an example of an n-type Si(001) semiconductor substrate. Fig. 1 shows that the Schottky barrier height was limited within a certain range for various metals. In Fig. 1, reference numeral 1 denotes an area representing the range in which the Schottky barrier heights of conventionally fabricated metal/n-Si interfaces fall and 2 denotes a line which represents an absolute upper limit of the Schottky barrier height of metal/n-Si interfaces corresponding to the bandgap  $E_g = 1.12$  eV. With different metals, there are always upper and lower limits of the Schottky

barrier heights.

Consequently, it has heretofore been impossible to freely control the Schottky height of metal/semiconductor interfaces.

The present invention is directed to overcoming the problem of uncontrollability of the Schottky barrier height between an electrode metal and a semiconductor, which problem has been an important subject since a transistor was invented.

Also, the present invention is aimed at solving the scientific and technological problem of uncontrollability of Ohmic electrodes, which has heretofore been considered a different problem from the uncontrollability of Schottky barrier height.

Further, the present invention is intended to provide a systematic technology which can control both Schottky electrodes and Ohmic electrodes, that have been treated separately one from another, based on a single principle that allows understanding them consistently. More specifically, the present invention is directed to overcoming the problem of uncontrollability of pinning of Fermi level of the interface of metal/semiconductor that has been impossible to control conventionally.

Therefore, an object of the present invention is to provide a method for fabricating Schottky electrode or Ohmic electrode formed at the interface between an electrode metal/semiconductor, which enables freely controlling electric properties of the electrode formed on the semiconductor.

Another object of the present invention is to provide an electrode structure comprising an electrode having a controlled Schottky barrier height of the interface between the electrode metal and the semiconductor.

According to a first aspect of the present invention, there is provided a method of fabricating a layer of an electrode metal on a surface of a semiconductor, comprising the step of:

decreasing a surface states density of the surface of the semiconductor.

According to a second aspect of the present invention, there is provided a method of fabricating a layer of an electrode metal on a surface of a semiconductor, comprising the step of:

controlling a Schottky barrier height of a rectifying Schottky electrode formed on the surface of the semiconductor.

Here, the control of the Schottky barrier height of the Schottky electrode may be carried out by controlling flatness of an electrode metal/semiconductor interface.

The control of the Schottky barrier height of the Schottky electrode may be carried out by controlling a step density on an atomic level of an electrode metal/semiconductor interface.

The control of the Schottky barrier height of the Schottky electrode may be carried out by controlling selecting a work function of the metal.

The control of the Schottky barrier height of the Schottky electrode may be carried out by controlling the Schottky barrier height of the Schottky electrode under conditions without giving thermal hysteresis.

According to a third aspect of the present invention, there is provided a method of fabricating a layer of an electrode metal on a surface of a semiconductor, comprising the step of:

fabricating a Schottky electrode from a metal having a high work function, and fabricating an Ohmic electrode from a metal having a low work function, for an n-type semiconductor, or fabricating a Schottky electrode from a metal having a low work function and an Ohmic electrode from a metal having a high work function, for a p-type semiconductor.

Here, the method may further comprise the step of heating.

According to a fourth aspect of the present invention, there is provided a method of fabricating an Ohmic electrode, comprising the step of: forming flat electrode metal/semiconductor interface on an atomic level.

According to a fifth aspect of the present invention, there is provided a method of fabricating an Ohmic electrode, comprising the step of: forming an electrode metal/semiconductor interface having a low step density on an atomic level.

According to a sixth aspect of the present invention, there is provided a method of fabricating an electrode, comprising the step of:

fabricating an Ohmic electrode as described above in a highly integrated electronic device.

Here, the semiconductor may be made of a semiconductor selected from the group consisting of Si and SiC.

The electrode metal may be selected from the group consisting of Al, Au, Mo and Ti.

According to a seventh aspect of the present invention, there is provided a Schottky electrode structure provided on a semiconductor having an interface portion which is flat on an atomic level.

According to an eighth aspect of the present invention, there is provided a Schottky electrode structure provided on a semiconductor having a Schottky barrier height which is impossible to realize by conventional method.

According to a ninth aspect of the present invention, there is provided a Schottky electrode structure provided on a semiconductor containing no high concentration impurity.

According to a tenth aspect of the present invention, there is provide an Ohmic electrode structure having a Schottky barrier height which is substantially zero.

Here, the semiconductor may be made of a semiconductor selected from the group consisting of Si and SiC.

The electrode metal may be selected from the group consisting of Al, Au, Mo and Ti.

According to an eleventh aspect of the present invention, there is provided a method of fabricating an electrode, comprising the step of:

oxidizing a surface layer of silicon or silicon carbide on a surface of a semiconductor and removing the resulting oxide film.

Here, the oxidizing of the silicon or silicon carbide may be carried out by heating the silicon or silicon carbide in an oxidative gaseous atmosphere.

Removing the oxide film may be carried out by reacting the oxide film with a reducing liquid or gas.

The silicon or silicon carbide may be n-type silicon or n-type silicon carbide, and wherein the electrode metal is a metal having a work function lower than that of noble metals.

The silicon carbide may be p-type silicon carbide, and wherein the electrode material is a noble metal or a metal having a work function of a level substantially equal to that of noble metals.

The electrode material may be titanium (Ti).

The electrode material may be aluminum (Al).

The above and other objects, effects, features and advantages of the present invention will become more apparent from the following description of the embodiment thereof taken in conjunction with the accompanying drawings.

Fig. 1 is a graph plotting Schottky barrier height of a Schottky electrode fabricated on an n-type Si(001) substrate by a conventional method against the work function of the electrode metal;

Fig. 2 is a graph illustrating regions representing Schottky barrier heights realized by the fabrication method of the present invention;

Fig. 3 is a graph illustrating current-voltage characteristics of Ti electrodes on SiC according to examples of the present invention;

Fig. 4 is a graph illustrating current-voltage characteristics of a Ti electrode on SiC which has been subjected to a conventional treatment with 5% hydrofluoric acid;

Fig. 5 is a graph illustrating current-voltage characteristics of an Al electrode on SiC according to the present invention;

Fig. 6 is a graph illustrating current-voltage characteristics of Al electrodes on SiC according to the present invention;

Fig. 7 is a graph illustrating current-voltage characteristics of an Al electrode on Si(111) which has been subjected to a conventional treatment with 5% hydrofluoric acid;

Fig. 8A is a sketch prepared based on an optical micrograph of the surface of a Ti electrode fabricated by the fabrication method according to EXAMPLE 4 of the present invention;

Fig. 8B is a schematic cross sectional view showing the Ti electrode illustrated in Fig. 8A;

Fig. 9A is a sketch prepared based on an optical micrograph of the surface of an Ni electrode fabricated by a conventional fabrication method;

Fig. 9B is a schematic cross sectional view showing the Ti electrode illustrated in Fig. 9A;

Fig. 10 is a graph illustrating logarithmic current-voltage characteristics of Au electrodes on 6H-SiC(0001) substrates according to EXAMPLE 7 of the present invention;

Fig. 11 is a graph plotting Schottky barrier height of electrode metals fabricated on 6H-SiC(0001) substrates against the work function of the electrode metals; and

Fig. 12 is a graph illustrating new areas for Schottky barrier heights of electrode metals fabricated on 6H-SiC(0001) substrates using the techniques of the present invention.

In order to solve the problem of uncontrollability of Schottky barrier height, it is only necessary to decrease the interface states density of the interface between an electrode metal and a semiconductor on which the electrode metal layer is formed. According to the present invention, a decrease in the interface states density is realized by decreasing the surface states density of the semiconductor before deposition of a metal thereon. The decrease in the surface states density can be realized primarily by flattening the surface of a semiconductor on an atomic level.

Flattening of the surface of a semiconductor results in a decrease in an atomic step density which generates dangling bond density which is a cause of surface states and in an amount of unstable atoms adsorbed on the surface of the semiconductor. According to the present invention, it has been found for the first time that flattening of the surface of a semiconductor on an atomic level decreases the surface states density of the semiconductor and that a decrease in the surface states density is effective for decreasing the interface states density of the electrode metal/semiconductor structure.

Recently, the technology of flattening the surface of semiconductors on an atomic level has developed rapidly and a variety of methods have been proposed. The present invention uses the newest known atomic level surface flattening

technologies to demonstrate the above effect. However, the present invention should not be construed as being limited to specific atomic level surface flattening techniques. There have been known several important techniques for flattening surfaces of semiconductors on an atomic level, all of which have been proved useful in decreasing interface level density according to the present invention.

The present invention is based on a principle contrary to the conventional method in which particularly in the case of Ohmic contact, the desired Ohmic contact has been realized by intentionally decreasing ideality of interface, i.e., abruptness of structural connection.

Description will be made on how to flatten the surface of a semiconductor on an atomic level. An example of such a method is to set up conditions of oxidation appropriately so that oxidation can proceed flat on an atomic level, thus making the surface of the semiconductor after etching more flattened than the original surface.

Another method is a treatment with dilute hydrofluoric acid adjusted to have an appropriate pH. The pH of the solution can be rendered alkaline with ammonia water. Such a solution has an activity of flattening the surface of a semiconductor on an atomic level by means of a weak etching action of a lot of OH groups contained in the solution. Similarly, a semiconductor may be immersed in boiling water. This method can flatten the surface of a semiconductor on an atomic level by means of a weak etching action of deionized water.

High temperature heat treatment in hydrogen gas is also effective for flattening the surface of a semiconductor. Homoepitaxial growth can accelerate surface migration of atoms at relatively low growth rates to flatten the surface of crystal growth. As the last example, a method utilizing electromigration can also be used for flattening the surface of a semiconductor on an atomic level. Electromigration is a phenomenon in which upon application of electric current to a sample, surface atoms will migrate in a direction the same as or opposite to the direction in which electric current flows. Use of this method semiconductor surfaces can be flattened depending on the conditions. The present invention is not limited to the above-described specific methods. Instead, any method that can flatten semiconductor surfaces on an atomic level may be used similarly and will be effective for decreasing interface levels.

Hereinbelow, the idea of flattening semiconductor surfaces on an atomic level will be described in more detail. To be flat on an atomic level means existence of wide flat terraces when viewed on an atomic level. This directly indicates that an atomic step density is low in the surface concerned. Atoms at a step generally have more dangling bonds than atoms on a terrace. While the dangling bonds on a terrace will disappear after the formation of an interface with a metal due to bonding with the metal, the dangling bonds at a step will not disappear completely because of the step or difference in height as high as the thickness of one atomic layer. Therefore, after the formation of an interface, a main cause of generation of interface states is dangling bonds at steps. In other words, a decrease in a step density will result in a decrease in an interface level density. Hence, in order to decrease an interface states density, it is sufficient to flatten the surface of a semiconductor so that its step density can be decreased. Thus, even if the surface is not flattened when viewed on a scale on the order of micrometers, existence of wide terraces in more minute regions will suffice for decreasing interface states. Therefore, electrode structures with an interface having wide terraces on an atomic level, even though they have uneven or rough surfaces when viewed in a broader region, will cause a decrease in surface states density and, hence, fall within the scope of the present invention as defined below in appended claims.

If the interface states density is reduced enough by one of the above-described methods, the pinning of Fermi level will disappear. On such a pinning-free interface, what determines its potential barrier is merely a difference between respective Fermi levels, i.e., a difference between respective work functions, of the metal and the semiconductor. In this case, Schottky-Mott model expressed by equations (1) and (2) above is followed. Therefore, in the case of an n-type semiconductor, use of a metal having a high work function results in the formation of a Schottky barrier while use of a metal having a low work function gives rise to an Ohmic contact. To control the Schottky barrier height, it is only necessary to select an appropriate metal with regard to work function. For p-type semiconductors, the same idea as that for n-type semiconductors can be applied except that relationship of the magnitudes of the work functions should be reversed.

According to the present invention, the Schottky barrier height of a semiconductor can be expanded to a minimum value of 0 eV (cf. Fig. 2, region (I)) and a maximum value equivalent to the bandgap (cf. Fig. 2, region (II)).

Also, controlling the degree of pinning will in effect vary the Schottky height and, hence, controlling interface level density will enable the Schottky barrier height even when the same metal is used. That pinning can be controlled means that the Schottky barrier height can be controlled at will for each metal. As a result, the region where the Schottky barrier height can be controlled is expanded to regions (III) and (IV) in Fig. 2.

As described above, the present invention has made it possible to expand the region where the Schottky barrier height can appear from region (I) to regions (I) to (IV) in Fig. 2. Therefore, for a given metal, electrodes having the Schottky barrier heights within one of the regions (I) to (IV) also fall within the scope of the present invention. The present invention is generally applicable and operable regardless of the kind of metal and for all n-type and p-type semiconductor substrates, can be set up the regions (I) to (IV) as illustrated in Fig. 2 according to the present invention. Table 1 above indicates the Schottky barrier height regions of the present invention for representative semiconductor materials.

Another important feature of the present invention is that control of Schottky/Ohmic property can be performed without heat treatment. However, if heat treatment is carried out after the deposition of electrode metals, still a flat interface can be obtained since originally a flat surface on an atomic level is provided, an interface reaction between the metal and the semiconductor occurs uniformly in the interface therebetween. Therefore, the present invention is also effective to electrodes which are subjected to heat treatment.

While not intended to be bound thereto, the present invention can be applied suitably to fabrication of electrodes on silicon carbide (SiC). While SiC is a material with which p- and n-type semiconductors can be used with ease, they have various excellent physical properties such as large a large bandgap. The present invention will be explained further taking SiC as an example. Since in the present invention, processes are used that do not involve heat treatment, no appreciable interface chemical reaction does occur between the metal and the semiconductor. Therefore, the resulting interface receives the conditions of the surface of the semiconductor without any change, and the interface has electrical characteristics which depend on structural and chemical properties of the surface of SiC before the deposition of the electrode metal. In other words, control of the conditions of the surface of SiC makes it possible to control electric properties freely.

When no treatment is performed on the surface of SiC, a natural oxide film is formed thereon. Also, a lot of water and/or impurity atoms are adsorbed on the SiC surface. Further, in the case of as ground surfaces, there are near the surface a lot of impurity atoms contaminating or defects induced upon grinding. Such conditions depend strongly on the process by which the SiC surface is fabricated so that the resulting surface does not always have the same surface atomic conditions and surface electronic state and then unstable.

In the present invention, a method is used which depends strongly on the conditions of surface atoms as described above. Therefore, such an unstable surface layer must be removed. For this purpose, SiC is oxidized and then the resulting oxide film is removed. The oxidation and removal of the oxide film may be performed simultaneously.

As a specific example of oxidation method for oxidizing silicon carbide (SiC), there can be used a method in which SiC is heated in an oxidizing gas atmosphere. The oxidation can be carried out at a heating temperature within the range of usually 800 to 1,250°C, preferably 950 to 1,150°C.

Concerning the selection of metals for use as an electrode material, a lot of metal materials with which Ohmic electrodes have not been realized by the conventional high temperature heat treatment can be used for forming Ohmic electrodes according to surface condition controlling technique in the fabrication method for fabricating electrodes on SiC according to the present invention. Properly speaking, a theoretical approach for realizing an Ohmic contact for n-type semiconductors is to use metal materials having a low work function. However, conventionally, Ohmic contacts were obtained by coarsening or roughening the interface by means of high temperature heat treatment to provide the interface with a non-ideal (non-uniform) structure and metal materials having a high work function which are difficult to oxidize were used in order to prevent the high temperature oxidation. On the contrary, in the present invention, heat treatment does not have to be done so that the interface is abrupt enough to be ideal one and then it is possible to realize an Ohmic contact for those metal materials which do not have high work function naturally. Here, metals which do not have high work functions are those metal materials composed mainly of elements other than noble metals (Ni, Pd, Pt, Cu, Ag, and Au) having high work functions, such as Ni which has been used conventionally. More specifically, a wide variety of metals can be used, including, for example, Mg, Ca, Sr, Ba, Sc, Y, La, Ti, Zr, Hf, V, Nb, Ta, Cr, Mn, Re, Fe, Al, Ga, In, Tl and the like. Among these, those metals having not so high an oxidizing capability, e.g., Ti and Al, are preferred.

In order to realize Ohmic contacts with p-type semiconductors, theoretically, metal materials having high work functions should be used. Conventionally, however, Ohmic contacts were formed by addition of impurities in high concentrations and, hence, aluminum (Al) has been used as an electrode metal because it can serve as a p-type impurity. However, Al has a low work function and is not suited as a metal for p-type metals. In the present invention, metals having high work functions are used. More specifically, metals which can be used for p-type semiconductors for forming Ohmic contacts include noble metals such as Ni, Pd, Pt, Cu, Ag, and Al and metals having approximately the same work function as the noble metals, such as Co, Rh, Ir, Ru, Os, and Re.

In the case of n-type SiC, if heat treatment is required after the formation of electrodes, a metal which is resistant to oxidation and has a high work function can be deposited on the above-described electrode metals having low work functions to prevent oxidation of the electrode portions. Similar effects can be obtained by depositing two or more metals having low work functions on a metal forming a metal semiconductor interface. Therefore, if heating is needed or desired, the above-described effect of the present invention cannot be deteriorated. What is important in the present invention is to use a metal having a low work function for an n-type SiC and a metal having a high work function for a p-type SiC. Practically, metals are divided into low and high work function metals when they have work functions up to 4.5 eV or higher than 4.5 eV. However, 4.5 eV is not a strict threshold value. This is because when a metal is deposited on SiC at ambient (room) temperature, e.g., about 20°C, mutual diffusion of the atoms constituting the metal and the atoms constituting the SiC semiconductor may occur on the metal/semiconductor interface and effective work function alters, if the metal used is highly reactive. So, 4.5 eV is to be understood to be a practical standard for classifying

metals.

More specifically, the present invention comprises an oxidation process using an oxidative gas. Usually, a sample is placed in an oxidative atmosphere in an apparatus which enables heating of the sample, such as electric oven, and the sample is heated at a temperature within the range of 800 to 1,250°C. With this treatment, the surface of the sample becomes insulating due to formation of an oxide film thereon and a sufficient electric contact is not achieved. Then, the oxide film is removed with a reducing liquid or gas. It is often the case that the atoms on the surface of SiC are arranged or accumulate in a manner different from that the atoms in the bulk of the SiC. The oxidation process in an oxidative gaseous atmosphere is meant to oxidize such a denatured surface layer and make the surface layer ready to be removed by a liquid process including dissolving the surface oxide layer with a reducing liquid to remove it, or gaseous process involving reducing the surface oxide layer with a reducing gas to convert the oxide layer to a semiconductor of non-oxidized state.

In conventional processes for fabricating electrodes, immersion or dipping of a semiconductor in a dilute hydrofluoric acid has been conducted to remove spontaneous oxide film on the surface of SiC. However, no intentional or artificial oxidation of SiC has been performed so that the unstable surface layer has not been removed completely, thus failing to provide stable Ohmic contacts.

According to the present invention, development of Schottky and Ohmic electrodes, which has heretofore been made relying on experience or empirical rules, can be made in a shorter time than before since the present invention is based on a systematized knowledge. Thus, efforts for the development of electrodes can be minimized. The method for fabricating electrodes according to the present invention does not need heat treatment, which makes a great increase in stability of the electrode structure as compared with the conventional method in which heat treatment is essential. Further, in the case of fabricating Ohmic electrodes, conventional methods use doping semiconductors with impurities in high concentrations. In the present invention, however, high concentration doping is unnecessary so that Ohmic electrodes can be fabricated simply and conveniently. In contrast to the conventional methods in which leakage current in the Schottky barrier is used, the method for fabricating electrodes according to the present invention can reduce the Schottky barrier height to zero so that high performance Ohmic electrodes having theoretically no interface resistance that has not been achieved conventionally.

According to the present invention, Schottky barrier heights, that have been almost impossible to control by conventional methods, can be controlled freely by controlling interface level density and selecting work function of metals.

In practicing the present invention, it is only necessary to make the surface of a semiconductor as flat as possible on an atomic level. There are various kinds of known techniques for flattening the surface of a semiconductor on an atomic level and all such techniques can be used in the present invention. Therefore, there is no technical difficulty in practicing the present invention and the present invention can be applied to various metals and semiconductors simply and conveniently.

Hereinafter, the present invention will be described in greater detail by examples with reference to the attached drawings. However, the present invention should not be construed as being limited thereto.

#### EXAMPLE 1 Confirmation of Ohmic Property (SiC-Ti Structure)

In the instant example, vacuum sublimated n-type 6H-SiC was used as a semiconductor substrate immediately after it was ground. The substrate had a carrier density of about  $1 \times 10^{17} \text{ cm}^{-3}$ . At this carrier density, usually, the semiconductor was not metallic and it was difficult to produce an Ohmic contact. The substrate was cleaned using methanol and trichloroethylene, and then placed in an electric oven filled with an oxygen gas atmosphere and oxidized at 300 °C for 30 minutes, followed by 800°C for 10 minutes. Thus an oxide film of about 5 nm thick was formed. The substrate was dipped in 5% hydrofluoric acid to remove the oxide film.

On the thus-obtained SiC substrate was deposited titanium (Ti), which is a representative high melting metal and has a low work function. The work function of Ti was 4.4 eV, which is by 0.9 eV lower than Ni, which has conventionally been used as an Ohmic electrode and has a work function of 5.3 eV. The SiC substrate used was not heated previously. The thickness of deposited film was about 500 nm. Deposition was not carried out on the entire surface of the semiconductor but through a metal mask formed with a round hole of 0.30 mm in diameter for subsequent electrical measurements.

Fig. 3 is a graph illustrating current-voltage (I-V) characteristics of the sample taken out of the vacuum apparatus (cf. line 3a). As apparent from Fig. 3, the line 3a is a straight line. Lack of nonlinearity as shown by the straight line 3a in Fig. 3 clearly indicates that the electrode obtained is Ohmic, that is, current is proportional to voltage. The interface resistance of the resulting electrode was  $6.7 \times 10^{-2} \Omega \text{ cm}^2$ . The electrode made of a SiC material having a low carrier density as low as  $2 \times 10^{17} \text{ cm}^{-3}$  had an Ohmic contact which had theoretically the lowest resistance.

An electrode structure was fabricated in the same manner as in EXAMPLE 1 except that no oxidative etching was conducted but only dipping in 5% hydrofluoric acid was performed (COMPARATIVE EXAMPLE 1). The comparative electrode structure showed no Ohmic property but exhibited Schottky property (Fig. 4). In Fig. 4, curves 4a and 4b

show normal and reverse direction leakage currents, respectively.

#### EXAMPLE 2 Confirmation of Ohmic Property (SiC-Al structure)

Next, an electrode structure was fabricated in the same manner as in EXAMPLE 1 except that instead of Ti was used aluminum (Al), which is a non-transient, low melting metal and belonging to the group (III) of the periodic table. In this case, too, was obtained an Ohmic contact similar to that fabricated in EXAMPLE 1. The work function of Al is 4.3 eV. Fig. 5 shows current-voltage characteristics of the aluminum electrode fabricated under the same conditions as the Ti electrode. Similarly to EXAMPLE 1, a line 5 representing the current-voltage characteristics of the Al electrode showed linearity and the interface resistance was about  $1.4 \times 10^{-2} \Omega \text{cm}^2$ . The electrode made of a SiC material having a low carrier density as low as  $2 \times 10^{17} \text{ cm}^{-3}$  had an Ohmic contact which had theoretically the lowest resistance.

What is common between EXAMPLE 1 and EXAMPLE 2 is that the both metals used have work functions by about 1 eV lower than those of noble metals used as electrode metal for SiC in the conventional methods. The both metals tested here exhibited effects which attain the objects of the present invention.

#### EXAMPLE 3 Confirmation of Ohmic Property (Si-Al structure)

The instant example is to show that the present invention is applicable to Si substrates and also realize Ohmic contacts. As a semiconductor substrate was used an n-type Si substrate having a carrier density of  $7 \times 10^{16} \text{ cm}^{-3}$ . The substrate was cleaned using methanol and trichloroethylene, and then placed in an electric oven filled with an oxygen gas atmosphere and oxidized at  $300^\circ\text{C}$  for 30 minutes, followed by  $800^\circ\text{C}$  for 10 minutes. Thus an oxide film of about 50 nm thick was formed. The substrate was dipped in 5% hydrofluoric acid to remove the oxide film. The substrate thus obtained was dipped in hot water to make the surface of the semiconductor substrate flat on an atomic level. Thereafter, aluminum was deposited on the surface as an electrode metal. Fig. 6 illustrates current-voltage characteristics of the resulting electrode structure. A line 6a, which is a straight line, represents the sample with 5% hydrofluoric acid treatment. A line 6b, which is also a straight line, represents the sample with hot water treatment after 5% hydrofluoric acid treatment. A line 6c, which is also a straight line, represents the sample with 5% hydrofluoric acid treatment followed by hot water treatment. Here, by the term "hot water treatment" is meant a treatment with heated deionized water at a temperature below  $100^\circ\text{C}$ . From Fig. 6, it is apparent that the electrode fabricated according to the present invention has an Ohmic contact having a good linearity of current-voltage characteristics (the line 6c). Heretofore, as illustrated in Fig. 1, no metal could provide an Ohmic contact for Si substrates without high concentration doping. In fact, a comparative sample having an Si(111) substrate which did not subjected to high concentration doping and having a carrier density of  $7 \times 10^{16} \text{ cm}^{-3}$  (COMPARATIVE EXAMPLE 2) gave a Schottky barrier whose  $\phi_{\text{bn}}$  was 0.69 eV after receiving the same 5% hydrofluoric acid treatment as in the instant example (Fig. 7). In Fig. 7, curves 7a and 7b denote current flows in normal and reverse directions, respectively. Comparing the lines 6a to 6c in Fig. 6, it is observed that according as flattening processes are added or flatness increases, current increases and contact resistance decreases. In the instant example (the line 6c in Fig. 6), the doping concentration was  $7 \times 10^{16} \text{ cm}^{-3}$ , at which the width of the depletion layer is sufficiently thick and no tunneling will occur theoretically. Therefore, the Ohmic property observed in the sample of the instant example is considered to be attributable to a sufficiently decreased Schottky barrier.

#### EXAMPLE 4 Structural Uniformity of Electrode Structure

A Ti electrode was fabricated in the same manner as in EXAMPLE 1. Fig. 8A is an illustrative view prepared based on an optical micrograph of the surface of the Ti electrode. Fig. 8B is an expanded schematic cross sectional view showing the Ti electrode shown in Fig. 8A. As COMPARATIVE EXAMPLE 3, was prepared an Ni electrode by a conventional heat treatment method. The Ni electrode fabricated by cleaning using methanol and trichloroethylene, the same n-type SiC substrate as used in EXAMPLE 1, depositing Ni thereon by vapor deposition and then heating the substrate at  $1,000^\circ\text{C}$  for 60 minutes. Fig. 9A is an illustrative view prepared based on an optical micrograph of the surface of the Ni electrode. Fig. 9B is an expanded schematic cross sectional view showing the Ni electrode shown in Fig. 8A. In Figs. 8A and 9A, reference numeral 11 denotes an SiC substrate, 12 is an outline contour line of the electrode, 13 is an Ni electrode, and 14 is a Ti electrode. The both Ni and Ti electrodes were in the form of a disk of 0.3 mm in diameter. From Figs. 8A, 8B, 9A and 9B, it is apparent that the Ti electrode fabricated on SiC fabricated without heat treatment in accordance with the present invention has a high flatness in surface. The Ni electrode 13 shown in Fig. 9A has a rough surface, clearly lacking structural uniformity. In contrast, in the Ti electrode 14 of the present invention, no region is observed where surface conditions are different, and the area inside a contour line 12 of the electrode 14 is uniform in appearance and highly flat, thus presenting excellent structure for Ohmic structure. The electrode fabricated according to the method of the present invention (Fig. 8B) had a surface with an unevenness (X1) of 5 nm or

less. On the contrary, the electrode fabricated by the conventional method (Fig. 9B) had a surface with an unevenness ( $\times 2$ ) of about 200 nm. This clearly indicates that the electrode fabricated by the method of the present invention had a surface flatness much superior to the electrode fabricated by the conventional method.

#### EXAMPLE 5 Dependence on Atomic Level Flattening Treatment - Epitaxial Growth

The same SiC substrate immediately after grinding as used in EXAMPLE 1 was dipped in boiling water (100°C) for 10 minutes. On the other hand, a sample was prepared by homoepitaxially growing SiC on the same SiC substrate after grinding as used in EXAMPLE 1. The sample was dipped in boiling water (100°C) for 10 minutes. Then, difference in current-voltage characteristics between the epitaxial SiC substrate and the SiC substrate immediately after grinding were examined. In the case of the epitaxial SiC substrate, an expectation will be made that flattening in surface proceeds sufficiently so that the interface level density decreases and as a result, the Schottky barrier height decreased and Ohmic property increases. In fact, the SiC substrate immediately after grinding had an interface resistance of  $1.2 \times 10^{-2} \Omega \text{cm}^2$  (the line 3c in Fig. 3) while the epitaxial SiC substrate had an improved interface resistance of  $6 \times 10^{-3} \Omega \text{cm}^2$  (the line 3d in Fig. 3). From this it follows that epitaxial growth is effective for flattening on an atomic level the surface of a semiconductor and for decreasing interface level density of the semiconductor.

#### EXAMPLE 6 Dependence on Atomic Level Flattening Treatment - pH Adjusted Dilute Hydrofluoric Acid Treatment

An oxidized/etched substrate having a current-voltage characteristics represented by the line 3a in Fig. 3 as used in EXAMPLE 1 was dipped in a pH adjusted dilute hydrofluoric acid for 10 minutes. Then, a metal was deposited on the surface of the thus obtained substrate. In Fig. 3, the line 3b represents the current-voltage characteristics of the electrode sample. In this case, the dilute hydrofluoric acid was adjusted to pH 10. Comparison of the line 3b with the line 3a shows that the interface resistance is improved to  $1.5 \times 10^{-2} \Omega \text{cm}^2$ . As demonstrated in the instant example, pH adjusted dilute hydrofluoric acid treatment is also effective in decreasing interface level density.

#### EXAMPLE 7 Fabrication of a Schottky Electrode Showing Less Leakage

Fig. 10 illustrates current-voltage characteristics of gold (Au) electrode on 6H-SiC(0001) face. Lines 10a, 10b and 10c show normal direction leakage currents and 10a', 10b' and 10c' show reverse direction leakage currents. In the case of SiC surface with usual 5% hydrofluoric acid treatment, the reverse direction leakage current was on the order of  $10^{-7} \text{ A/cm}^2$  (line 10a'). When oxidation/etching treatment was conducted, the reverse direction leakage current was decreased to  $10^{-19} \text{ A/cm}^2$  or less (line 10b'), thus showing a drastically improvement in leakage characteristics by 12 digits. Furthermore, with additional boiling water treatment, the reverse direction leakage current was further improved by 2 digits to  $10^{-21} \text{ A/cm}^2$  (line 10c'). This indicates that oxidation/etching treatment and boiling water treatment which accelerate flattening of the surface of the semiconductor weaken the pinning of the Schottky barrier. To note, in the instant example, the electrode itself was subjected to no heat treatment. Therefore, the instant example clearly shows that high quality Schottky electrode can be fabricated without heat treatment of the electrode.

#### EXAMPLE 8 Control of Pinning and Schottky Barrier Height

Fig. 11 illustrate Schottky barrier height for various metals deposited on 6H-SiC(0001) face. The horizontal axis indicates work function of the metal. In the case of usual pretreatment with 5% hydrofluoric acid, the Schottky barrier height does not substantially depend on the work function of the metal and S factor which indicates an inclination of the line is about 0.2 (line 11a). Then, atomic level flattening of SiC was conducted by oxidation/etching treatment,  $S=0.8$  was obtained, which indicates almost pinning free state (line 11b). Further, boiling water treatment gives rise to  $S=1.0$ , which indicates no pinning is observed (line 11c). Thus, the present invention realized pinning free state for those semiconductors which inherently show pinning. As a result, the Schottky barrier height can be freely changed merely by changing the work function of the metal as illustrated in Fig. 11 clearly. When the same metal is used, change in the process of atomic level flattening of the surface of the semiconductor results in varied Schottky barrier height. Note that for Ti electrodes, Schottky barrier heights were theoretically estimated from contact resistance values.

Fig. 12 illustrates Schottky barrier heights of Schottky electrodes fabricated on 6H-SiC(0001) substrates by the conventional method and by the methods of the examples of the present invention. For strict comparison, conventional electrodes were fabricated on clean surfaces and I-V characteristics values measured at room temperature were used. The data of the conventional electrodes exist in the region (0). Ti, Mo and Au electrodes subjected to oxidation/etching treatment and boiling water treatment according to the present invention are plotted in regions (I), (IV) and (II), respectively. The data show that the present invention made it possible to realize Schottky barrier heights beyond the lower limit (region (I)) and beyond the upper limit (region (II)) that were impossible to achieve by the conventional method.

**EP 0 789 388 A2**

The Mo electrode plotted in region (IV) gives the same Schottky barrier height as that of the conventional Ti electrode having lower work function. This means that to give a certain Schottky barrier height, those metals that were considered inappropriate in view of pinning action can be used in the method of the present invention.

As described above, Schottky barrier height of semiconductors can be freely controlled according to the present invention.

Table 2 summarizes the results of examples and Comparative examples above.

10

15

20

25

30

35

40

45

50

55

Table 2

|        | Substrate | Electrode<br>Metal | Treatment                       | Figure              | Interface<br>Resistance<br>( $10^{-2}\Omega\text{cm}^2$ ) | Reverse<br>Direction<br>Leakage<br>Current<br>(A/cm <sup>2</sup> ) | Surface<br>Unevenness<br>(nm) |
|--------|-----------|--------------------|---------------------------------|---------------------|-----------------------------------------------------------|--------------------------------------------------------------------|-------------------------------|
|        |           |                    |                                 |                     |                                                           |                                                                    |                               |
| Ex. 1  | SiC       | Ti                 | A+B                             | Fig. 3              | 6.7                                                       |                                                                    |                               |
| C.Ex.1 | SiC       | Ti                 | B                               | Line (a)<br>Fig. 4  |                                                           |                                                                    |                               |
| Ex. 2  | SiC       | Al                 | A+B                             | Fig. 5              | 1.4                                                       |                                                                    |                               |
| Ex. 3  | Si        | Al                 | A+B                             | Fig. 6              |                                                           |                                                                    |                               |
|        | Si        | Al                 | B+C                             | Line (a)<br>Fig. 6  |                                                           |                                                                    |                               |
|        | Si        | Al                 | A+B+C                           | Line (b)<br>Fig. 6  |                                                           |                                                                    |                               |
| C.Ex.2 | Si        | Al                 |                                 | Line (c)<br>Fig. 7  |                                                           |                                                                    |                               |
| Ex. 4  | SiC       | Ti                 | A+B                             | Fig. 8A,<br>Fig. 8B |                                                           |                                                                    | 52                            |
| C.Ex.3 | SiC       | Ni                 | Cleaning*<br>Heating<br>1,000°C | Fig. 9A,<br>Fig. 9B |                                                           |                                                                    | 200                           |

Table 2 (Continued)

|         | Electrode              |                  | Treatment | Figure  | Interface Resistance<br>( $10^{-2}\Omega\text{cm}^2$ ) | Reverse Direction Leakage Current<br>(A/cm <sup>2</sup> ) | Surface Unevenness<br>(nm) |
|---------|------------------------|------------------|-----------|---------|--------------------------------------------------------|-----------------------------------------------------------|----------------------------|
|         | Substrate              | Metal            |           |         |                                                        |                                                           |                            |
| Ex. 5   | SiC<br>(Bulk)          | Ti               | A+B+C     | Fig. 3  | 1.2                                                    |                                                           |                            |
|         | SiC-SiC<br>(Epitaxial) | Ti               | A+B+C     | Fig. 3  | 0.6                                                    |                                                           |                            |
| Ex. 6   | SiC                    | Ti               | A+B*      | Fig. 3  | 1.5                                                    |                                                           |                            |
| Ex. 7   | 6H-SiC<br>(0001)       | Au               | A+B       | Fig. 10 |                                                        | 10 <sup>-19</sup>                                         |                            |
|         | 6H-SiC<br>(0001)       | Au               | A+B+C     | Fig. 10 |                                                        | 10 <sup>-21</sup>                                         |                            |
| C.Ex. 4 | 6H-SiC<br>(0001)       | Au               | B         | Fig. 10 |                                                        | 10 <sup>-7</sup>                                          |                            |
| Ex. 8   | 6H-SiC<br>(0001)       | Ti,<br>Mo,<br>Ni | A+B+C     | Fig. 11 |                                                        |                                                           |                            |

\*: with methanol and trichloroethylene

The present invention has been described in detail with respect to an embodiment, and it will now be apparent

from the foregoing to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and it is the intention, therefore, in the appended claims to cover all such changes and modifications as fall within the true spirit of the invention.

**Claims**

1. A method of fabricating a layer of an electrode metal on a surface of a semiconductor, characterized by comprising the step of:  
decreasing a surface states density of said surface of said semiconductor.
2. A method of fabricating a layer of an electrode metal on a surface of a semiconductor, characterized by comprising the step of:  
controlling a Schottky barrier height of a rectifying Schottky electrode formed on said surface of said semiconductor.
3. The method as claimed in claim 2, characterized in that said control of the Schottky barrier height of said Schottky electrode is carried out by controlling flatness of an electrode metal/semiconductor interface.
4. The method as claimed in claim 2, characterized in that said control of the Schottky barrier height of said Schottky electrode is carried out by controlling a step density on an atomic level of an electrode metal/semiconductor interface.
5. The method as claimed in claim 2, characterized in that said control of the Schottky barrier height of said Schottky electrode is carried out by controlling selecting a work function of the metal.
6. The method as claimed in claim 2, characterized in that said control of the Schottky barrier height of said Schottky electrode is carried out by controlling the Schottky barrier height of the Schottky electrode under conditions without giving thermal hysteresis.
7. A method of fabricating a layer of an electrode metal on a surface of a semiconductor, characterized by comprising the step of:  
fabricating a Schottky electrode from a metal having a high work function, and fabricating an Ohmic electrode from a metal having a low work function, for an n-type semiconductor, or  
fabricating a Schottky electrode from a metal having a low work function and an Ohmic electrode from a metal having a high work function, for a p-type semiconductor.
8. The method as claimed in any one of claims 2 to 7, characterized by further comprising the step of heating.
9. A method of fabricating an Ohmic electrode, characterized by comprising the step of: forming flat electrode metal/semiconductor interface on an atomic level.
10. A method of fabricating an Ohmic electrode, characterized by comprising the step of: forming an electrode metal/semiconductor interface having a low step density on an atomic level.
11. A method of fabricating an electrode, characterized by comprising the step of:  
fabricating an Ohmic electrode as claimed in any one of claim 1 to 10 in a highly integrated electronic device.
12. The method as claimed in any one of claims 1 to 11, characterized in that said semiconductor is made of a semiconductor selected from the group consisting of Si and SiC.
13. The method as claimed in any one of claims 1 to 12, characterized in that said electrode metal is selected from the group consisting of Al, Au, Mo and Ti.
14. A Schottky electrode structure provided on a semiconductor characterized by having an interface portion which is flat on an atomic level.

**EP 0 789 388 A2**

15. A Schottky electrode structure provided on a semiconductor characterized by having a Schottky barrier height which is impossible to realize by conventional method.
- 5 16. An Ohmic electrode structure provided on a semiconductor characterized by containing no high concentration impurity.
17. An Ohmic electrode structure characterized by having a Schottky barrier height which is substantially zero.
- 10 18. The electrode structure as claimed in any one of claims 14 to 17, characterized in that said semiconductor is made of a semiconductor selected from the group consisting of Si and SiC.
19. The electrode structure as claimed in any one of claims 14 to 17, characterized in that said electrode metal is selected from the group consisting of Al, Au, Mo and Ti.
- 15 20. A method of fabricating an electrode, characterized by comprising the step of:  
oxidizing a surface layer of silicon or silicon carbide and removing the resulting oxide film.
- 20 21. The method as claimed in claim 20, characterized in that said oxidizing of the silicon or silicon carbide is carried out by heating the silicon or silicon carbide in an oxidative gaseous atmosphere.
22. The method as claimed in claim 20, characterized in that said removing the oxide film is carried out by reacting the oxide film with a reducing liquid or gas.
- 25 23. The method as claimed in any one of claims 20 to 22, characterized in that said silicon or silicon carbide is n-type silicon or n-type silicon carbide, and wherein said electrode metal is a metal having a work function lower than that of noble metals.
- 30 24. The method as claimed in any one of claims 20 to 22, characterized in that said silicon carbide is p-type silicon carbide, and wherein said electrode material is a noble metal or a metal having a work function of a level substantially equal to that of noble metals.
25. The method as claimed in claim 23, characterized in that said electrode material is titanium (Ti).
- 35 26. The method as claimed in claim 23, characterized in that said electrode material is aluminum (Al).
27. A method of producing a Schottky diode or other semiconductor device having electrodes which includes fabricating electrodes by any method or combination of methods as claimed in any of claims 9 to 13 or 20 to 26 or which includes fabricating electrodes by patterning or fabricating in a pattern a layer of electrode metal produced by any method claimed in claims 1 to 8.
- 40 28. A semiconductor device having at least two metal electrodes formed on a semiconductor surface and wherein the flatness of the semiconductor surface is different at each interface with said two respective metal electrodes.
- 45 29. A device according to claim 28 wherein the electrodes are ohmic and Schottky electrodes respectively, and the interfaces therewith are atomically flat and other than atomically flat respectively.
- 50
- 55

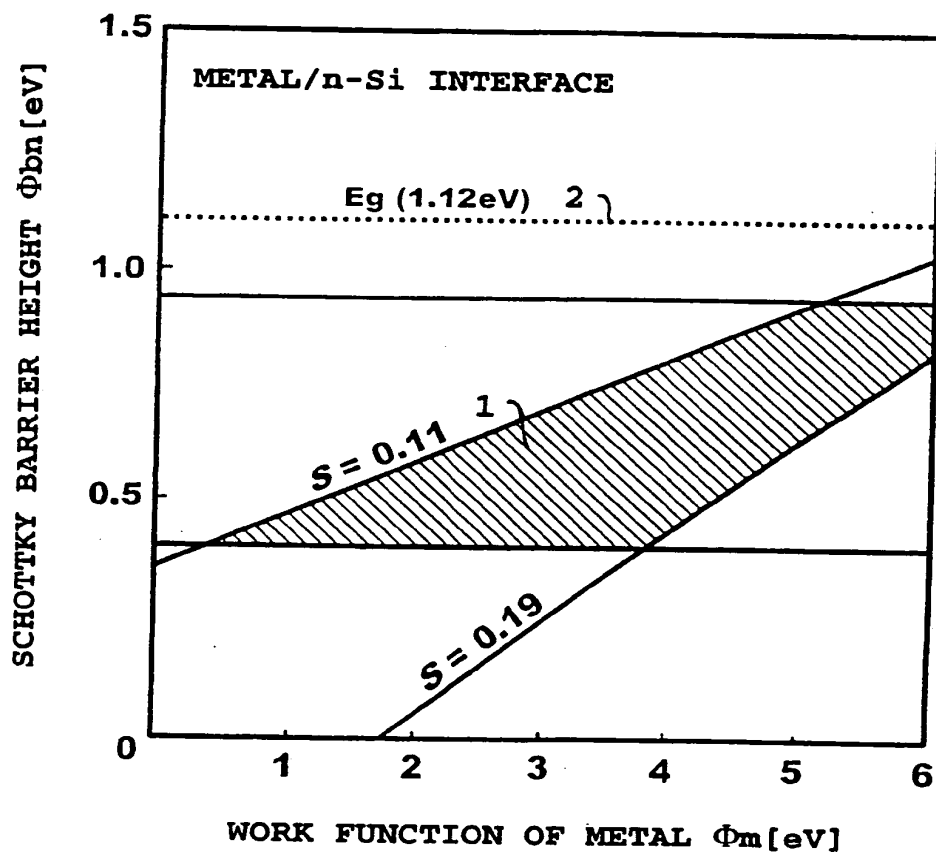


**FIG. 1**  
(PRIOR ART)

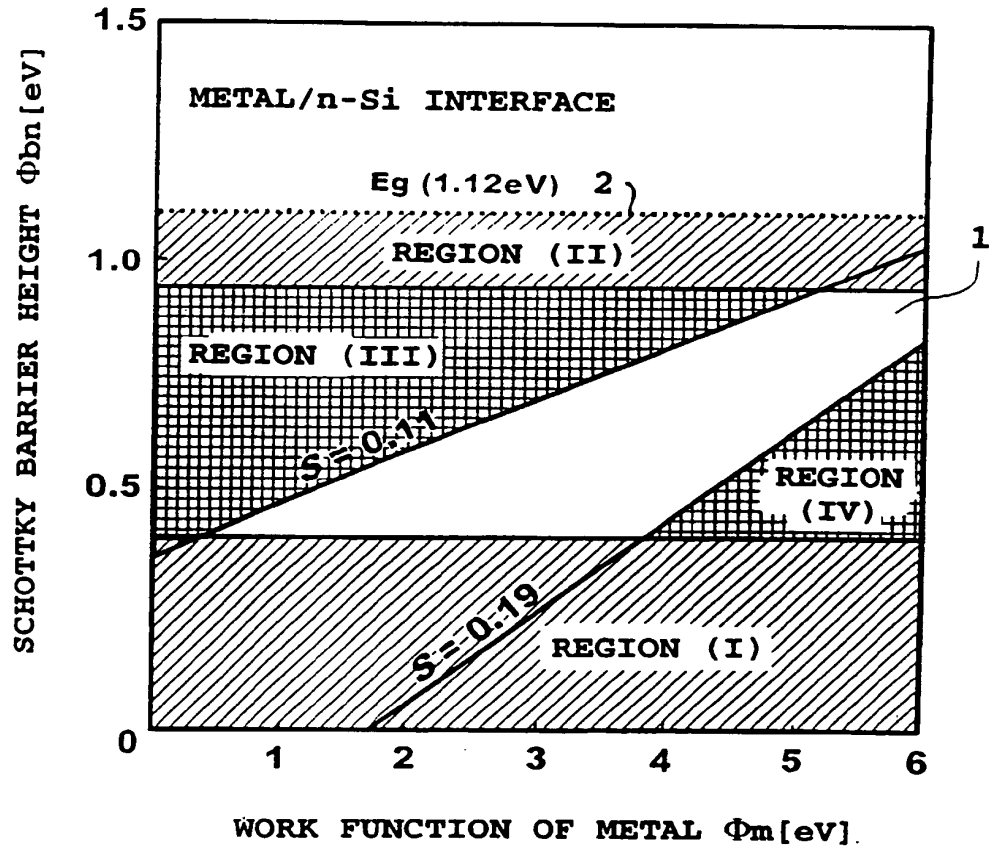


**FIG. 2**

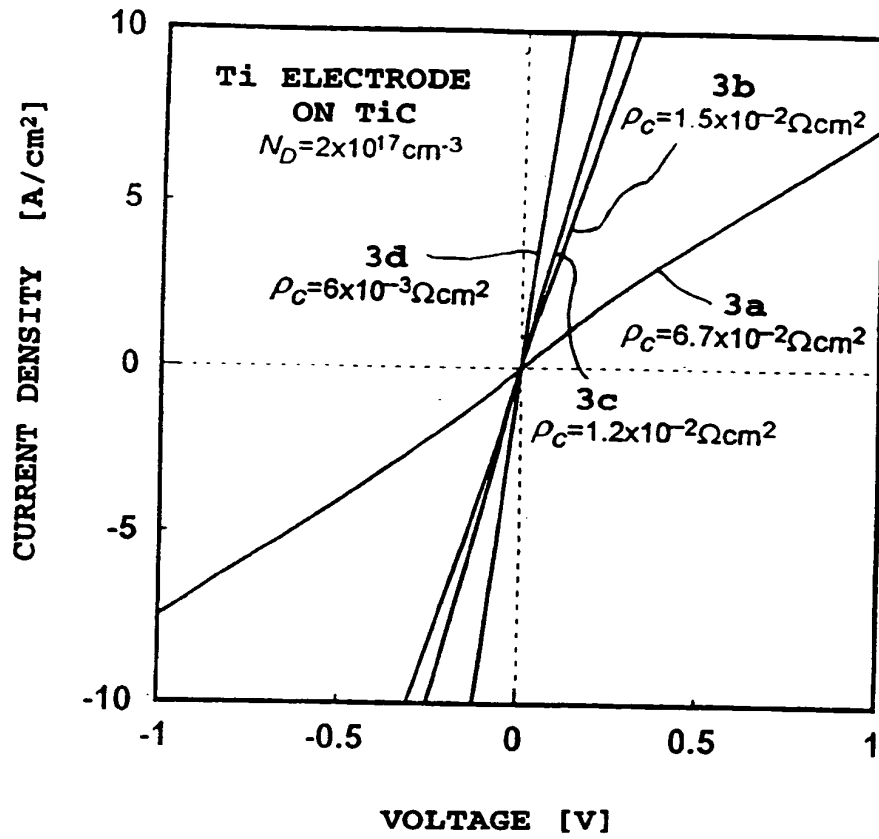


**FIG. 3**

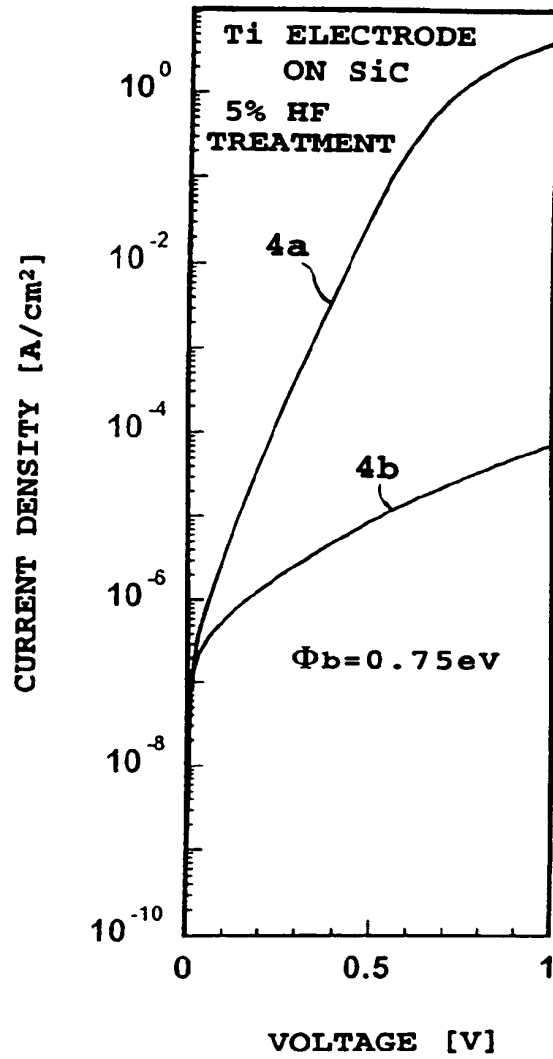


FIG. 4

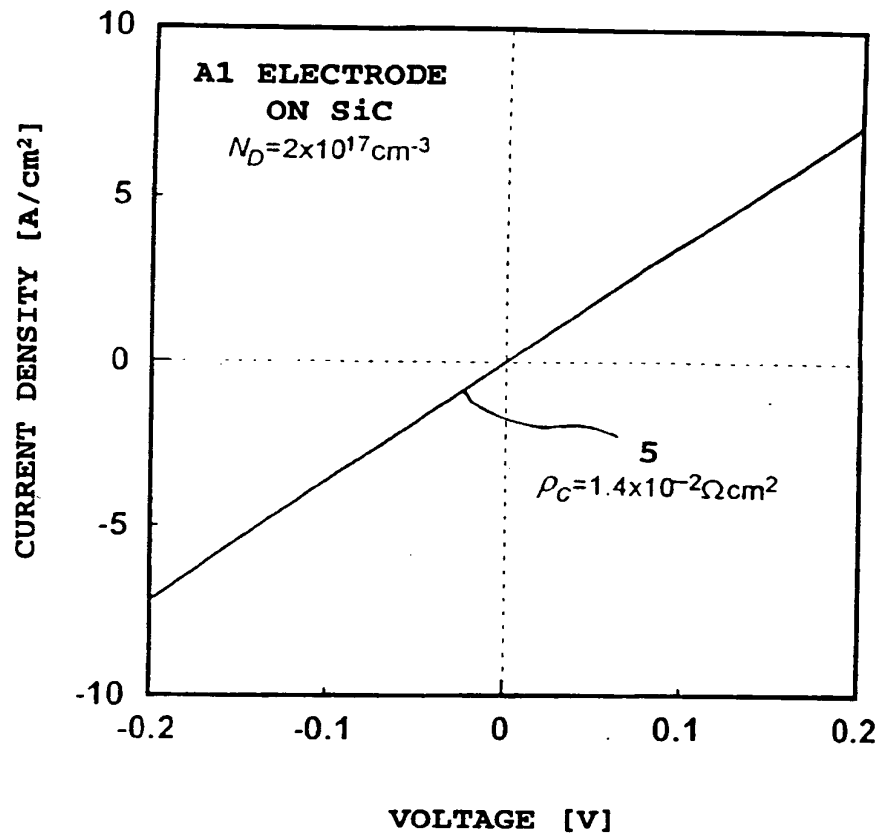


FIG. 5

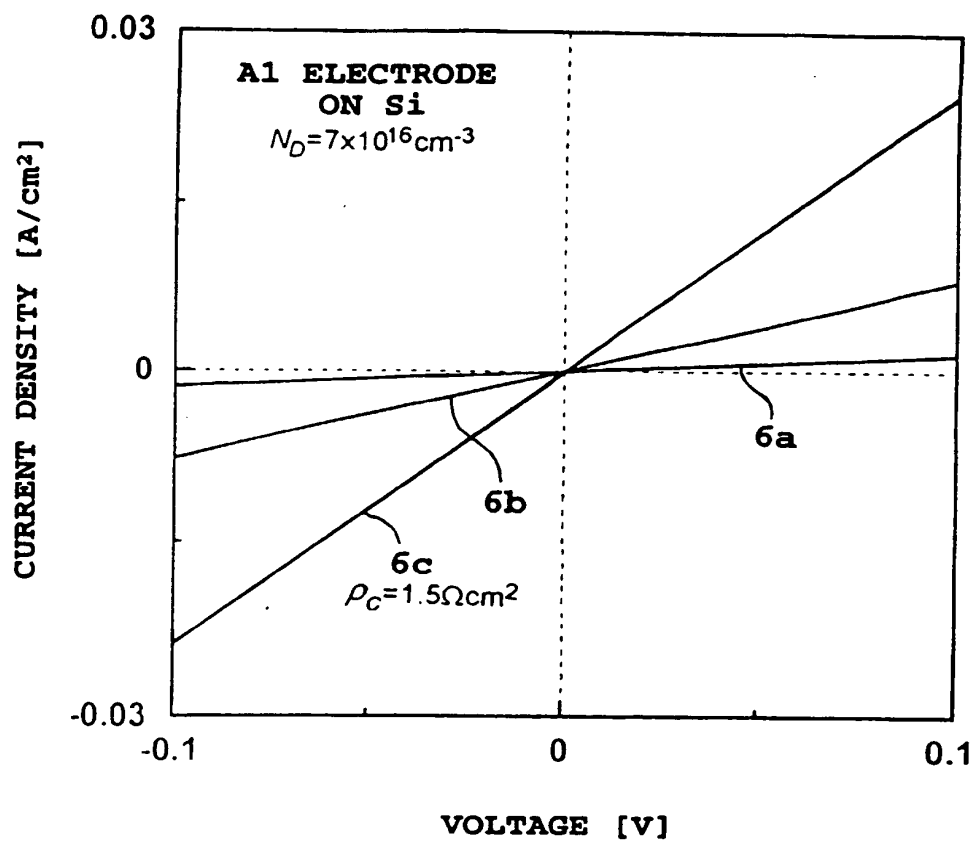


**FIG. 6**

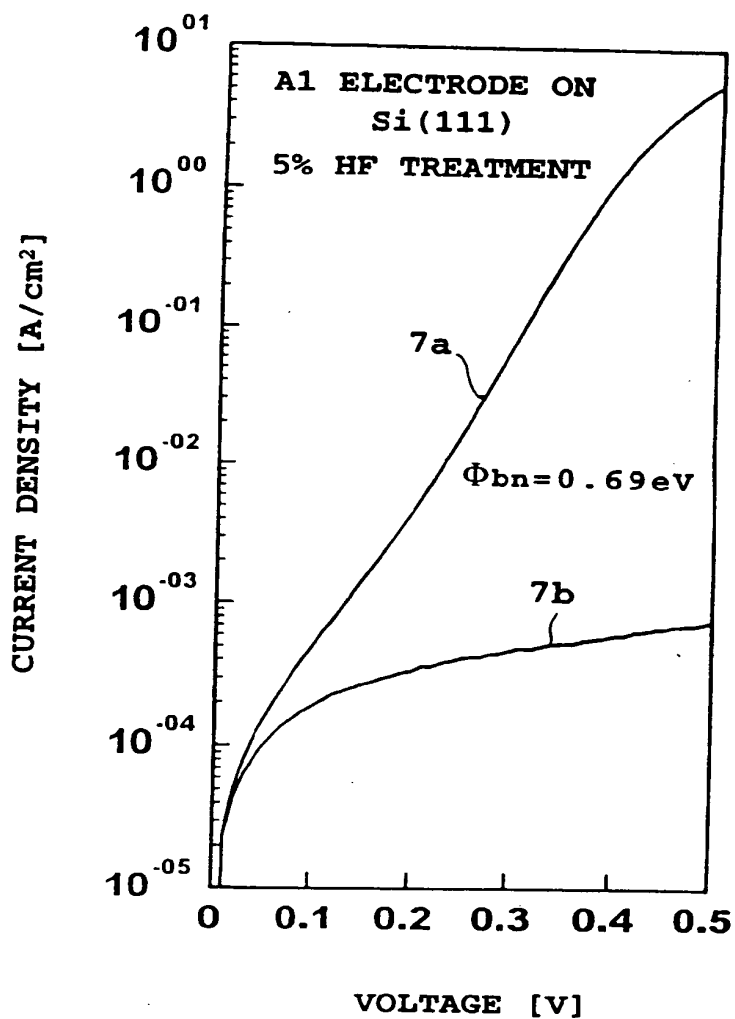


FIG. 7

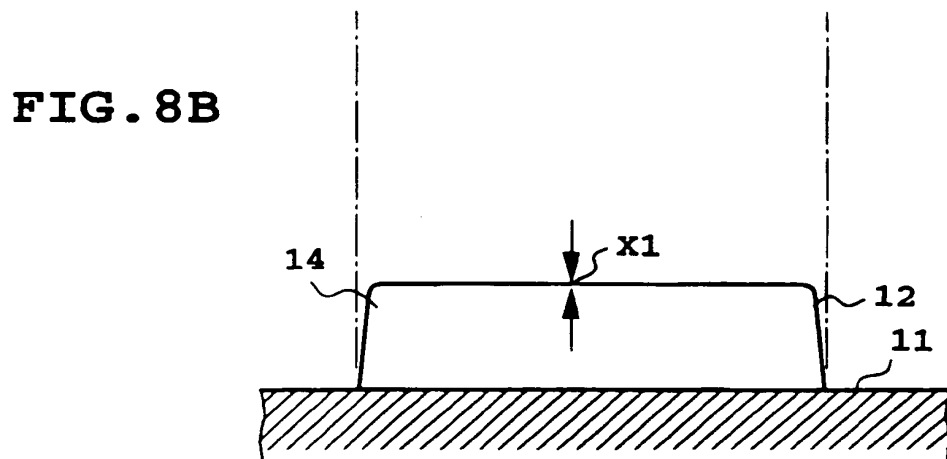
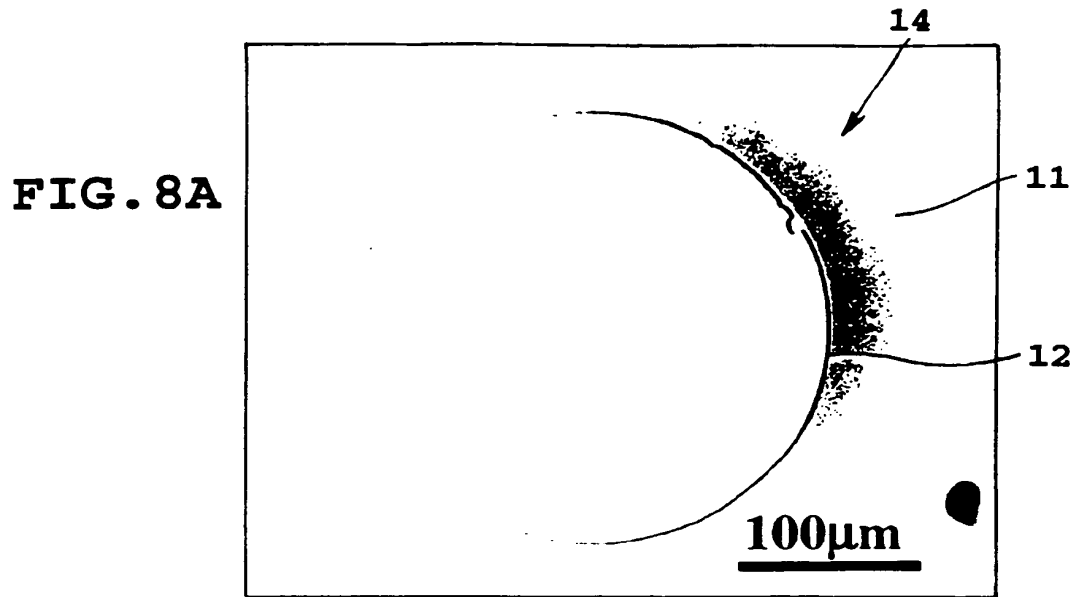


FIG. 9A

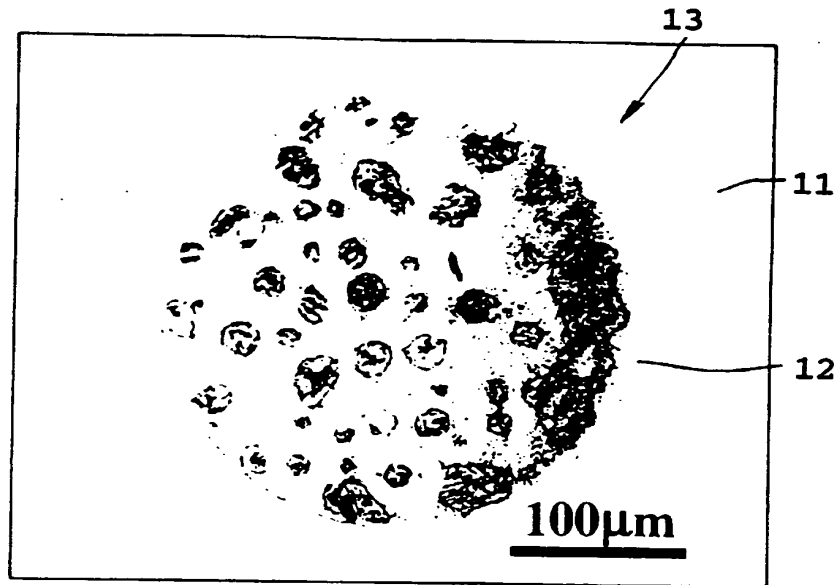
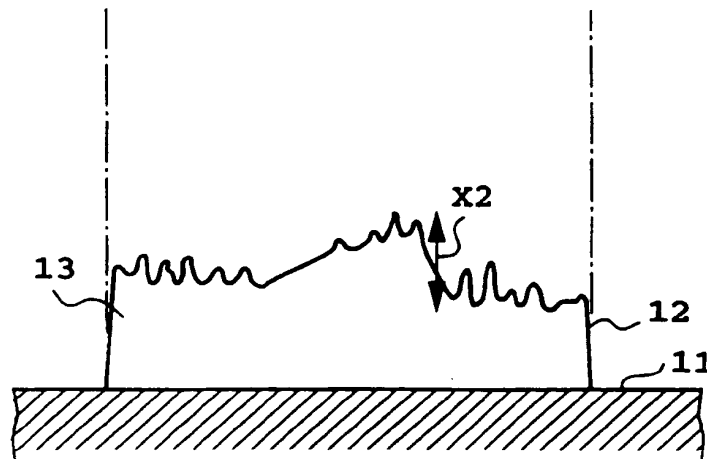


FIG. 9B



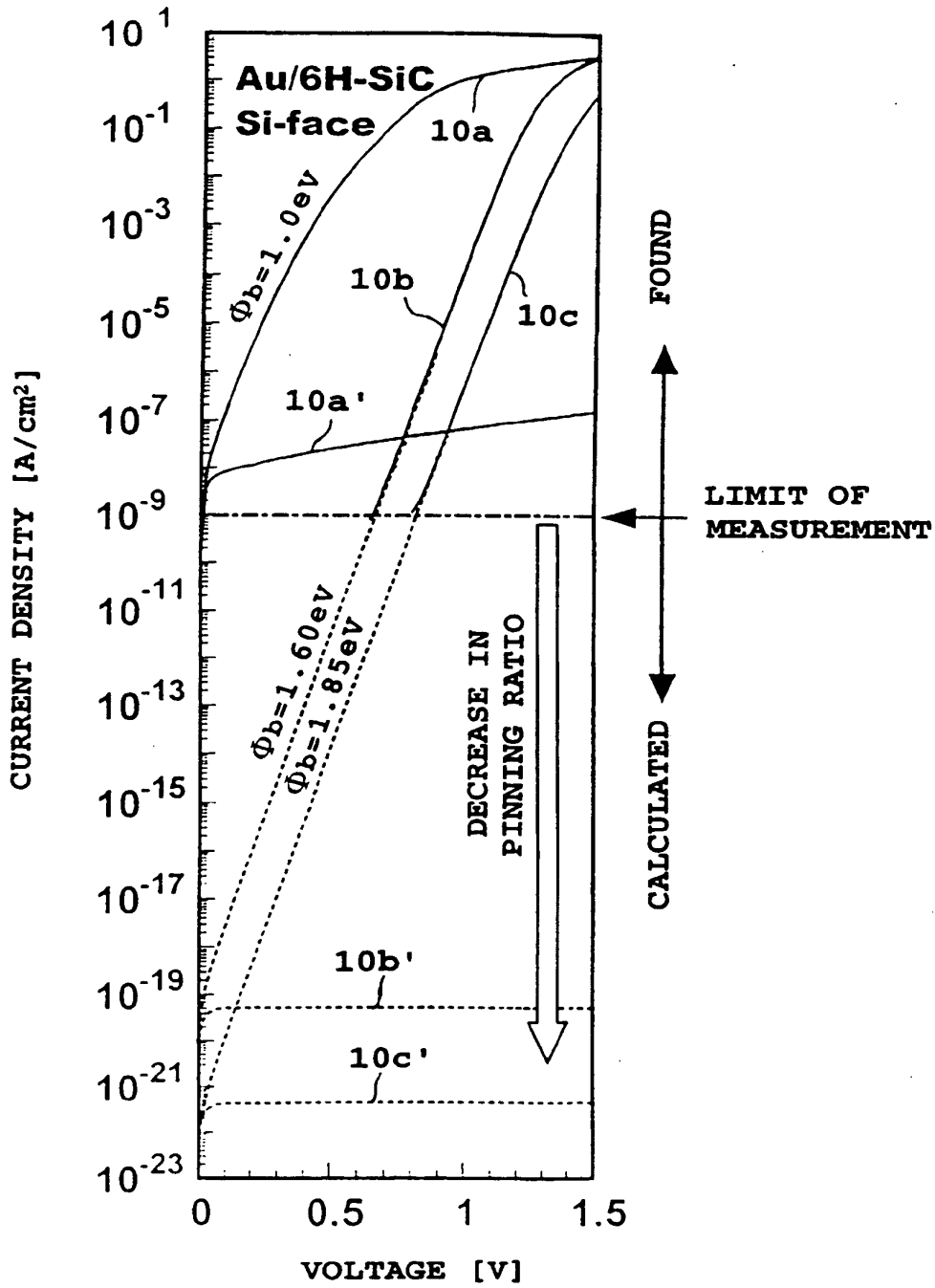


**FIG. 10**

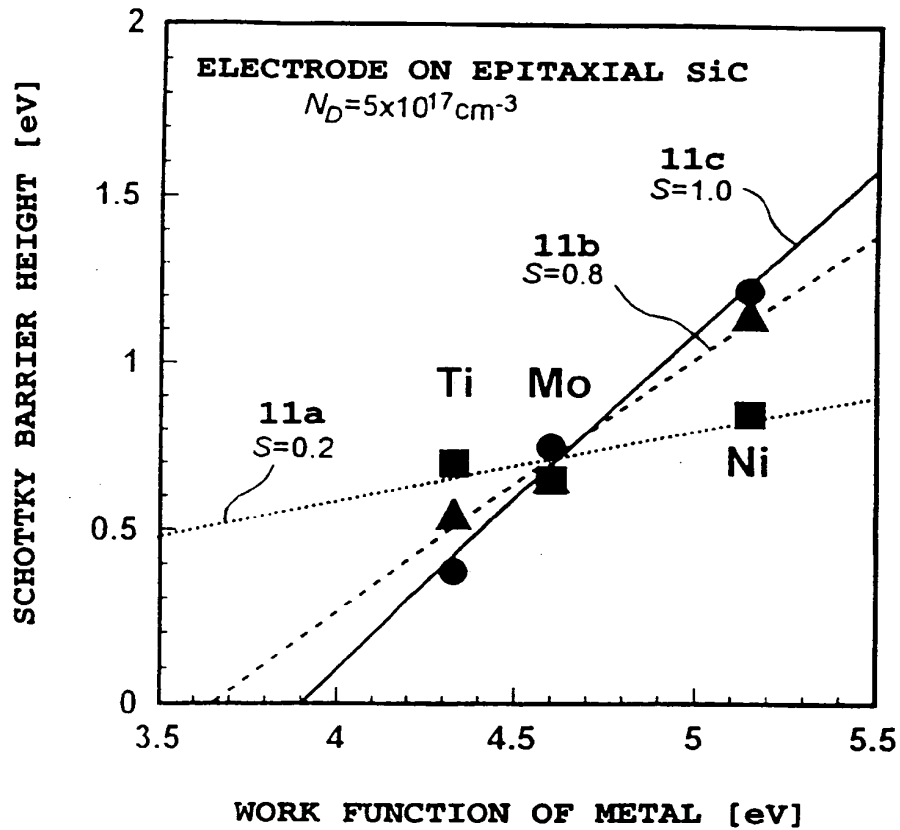


FIG. 11

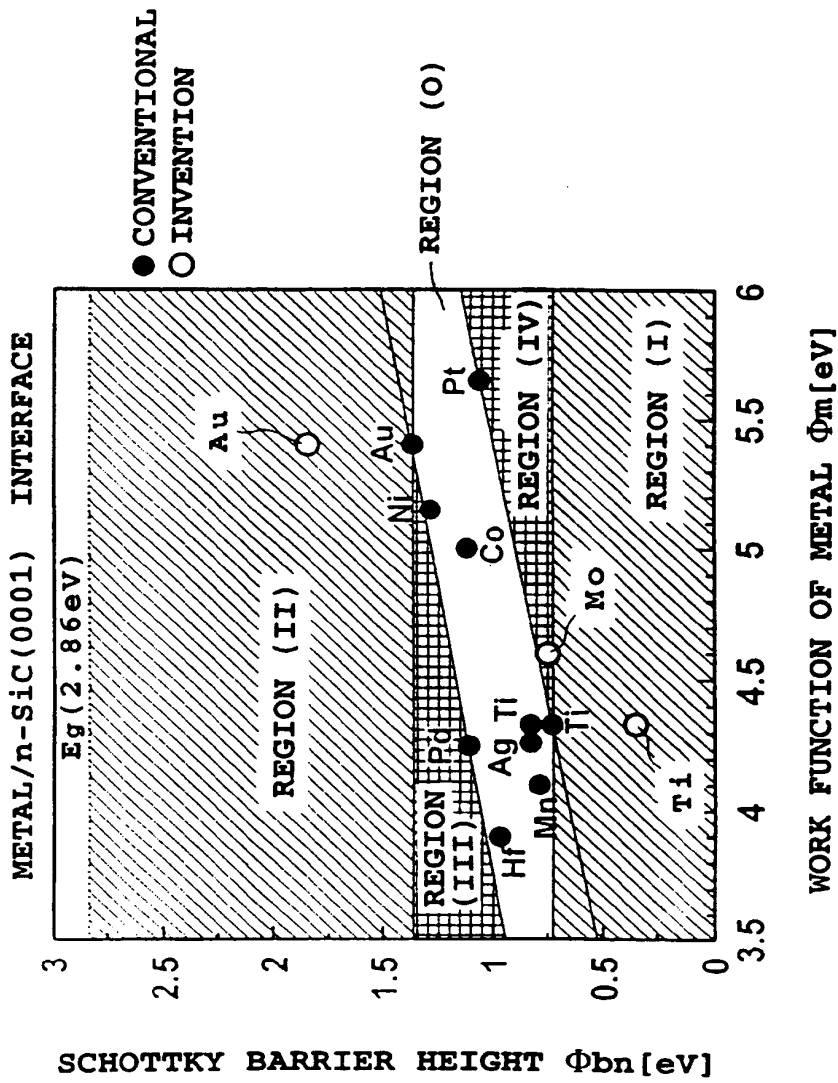


FIG.12



(19)



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11)

EP 0 789 388 A3

(12)

## EUROPEAN PATENT APPLICATION

(88) Date of publication A3:  
16.09.1998 Bulletin 1998/38

(51) Int Cl.<sup>6</sup>: H01L 21/285, H01L 21/04

(43) Date of publication A2:  
13.08.1997 Bulletin 1997/33

(21) Application number: 96306139.5

(22) Date of filing: 22.08.1996

(84) Designated Contracting States:  
DE FR GB

(30) Priority: 25.08.1995 JP 216935/95  
25.03.1996 JP 68018/96

(71) Applicant: AGENCY OF INDUSTRIAL SCIENCE  
AND TECHNOLOGY  
Chiyoda-ku Tokyo (JP)

(72) Inventors:  
• Hara, Shiro  
Tsukuba-shi, Ibaraki (JP)

• Kajimura, Koji  
Tsukuba-shi, Ibaraki (JP)  
• Okushi, Hideyo  
Tsukuba-shi, Ibaraki (JP)  
• Teraji, Tokuyuki  
Tsukuba-shi, Ibaraki (JP)

(74) Representative: Beresford, Keith Denis Lewis  
BERESFORD & Co.  
2-5 Warwick Court  
High Holborn  
London WC1R 5DJ (GB)

(54) Structure and fabrication method for schottky and ohmic electrodes onto semiconductor devices

(57) A novel electrode structure for Schottky electrodes and Ohmic electrodes and novel methods of fabricating electrodes by freely controlling electric characteristics of electrodes on semiconductors. Interface states density of a semiconductor (11) after deposition of an electrode metal (13, 14) is decreased by flattening the surface of the semiconductor on an atomic level to freely control the Schottky barrier height. The method can realize an ideal Ohmic electrode having a Schottky barrier height of substantially zero. The Schottky barrier height is varied freely by decreasing the interface level density and selecting work function of the electrode metal. The method can provide stable Schottky and Ohmic electrodes (13, 14) without need of heat treatment. Further, the method can provide Ohmic electrodes without high concentration doping.

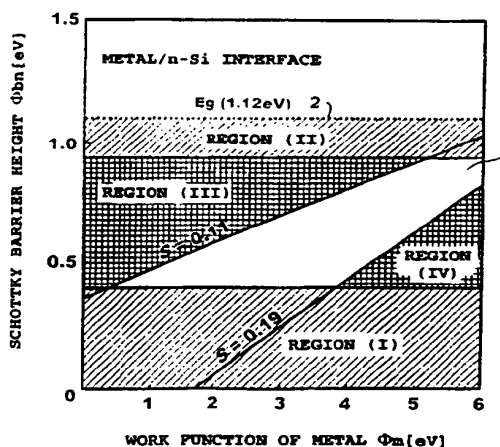


FIG. 2

EP 0 789 388 A3



European Patent  
Office

# PARTIAL EUROPEAN SEARCH REPORT

Application Number

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

EP 96 30 6139

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                              |                                  |                                              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|----------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Citation of document with indication, where appropriate, of relevant passages                                                                                                                                                                | Relevant to claim                | CLASSIFICATION OF THE APPLICATION (Int.CI.6) |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | S. M. SZE: "Physics or Semiconductor Devices"<br>1981, JOHN WILEY & SONS, NEW YORK<br>XP002063071<br>* page 245 - page 311 *                                                                                                                 | 2, 5, 7, 8, 17                   | H01L21/285<br>H01L21/04                      |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | US 4 301 592 A (LIN HUNG CHANG) 24 November 1981<br>* column 2, line 63 - column 3, line 32; figures 2, 3 *                                                                                                                                  | 1                                |                                              |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | EP 0 111 364 A (PHILIPS NV) 20 June 1984<br>* abstract; figure 2 *                                                                                                                                                                           | 2, 7                             |                                              |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | ADEGBOYEGA G A ET AL: "SCHOTTKY CONTACT BARRIER HEIGHT ENHANCEMENT ON P-TYPE SILICON BY WET CHEMICAL ETCHING"<br>APPLIED PHYSICS A. SOLIDS AND SURFACES, vol. A48, no. 4, 1 April 1989, pages 391-395, XP000112320<br>* the whole document * | 20, 22                           |                                              |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                              |                                  | TECHNICAL FIELDS SEARCHED (Int.CI.6)         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                              |                                  | H01L                                         |
| <b>INCOMPLETE SEARCH</b><br>The Search Division considers that the present application, or one or more of its claims, does not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.<br>Claims searched completely:<br>Claims searched incompletely:<br>Claims not searched:<br>Reason for the limitation of the search:<br>see sheet C                                                         |                                                                                                                                                                                                                                              |                                  |                                              |
| Place of search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                              | Date of completion of the search | Examiner                                     |
| THE HAGUE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                              | 15 June 1998                     | Königstein, C                                |
| CATEGORY OF CITED DOCUMENTS<br>X particularly relevant if taken alone<br>Y particularly relevant if combined with another document of the same category<br>A technological background<br>O non-written disclosure<br>P intermediate document<br>T theory or principle underlying the invention<br>E earlier patent document, but published on or after the filing date<br>D document cited in the application<br>L document cited for other reasons<br>& member of the same patent family, corresponding document |                                                                                                                                                                                                                                              |                                  |                                              |



European Patent  
Office

INCOMPLETE SEARCH  
SHEET C

Application Number  
EP 96 30 6139

Claim(s) searched completely:  
1-5,7-14,16-29

Claim(s) searched incompletely:  
6,15

Reason for the limitation of the search:

The subclaim 6 describes the fabrication of a Schottky electrode characterized in that the Schottky barrier height is controlled 'under conditions without giving thermal hysteresis'.

The claim 15 describes a Schottky electrode characterised by having a Schottky barrier height 'which is impossible to realize by conventional method'.

The wording used in these two claims is not clear (Art. 84 EPC).

In claim 6, it is not clear what (effect) gives the thermal hysteresis and how this can be achieved.

In claim 15, it is not clear what is meant with 'conventional method'.

## PARTIAL EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 6139

| DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                                                                                   | CLASSIFICATION OF THE APPLICATION (Int.Cl.6)  |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Category                            | Citation of document with indication, where appropriate, of relevant passages                                                                                                                                                                                                                                                                                                     | Relevant to claim                             |
| X                                   | CHANDRIKA NARAYAN: "TUNING OF THE SCHOTTKY BARRIER HEIGHT USING BI-METALLIC LAYERED STRUCTURES"<br>APPLIED PHYSICS LETTERS,<br>vol. 59, no. 20, 11 November 1991,<br>pages 2541-2542, XP000330120<br>* the whole document *                                                                                                                                                       | 2.5                                           |
| X                                   | PATENT ABSTRACTS OF JAPAN<br>vol. 095, no. 003, 28 April 1995<br>& JP 06 333892 A (FUJI ELECTRIC CORP RES & DEV LTD), 2 December 1994,<br>* abstract *                                                                                                                                                                                                                            | 3                                             |
| A                                   | US 5 087 322 A (LILLIENFELD DAVID ET AL)<br>11 February 1992<br>* the whole document *                                                                                                                                                                                                                                                                                            | 29                                            |
| A                                   | EP 0 452 661 A (IBM) 23 October 1991<br>* the whole document *                                                                                                                                                                                                                                                                                                                    |                                               |
| A                                   | US 4 060 820 A (PUCEL ROBERT A ET AL) 29 November 1977<br>* the whole document *                                                                                                                                                                                                                                                                                                  |                                               |
| P.X                                 | TERAJI T ET AL: "Ohmic contacts to n-type 6H-SiC without post-annealing"<br>III-NITRIDE, SiC AND DIAMOND MATERIALS FOR ELECTRONIC DEVICES. SYMPOSIUM,<br>III-NITRIDE, SiC AND DIAMOND MATERIALS FOR ELECTRONIC DEVICES. SYMPOSIUM, SAN FRANCISCO, CA, USA, 8-12 APRIL 1996, 1996, PITTSBURGH, PA, USA, MATER. RES. SOC. USA, pages 149-154, XP002068069<br>* the whole document * | 1-4,<br>9-14,<br>16-20,<br>22,23,<br>25,27,29 |

-/-



European Patent  
Office

## PARTIAL EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 6139

| DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                                                                                                                          |                   | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|----------------------------------------------|
| Category                            | Citation of document with indication where appropriate of relevant passages                                                                                                                                                                                                                                                                                                                                              | Relevant to claim |                                              |
| P.X                                 | HARA S ET AL: "Pinning-controlled metal/semiconductor interfaces"<br>THIRD INTERNATIONAL CONFERENCE ON INTELLIGENT MATERIALS. THIRD EUROPEAN CONFERENCE ON SMART STRUCTURES AND MATERIALS, LYON, FRANCE. 3-5 JUNE 1996. vol. 2779, ISSN 0277-786X, PROCEEDINGS OF THE SPIE - THE INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING, 1996, SPIE-INT. SOC. OPT. ENG, USA, pages 802-806, XP002068070<br>* the whole document * | 1,2,7             |                                              |
|                                     |                                                                                                                                                                                                                                                                                                                                                                                                                          |                   | TECHNICAL FIELDS SEARCHED (Int.Cl.6)         |
|                                     |                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |                                              |
|                                     |                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |                                              |

EPO FORM 1503 03/92 (P04C10)



**PATENT APPLICATION FEE DETERMINATION RECORD**  
Effective October 1, 2003

Application or Docket Number

10/342576

**CLAIMS AS FILED - PART I**

|                                                           | (Column 1)   | (Column 2)   |
|-----------------------------------------------------------|--------------|--------------|
| TOTAL CLAIMS                                              |              |              |
| FOR                                                       | NUMBER FILED | NUMBER EXTRA |
| TOTAL CHARGEABLE CLAIMS                                   | minus 20 =   | *            |
| INDEPENDENT CLAIMS                                        | minus 3 =    | *            |
| MULTIPLE DEPENDENT CLAIM PRESENT <input type="checkbox"/> |              |              |

\* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY  
TYPE ☐

OR OTHER THAN  
SMALL ENTITY

| RATE      | FEE    |
|-----------|--------|
| BASIC FEE | 385.00 |
| XS 9=     |        |
| X43=      |        |
| +145=     |        |
| TOTAL     |        |

| RATE      | FEE    |
|-----------|--------|
| BASIC FEE | 770.00 |
| XS18=     |        |
| X86=      |        |
| +290=     |        |
| TOTAL     |        |

**CLAIMS AS AMENDED - PART II**

|                                                                         | (Column 1) | (Column 2)                       | (Column 3)                         |
|-------------------------------------------------------------------------|------------|----------------------------------|------------------------------------|
| AMENDMENT A                                                             | 4/12/4     | CLAIMS REMAINING AFTER AMENDMENT | HIGHEST NUMBER PREVIOUSLY PAID FOR |
| Total                                                                   | 32         | Minus                            | 45                                 |
| Independent                                                             | 2          | Minus                            | 6                                  |
| FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <input type="checkbox"/> |            |                                  |                                    |

SMALL ENTITY

OR OTHER THAN  
SMALL ENTITY

| RATE            | ADDITIONAL FEE |
|-----------------|----------------|
| XS 9=           |                |
| X43=            |                |
| +145=           |                |
| TOTAL ADDIT FEE |                |

| RATE            | ADDITIONAL FEE |
|-----------------|----------------|
| XS18=           |                |
| X86=            |                |
| +290=           |                |
| TOTAL ADDIT FEE |                |

|                                                                         | (Column 1) | (Column 2)                       | (Column 3)                         |
|-------------------------------------------------------------------------|------------|----------------------------------|------------------------------------|
| AMENDMENT B                                                             |            | CLAIMS REMAINING AFTER AMENDMENT | HIGHEST NUMBER PREVIOUSLY PAID FOR |
| Total                                                                   | *          | Minus                            | **                                 |
| Independent                                                             | *          | Minus                            | ***                                |
| FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <input type="checkbox"/> |            |                                  |                                    |

| RATE            | ADDITIONAL FEE |
|-----------------|----------------|
| XS 9=           |                |
| X43=            |                |
| +145=           |                |
| TOTAL ADDIT FEE |                |

| RATE            | ADDITIONAL FEE |
|-----------------|----------------|
| XS18=           |                |
| X86=            |                |
| +290=           |                |
| TOTAL ADDIT FEE |                |

|                                                                         | (Column 1) | (Column 2)                       | (Column 3)                         |
|-------------------------------------------------------------------------|------------|----------------------------------|------------------------------------|
| AMENDMENT C                                                             |            | CLAIMS REMAINING AFTER AMENDMENT | HIGHEST NUMBER PREVIOUSLY PAID FOR |
| Total                                                                   | *          | Minus                            | **                                 |
| Independent                                                             | *          | Minus                            | ***                                |
| FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM <input type="checkbox"/> |            |                                  |                                    |

| RATE            | ADDITIONAL FEE |
|-----------------|----------------|
| XS 9=           |                |
| X43=            |                |
| +145=           |                |
| TOTAL ADDIT FEE |                |

| RATE            | ADDITIONAL FEE |
|-----------------|----------------|
| XS18=           |                |
| X86=            |                |
| +290=           |                |
| TOTAL ADDIT FEE |                |

- \* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
- \*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
- \*\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

| Claim |          | Date |  |  |  |  |  |  |  |  |  |  |  |
|-------|----------|------|--|--|--|--|--|--|--|--|--|--|--|
| Final | Original |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 1        |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 2        |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 3        |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 4        |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 5        |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 6        |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 7        |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 8        |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 9        |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 10       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 11       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 12       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 13       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 14       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 15       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 16       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 17       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 18       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 19       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 20       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 21       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 22       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 23       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 24       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 25       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 26       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 27       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 28       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 29       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 30       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 31       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 32       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 33       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 34       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 35       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 36       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 37       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 38       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 39       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 40       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 41       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 42       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 43       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 44       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 45       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 46       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 47       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 48       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 49       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 50       |      |  |  |  |  |  |  |  |  |  |  |  |

| Claim |          | Date |  |  |  |  |  |  |  |  |  |  |  |
|-------|----------|------|--|--|--|--|--|--|--|--|--|--|--|
| Final | Original |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 51       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 52       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 53       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 54       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 55       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 56       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 57       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 58       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 59       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 60       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 61       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 62       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 63       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 64       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 65       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 66       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 67       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 68       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 69       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 70       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 71       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 72       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 73       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 74       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 75       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 76       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 77       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 78       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 79       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 80       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 81       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 82       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 83       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 84       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 85       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 86       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 87       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 88       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 89       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 90       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 91       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 92       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 93       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 94       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 95       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 96       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 97       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 98       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 99       |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 100      |      |  |  |  |  |  |  |  |  |  |  |  |

| Claim |          | Date |  |  |  |  |  |  |  |  |  |  |  |
|-------|----------|------|--|--|--|--|--|--|--|--|--|--|--|
| Final | Original |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 101      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 102      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 103      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 104      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 105      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 106      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 107      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 108      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 109      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 110      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 111      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 112      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 113      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 114      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 115      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 116      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 117      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 118      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 119      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 120      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 121      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 122      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 123      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 124      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 125      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 126      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 127      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 128      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 129      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 130      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 131      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 132      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 133      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 134      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 135      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 136      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 137      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 138      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 139      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 140      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 141      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 142      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 143      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 144      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 145      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 146      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 147      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 148      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 149      |      |  |  |  |  |  |  |  |  |  |  |  |
|       | 150      |      |  |  |  |  |  |  |  |  |  |  |  |

If more than 150 claims or 10 actions  
staple additional sheet here

(LEFT INSIDE)



## UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

## NOTICE OF ALLOWANCE AND FEE(S) DUE

08791 7590 06/21/2004

BLAKELY SOKOLOFF TAYLOR & ZAFMAN  
12400 WILSHIRE BOULEVARD, SEVENTH FLOOR  
LOS ANGELES, CA 90025

EXAMINER

KANG, DONGHEE

ART UNIT

PAPER NUMBER

2811

DATE MAILED: 06/21/2004

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
| 10/342,576      | 01/14/2003  | Daniel E. Grupp      | 3771P004            | 9775             |

TITLE OF INVENTION: INSULATED GATE FIELD EFFECT TRANSISTOR HAVING PASSIVATED SCHOTTKY BARRIERS TO THE CHANNEL

| APPLN. TYPE    | SMALL ENTITY | ISSUE FEE | PUBLICATION FEE | TOTAL FEE(S) DUE | DATE DUE   |
|----------------|--------------|-----------|-----------------|------------------|------------|
| nonprovisional | YES          | \$665     | \$300           | \$965            | 09/21/2004 |

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. **PROSECUTION ON THE MERITS IS CLOSED.** THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN **THREE MONTHS** FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. **THIS STATUTORY PERIOD CANNOT BE EXTENDED.** SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE REFLECTS A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE APPLIED IN THIS APPLICATION. THE PTOL-85B (OR AN EQUIVALENT) MUST BE RETURNED WITHIN THIS PERIOD EVEN IF NO FEE IS DUE OR THE APPLICATION WILL BE REGARDED AS ABANDONED.

## HOW TO REPLY TO THIS NOTICE:

## I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status is changed, pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above and notify the United States Patent and Trademark Office of the change in status, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check the box below and enclose the PUBLICATION FEE and 1/2 the ISSUE FEE shown above.

☐ Applicant claims SMALL ENTITY status.  
See 37 CFR 1.27.

II. PART B - FEE(S) TRANSMITTAL should be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). Even if the fee(s) have already been paid, Part B - Fee(s) Transmittal should be completed and returned. If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

**IMPORTANT REMINDER:** Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

# **PART B - FEE(S) TRANSMITTAL**

**Complete and send this form, together with applicable fee(s), to: Mail**

**Mail Stop ISSUE FEE  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
or Fax (703) 746-4000**

**INSTRUCTIONS:** This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

08791 7590 06/21/2004

**BLAKELY SOKOLOFF TAYLOR & ZAFMAN  
12400 WILSHIRE BOULEVARD, SEVENTH FLOOR  
LOS ANGELES, CA 90025**

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

## **Certificate of Mailing or Transmission**

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO, on the date indicated below.

|                    |
|--------------------|
| (Depositor's name) |
| (Signature)        |
| (Date)             |

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
| 10/342,576      | 01/14/2003  | Daniel E. Grupp      | 3771P004            | 9775             |

**TITLE OF INVENTION: INSULATED GATE FIELD EFFECT TRANSISTOR HAVING PASSIVATED SCHOTTKY BARRIERS TO THE CHANNEL**

| APPLN. TYPE    | SMALL ENTITY | ISSUE FEE | PUBLICATION FEE | TOTAL FEE(S) DUE | DATE DUE   |
|----------------|--------------|-----------|-----------------|------------------|------------|
| nonprovisional | YES          | \$665     | \$300           | \$965            | 09/21/2004 |

| EXAMINER      | ART UNIT | CLASS-SUBCLASS |
|---------------|----------|----------------|
| KANG, DONGHEE | 2811     | 257-024000     |

**1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).**

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

**2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.**

|   |       |
|---|-------|
| 1 | _____ |
| 2 | _____ |
| 3 | _____ |

## **3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)**

**PLEASE NOTE:** Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent); ☐ individual ☐ corporation or other private group entity ☐ government

## **4a. The following fee(s) are enclosed:**

- ☐ Issue Fee
- ☐ Publication Fee
- ☐ Advance Order - # of Copies \_\_\_\_\_

## **4b. Payment of Fee(s):**

- ☐ A check in the amount of the fee(s) is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The Director is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number \_\_\_\_\_ (enclose an extra copy of this form).

Director for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature)

(Date)

**NOTE:** The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Alexandria, Virginia 22313-1450. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS.** SEND TO: Commissioner for Patents, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMIT THIS FORM WITH FEE(S)



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NO.                                                                                      | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|------------------------------------------------------------------------------------------------------|-------------|----------------------|---------------------|------------------|
| 10/342,576                                                                                           | 01/14/2003  | Daniel E. Grupp      | 3771P004            | 9775             |
| 08791                                                                                                | 7590        | 06/21/2004           | EXAMINER            |                  |
| BLAKELY SOKOLOFF TAYLOR & ZAFMAN<br>12400 WILSHIRE BOULEVARD, SEVENTH FLOOR<br>LOS ANGELES, CA 90025 |             |                      | KANG, DONGHEE       |                  |
|                                                                                                      |             |                      | ART UNIT            | PAPER NUMBER     |
|                                                                                                      |             |                      | 2811                |                  |
| DATE MAILED: 06/21/2004                                                                              |             |                      |                     |                  |

## Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) system (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (703) 305-1383. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (703) 305-8283.

|                               |                        |                     |  |
|-------------------------------|------------------------|---------------------|--|
| <b>Notice of Allowability</b> | <b>Application No.</b> | <b>Applicant(s)</b> |  |
|                               | 10/342,576             | GRUPP ET AL.        |  |
|                               | <b>Examiner</b>        | <b>Art Unit</b>     |  |
|                               | Donghee Kang           | 2811                |  |

**-- Th MAILING DATE of this communication appears on the cover sheet with the correspond nce address--**

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to 05-07-04.
2. ☒ The allowed claim(s) is/are 1-16 and 34-49.
3. ☒ The drawings filed on 04-12-04 are accepted by the Examiner.
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
  - a) ☐ All    b) ☐ Some\*    c) ☐ None    of the:
    1. ☐ Certified copies of the priority documents have been received.
    2. ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
    3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

\* Certified copies not received: \_\_\_\_\_.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.

**THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.**

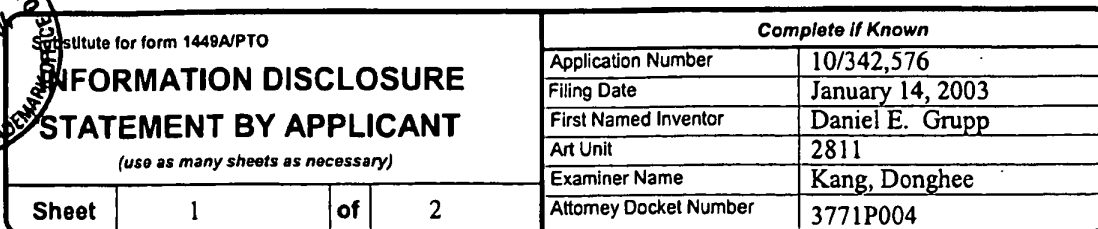
5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
  6. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
    - (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      - 1) ☐ hereto or 2) ☐ to Paper No./Mail Date \_\_\_\_\_.
    - (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date \_\_\_\_\_.
- Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).**
7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

**Attachm nt(s)**

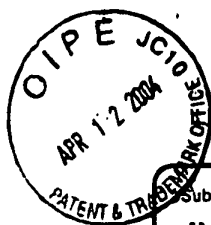
- |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ol style="list-style-type: none"> <li>1. <input type="checkbox"/> Notice of References Cited (PTO-892)</li> <li>2. <input type="checkbox"/> Notice of Draftsperson's Patent Drawing Review (PTO-948)</li> <li>3. <input checked="" type="checkbox"/> Information Disclosure Statements (PTO-1449 or PTO/SB/08),<br/>Paper No./Mail Date <u>05-07-04</u></li> <li>4. <input type="checkbox"/> Examiner's Comment Regarding Requirement for Deposit<br/>of Biological Material</li> </ol> | <ol style="list-style-type: none"> <li>5. <input type="checkbox"/> Notice of Informal Patent Application (PTO-152)</li> <li>6. <input type="checkbox"/> Interview Summary (PTO-413),<br/>Paper No./Mail Date _____</li> <li>7. <input type="checkbox"/> Examiner's Amendment/Comment</li> <li>8. <input type="checkbox"/> Examiner's Statement of Reasons for Allowance</li> <li>9. <input type="checkbox"/> Other _____</li> </ol> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

*Kang Donghee*

Donghee Kang  
Primary Examiner  
Art Unit: 2811

[illegible]

Send To: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450



|                                                          |   |    |   |                          |                  |
|----------------------------------------------------------|---|----|---|--------------------------|------------------|
| Substitute for form 1449A/PTO                            |   |    |   | <b>Complete if Known</b> |                  |
| <b>INFORMATION DISCLOSURE<br/>STATEMENT BY APPLICANT</b> |   |    |   | Application Number       | 10/342,576       |
|                                                          |   |    |   | Filing Date              | January 14, 2003 |
|                                                          |   |    |   | First Named Inventor     | Daniel E. Grupp  |
|                                                          |   |    |   | Art Unit                 | 2811             |
|                                                          |   |    |   | Examiner Name            | Kang, Donghee    |
| Sheet                                                    | 2 | of | 2 | Attorney Docket Number   | 3771P004         |

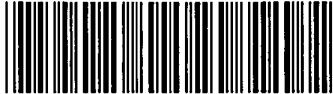
| NON PATENT LITERATURE DOCUMENTS |              |                                                                                                                                                                                                                                                                                                         |    |
|---------------------------------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Examiner<br>Initials*           | Cite<br>No.† | Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.                                         | T‡ |
| PHIL                            |              | International Search Report, PCT/US03/25057, Mailing Date December 18, 2003                                                                                                                                                                                                                             |    |
|                                 |              | S. M., SZE, "Metal-Semiconductor Contacts", Physics of Semiconductor Devices, New Your, John Wiley & Sons, US, 1981 Pgs. 245-311, XP002068071                                                                                                                                                           |    |
|                                 |              | T, TERAJI et al., "Ohmic Contacts To N. Type 6H.SIC Without Post-Annealing", Materials Research Society Symposium Proceedings, Materials Research Society, Pittsburg, PA, US, April 8, 1996, Pgs. 149-154, XP002068069                                                                                  |    |
|                                 |              | V.S. BANNIKOV et al., "Field-Effect Transistor With Metal-(Tunneling-Insulator)-Semiconductor Contacts and A Gate Insulator Made of A Langmuir-Blodgett Film", Soviet Technoical Physics Letters, American Institute of Physics, New York, US, Vol. 15, No. 3, March 1, 1989, Pgs. 211-212, XP000102701 |    |
|                                 |              | L.M. PORTER et al., "A Critical Review of Ohmic and Rectifying Contacts For Silicon Carbide", Materials Science and Engineering, Vol. 34, No. 2, November 1, 1995, Pgs. 83-105, XP004000935                                                                                                             |    |
|                                 |              | S. HARA et al., "Pinning-Controlled Metal/Semiconductor Interfaces", Proceedings of the Spie, Bellingham, VA, US, Vol. 2779, June 3, 1996, Pgs. 802-806, XP002068070                                                                                                                                    |    |
|                                 |              |                                                                                                                                                                                                                                                                                                         |    |

|                       |                     |                    |          |
|-----------------------|---------------------|--------------------|----------|
| Examiner<br>Signature | <i>Kang Donghee</i> | Date<br>Considered | 06-09-04 |
|-----------------------|---------------------|--------------------|----------|

\*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication.

†Applicant's unique citation designation number. ‡Applicant is to place a check mark here if English language Translation is attached.

Based on PTO/SB/08B (08-03) as modified by Blakely, Solokoff, Taylor & Zafman (wtr) 08/11/2003.  
Send To: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450

|                                                                                                                  |                 |              |  |
|------------------------------------------------------------------------------------------------------------------|-----------------|--------------|--|
| <b>Issue Classification</b><br> | Application No. | Applicant(s) |  |
|                                                                                                                  | 10/342,576      | GRUPP ET AL. |  |
|                                                                                                                  | Examiner        | Art Unit     |  |
|                                                                                                                  | Donghee Kang    | 2811         |  |

| ISSUE CLASSIFICATION                                                                                                     |   |          |   |       |                                                                                                                                           |                                   |    |    |    |                          |                    |
|--------------------------------------------------------------------------------------------------------------------------|---|----------|---|-------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|----|----|----|--------------------------|--------------------|
| ORIGINAL                                                                                                                 |   |          |   |       | CROSS REFERENCE(S)                                                                                                                        |                                   |    |    |    |                          |                    |
| CLASS                                                                                                                    |   | SUBCLASS |   |       | CLASS                                                                                                                                     | SUBCLASS (ONE SUBCLASS PER BLOCK) |    |    |    |                          |                    |
| 257                                                                                                                      |   | 24       |   |       | 257                                                                                                                                       | 25                                | 27 | 30 | 37 | 38                       | 39                 |
| INTERNATIONAL CLASSIFICATION                                                                                             |   |          |   |       |                                                                                                                                           |                                   |    |    |    |                          |                    |
| H                                                                                                                        | 0 | 1        | L | 29/06 |                                                                                                                                           |                                   |    |    |    |                          |                    |
| H                                                                                                                        | 0 | 1        | L | 39/22 |                                                                                                                                           |                                   |    |    |    |                          |                    |
|                                                                                                                          |   |          |   | /     |                                                                                                                                           |                                   |    |    |    |                          |                    |
|                                                                                                                          |   |          |   | /     |                                                                                                                                           |                                   |    |    |    |                          |                    |
|                                                                                                                          |   |          |   | /     |                                                                                                                                           |                                   |    |    |    |                          |                    |
| _____<br>(Assistant Examiner) (Date)                                                                                     |   |          |   |       | <br>KANG, DONGHEE 06-07-04<br>(Primary Examiner) (Date) |                                   |    |    |    | Total Claims Allowed: 32 |                    |
|                                                                                                                          |   |          |   |       |                                                                                                                                           |                                   |    |    |    | O.G.<br>Print Claim(s)   | O.G.<br>Print Fig. |
| <br>(Legal Instruments Examiner) (Date) |   |          |   |       |                                                                                                                                           |                                   |    |    |    | 1                        | 2                  |

|                                                                                        |          |       |          |       |          |       |          |       |          |                              |          |                               |          |                                 |          |
|----------------------------------------------------------------------------------------|----------|-------|----------|-------|----------|-------|----------|-------|----------|------------------------------|----------|-------------------------------|----------|---------------------------------|----------|
| <input type="checkbox"/> Claims renumbered in the same order as presented by applicant |          |       |          |       |          |       |          |       |          | <input type="checkbox"/> CPA |          | <input type="checkbox"/> T.D. |          | <input type="checkbox"/> R.1.47 |          |
| Final                                                                                  | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final                        | Original | Final                         | Original | Final                           | Original |
| 1                                                                                      | 1        |       | 31       |       | 61       |       | 91       |       | 121      |                              | 151      |                               | 181      |                                 |          |
| 2                                                                                      | 2        |       | 32       |       | 62       |       | 92       |       | 122      |                              | 152      |                               | 182      |                                 |          |
| 3                                                                                      | 3        |       | 33       |       | 63       |       | 93       |       | 123      |                              | 153      |                               | 183      |                                 |          |
| 4                                                                                      | 4        | 19    | 34       |       | 64       |       | 94       |       | 124      |                              | 154      |                               | 184      |                                 |          |
| 5                                                                                      | 5        | 20    | 35       |       | 65       |       | 95       |       | 125      |                              | 155      |                               | 185      |                                 |          |
| 6                                                                                      | 6        | 21    | 36       |       | 66       |       | 96       |       | 126      |                              | 156      |                               | 186      |                                 |          |
| 7                                                                                      | 7        | 22    | 37       |       | 67       |       | 97       |       | 127      |                              | 157      |                               | 187      |                                 |          |
| 8                                                                                      | 8        | 23    | 38       |       | 68       |       | 98       |       | 128      |                              | 158      |                               | 188      |                                 |          |
| 9                                                                                      | 9        | 24    | 39       |       | 69       |       | 99       |       | 129      |                              | 159      |                               | 189      |                                 |          |
| 10                                                                                     | 10       | 25    | 40       |       | 70       |       | 100      |       | 130      |                              | 160      |                               | 190      |                                 |          |
| 11                                                                                     | 11       | 26    | 41       |       | 71       |       | 101      |       | 131      |                              | 161      |                               | 191      |                                 |          |
| 12                                                                                     | 12       | 27    | 42       |       | 72       |       | 102      |       | 132      |                              | 162      |                               | 192      |                                 |          |
| 13                                                                                     | 13       | 28    | 43       |       | 73       |       | 103      |       | 133      |                              | 163      |                               | 193      |                                 |          |
| 14                                                                                     | 14       | 29    | 44       |       | 74       |       | 104      |       | 134      |                              | 164      |                               | 194      |                                 |          |
| 15                                                                                     | 15       | 30    | 45       |       | 75       |       | 105      |       | 135      |                              | 165      |                               | 195      |                                 |          |
| 16                                                                                     | 16       | 17    | 46       |       | 76       |       | 106      |       | 136      |                              | 166      |                               | 196      |                                 |          |
|                                                                                        | 17       | 18    | 47       |       | 77       |       | 107      |       | 137      |                              | 167      |                               | 197      |                                 |          |
|                                                                                        | 18       | 31    | 48       |       | 78       |       | 108      |       | 138      |                              | 168      |                               | 198      |                                 |          |
|                                                                                        | 19       | 32    | 49       |       | 79       |       | 109      |       | 139      |                              | 169      |                               | 199      |                                 |          |
|                                                                                        | 20       |       | 50       |       | 80       |       | 110      |       | 140      |                              | 170      |                               | 200      |                                 |          |
|                                                                                        | 21       |       | 51       |       | 81       |       | 111      |       | 141      |                              | 171      |                               | 201      |                                 |          |
|                                                                                        | 22       |       | 52       |       | 82       |       | 112      |       | 142      |                              | 172      |                               | 202      |                                 |          |
|                                                                                        | 23       |       | 53       |       | 83       |       | 113      |       | 143      |                              | 173      |                               | 203      |                                 |          |
|                                                                                        | 24       |       | 54       |       | 84       |       | 114      |       | 144      |                              | 174      |                               | 204      |                                 |          |
|                                                                                        | 25       |       | 55       |       | 85       |       | 115      |       | 145      |                              | 175      |                               | 205      |                                 |          |
|                                                                                        | 26       |       | 56       |       | 86       |       | 116      |       | 146      |                              | 176      |                               | 206      |                                 |          |
|                                                                                        | 27       |       | 57       |       | 87       |       | 117      |       | 147      |                              | 177      |                               | 207      |                                 |          |
|                                                                                        | 28       |       | 58       |       | 88       |       | 118      |       | 148      |                              | 178      |                               | 208      |                                 |          |
|                                                                                        | 29       |       | 59       |       | 89       |       | 119      |       | 149      |                              | 179      |                               | 209      |                                 |          |
|                                                                                        | 30       |       | 60       |       | 90       |       | 120      |       | 150      |                              | 180      |                               | 210      |                                 |          |

Donghee Kang

2811

[illegible]

| Class      | Subclass     | Date     | Examiner    |
|------------|--------------|----------|-------------|
| <b>257</b> | <b>24,25</b> | 6/7/2004 | <b>KANG</b> |
| 257        | 27,30        | 6/7/2004 | KANG        |
| 257        | 37-39        | 6/7/2004 | KANG        |
|            |              |          |             |

[illegible]

## PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail**

**Mail Stop ISSUE FEE**  
**Commissioner for Patents**  
**P.O. Box 1450**  
**Alexandria, Virginia 22313-1450**  
**(703) 746-4000**

or **Fax**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee payments.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

08791 7590 06/21/2004

**BLAKELY SOKOLOFF TAYLOR & ZAFMAN**  
**12400 WILSHIRE BOULEVARD, SEVENTH FLOOR**  
**LOS ANGELES, CA 90025**

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

**Certificate of Mailing or Transmission**

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO, on the date indicated below.

|                           |                    |
|---------------------------|--------------------|
| <u>Patricia A. Balero</u> | (Depositor's name) |
| <u>[Signature]</u>        | (Signature)        |
| <u>September 20, 2004</u> | (Date)             |

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|-----------------|-------------|----------------------|---------------------|------------------|
| 10/342,576      | 01/14/2003  | Daniel E. Grupp      | 3771P004            | 9775             |

TITLE OF INVENTION: INSULATED GATE FIELD EFFECT TRANSISTOR HAVING PASSIVATED SCHOTTKY BARRIERS TO THE CHANNEL

| APPLN. TYPE    | SMALL ENTITY | ISSUE FEE | PUBLICATION FEE | TOTAL FEE(S) DUE | DATE DUE   |
|----------------|--------------|-----------|-----------------|------------------|------------|
| nonprovisional | YES          | \$665     | \$300           | \$965            | 09/21/2004 |

| EXAMINER      | ART UNIT | CLASS-SUBCLASS |
|---------------|----------|----------------|
| KANG, DONGHEE | 2811     | 257-024000     |

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

**BLAKEEY SOKOLOFF**  
**1 TAYLOR & ZAFMAN LLP**

2 \_\_\_\_\_  
 3 \_\_\_\_\_

## 3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

ACORN TECHNOLOGIES, INC.

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

PACIFIC PALISADES, CA

Please check the appropriate assignee category or categories (will not be printed on the patent); ☐ individual ☐ corporation or other private group entity ☐ government

## 4a. The following fee(s) are enclosed:

- ☒ Issue Fee
- ☒ Publication Fee
- ☒ Advance Order - # of Copies 10

## 4b. Payment of Fee(s):

- ☒ A check in the amount of the fee(s) is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☒ The Director is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number 02-2666 (enclose an extra copy of this form).

Director for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) (Date)

Tarek N. Fahmi Reg. No.: 41,402 9/20/04

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

09/24/2004 WASFAM2 00000072 022666 10342576

01 FC:2501 665.00 DP  
 02 FC:1504 300.00 DP  
 03 FC:8001 30.00 DA

TRANSMIT THIS FORM WITH FEE(S)

GF Exhibit 1004 - 158/165

**REVOCATION OF PREVIOUS POWERS OF ATTORNEY WITH NEW  
GENERAL POWER OF ATTORNEY TO PROSECUTE APPLICATIONS AND REEXAMINATION  
PROCEEDINGS BEFORE THE UNITED STATES PATENT AND TRADEMARK OFFICE**

I hereby revoke all previous powers of attorney given in the application(s), reexamination proceeding(s) and/or patent(s) listed below and appoint:

Practitioners associated with the Customer Number

**27571**

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications and reexamination proceedings assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application(s), reexamination proceeding(s) and/or patent(s) listed below to the address associated with Customer Number 27571.

Assignee Name and Address:

Acom Technologies, Inc.  
1200 Prospect Street, Suite 475  
La Jolla, California 92037

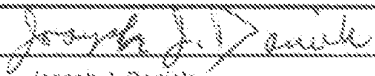
A statement under 37 CFR 3.73(b) is attached.

List of application(s), reexamination proceeding(s) and/or patent(s):

See Attached List.

**SIGNATURE OF ASSIGNEE OF RECORD**

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

|           |                                                                                     |           |              |
|-----------|-------------------------------------------------------------------------------------|-----------|--------------|
| Signature |  | Date      | 3/14/2012    |
| Name      | Joseph J. Daniele                                                                   | Telephone | 858-551-1552 |
| Title     | Chief Operating Officer                                                             |           |              |

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Acorn Technologies, Inc.

States that it is:

1. ☒ The assignee of the entire right, title, and interest, or
2. ☐ an assignee of less than the entire right, title and interest  
(The extent (by percentage) of its ownership interest is: \_\_\_\_\_%)

in the patent applicants/patents identified in the attached spreadsheet by virtue of either:

A. ☒ An assignment from the inventor(s) of the patent applications/patents identified in the attached spreadsheet. The assignment was recorded in the United States Patent and Trademark Office at the Reel and Frame listed thereon.

OR

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: \_\_\_\_\_ To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.
2. From: \_\_\_\_\_ To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.
3. From: \_\_\_\_\_ To: \_\_\_\_\_  
The document was recorded in the United States Patent and Trademark office at  
Reel \_\_\_\_\_, Frame \_\_\_\_\_, or for which a copy thereof is attached.

Additional documents in the chain of title are listed on a supplemental sheet.

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Tarek N. Fahmy/  
Signature

March 26, 2013  
Date

Tarek N. Fahmy  
Printed or Typed Name

866-877-4883  
Telephone Number

Attorney of Record  
Title

| AppNumber | FileDate  | AssignmentTo            | Reel   | Frame | Ref No.           |
|-----------|-----------|-------------------------|--------|-------|-------------------|
| 10/217758 | 12-Aug-02 | Acom Technologies, Inc. | 013195 | 0068  | 40003771-0003-002 |
| 11/181217 | 13-Jul-05 | Acom Technologies, Inc. | 13195  | 0068  | 40003771-0003-003 |
| 10/753504 | 07-Jan-04 | Acom Technologies, Inc. | 015453 | 0248  | 40003771-0003-005 |
| 10/753504 | 07-Jan-04 | Acom Technologies, Inc. | 016115 | 0318  | 40003771-0003-005 |
| 10/753504 | 07-Jan-04 | Acom Technologies, Inc. | 018401 | 0333  | 40003771-0003-005 |
| 12/197996 | 25-Aug-08 | Acom Technologies, Inc. | 022077 | 0447  | 40003771-0003-403 |
| 13/022522 | 07-Feb-11 | Acom Technologies, Inc. | 022077 | 0447  | 40003771-0003-453 |
| 10/342576 | 14-Jan-03 | Acom Technologies, Inc. | 016771 | 0810  | 40003771-0004-002 |
| 11/403185 | 11-Apr-06 | Acom Technologies, Inc. | 018181 | 0437  | 40003771-0004-403 |
| 10/754966 | 09-Jan-04 | Acom Technologies, Inc. | 18181  | 437   | 40003771-0004-004 |
| 13/022559 | 07-Feb-11 | Acom Technologies, Inc. | 018181 | 0437  | 40003771-0004-453 |
| 10/832576 | 26-Apr-04 | Acom Technologies, Inc. | 015846 | 0802  | 40003771-0005-002 |
| 11/010048 | 09-Dec-04 | Acom Technologies, Inc. | 016081 | 0879  | 40003771-0007-002 |
| 11/166286 | 23-Jun-05 | Acom Technologies, Inc. | 016729 | 0283  | 40003771-0008-002 |
| 13/019789 | 02-Feb-11 | Acom Technologies, Inc. | 016729 | 0283  | 40003771-0008-004 |
| 11/678397 | 23-Feb-07 | Acom Technologies, Inc. | 019424 | 0808  | 40003771-0009-002 |
| 12/878930 | 09-Sep-10 | Acom Technologies, Inc. | 019424 | 0808  | 40003771-0009-004 |
| 12/253769 | 17-Oct-08 | Acom Technologies, Inc. | 022058 | 0069  | 40003771-0010-002 |
| 12/253835 | 17-Oct-08 | Acom Technologies, Inc. | 022063 | 0521  | 40003771-0011-002 |
| 12/549227 | 27-Aug-09 | Acom Technologies, Inc. | 023159 | 0144  | 40003771-0014-002 |
| 61/537433 | 21-Sep-11 | Acom Technologies, Inc. | 027228 | 0055  | 40003771-0015-051 |

## Electronic Acknowledgement Receipt

|                                             |                                                                                           |
|---------------------------------------------|-------------------------------------------------------------------------------------------|
| <b>EFS ID:</b>                              | 12396385                                                                                  |
| <b>Application Number:</b>                  | 10342576                                                                                  |
| <b>International Application Number:</b>    |                                                                                           |
| <b>Confirmation Number:</b>                 | 9775                                                                                      |
| <b>Title of Invention:</b>                  | INSULATED GATE FIELD EFFECT TRANSISTOR HAVING PASSIVATED SCHOTTKY BARRIERS TO THE CHANNEL |
| <b>First Named Inventor/Applicant Name:</b> | Daniel E. Grupp                                                                           |
| <b>Customer Number:</b>                     | 8791                                                                                      |
| <b>Filer:</b>                               | Tarek N. Fahmi                                                                            |
| <b>Filer Authorized By:</b>                 |                                                                                           |
| <b>Attorney Docket Number:</b>              | 40003771-0004-002                                                                         |
| <b>Receipt Date:</b>                        | 26-MAR-2012                                                                               |
| <b>Filing Date:</b>                         | 14-JAN-2003                                                                               |
| <b>Time Stamp:</b>                          | 19:17:16                                                                                  |
| <b>Application Type:</b>                    | Utility under 35 USC 111(a)                                                               |

### Payment information:

|                        |    |
|------------------------|----|
| Submitted with Payment | no |
|------------------------|----|

### File Listing:

| Document Number | Document Description | File Name              | File Size(Bytes)/<br>Message Digest      | Multi Part /.zip | Pages (if appl.) |
|-----------------|----------------------|------------------------|------------------------------------------|------------------|------------------|
| 1               |                      | Acorn_executed_POA.pdf | 325167                                   | yes              | 3                |
|                 |                      |                        | 80c6d19a8e22bf29e157c34ec08b5aba90fe056d |                  |                  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Multipart Description/PDF files in .zip description |        |     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|--------|-----|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Document Description                                | Start  | End |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Power of Attorney                                   | 1      | 1   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Assignee showing of ownership per 37 CFR 3.73(b).   | 2      | 3   |
| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                     |        |     |
| <b>Information:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                     |        |     |
| <b>Total Files Size (in bytes):</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                     | 325167 |     |
| <p>This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.</p> <p><b><u>New Applications Under 35 U.S.C. 111</u></b><br/> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.</p> <p><b><u>National Stage of an International Application under 35 U.S.C. 371</u></b><br/> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.</p> <p><b><u>New International Application Filed with the USPTO as a Receiving Office</u></b><br/> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.</p> |                                                     |        |     |



# UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 10/342,576         | 01/14/2003            | Daniel E. Grupp       | 40003771-0004-002      |

27571  
TAREK N. FAHMI, APC  
84 W. Santa Clara St.  
Suite 550  
San Jose, CA 95113

**CONFIRMATION NO. 9775**  
**POA ACCEPTANCE LETTER**



Date Mailed: 04/03/2012

## NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 03/26/2012.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/ttkim/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE  
United States Patent and Trademark Office  
Address: COMMISSIONER FOR PATENTS  
P.O. Box 1450  
Alexandria, Virginia 22313-1450  
www.uspto.gov

| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|--------------------|-----------------------|-----------------------|------------------------|
| 10/342,576         | 01/14/2003            | Daniel E. Grupp       | 40003771-0004-002      |

8791  
BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP  
1279 OAKMEAD PARKWAY  
SUNNYVALE, CA 94085-4040

**CONFIRMATION NO. 9775**  
**POWER OF ATTORNEY NOTICE**



Date Mailed: 04/03/2012

**NOTICE REGARDING CHANGE OF POWER OF ATTORNEY**

This is in response to the Power of Attorney filed 03/26/2012.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/ttkim/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101