Demonstratives of Patent Owner Greenthread, LLC

IPR2024-00017 (’195 patent)
IPR2024-00018 (’502 patent)
IPR2024-00021 (’222 patent)

USPTO Patent Trial and Appeal Board

Oral Hearing: January 31, 2025

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Overview of Issues

1. The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.
2. The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."
3. Dr. Banerjee confirmed the "electric field" must start in the "surface layer."
4. Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."
5. Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."
6. Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
7. The "movement of carriers" depends on the sum of all of the fields in the "surface layer."
8. Petitioners have the burden to analyze all of the fields in the "surface layer."
9. Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
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12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

1. Movement of Carriers from the Active Region

- All of the Challenged Claims require "movement of carriers" from the "active region."

US 8,421,195

1. A CMOS Semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of said surface layer;
a single drift layer disposed between the other surface of said surface layer and said substrate, said drift layer having a graded concentration of dopants extending between said surface layer and said substrate, said drift layer further having a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and
at least one well region disposed in said single drift layer, said well region having a graded concentration of dopants and a second static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate.

-00017: Ex. 1001 ('195 pat.) at 4:13-29

US 9,190,502

7. A semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of said surface layer;
a single drift layer disposed between the other surface of said surface layer and said substrate, said drift layer having a graded concentration of dopants generating a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and
at least one well region disposed in said single drift layer, said well region having a graded concentration of dopants generating a second static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate.

-00018: Ex. 1001 ('502 pat.) at 4:52-67

US 11,121,222

44. A CMOS Semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of the surface layer;
a single drift layer disposed between the other surface of the surface layer and the substrate, the drift layer having a graded concentration of dopants extending between the surface layer and the substrate, the drift layer further having a first static unidirectional electric drift field to aid the movement of carriers from the surface layer to an area of the substrate where there are no active regions; and
at least one well region disposed in the single drift layer, the well region having a graded concentration of dopants and a second static unidirectional electric drift field to aid the movement of carriers from the surface layer to the area of the substrate where there are no active regions.

-00021: Ex. 1001 ('222 pat.) at 8:21-39

-00017: PO Resp. [45] at 1-4, 7-16, 25; PO Sur-Reply [59] at 1-7. 10, 14-20

1. Movement of Carriers from the Active Region

- The "active region" is located in the "surface layer."

UNITED STATES DISTRICT COURT
WESTERN DISTRICT OF TEXAS
WACO DIVISION

Greenthread, LLC
Plaintiff,
v.
Intel Corporation;
Dell Inc.; and
Dell Technologies Inc.
Defendants.

Civil Action No. 6:22-cv-105-ADA

JURY TRIAL DEMANDED

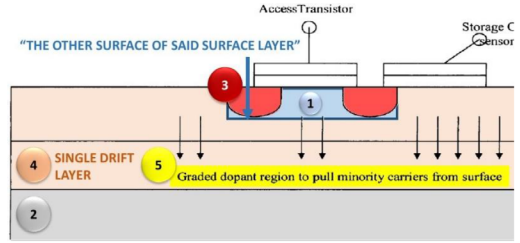
GREENTHREAD'S RESPONSIVE CLAIM CONSTRUCTION BRIEF

EXEMPLARY CLAIMS 195:1 & 842:1

Term	U.S. Patent No. 8,421,195, Claim 1 (195:1)
1	A CMOS Semiconductor device comprising: a **surface layer**;
2	a **substrate**;
3	an **active region** including a source and a drain, disposed on one surface of said surface layer;
4 5	a single drift layer disposed between the other surface of said surface layer and said substrate, said drift layer having a graded concentration of dopants extending between said surface layer and said substrate, said drift layer further having a first static **unidirectional electric drift field** **to aid the movement of minority carriers from said surface layer to said substrate**; and
6	at least one **well region** disposed in said single drift layer, said well region having a graded concentration of dopants and a second static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate.

-00017: Ex. 1030 at 6

Ex. 1, ¶30. The "active region" is a doped region where a transistor can be formed. *Id.*, ¶31; Ex. 2, 1:61-63; 2:18-23; 3:1-3, 30-33. Next, the claim specifies there is a single drift layer disposed between "the other surface of said surface layer" and the substrate. The single drift layer has a graded concentration of dopants. Ex. 1, ¶32.



The graded dopants create an electric field that aids the movement of minority carriers (holes in the example shown in Fig. 5B) from the surface layer to the substrate. Ex. 1, ¶¶32-33; Ex. 2, 3:17-

-00017: Ex. 1030 (Claim Constr. Brief) at 16

1. Movement of Carriers from the Active Region

- The Petition acknowledges that the "active region" is located in the "surface layer."

IN THE UNITED STATES PATENT AND TRADEMARK OFFIC

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INC.;
OMNIVISION TECHNOLOGIES, INC.; AND
AMS SENSORS USA INC.,
Petitioner,

v.

GREENTHREAD, LLC,
Patent Owner.

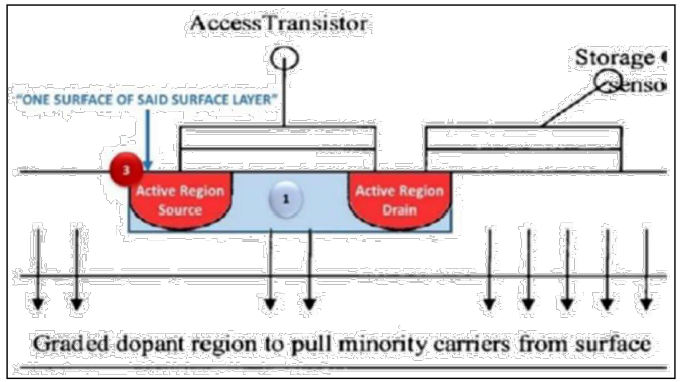
Case No. IPR2024-00017
Patent No. 8,421,195

PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT N 8,421,195

UNDER 35 U.S.C. §§ 312 AND 37 C.F.R. § 42.104

b. Element [1.1]: "a surface layer;"

Payne discloses, or at a minimum, renders obvious this element. Ex.1003, ¶¶74-76. According to Patent Owner ("PO"), a "surface layer" is "a layer at the surface of the silicon" (or "a layer at the surface of the semiconductor device")—which PO annotated in blue below—"where the active region [(red)] is located." Ex.1030, 6, 9, 12, 13; Ex.1033.

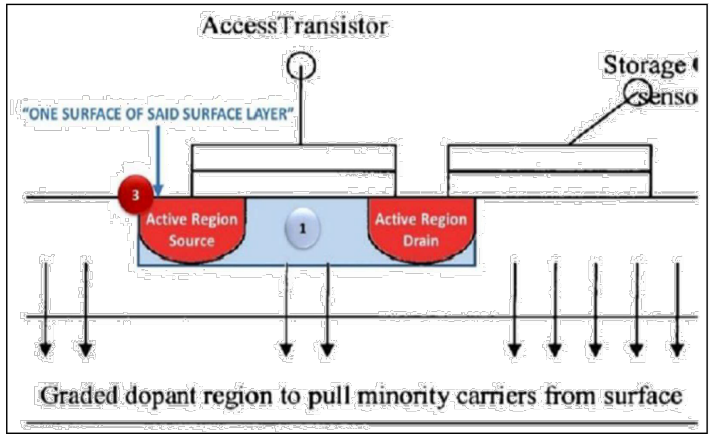


Ex.1001, FIG. 5(b); Ex.1030, 7, 12.

-00017: Petition [1] at 9-10

d. Element [1.3]: "an active region including a source and a drain, disposed on one surface of said surface layer;"

Payne discloses or renders obvious this element. Ex.1003, ¶¶79-83. According to PO, Figure 5(b) of the '195 Patent depicts an active region (red) "disposed on one surface [(top surface)] of said surface layer":



Ex.1001, FIG. 5(b); Ex.1030, 6-7, 11 ("[T]he 'active region' is part of the 'surface layer' … When the claim says the active region is 'disposed on one surface of the surface layer,' it means the active region is located on the 'ceiling' of the silicon ***inside*** the silicon.") (emphasis in original), 12.

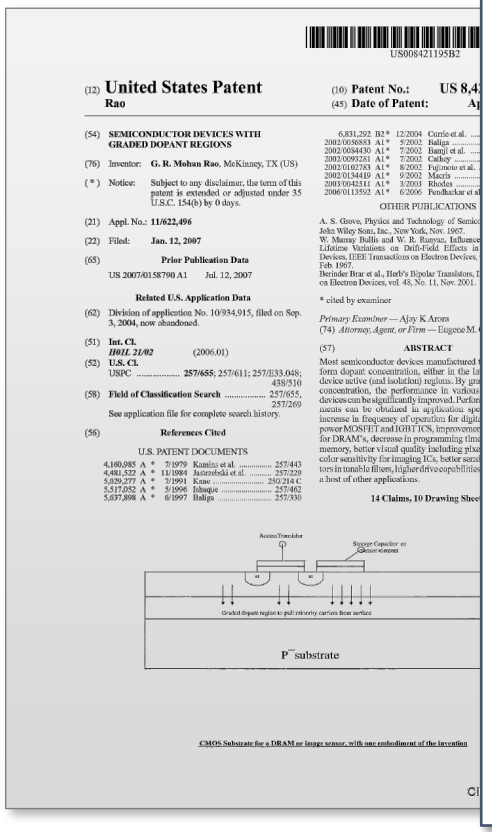
-00017: Petition [1] at 13-14

-00017: PO Resp. [45] at 13-16; PO Sur-Reply [59] at 3-5

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

1. Movement of Carriers from the Active Region

- The specification explains that "spurious minority carriers" interfere with the "active circuitry at the surface."



US008421195B2

(12) **United States Patent**
Rao

(10) **Patent No.: US 8,4**
(45) **Date of Patent: A**

(54) **SEMICONDUCTOR DEVICES WITH GRADED DOPANT REGIONS**

(76) Inventor: **G. R. Mohan Rao**, McKinney, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/622,496**

(22) Filed: **Jan. 12, 2007**

(65) **Prior Publication Data**

US 2007/0158790 A1 Jul. 12, 2007

Related U.S. Application Data

(62) Division of application No. 10/934,915, filed on Sep. 3, 2004, now abandoned.

(51) **Int. Cl.**
H01L 21/02 (2006.01)

(52) **U.S. Cl.**
USPC **257/655**; 257/611; 257/E33.048; 438/510

(58) **Field of Classification Search** 257/655, 257/269
See application file for complete search history.

(56) **References Cited**

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on Electron Devices, vol. 48, No. 11, Nov. 2001.

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Primary Examiner — Ajay K Arora
(74) *Attorney, Agent, or Firm* — Eugene M.

(57) **ABSTRACT**

Most semiconductor devices manufactured
form dopant concentration, either in the la
device active (and isolation) regions. By gra
concentration, the performance in various
devices can be significantly improved. Perfor
ments can be obtained in application spe
increase in frequency of operation for digit
power MOSFET and IGBT ICS, improvemen
for DRAM's, decrease in programming time
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color sensitivity for imaging ICs, better acou
tors in tunable filters, higher drive capabilities
a host of other applications.

14 Claims, 10 Drawing Shee

Access Transistor
Storage Capacitor or Reference element
Graded dopant region to pull minority carriers from surface
P⁻ substrate

CMOS Substrate for a DRAM or image sensor, with one embodiment of the invention

As illustrated in FIGS. **5**(*a*), **5**(*b*), **5**(*c*), donor gradient is also of benefit to very large scale integrated circuits (VLSI)—VLSI logic, DRAM, nonvolatile memory like NAND flash. Spurious minority carriers can be generated by clock switching in digital VLSI logic and memory IC'S. These unwanted carriers can discharge dynamically-held 'actively held high' nodes. Statically held nodes (with V_{cc}) can not be affected, in most cases. Degradation of refresh time in DRAM's is one of the results, because the capacitor holds charge dynamically. Similarly, degradation of CMOS digital images, in digital imaging IC's is another result of the havoc caused by minority carriers. Pixel and color resolution can be significantly enhanced in imaging IC's with the embodiments described here. Creating 'Sub Terrain' recombination centers underneath the wells (gold doping, platinum doping) as is done in some high-voltage diodes is not practical for VLSI circuits. Hence, a novel technique has been described here by creating a drift field to sweep these unwanted minority carriers into the substrate as quickly as possible, from the active circuitry at the surface. In a preferred embodiment, the subterrain n-layer

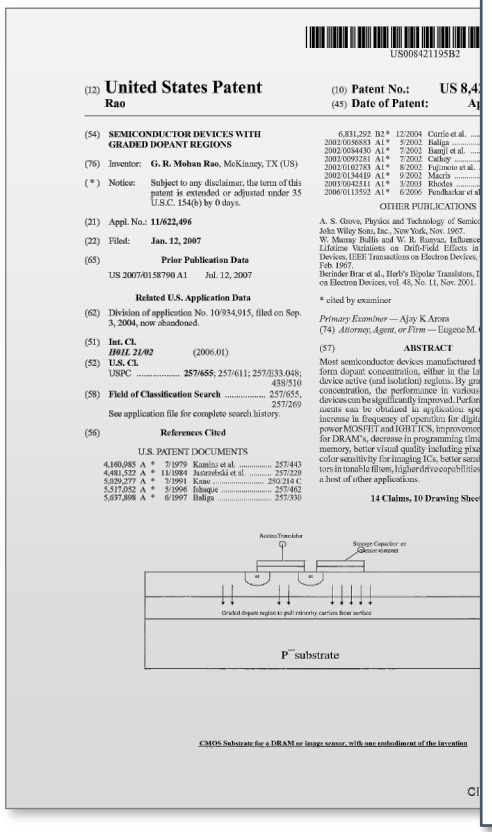
-00017: Ex. 1001 at 3:14-33

the surface. In a preferred embodiment, the subterrain n-layer has a graded donor concentration to sweep the minority carriers deep into the substrate. One or more of such layers can also be implemented through wafer to wafer bonding or similar "transfer" mechanisms. This n-layer can be a deeply-implanted layer. It can also be an epitaxial layer. The n-well and p-well also can be graded or retrograded in dopants, as desired, to sweep those carriers away from the surface as well.

-00017: Ex. 1001 ('195 pat.) at 3:33-40

1. Movement of Carriers from the Active Region

- The specification discloses using a "drift field" to "sweep these unwanted minority carriers from the active circuitry at the surface into the substrate."



US008421195B2

(12) **United States Patent**
Rao

(10) Patent No.: US 8,4
(45) Date of Patent: A

(54) **SEMICONDUCTOR DEVICES WITH GRADED DOPANT REGIONS**

(76) Inventor: **G. R. Mohan Rao**, McKinney, TX (US)

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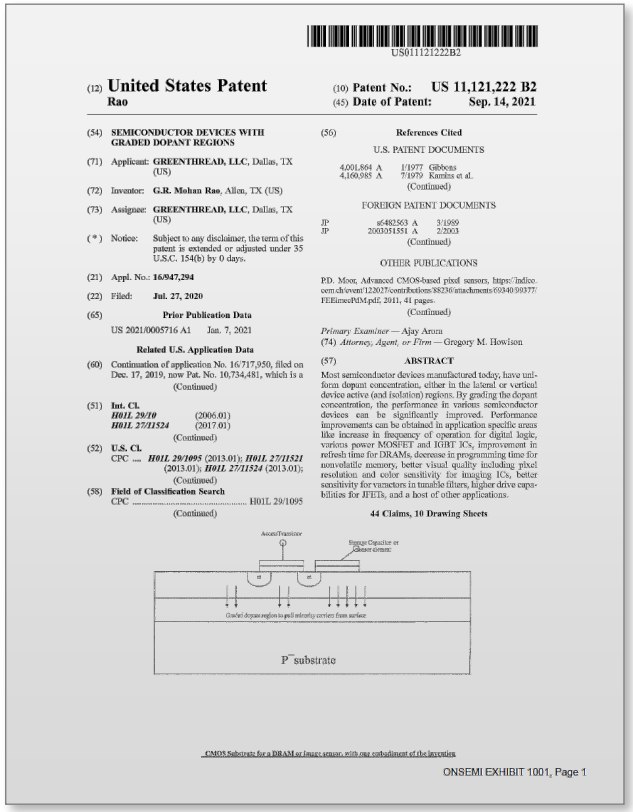
-00017: Ex. 1001 at 3:14-33

the surface. In a preferred embodiment, the subterrain n-layer has a graded donor concentration to sweep the minority carriers deep into the substrate. One or more of such layers can also be implemented through wafer to wafer bonding or similar "transfer" mechanisms. This n-layer can be a deeply-implanted layer. It can also be an epitaxial layer. The n-well and p-well also can be graded or retrograded in dopants, as desired, to sweep those carriers away from the surface as well.

-00017: Ex. 1001 ('195 pat.) at 3:33-40

1. Movement of Carriers from the Active Region

- Fig. 5B shows how an electric field moves minority carriers (positively-charged “holes”) from the active region at the surface.
- The positively-charged holes move in the same direction as the electric field.



US011121222B2

(12) **United States Patent**
Rao

(10) **Patent No.: US 11,121,222 B2**
(45) **Date of Patent: Sep. 14, 2021**

(54) **SEMICONDUCTOR DEVICES WITH GRADED DOPANT REGIONS**

(71) Applicant: **GREENTHREAD, LLC**, Dallas, TX (US)

(72) Inventor: **G.R. Mohan Rao**, Allen, TX (US)

(73) Assignee: **GREENTHREAD, LLC**, Dallas, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/947,294**

(22) Filed: **Jul. 27, 2020**

(65) **Prior Publication Data**

US 2021/0005716 A1 Jan. 7, 2021

Related U.S. Application Data

(60) Continuation of application No. 16/717,950, filed on Dec. 17, 2019, now Pat. No. 10,734,481, which is a (Continued)

(51) **Int. Cl.**
H01L 29/10 (2006.01)
H01L 27/11524 (2017.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01L 29/1095*** (2013.01); ***H01L 27/11521*** (2013.01); ***H01L 27/11524*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01L 29/1095
(Continued)

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Primary Examiner — Ajay Arora
(74) *Attorney, Agent, or Firm* — Gregory M. Howison

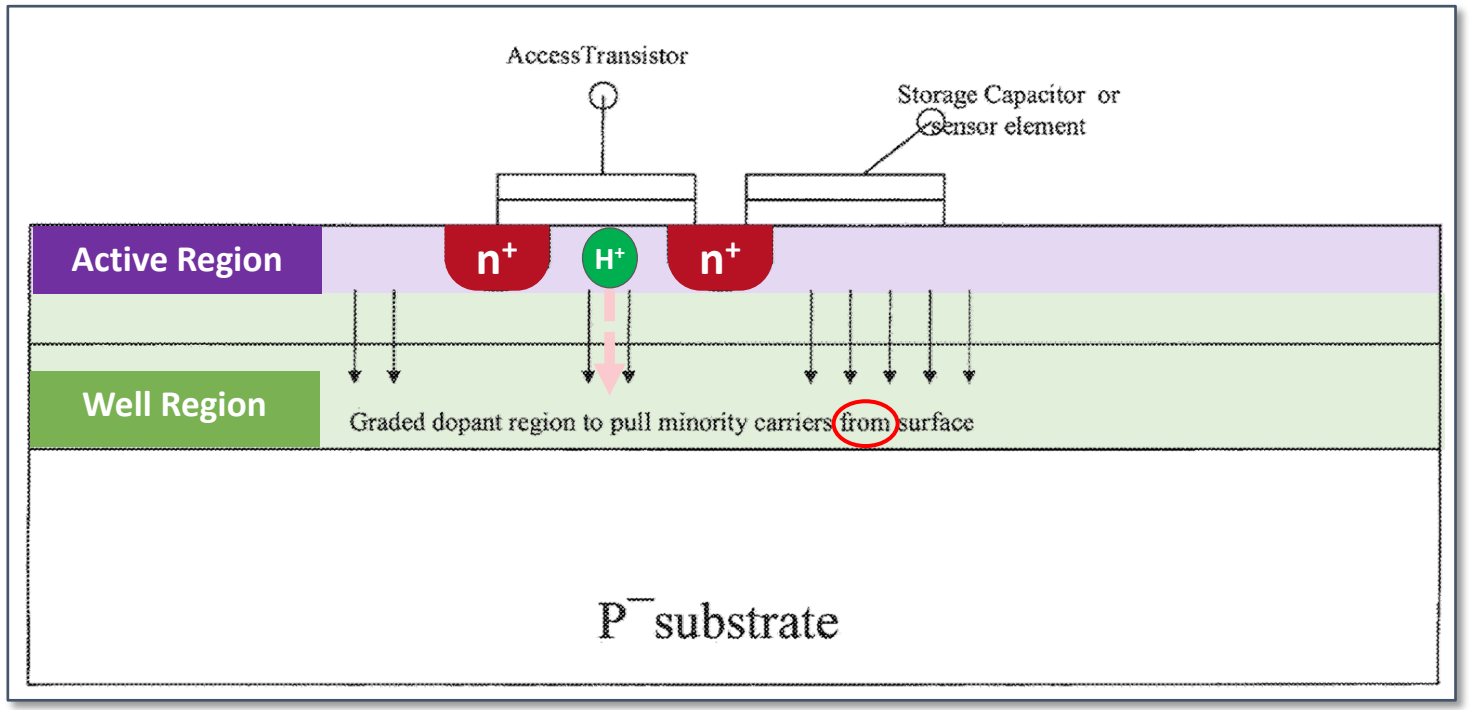
(57) **ABSTRACT**

Most semiconductor devices manufactured today, have uniform dopant concentration, either in the lateral or vertical device active (and isolation) regions. By grading the dopant concentration, the performance in various semiconductor devices can be significantly improved. Performance improvements can be obtained in application specific areas like increase in frequency of operation for digital logic, various power MOSFET and IGBT ICs, improvement in refresh time for DRAMs, decrease in programming time for nonvolatile memory, better visual quality including pixel resolution and color sensitivity for imaging ICs, better sensitivity for varactors in tunable filters, higher drive capabilities for JFETs, and a host of other applications.

44 Claims, 10 Drawing Sheets

CMOS Substrate for a DRAM or image sensor, with one embodiment of the invention

ONSEMI EXHIBIT 1001, Page 1



-00017: Ex. 1001 (’481 pat.) at Fig. 5B

1. Movement of Carriers from the Active Region

- The Challenged Claims do not mix apparatus and method limitations.

US 8,421,195

1. A CMOS Semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of said surface layer;
a single drift layer disposed between the other surface of said surface layer and said substrate, said drift layer having a graded concentration of dopants extending between said surface layer and said substrate, said drift layer further having a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and
at least one well region disposed in said single drift layer, said well region having a graded concentration of dopants and a second static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate.

-00017: Ex. 1001 ('195 pat.) at 4:13-29

US 9,190,502

7. A semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of said surface layer;
a single drift layer disposed between the other surface of said surface layer and said substrate, said drift layer having a graded concentration of dopants generating a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and
at least one well region disposed in said single drift layer, said well region having a graded concentration of dopants generating a second static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate.

-00018: Ex. 1001 ('502 pat.) at 4:52-67

US 11,121,222

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at least one well region disposed in the single drift layer, the well region having a graded concentration of dopants and a second static unidirectional electric drift field to aid the movement of carriers from the surface layer to the area of the substrate where there are no active regions.

-00021: Ex. 1001 ('222 pat.) at 8:21-39

-00017: PO Sur-Reply [59] at 11-12

1. Movement of Carriers from the Active Region

- The Challenged Claims recite structural limitations that require movement from the "surface layer."

US 8,421,195

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a surface layer;
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a substrate;
an active region including a source and a drain, disposed on one surface of the surface layer;
a single drift layer disposed between the other surface of the surface layer and the substrate, the drift layer having a graded concentration of dopants extending between the surface layer and the substrate, the drift layer further having a first static unidirectional electric drift field to aid the movement of carriers from the surface layer to an area of the substrate where there are no active regions; and
at least one well region disposed in the single drift layer, the well region having a graded concentration of dopants and a second static unidirectional electric drift field to aid the movement of carriers from the surface layer to the area of the substrate where there are no active regions.

-00021: Ex. 1001 ('222 pat.) at 8:21-39

-00017: PO Resp. [45] at 1-4, 7-16, 25; PO Sur-Reply [59] at 1-7. 10, 14-20

1. Movement of Carriers from the Active Region

- *ParkerVision* addressed claims with insufficient structural limitations.

Here, the apparatus claims are most similar to those in *Ericsson* and are fundamentally dissimilar to those in *Ball Aerosol*. The '940 patent's apparatus claims are drawn to "[a]n apparatus *for frequency upconversion*" (claim 4) or "[a]n apparatus *for communicating*" (claim 22), all of which comprise "a switch module *to receive*" an oscillating signal and a bias signal, wherein the oscillating signal "*causes* said switch module *to gate* said bias signal and thereby *generate* a periodic signal having a plurality of harmonics." '940 patent, col. 67, ll. 25–33 (emphases added); *id.* col. 69, ll. 19–32 (emphases added). Accordingly, just as D-Link's products only required a component that was reasonably capable of "arranging information for transmission . . . which identifies a type of payload information . . .," *Ericsson*, 773 F.3d at 1217, Nozawa's circuit requires only an oscillating signal that is reasonably capable of gating the bias signal in a manner that generates a periodic signal having a plurality of harmonics. And, unlike in *Ball Aerosol*, the claims here recite no structural limitations that would preclude a prior art reference that discloses a different structure from performing the claimed function.

ParkerVision, Inc. v. Qualcomm Inc., 903 F.3d 1354, 1361, 1362 (Fed. Cir. 2018)

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. Dr. Banerjee confirmed the "electric field" must start in the "surface layer."
4. Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."
5. Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."
6. Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
7. The "movement of carriers" depends on the sum of all of the fields in the "surface layer."
8. Petitioners have the burden to analyze all of the fields in the "surface layer."
9. Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

2. Movement of Minority Carriers from the Active Region

- The ’195 and ’502 claims require “movement of minority carriers.”

US 8,421,195

1. A CMOS Semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of said surface layer;
a single drift layer disposed between the other surface of said surface layer and said substrate, said drift layer having a graded concentration of dopants extending between said surface layer and said substrate, said drift layer further having a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and
at least one well region disposed in said single drift layer, said well region having a graded concentration of dopants and a second static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate.

-00017: Ex. 1001 (’195 pat.) at 4:13-29

US 9,190,502

7. A semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of said surface layer;
a single drift layer disposed between the other surface of said surface layer and said substrate, said drift layer having a graded concentration of dopants generating a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and
at least one well region disposed in said single drift layer, said well region having a graded concentration of dopants generating a second static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate.

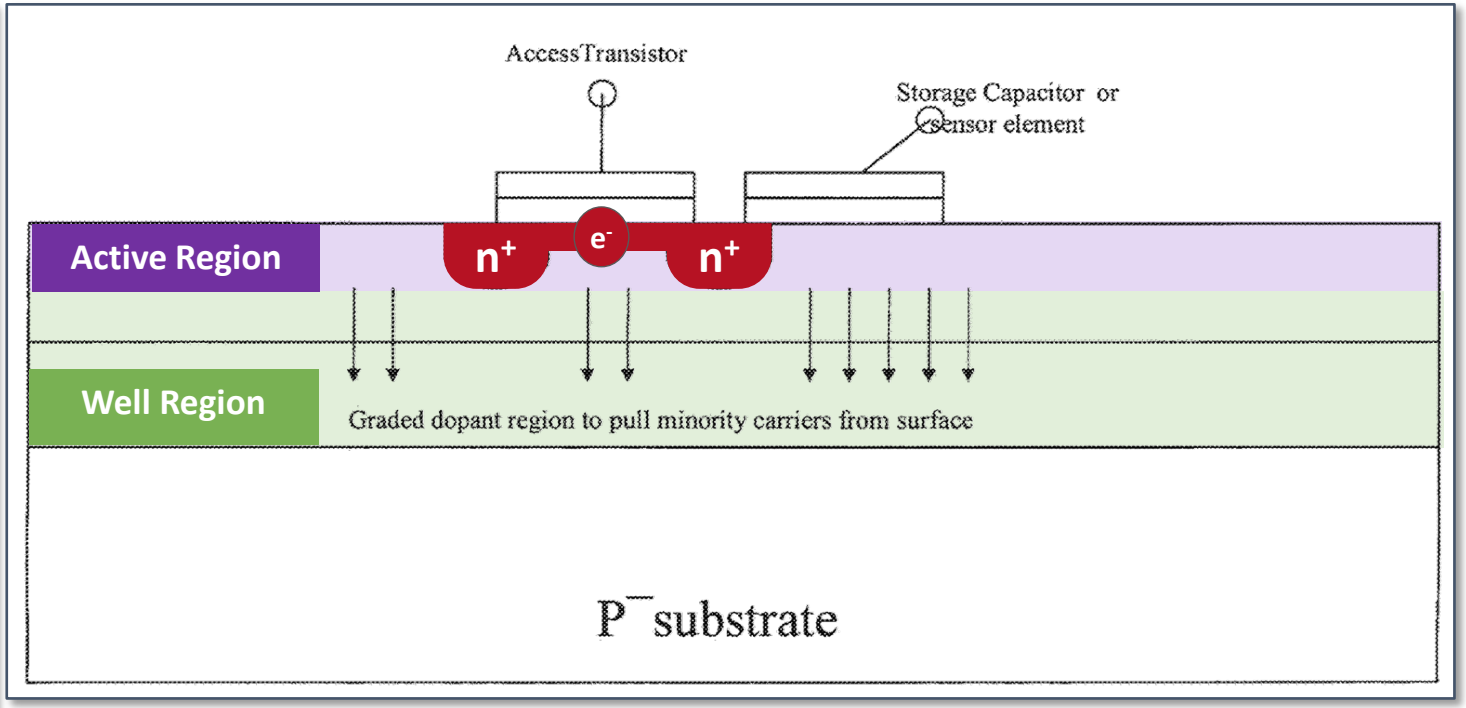
-00018: Ex. 1001 (’502 pat.) at 4:52-67

2. Movement of Minority Carriers from the Active Region

- The specification explains the "majority carriers" are the majority carrier in the MOSFET channel.

Bipolar Junction transistors (BJT) are minority carrier devices as the principle device conduction mechanism. However, majority carriers also a small yet finite role in modulating the conductivity in BJTs. Consequently, both carriers (electrons and holes) play a role in the switching performance of BJTs. The maximum frequency of operation in BJTs is limited by the base transit time as well as the quick recombination of the majority carriers when the device is switched off (prior to beginning the next cycle). The dominant carrier mechanism in BJTs is carrier diffusion. Carrier drift current component is fairly small, especially in uniformly doped base BJTs. Efforts have been made in graded base transistors to create an 'aiding drift field', to enhance the diffusing minority carrier's speed from emitter to collector. However, most semiconductor devices, including various power MOSFETs (traditional, DMOS, lateral, vertical and a host of other configurations), IGBT's (Insulated Gated Base Transistors), still use a uniformly doped drift epitaxial region in the base. FIG. **1** shows the relative doping concentration versus distance in a BJT. FIG. **2** shows the uniformly doped epi region' in a IGBT. In contrast to BJTs, MOS devices are majority carrier devices for conduction. The conduction is channel dominated. The channel can be a surface in one plane in planar devices. The surface can also be on the sidewalls in a vertical device. Other

-00017: Ex. 1001 at 1:23-45



-00017: Ex. 1001 ('195 pat.) at Fig. 5B

[3] Because the channel is formed by electrons with a **n**egative charge, the MOSFET is referred to as an **n**-channel MOSFET, and the "minority carriers" are holes.

-00017: Ex. 2057 (Glew Decl.) at ¶36, n. 3

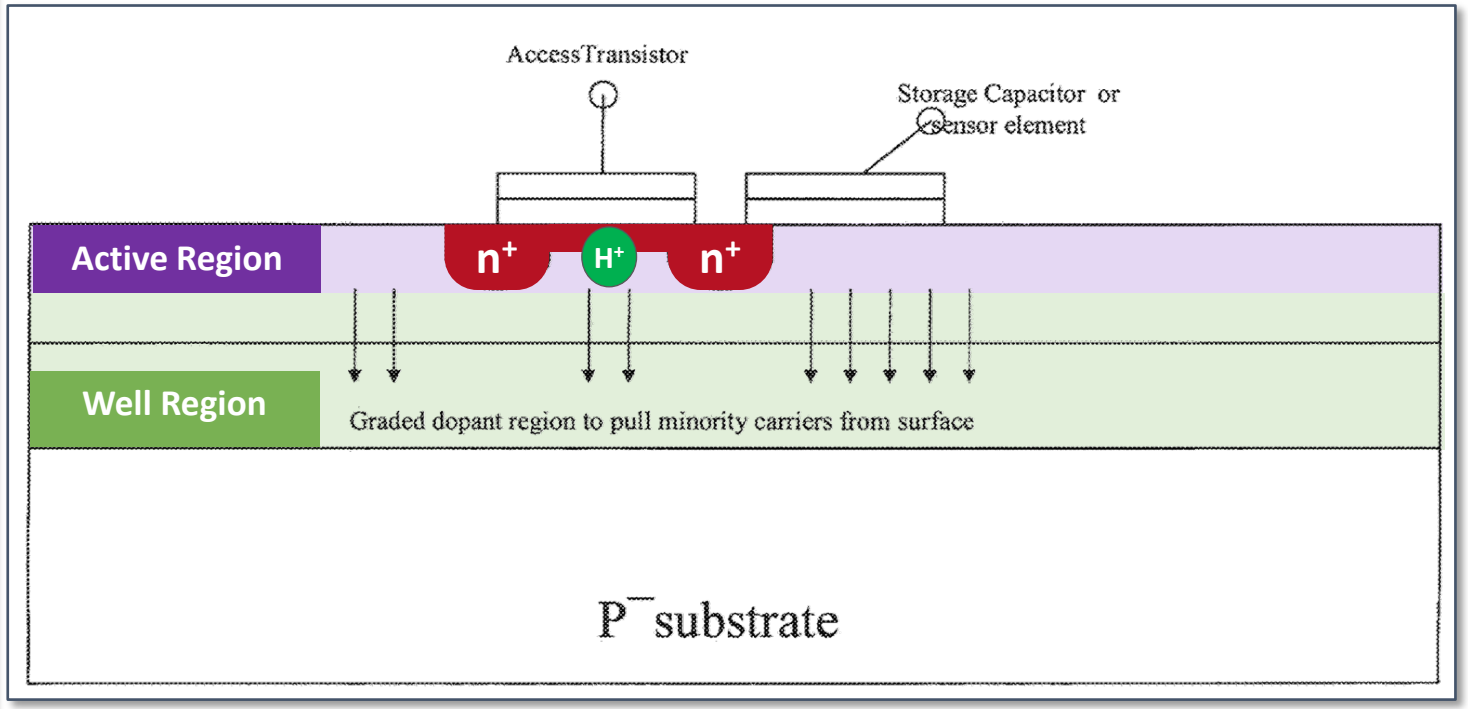
-00017: Ex. 2057, ¶¶35-37; PO Resp. [45] at 4, 7-16; Ex. 1063, 25:6-26:1, 142:16-22; 149:9-151:9; Ex. 2078, 293:5-294:8; PO Sur-Reply [59] at 1, 3-5, 6-7. 10, 14-20

2. Movement of Minority Carriers from the Active Region

- The "spurious minority carriers" interfere with the "active circuitry at the surface."

As illustrated in FIGS. **5**(*a*), **5**(*b*), **5**(*c*), donor gradient is also of benefit to very large scale integrated circuits (VLSI)– VLSI logic, DRAM, nonvolatile memory like NAND flash. Spurious minority carriers can be generated by clock switching in digital VLSI logic and memory IC'S. These unwanted carriers can discharge dynamically-held 'actively held high' nodes. Statically held nodes (with V_{cc}) can not be affected, in most cases. Degradation of refresh time in DRAM's is one of the results, because the capacitor holds charge dynamically. Similarly, degradation of CMOS digital images, in digital imaging IC's is another result of the havoc caused by minority carriers. Pixel and color resolution can be significantly enhanced in imaging IC's with the embodiments described here. Creating 'Sub Terrain' recombination centers underneath the wells (gold doping, platinum doping) as is done in some high-voltage diodes is not practical for VLSI circuits. Hence, a novel technique has been described here by creating a drift field to sweep these unwanted minority carriers into the substrate as quickly as possible, from the active circuitry at the surface. In a preferred embodiment, the subterrain n-layer has a graded donor concentration to sweep the minority carriers deep into the substrate. One or more of such layers can also be implemented through wafer to wafer bonding or similar "transfer" mechanisms. This n-layer can be a deeply-implanted layer. It can also be an epitaxial layer. The n-well and p-well also can be graded or retrograded in dopants, as desired, to sweep those carriers away from the surface as well.

-00017: Ex. 1001 at 3:14-40



-00017: Ex. 1001 ('195 pat.) at Fig. 5B

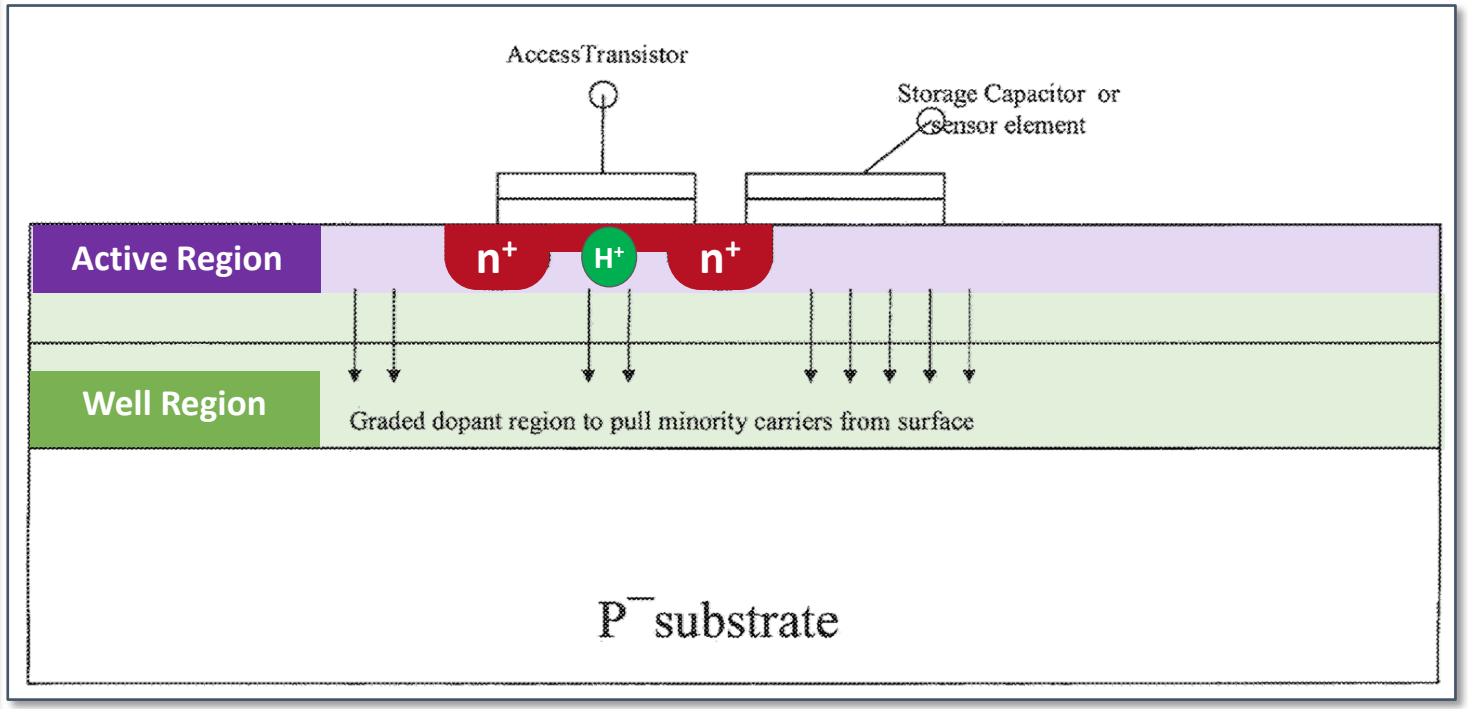
-00017: Ex. 2057, ¶¶35-37; PO Resp. [45] at 4, 7-16; Ex. 1063, 25:6-26:1, 142:16-22; 149:9-151:9; Ex. 2078, 293:5-294:8; PO Sur-Reply [59] at 1, 3-5, 6-7. 10, 14-20

2. Movement of Minority Carriers from the Active Region

- The "minority carriers" interfere with the MOSFET's channel.

As illustrated in FIGS. **5**(*a*), **5**(*b*), **5**(*c*), donor gradient is also of benefit to very large scale integrated circuits (VLSI)– VLSI logic, DRAM, nonvolatile memory like NAND flash. Spurious minority carriers can be generated by clock switching in digital VLSI logic and memory IC'S. These unwanted carriers can discharge dynamically-held 'actively held high' nodes. Statically held nodes (with V_{cc}) can not be affected, in most cases. Degradation of refresh time in DRAM's is one of the results, because the capacitor holds charge dynamically. Similarly, degradation of CMOS digital images, in digital imaging IC's is another result of the havoc caused by minority carriers. Pixel and color resolution can be significantly enhanced in imaging IC's with the embodiments described here. Creating 'Sub Terrain' recombination centers underneath the wells (gold doping, platinum doping) as is done in some high-voltage diodes is not practical for VLSI circuits. Hence, a novel technique has been described here by creating a drift field to sweep these unwanted minority carriers into the substrate as quickly as possible, from the active circuitry at the surface. In a preferred embodiment, the subterrain n-layer has a graded donor concentration to sweep the minority carriers deep into the substrate. One or more of such layers can also be implemented through wafer to wafer bonding or similar "transfer" mechanisms. This n-layer can be a deeply-implanted layer. It can also be an epitaxial layer. The n-well and p-well also can be graded or retrograded in dopants, as desired, to sweep those carriers away from the surface as well.

-00017: Ex. 1001 at 3:14-40



-00017: Ex. 1001 ('195 pat.) at Fig. 5B

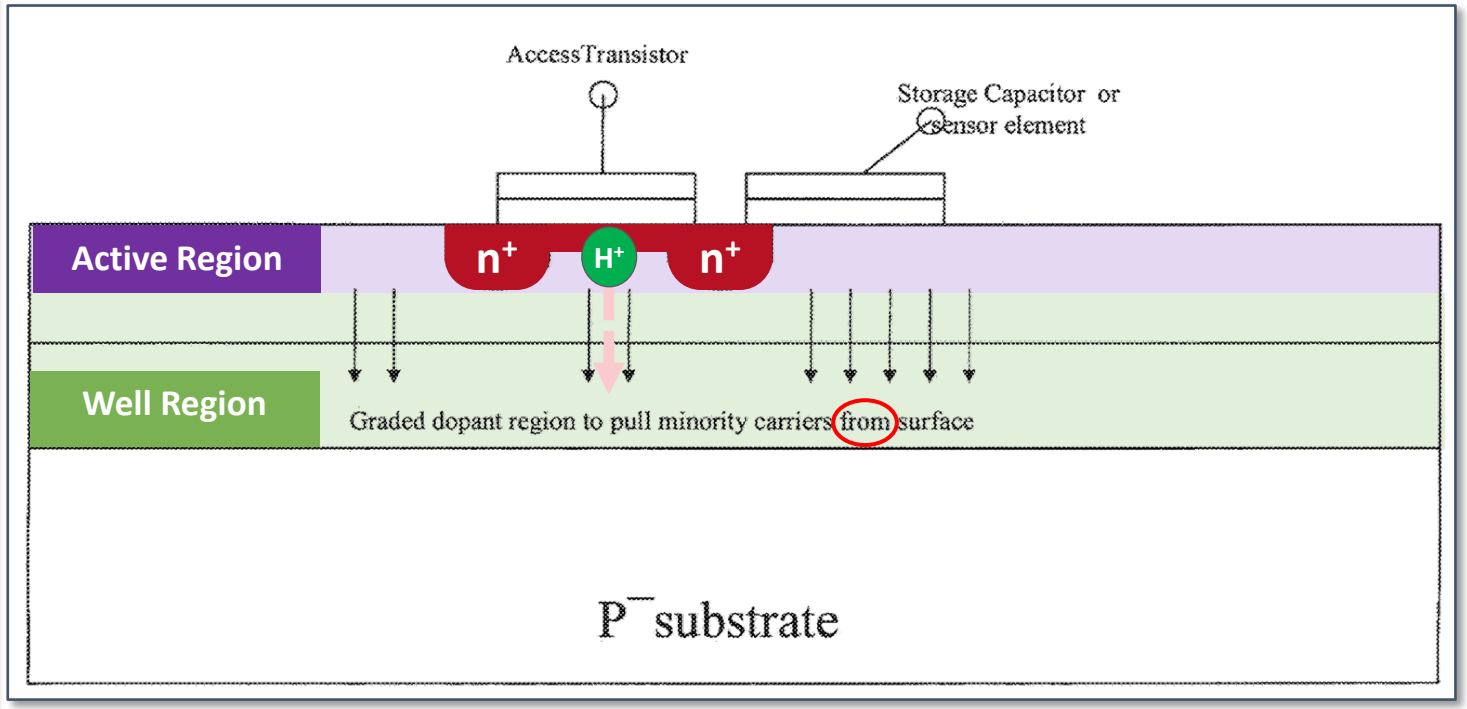
-00017: Ex. 2057, ¶¶35-37; PO Resp. [45] at 4, 7-16; Ex. 1063, 25:6-26:1, 142:16-22; 149:9-151:9; Ex. 2078, 293:5-294:8; PO Sur-Reply [59] at 1, 3-5, 6-7. 10, 14-20

2. Movement of Minority Carriers from the Active Region

- A "drift field" with a "graded dopant region" sweeps the minority carriers from the surface.

As illustrated in FIGS. **5**(*a*), **5**(*b*), **5**(*c*), donor gradient is also of benefit to very large scale integrated circuits (VLSI)– VLSI logic, DRAM, nonvolatile memory like NAND flash. Spurious minority carriers can be generated by clock switching in digital VLSI logic and memory IC'S. These unwanted carriers can discharge dynamically-held 'actively held high' nodes. Statically held nodes (with V_{cc}) can not be affected, in most cases. Degradation of refresh time in DRAM's is one of the results, because the capacitor holds charge dynamically. Similarly, degradation of CMOS digital images, in digital imaging IC's is another result of the havoc caused by minority carriers. Pixel and color resolution can be significantly enhanced in imaging IC's with the embodiments described here. Creating 'Sub Terrain' recombination centers underneath the wells (gold doping, platinum doping) as is done in some high-voltage diodes is not practical for VLSI circuits. Hence, a novel technique has been described here by creating a drift field to sweep these unwanted minority carriers into the substrate as quickly as possible, from the active circuitry at the surface. In a preferred embodiment, the subterrain n-layer has a graded donor concentration to sweep the minority carriers deep into the substrate. One or more of such layers can also be implemented through wafer to wafer bonding or similar "transfer" mechanisms. This n-layer can be a deeply-implanted layer. It can also be an epitaxial layer. The n-well and p-well also can be graded or retrograded in dopants, as desired, to sweep those carriers away from the surface as well.

-00017: Ex. 1001 at 3:14-40



-00017: Ex. 1001 ('195 pat.) at Fig. 5B

-00017: Ex. 2057, ¶¶35-37; PO Resp. [45] at 4, 7-16; Ex. 1063, 25:6-26:1, 142:16-22; 149:9-151:9; Ex. 2078, 293:5-294:8; PO Sur-Reply [59] at 1, 3-5, 6-7. 10, 14-20

2. Movement of Minority Carriers from the Active Region

- Dr. Glew explained that in Fig. 5B, the "minority carriers" are holes.

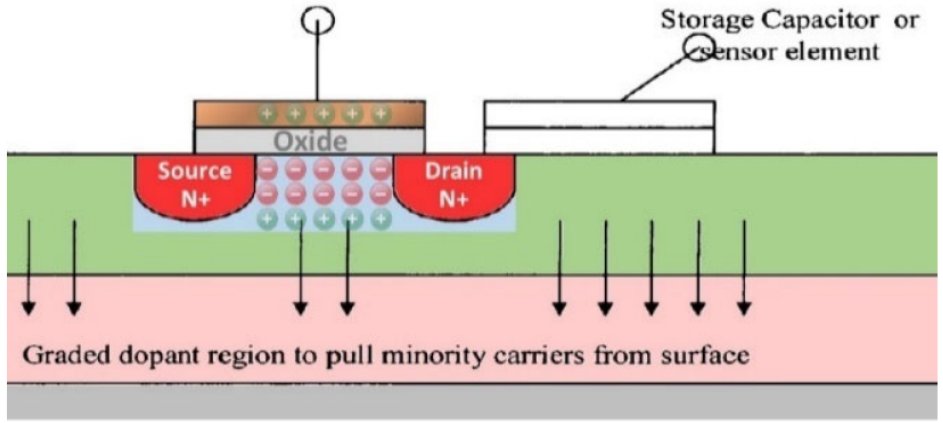
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36. When a positive voltage is applied to the gate, an electric field forms in the oxide. This positive electric field repels the "positive" holes downwards, while When enough electrons have accumulated in the surface layer below the oxide, they form a conductive channel (as annotated in Figure 5B below) of electrons between the source and the drain, and current can begin to flow through the transistor.



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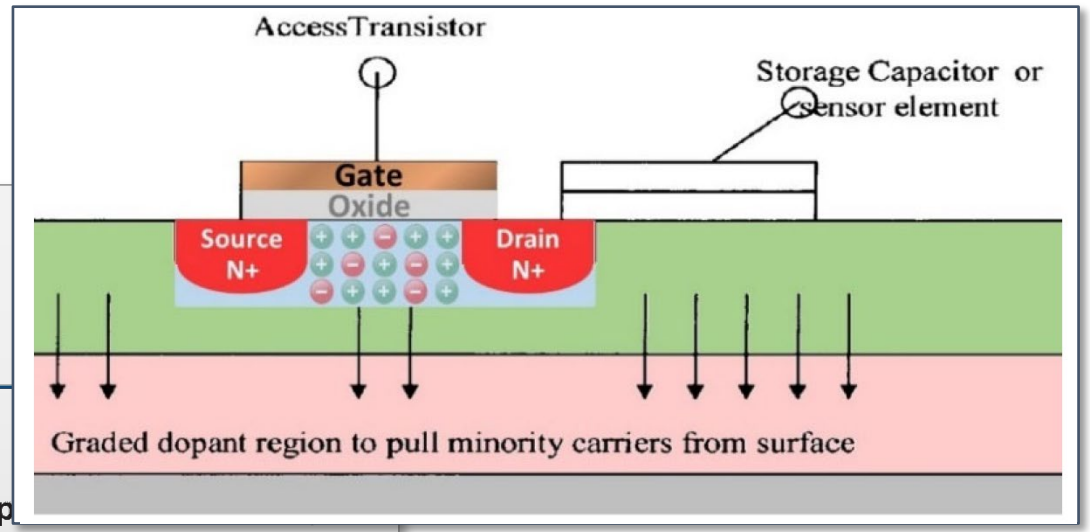
Ex. 1001, FIG. 5B (annotated). [3] In order to turn the transistor "off," the positive voltage is removed from the gate and the channel disappears as the holes return to the surface layer.

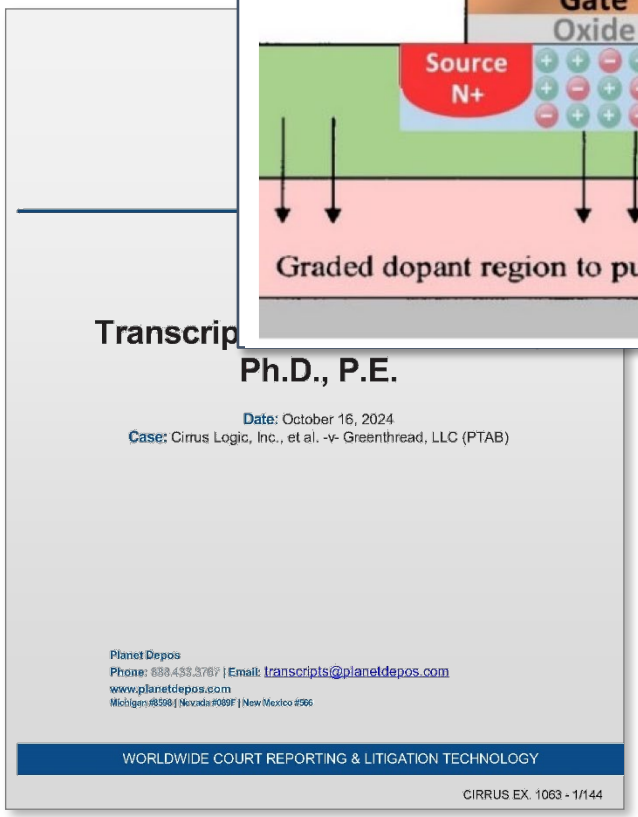
[3] Because the channel is formed by electrons with a **n**egative charge, the MOSFET is referred to as an **n**-channel MOSFET, and the "minority carriers" are holes.

-00017: Ex. 2057 (Glew Decl.) at ¶36, n. 3

2. Movement of Minority Carriers from the Active Region

- Dr. Glew explained that in Fig. 5B, the “minority carriers” are holes.





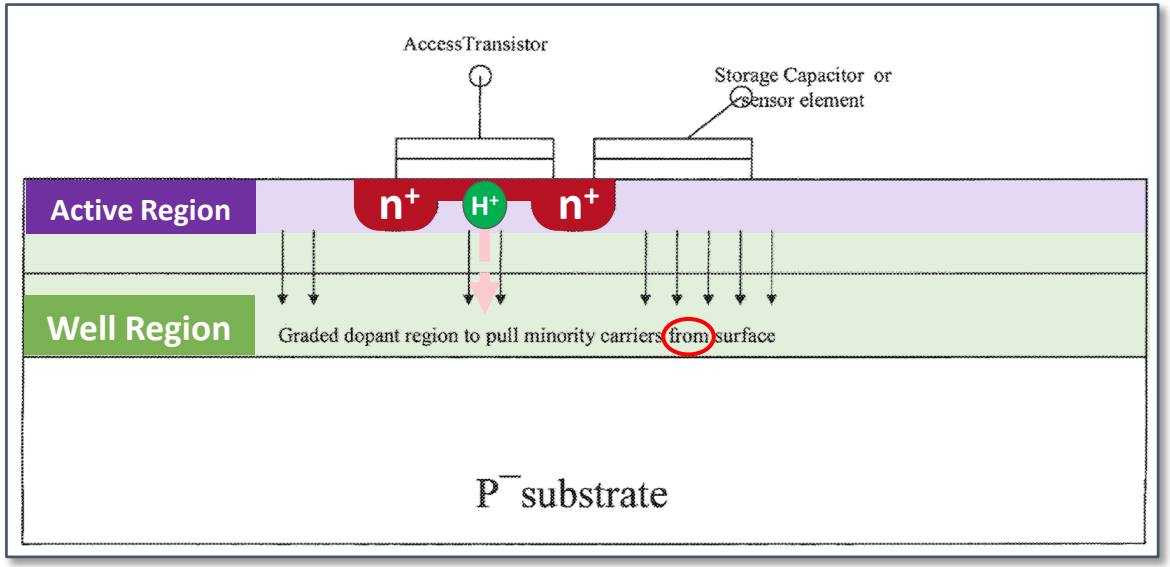
-00017: Ex. 2057 (Glew Decl.) , ¶35

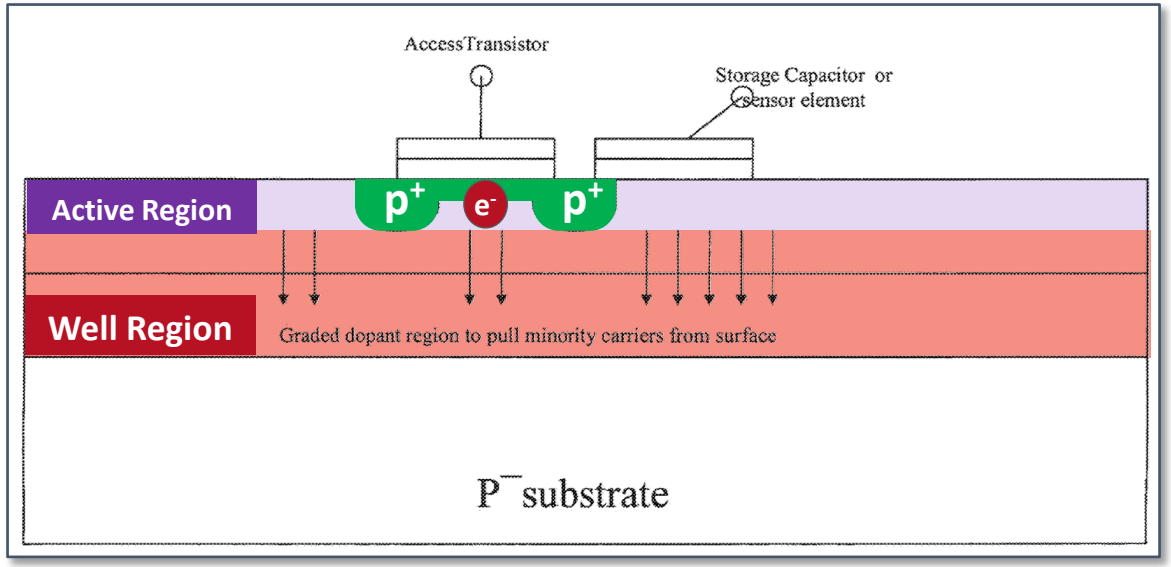
6 It is meant to be graded simply so that it
7 can pull minority carriers from the surface, the
8 minority carriers being positive charges for an NPN
9 transistor in its operating mode.
10 Q I'll come back to that one question again.
11 But is the dopant type on the pink layer --
12 is that p-type dopant?
13 MR. WHITEHURST: Object to form.
14 THE WITNESS: Specifically the patent, I
15 don't believe it describes that it has to be one
16 type or the other. When reading the patent, it
17 doesn't say this or that. It just says it has to be
18 constructed in order to pull minority carriers from
19 the surface.
20 The minority carriers in this case would be
21 p-type. In order for an NPN transistor to function
22 in the "on" state, it would need to have electrons
1 move from the source to the drain.

-00017: Ex. 1063 (Glew Dep. Tr.) at 25:6-26:1

2. Movement of Minority Carriers from the Active Region

- In an NMOS transistor, the "majority carrier" is an electron, and the "minority carrier" is a hole.
- In an PMOS transistor, the "majority carrier" is a hole, and the "minority carrier" is an electron.

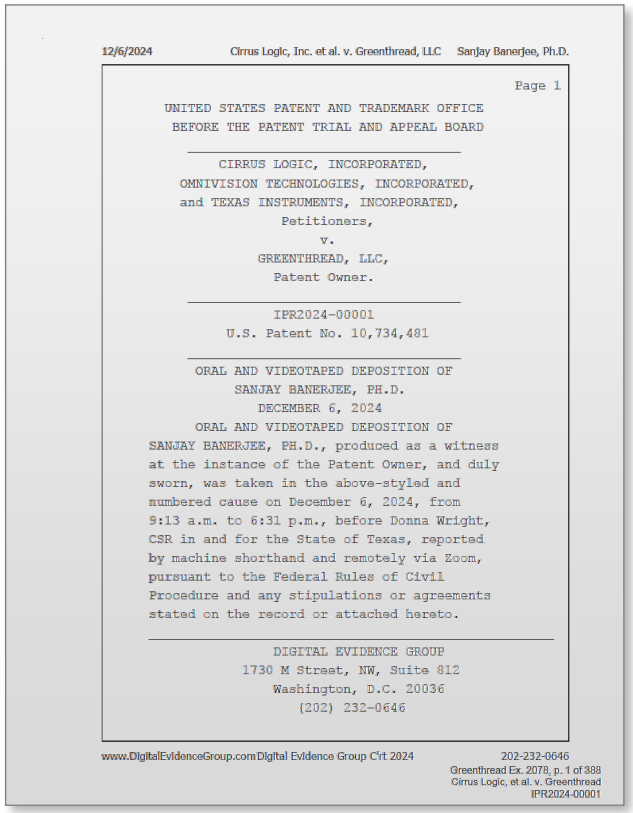




-00017: Ex. 1001 ('195 pat.) at Fig. 5B

2. Movement of Minority Carriers from the Active Region

- Dr. Banerjee confirmed that in a NMOS transistor, the majority carrier in the channel is an electron.



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UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INCORPORATED,
OMNIVISION TECHNOLOGIES, INCORPORATED,
and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,481

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

ORAL AND VIDEOTAPED DEPOSITION OF SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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5 Q. Now, in an NMOS transistor,
6 when a channel forms between the source and
7 the drain, which charge carrier is moving
8 from the source to the drain?
9 A. It's electrons.
10 Q. Please explain why when the
11 channel forms, the electrons move from the
12 source to the drain.
13 A. So here you have to apply two
14 voltages. You apply a positive gate voltage
15 at the top. That's going to attract
16 electrons towards the surface, but they
17 cannot keep flowing because in between the
18 gate electrode and the surface of the
19 substrate, you have electrical insulator. So
20 the minority carrier electrons will flow
21 towards the surface, but they cannot keep
22 going because they are blocked by an
1 electrical insulator.

2 Then if you apply a voltage to
3 the drain, that creates a lateral electric
4 field along the channel and that's the
5 electric field which will actually cause the
6 electrons to flow from the source, which is
7 generally held at ground potential to the
8 drain, which is held at a positive voltage.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 293:5-294:8

2. Movement of Minority Carriers from the Active Region

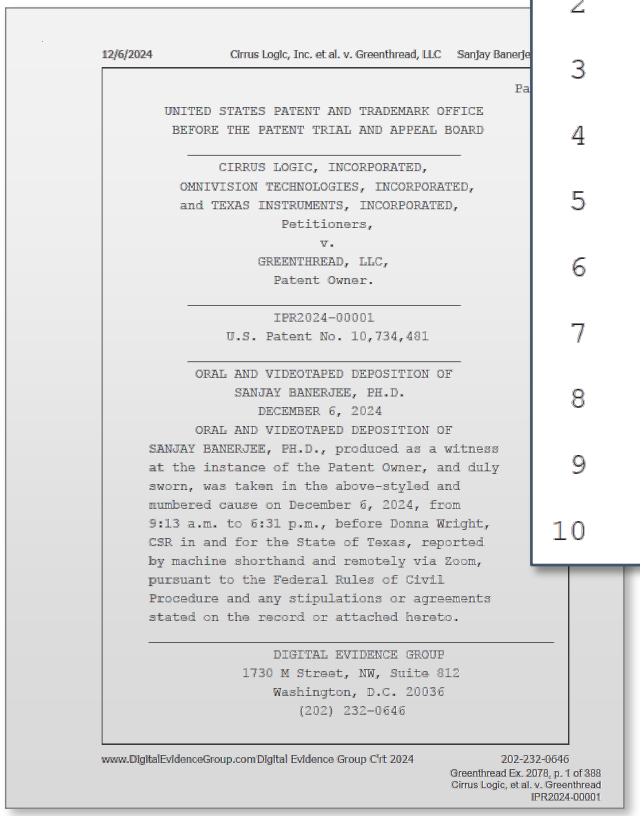


"Claims must always be read in light of the specification."

Philips v. AWH Corp., 415 F.3d 1303, 1315 (Fed. Cir. 2005) (quoting *In re Fout*, 674 F.2d 297, 300 (CPA 1982))

2. Movement of Minority Carriers from the Active Region

- Dr. Banerjee agreed that it is proper to "interpret" claims "in light of the specification."



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Q. Do you think it's relevant how Dr. Rao used the terms "majority carrier" and "minority carrier" in his specification?

MR. PAUL: Objection to form.

THE WITNESS: Yes, it is relevant, but I don't believe those were the same terms that are in dispute. So, once again, if you show me specific paragraphs, I can take a look at it.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 277:1-10, 277:19-278:13

Q. Now, if Dr. Rao used the terms the other way around in his specification, would you want to know that?

MR. PAUL: Objection to form.

THE WITNESS: Sure.

Q. (BY MR. WHITEHURST) And why would you want to know how Dr. Rao used the terms "majority" and "minority carrier"?

A. You know, you interpret the same language in the Rao patents in light of the specifications.

Q. And why do you interpret the claims in light of the specification?

MR. PAUL: Objection to form.

THE WITNESS: I'm not a lawyer, but that's how they do it by my counsel in prior cases also.

2. Movement of Minority Carriers from the Active Region

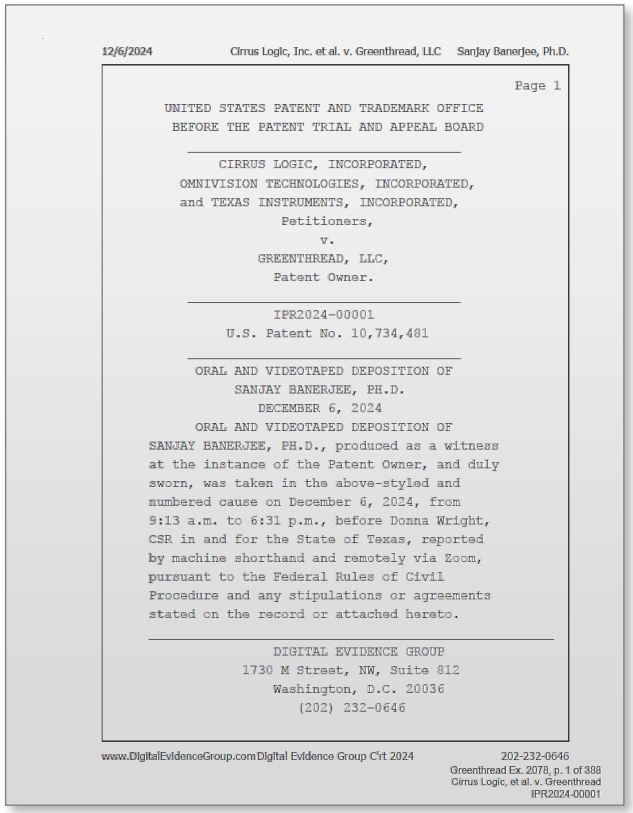


"A claim construction that 'excludes the preferred embodiment is rarely, if ever, correct and would require highly persuasive evidentiary support.' In this case, the specification, including the claims, supports a reading that encompasses the preferred embodiment."

SynQor, Inc. v. Artesyn Techs., Inc.,
709 F.3d 1365, 1378-79 (Fed. Cir. 2013) (internal citation omitted)

2. Movement of Minority Carriers from the Active Region

- Dr. Banerjee prepared his declaration based on his understanding of "majority" and "minority carriers."



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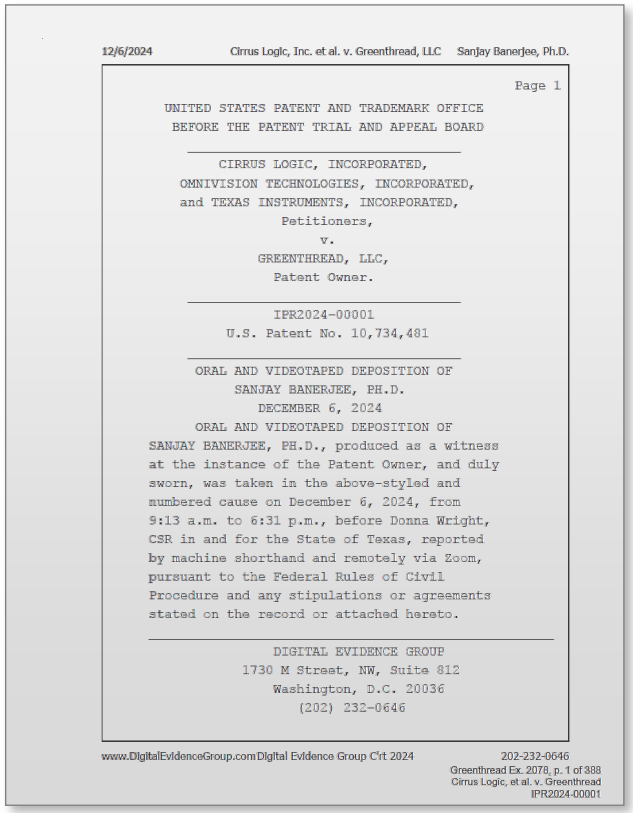
Greenthread Ex. 2078, p. 1 of 388
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22 Q. Now, I understand that, to you,
1 majority and minority carriers refers to
2 what's the majority or the minority carrier
3 in the well.
4 Did I summarize that fairly?
5 A. The majority carriers refer to
6 carriers that are provided by the dopant and
7 the other side is the minority carrier. If
8 you have a region where you have donors that
9 comes with the majority falls to the
10 minority.
11 Q. And I understand that that's
12 the position you have taken in your
13 declaration. My question is different.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 274:22-275:13

2. Movement of Minority Carriers from the Active Region

- Dr. Banerjee did not use the language of the specification.



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and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,481

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

ORAL AND VIDEOTAPED DEPOSITION OF SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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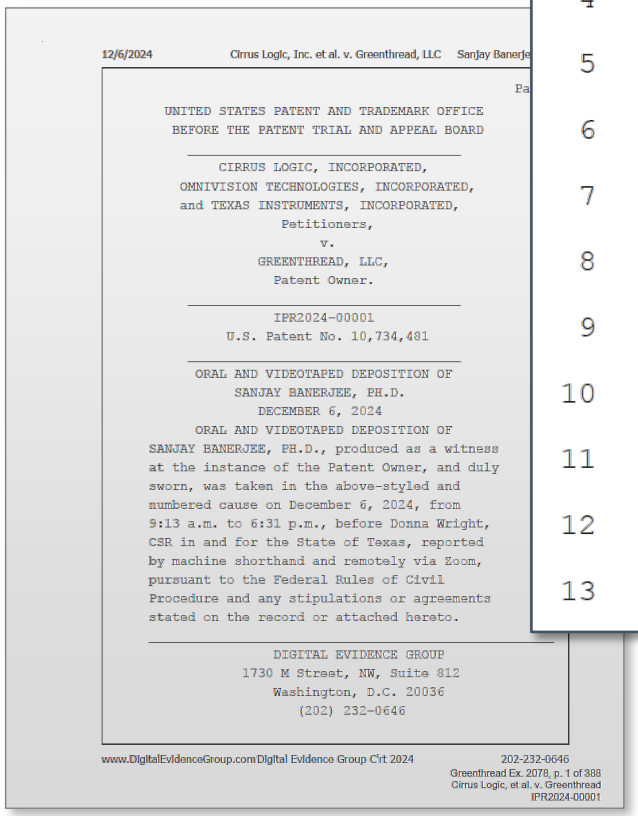
Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

12 Did you read the specification
13 in order to see how majority and minority
14 carriers are used in the specification?
15 A. In the patents?
16 Q. Yes, sir.
17 A. I don't recall. I mean, the
18 terms, majority and minority carriers, are
19 well-known terms in the art, but I
20 didn't resort to the language of the
21 specifications.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 274:12-21

2. Movement of Minority Carriers from the Active Region

- Dr. Banerjee could not recall how “minority carriers” was used in the specification.



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerje

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Q. (BY MR. WHITEHURST) Do you recall how Dr. Rao used the term "majority carrier" in his specification?

MR. PAUL: Objection to form.

THE WITNESS: I recall a figure in his patents, I believe on the cover page, in fact, where he shows these arrows drawing minority carriers away from the surface. I don't recall exactly what language he may have used in the specification.

Q. (BY MR. WHITEHURST) Do you recall how he used the term "minority carrier" in his specification?

A. As I said, I see minority carriers in these patents here, I see minority carriers listed on the figure on the cover page and being pulled away from the surface. I don't recall how he used those terms in the classification.

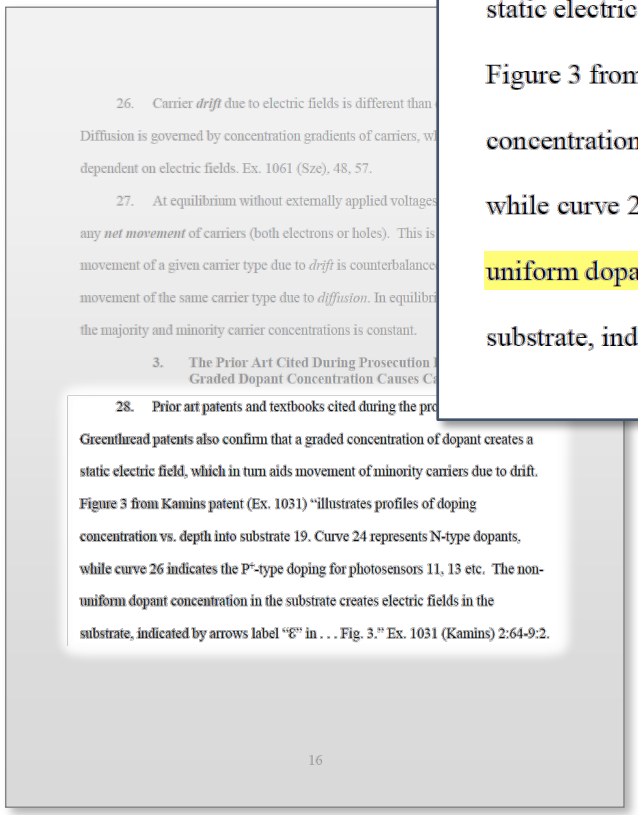
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 276:3-22

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."
5. Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."
6. Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
7. The "movement of carriers" depends on the sum of all of the fields in the "surface layer."
8. Petitioners have the burden to analyze all of the fields in the "surface layer."
9. Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

3. The Electric Field Must Start in the Surface Layer

- Dr. Banerjee explained the Kamins reference in his supplemental declaration.



28. Prior art patents and textbooks cited during the prosecution of Greenthread patents also confirm that a graded concentration of dopant creates a static electric field, which in turn aids movement of minority carriers due to drift. Figure 3 from Kamins patent (Ex. 1031) "illustrates profiles of doping concentration vs. depth into substrate 19. Curve 24 represents N-type dopants, while curve 26 indicates the P^+-type doping for photosensors 11, 13 etc. The non-uniform dopant concentration in the substrate creates electric fields in the substrate, indicated by arrows label "Ɛ" in . . . Fig. 3." Ex. 1031 (Kamins) 2:64-9:2.

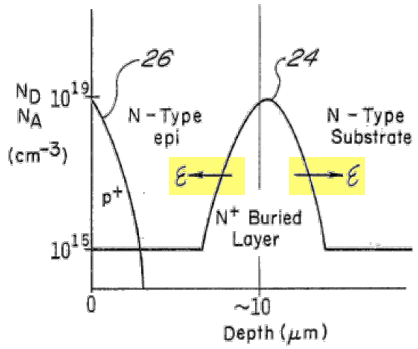


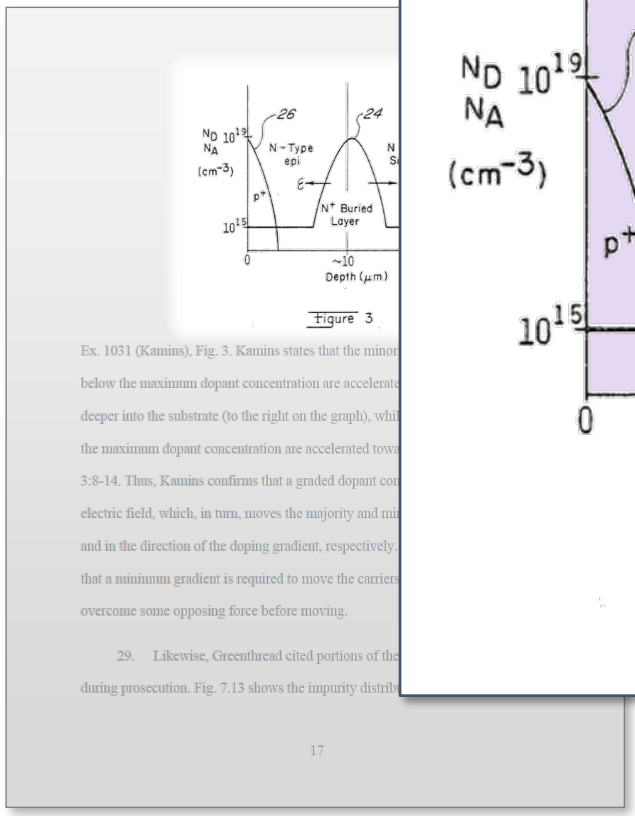
Figure 3

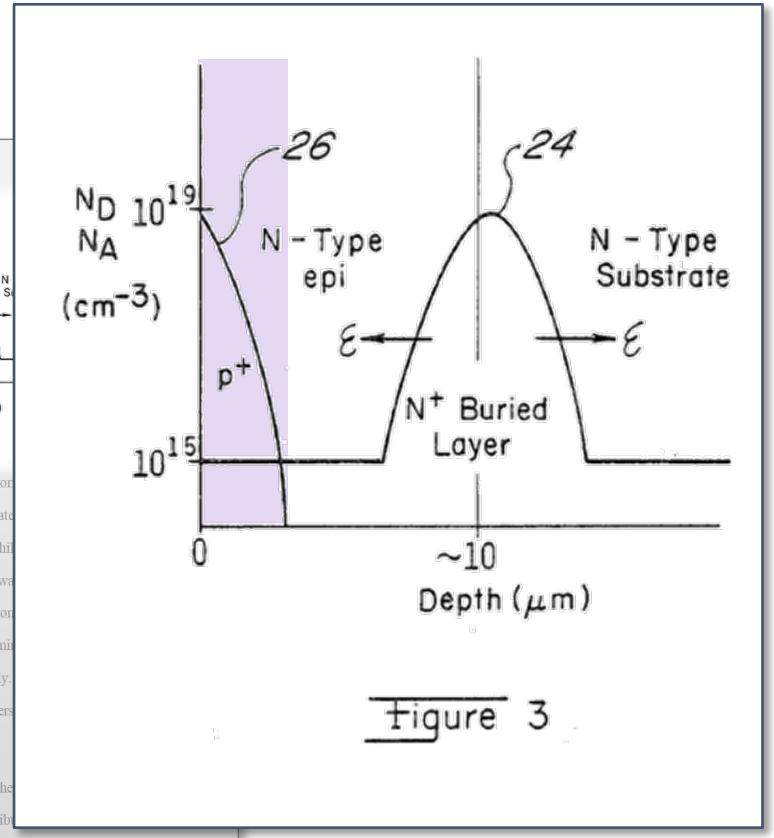
Ex. 1031 (Kamins), Fig. 3. Kamins states that the minority carrier holes created below the maximum dopant concentration are accelerated by the electric field deeper into the substrate (to the right on the graph), while carriers created above the maximum dopant concentration are accelerated towards the surface. *See id.*, 3:8-14. Thus, Kamins confirms that a graded dopant concentration creates a static electric field, which, in turn, moves the majority and minority carriers, opposite to and in the direction of the doping gradient, respectively. Kamins does not mention that a minimum gradient is required to move the carriers or that the carriers need to overcome some opposing force before moving.

-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

3. The Electric Field Must Start in the Surface Layer

- Dr. Banerjee explained that the "active region" would be between 0 and the curved line 26.





-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

11	Q. (BY MR. WHITEHURST) So the
12	active region would be somewhere between the
13	number zero and where the line labeled 26
14	intersects the X axis?
15	A. Approximately in that field.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 256:11-15

3. The Electric Field Must Start in the Surface Layer

- Dr. Banerjee explained that there is no electric field in the flat green region.

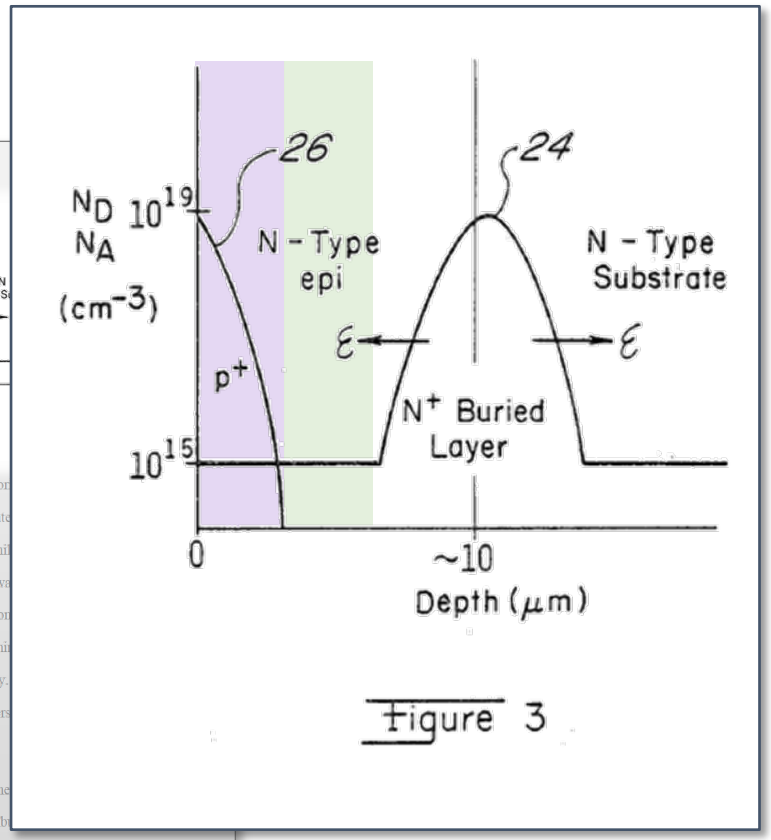


Figure 3

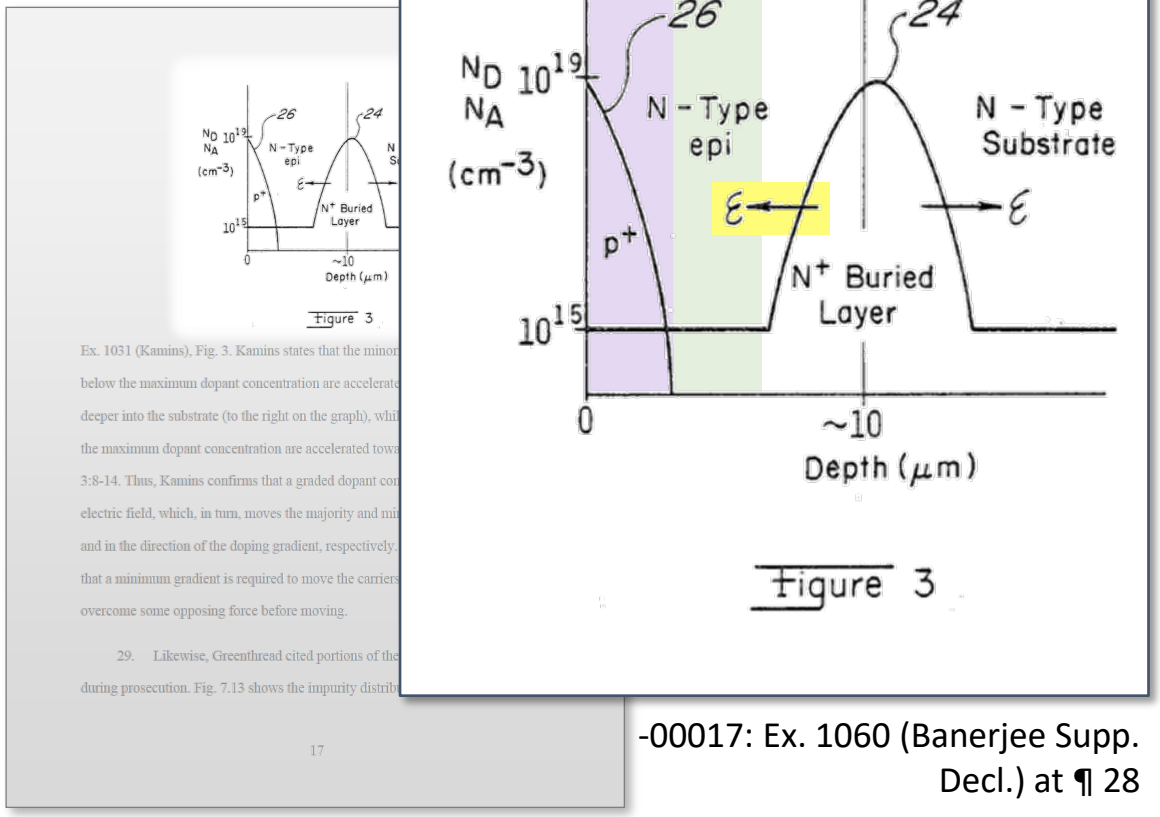
-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

2	Q.	My question is about the flat
3	section to the right of line 26 before it	
4	goes up.	
5	A.	Okay.
6	Q.	Would there be an electric
7	field in that flat region?	
8	A.	There should not be any
9	built-in electric fields in that flat region.	
10	Q.	Why not?
11	A.	Because the doping
12	concentration isn't changing as a function of	
13	depth.	

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 260:2-13

3. The Electric Field Must Start in the Surface Layer

- Dr. Banerjee testified that the upward "electric field" ends before the active region.



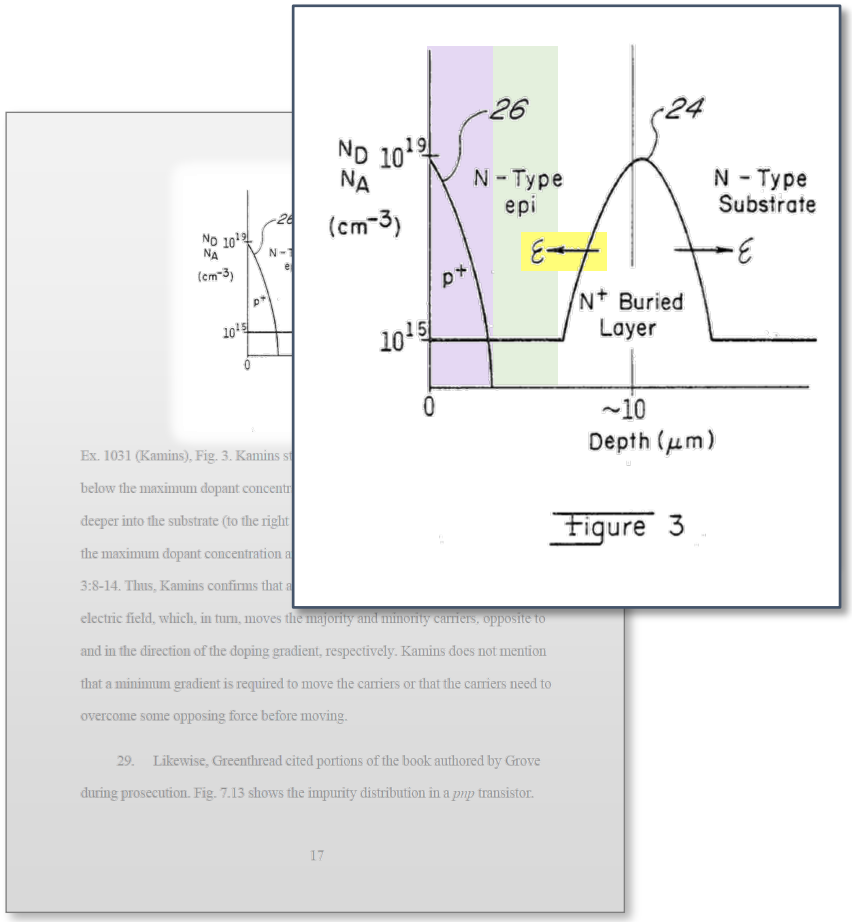
-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

12		Do you see the electric field
13	pointing in the upward direction, yes or no?	
14	A.	Yes, yes.
15	Q.	Do you agree that that electric
16	field ends before the surface?	
17	A.	Yes.
18	Q.	Do you agree that that electric
19	field ends before the active region?	
20	A.	In this case, yes.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 262:12-20

3. The Electric Field Must Start in the Surface Layer

- Dr. Banerjee testified that the upward "electric field" will not aid carrier movement from the active region because it is not in active region.



Q. (BY MR. WHITEHURST) So the electric field shown in Figure 3 that points in an upward direction will not aid movement of holes from the surface or the active region to the substrate for two reasons: One, because the electric field does not extend to the surface or the active region; and, two, because holes move in the same direction of the electric field.

Did I get that right?

MR. PAUL: Objection to form. Scope.

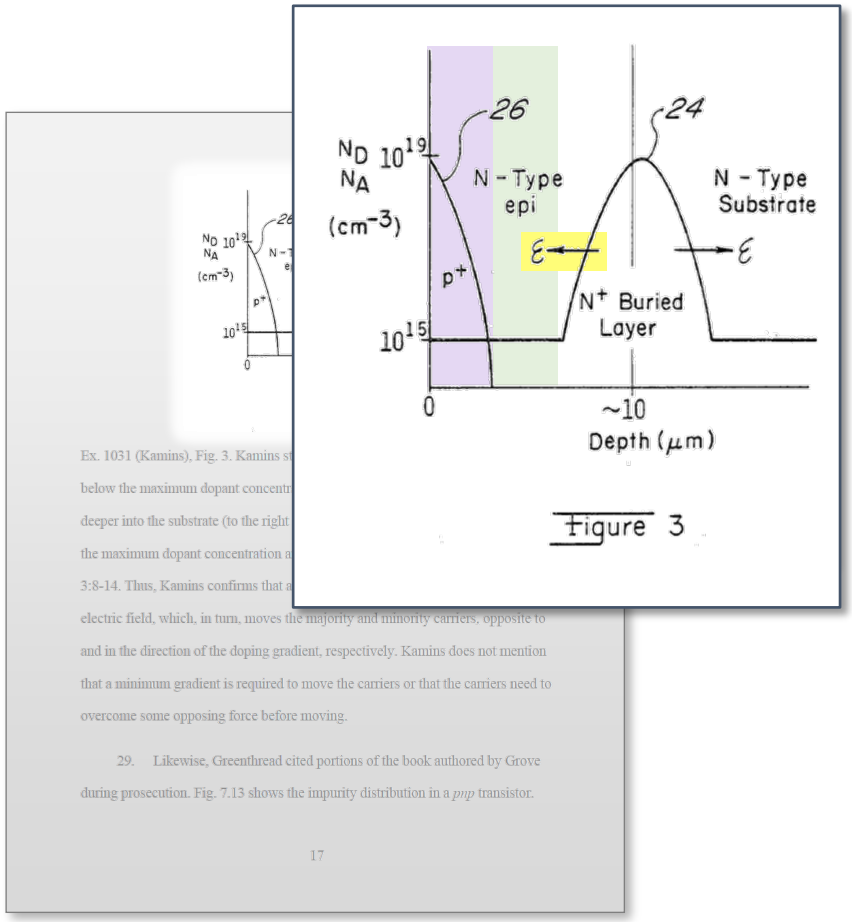
THE WITNESS: Yes, that electric field doesn't extend all the way to the surface. Therefore, there cannot be any drift velocity of the holes due to that electric field.

And, furthermore, even if it did extend to the surface, it points in the wrong direction and will cause the holes to move via drift towards the surface. But, remember, there is always an opposing diffusion part.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 266:4-267:4

3. The Electric Field Must Start in the Surface Layer

- Dr. Banerjee testified that the upward "electric field" will not aid carrier movement because it is pointing in the wrong direction.



Ex. 1031 (Kamins), Fig. 3. Kamins st
below the maximum dopant concentr
deeper into the substrate (to the right
the maximum dopant concentration a
3:8-14. Thus, Kamins confirms that a
electric field, which, in turn, moves the majority and minority carriers, opposite to
and in the direction of the doping gradient, respectively. Kamins does not mention
that a minimum gradient is required to move the carriers or that the carriers need to
overcome some opposing force before moving.

29. Likewise, Greenthread cited portions of the book authored by Grove during prosecution. Fig. 7.13 shows the impurity distribution in a *pnp* transistor.

17

Q. (BY MR. WHITEHURST) So the electric field shown in Figure 3 that points in an upward direction will not aid movement of holes from the surface or the active region to the substrate for two reasons: One, because the electric field does not extend to the surface or the active region; and, two, because holes move in the same direction of the electric field.

Did I get that right?

MR. PAUL: Objection to form. Scope.

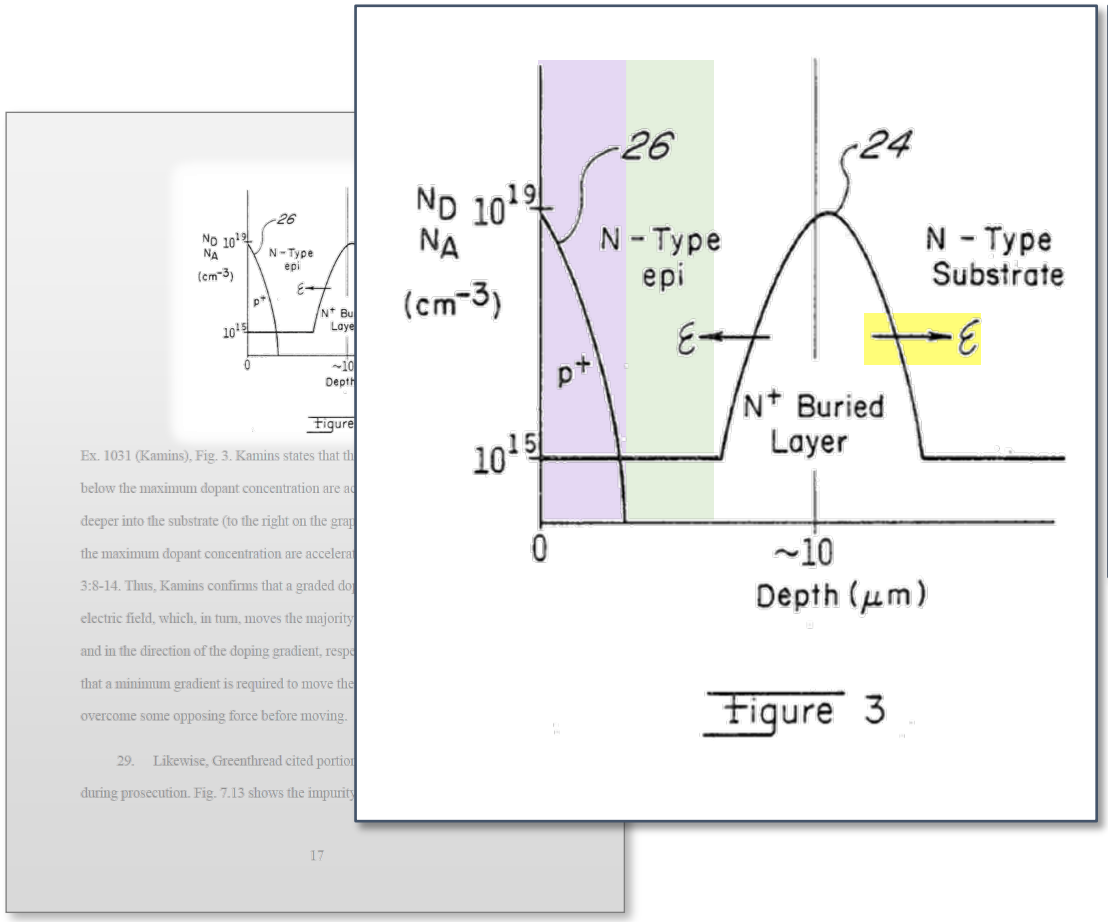
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And, furthermore, even if it did extend to the surface, it points in the wrong direction and will cause the holes to move via drift towards the surface. But, remember, there is always an opposing diffusion part.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 266:4-267:4

3. The Electric Field Must Start in the Surface Layer

- Dr. Banerjee testified that the downward "electric field" will not aid carrier movement from the active region because it is not in the active region.



Ex. 1031 (Kamins), Fig. 3. Kamins states that th
below the maximum dopant concentration are ac
deeper into the substrate (to the right on the grap
the maximum dopant concentration are accelerat
3:8-14. Thus, Kamins confirms that a graded do
electric field, which, in turn, moves the majority
and in the direction of the doping gradient, respe
that a minimum gradient is required to move the
overcome some opposing force before moving.

29. Likewise, Greenthread cited portio
during prosecution. Fig. 7.13 shows the impurity

17

Q. (BY MR. WHITEHURST) Now, let's stay with Figure 3, but turn to the electric field that's to the right pointing in the downward direction.

Do you see that?

A. Yes.

Q. Do you agree that the electric field that's pointing in the downward direction will not aid movement of holes from the surface or the active region to the substrate?

MR. PAUL: Objection to form. Scope.

THE WITNESS: That electric field points in the current direction. It enabled holes to drift towards the substrate, but it is too far away from the active region, and therefore will not have any impact in terms of drift motion of the holes on the active region towards the substrate.

Q. (BY MR. WHITEHURST) Now, because the electric field shown to the right of ten microns is too far from the surface in the active region, it will not aid movement of holes from the surface or the active region to the substrate?

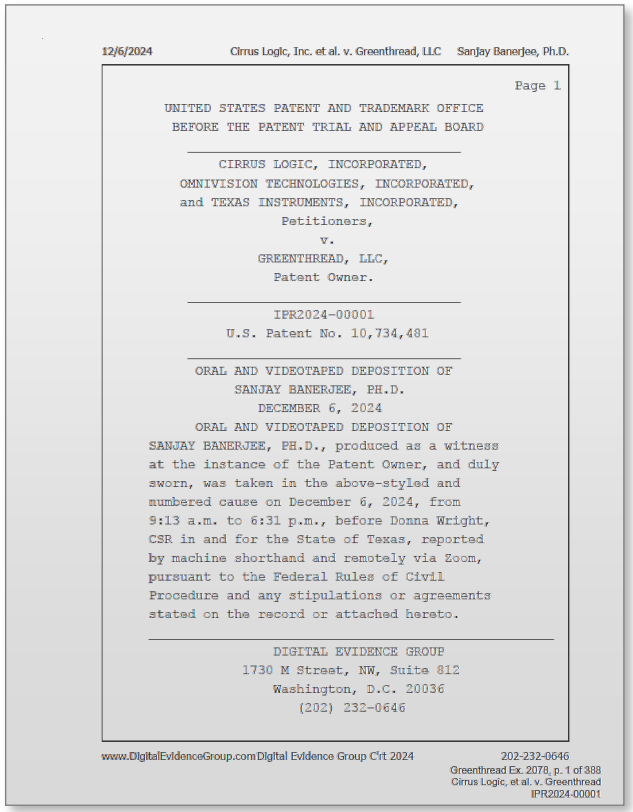
MR. PAUL: Objection to form. Scope.

THE WITNESS: Will not aid movement from the surface to the substrate of the holes in the active region due to the drift mechanism.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 268:3-269:13

3. The Electric Field Must Start in the Surface Layer

- Dr. Banerjee confirmed that in order for an "electric field" to aid movement <u>from</u> the "active region," the electric field" must start in the "active region."



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerjee, Ph.D.

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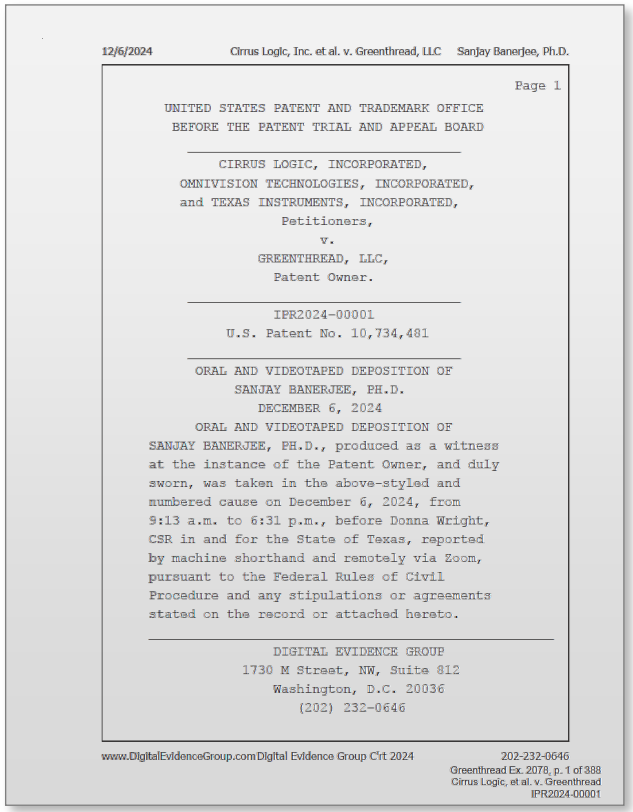
14 So when you're trying to
15 determine whether an electric field will aid
16 carrier movement from the active region to
17 the substrate, you have to know more than
18 just the direction of the electric field.
19 You also need to know where the electric
20 field starts.
21 Did I get that right?
22 MR. PAUL: Objection to form.
1 THE WITNESS: Yes, you need to
2 know the direction and the spatial
3 location here the electric field is
4 existing in order to determine the
5 drift motion.
6 Q. (BY MR. WHITEHURST) And why do
7 you need to know the specific location of the
8 electric field?

9 A. Because this collective
10 ensemble is the center of gravity, or a part,
11 if you will, of this collective ensemble of
12 holes, it's sensitive to the direction,
13 magnitude, and whether there is a nonzero
14 electric field in that center point of this
15 ensemble, if you will.
16 Q. And I think we agree if the
17 electric field starts or ends below the
18 active region, it will not aid carrier
19 movement from the active region?
20 A. If the electric field isn't
21 present in the active region, it will not aid
22 carrier movement via the drift mechanism for
1 this ensemble of failures in the active
2 region.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 272:14-274:2

3. The Electric Field Must Start in the Surface Layer

- Dr. Banerjee confirmed that you have to know the direction and location of the electric field.



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So when you're trying to determine whether an electric field will aid carrier movement from the active region to the substrate, you have to know more than just the direction of the electric field. You also need to know where the electric field starts.

Did I get that right?

MR. PAUL: Objection to form.

THE WITNESS: Yes, you need to know the direction and the spatial location where the electric field is existing in order to determine the drift motion.

Q. (BY MR. WHITEHURST) And why do you need to know the specific location of the electric field?

A. Because this collective ensemble is the center of gravity, or a part, if you will, of this collective ensemble of holes, it's sensitive to the direction, magnitude, and whether there is a nonzero electric field in that center point of this ensemble, if you will.

Q. And I think we agree if the electric field starts or ends below the active region, it will not aid carrier movement from the active region?

A. If the electric field isn't present in the active region, it will not aid carrier movement via the drift mechanism for this ensemble of failures in the active region.

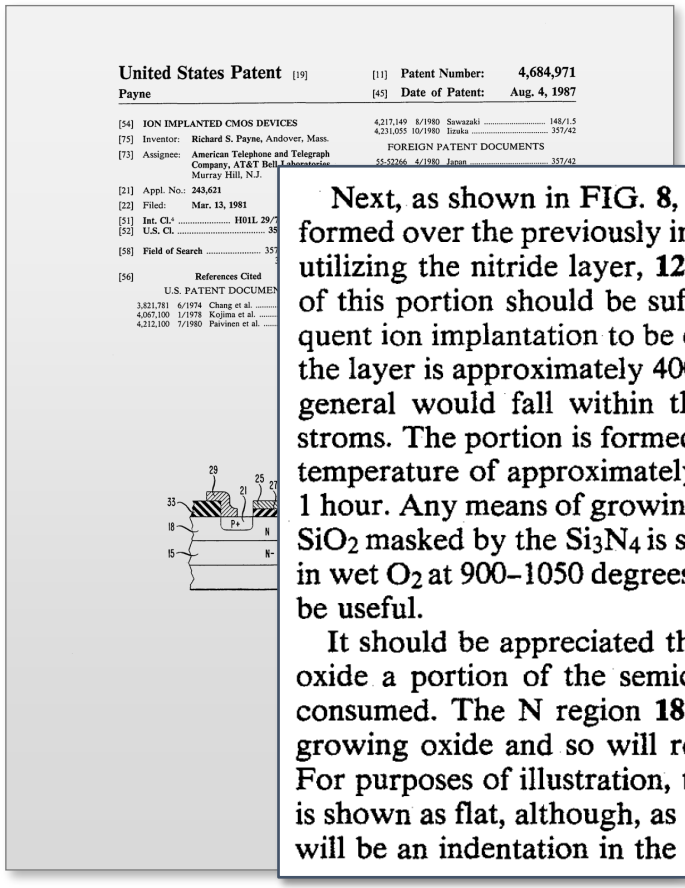
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 272:14-274:2

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. **Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
5. Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."
6. Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
7. The "movement of carriers" depends on the sum of all of the fields in the "surface layer."
8. Petitioners have the burden to analyze all of the fields in the "surface layer."
9. Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Payne <u>never</u> mentions carriers, much less moving minority carriers from the surface.



United States Patent [19]
Payne

[11] Patent Number: 4,684,971
[45] Date of Patent: Aug. 4, 1987

[54] ION IMPLANTED CMOS DEVICES
[75] Inventor: Richard S. Payne, Andover, Mass.
[73] Assignee: American Telephone and Telegraph Company, AT&T Bell Laboratories, Murray Hill, N.J.
[21] Appl. No.: 243,621
[22] Filed: Mar. 13, 1981
[51] Int. Cl.[4] H01L 29/7
[52] U.S. Cl. 35
[58] Field of Search 357

[56] References Cited
U.S. PATENT DOCUMEN

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4,212,100 7/1980 Paivinen et al.
4,217,149 8/1980 Sawazaki 148/1.5
4,231,055 10/1980 Iizuka 357/42
FOREIGN PATENT DOCUMENTS
55-52266 4/1980 Japan 357/42

Next, as shown in FIG. 8, a thick oxide portion **19** is formed over the previously implanted regions **18** and **15** utilizing the nitride layer, **12**, as a mask. The thickness of this portion should be sufficient to block the subsequent ion implantation to be described. In this example, the layer is approximately 4000 Angstroms thick, but in general would fall within the range 3000–4500 Angstroms. The portion is formed by heating in wet O_2 at a temperature of approximately 1000 degrees Celsius for 1 hour. Any means of growing the requisite thickness of SiO_2 masked by the Si_3N_4 is suitable. Typically, heating in wet O_2 at 900–1050 degrees Celsius for 1–4 hours will be useful.

It should be appreciated that in the formation of the oxide a portion of the semiconductor surface will be consumed. The N region **18** will diffuse ahead of the growing oxide and so will remain at the new surface. For purposes of illustration, the semiconductor surface is shown as flat, although, as a result of oxidation, there will be an indentation in the area of the N tub.

-00017: Ex. 1005 (Payne) at 4:38-59

a separate step is not ordinarily needed. The resulting impurity profile in both tubs thereby has the general shape illustrated in FIG. **11**, where the abscissa is depth and the ordinate is impurity concentration.

The oxide layer can then be stripped off, for example, with a solution of dilute HF, and fabrication may proceed in accordance with standard techniques to produce the CMOS device depicted in FIG. **10**. The p-channel device includes source and drain regions, **21** and **22**, respectively, of P^+ conductivity type formed with the N surface region, **18**. Similarly, the n-channel device includes source and drain regions, **23** and **24**, of N^+ conductivity type formed within the P surface region **20**. These source and drain regions would typically have a surface impurity concentration of approximately 10^{19}–10^{20} ions/cm^3 and a depth of 1 μm. It will be noted, therefore, that the n and p surface regions, **18** and **20**, will be present at the surface of their respective devices except for the areas comprising the source and drain. The depth of the surface regions should be at least as great as that of the source and drain regions.

The devices further include gate electrodes, **25** and **26**, typically comprising polycrystalline silicon, formed over gate oxide portions **27** and **28**. Ohmic contacts to source and drain regions are provided by metal portions, **29–32**, typically comprising aluminum, formed over field oxide portions **33–35** and contact windows in said oxide. These features and their method of fabrication are well-known in the art and consequently are not discussed in detail.

It will be appreciated that during the drive-in of the source and drain regions, **21–24**, the regions **18**, and **20** will also be driven somewhat further into the substrate, while the depth of the tubs **15** and **17** is essentially unaffected. In a typical device, the final depth of surface regions **18** and **20** would be approximately 1–2μ and the depth of tub regions **15** and **17** would be typically 3–8μ. The surface impurity concentration of the surface regions is typically $0.5–5\times10^{16}$ ions/cm^3 and that of the tub regions is typically 10^{15}–10^{16} ions/cm^3, with the former concentration being at least twice as much as the latter over these ranges.

The major advantage in formation of the high-low implant profile of FIG. **11** is illustrated in FIGS. **12** and

-00017: Ex. 1005 at 5:14-57

device. In a device fabricated in accordance with the present invention, as illustrated in FIG. **13**, the composite profiles remain high and then fall off rapidly at a much closer distance from the boundary. This is due to the high impurity concentration of surface regions **18** and **20** as well as the short diffusion lengths of these regions. On each side of the boundary, therefore, the high impurity concentration of the surface region (e.g., **18**) is compensated for only by the low concentration tub region of the adjacent device (**17**) and substantial overlap is permitted. In a typical device, it is expected

-00017: Ex. 1005 at 6:7-17

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners identify the "active region" in the "surface layer."

Payne discloses a single drift layer (SDL) to the same

Figure 5(b) does. Ex.1003, ¶¶85-87. In Payne's Figure 10, th

(tan) of Payne's nested well structure—with shallow wel

disposed in it—is an example of the claimed single drift laye

(ion implantation for tub 15), 4:19-30 (thermal drive-in to ac

for tub 15), 4:31-39, 5:7-17, 5:44-48, 5:48-50 ("In a typical

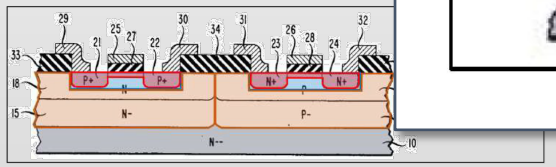
of surface regions 18 and 20 would be approximately 1-2μ

regions 15 and 17 would be typically 3-8μ."). This SDL (ta

'the other surface [(bottom surface)] of said surface lay

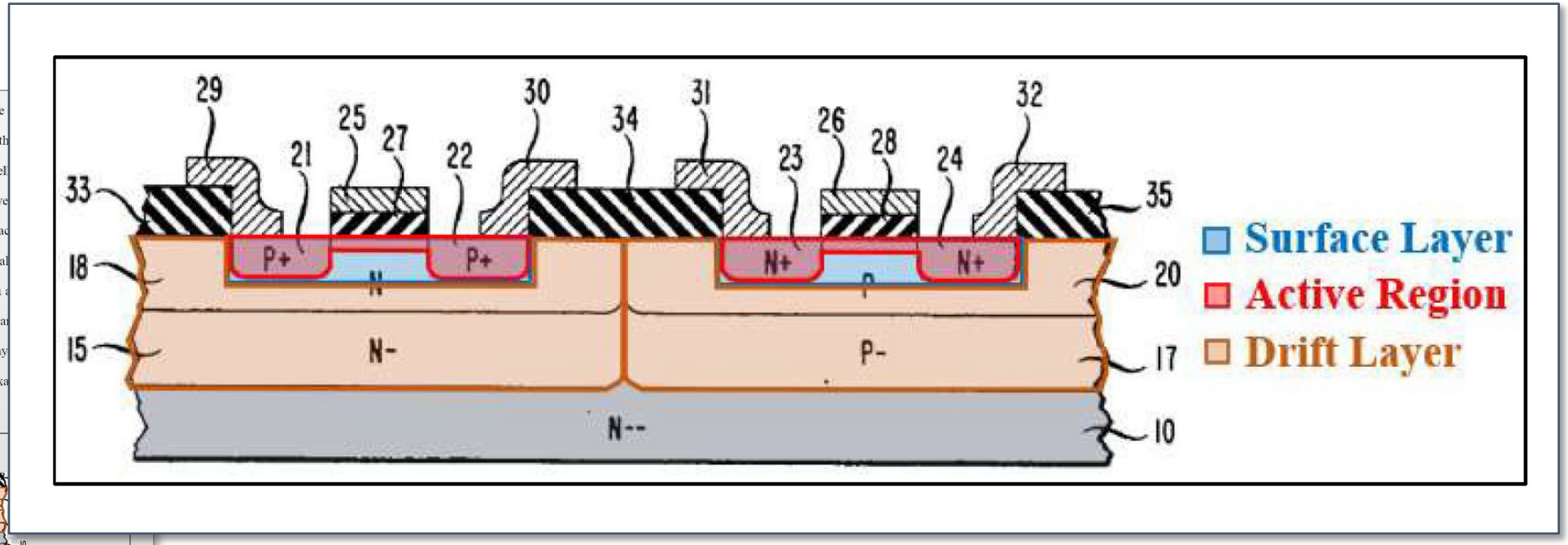
substrate [(grey)]" under PO's interpretation, and in exa

depicted in PO's annotated Figure 5(b) above.



Ex.1005, FIG. 10. Payne's tub 17 (right), in which shallow well 20 is disposed, is likewise an SDL (tan) disposed between a surface layer (blue) and the substrate (grey). Ex.1005, 4:3-30, 4:63-5:17, 5:44-50; Ex.1003, ¶87; §VIII.A.1.b.

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-00017: Petition [1] at 18

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners admit the graded-dopant concentration "starts at the bottom of the surface layer."

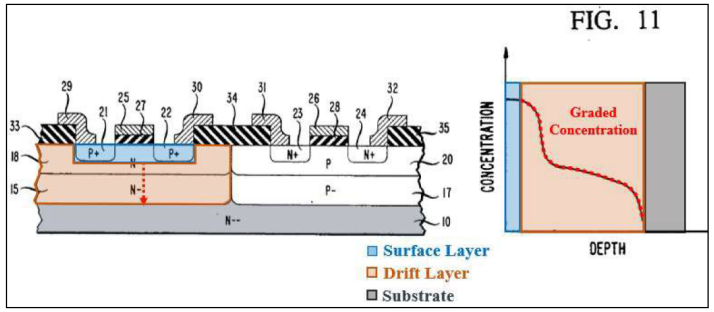
Payne meets all other claim requirements associated with the SDL to the same extent Figure 5(b) meets them. *See* below and elements [1.5]-[1.6]; Ex.1003, ¶¶88-93. Notably, as detailed in element [1.5], each of Payne's tubs 15/17 is a ***single*** drift layer (SDL) because it has a graded-dopant concentration that, according to PO, creates a unidirectional electric drift field that aids the movement of minority carriers in a ***single*** direction—from the surface layer to the substrate. Ex.1030, 7; Ex.1002, 253-54, 289-290; §VIII.A.1.f.

Graded-dopant concentration – The '195 Patent admits that graded-dopant concentrations were known, Ex.1001, 2:13-15, FIG. 1 ("Prior Art"), and that it was known to grade the dopant concentration in CMOS devices to affect the movement of minority carriers. *Id.*, 1:34-2:5, FIGS. 3(a)-3(d) (all "Prior art"). Payne's SDL has a graded-dopant concentration extending between the surface layer and the substrate. Ex.1003 ¶89. Payne explains that the "impurity profile in both tubs [15/17] thereby has the general shape illustrated in FIG. 11" which exhibits "[t]he major advantage" of a "***high-low implant profile***." Ex.1005, 2:38-41, 5:14-17, 5:56-57. Payne's Figure 11 (below right) illustrates the dopant concentration measured along the red dotted line in Figure 10 (below left), which starts at the bottom of the surface layer (blue) and extends to the substrate (grey). As shown below, Payne discloses a downward-

- 19 -

Graded-dopant concentration – The '195 Patent admits that graded-dopant concentrations were known, Ex.1001, 2:13-15, FIG. 1 ("Prior Art"), and that it was known to grade the dopant concentration in CMOS devices to affect the movement of minority carriers. *Id.*, 1:34-2:5, FIGS. 3(a)-3(d) (all "Prior art"). Payne's SDL has a graded-dopant concentration extending between the surface layer and the substrate. Ex.1003 ¶89. Payne explains that the "impurity profile in both tubs [15/17] thereby has the general shape illustrated in FIG. 11" which exhibits "[t]he major advantage" of a "***high-low implant profile***." Ex.1005, 2:38-41, 5:14-17, 5:56-57. Payne's Figure 11 (below right) illustrates the dopant concentration measured along the red dotted line in Figure 10 (below left), which starts at the bottom of the surface layer (blue) and extends to the substrate (grey). As shown below, Payne discloses a downward-sloping graded-dopant concentration in the SDL (tan) associated with Payne's PMOS transistor (left).[5]

FIG. 11



Ex.1005, FIGS. 10-11. Dr. Banerjee has annotated Figure 11 to reflect exemplary

-00017: Petition [1] at 19-20

The Petition fails, because none of Petitioners' references expressly teach "said drift layer further having a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate" or "said well region having a graded concentration of dopants [] to aid the movement of minority carriers from said surface layer" downward.

Moreover, moving carriers "from the active circuitry at the surface" is missing from the prior art. Both Payne and Onoda, at best, show a downward sloping gradient, with no information about whether, why, or how such a gradient might be useful. *Supra* Section VI. Petitioners rely entirely on post-hoc expert testimony and

-00017: PO Resp. [45] at 1, 25

the trajectory of individual electrons or holes." *Id.* at 239:20-240:3. If Dr. Banerjee cannot determine the location or path of travel of individual charge carriers, he cannot say whether they are in the "surface layer" (or "active region") and whether they move "from" the surface layer (or active region). If Dr. Banerjee does not know that, Petitioners cannot carry their burden.

-00017: PO Sur-Reply [59] at 10

-00017: PO Resp. [45] at 1-4, 7-16, 25; PO Sur-Reply [59] at 1-7. 10, 14-20

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

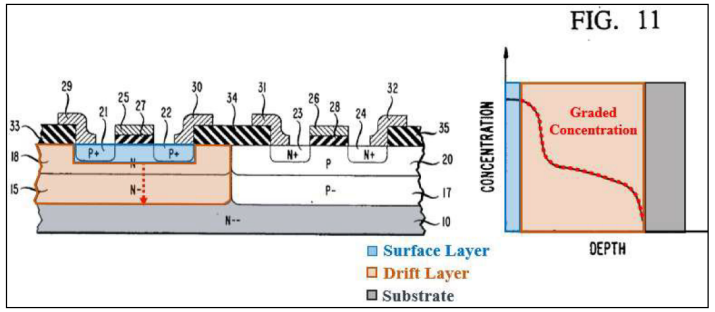
- The dopant concentration is flat in the "surface layer."

Payne meets all other claim requirements associated with the SDL to the same extent Figure 5(b) meets them. *See* below and elements [1.5]-[1.6]; Ex.1003, ¶¶88-93. Notably, as detailed in element [1.5], each of Payne's tubs 15/17 is a ***single*** drift layer (SDL) because it has a graded-dopant concentration that, according to PO, creates a unidirectional electric drift field that aids the movement of minority carriers in a ***single*** direction—from the surface layer to the substrate. Ex.1030, 7; Ex.1002, 253-54, 289-290; §VIII.A.1.f.

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- 19 -

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Ex.1005, FIGS. 10-11. Dr. Banerjee has annotated Figure 11 to reflect exemplary

-00017: Petition [1] at 19-20

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners identify an electric field that does not start in the surface layer.

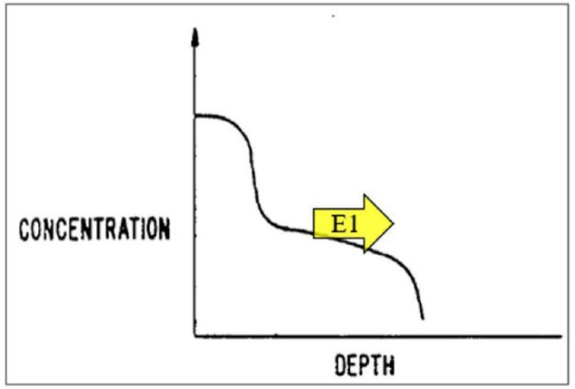
Moreover, this graded-dopant profile is determined by the ion-implantation and drive-in steps of the chip fabrication processes (described in Payne in relation to Figures 2 and 5-9 in particular) and thus the profile (and any resulting electric field) is static—it is set once the device has been fabricated and does not change. Ex.1003, ¶101; Ex.1005, 5:7-17, 5:44-55 (describing "the ***final*** depth" of tubs and surface regions and their typical ranges of impurity concentrations). During prosecution Applicant described "static" similarly, conceding that "Kamins (US 4,160,985), just like Applicant, discloses the presence of a 'static' drift field, 'because the drift field is created by graded concentration of dopants which does not change over time.'" Ex.1002, 318 (citing Ex.1009, 2:15-16, 2:64-3:2, 1:38-46, 3:8-11 and Ex.1002, 302-03), 333 (same).

Thus, according to Jastrzebski, Kamins, Applicant, and PO, Payne's profile generates a (first) "built-in" static unidirectional electric drift field (illustrated by the yellow arrow labelled "E1" below left) that aids the movement of minority carriers from the surface layer to the substrate.[6] Ex.1003, ¶¶103-105.

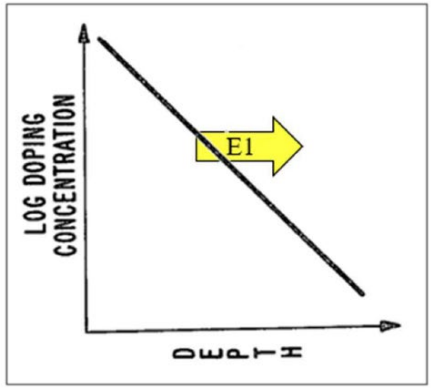
[6] The Ground I figures depict electric fields in N-wells, *e.g.*, Payne's nested N-wells 15/18. §§VIII.A.1.f-g. The electric fields would be pointing in the opposite direction in Payne's nested P-wells. In both cases, these electric fields result from the downward-sloping graded dopant concentrations in Payne's N-wells and P-wells

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Thus, according to Jastrzebski, Kamins, Applicant, and PO, Payne's profile generates a (first) "built-in" static unidirectional electric drift field (illustrated by the yellow arrow labelled "E1" below left) that aids the movement of minority carriers from the surface layer to the substrate.[6] Ex.1003, ¶¶103-105.



Ex.1005, FIG. 11



Ex.1010, FIG. 1b

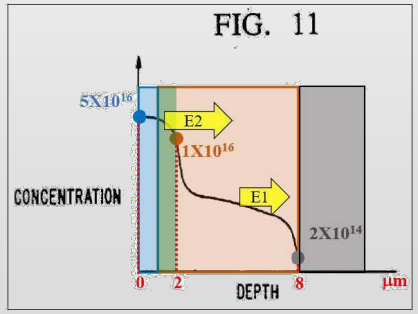
-00017: Petition [1] at 27-28

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners identified two electric fields that do not start in the surface layer.

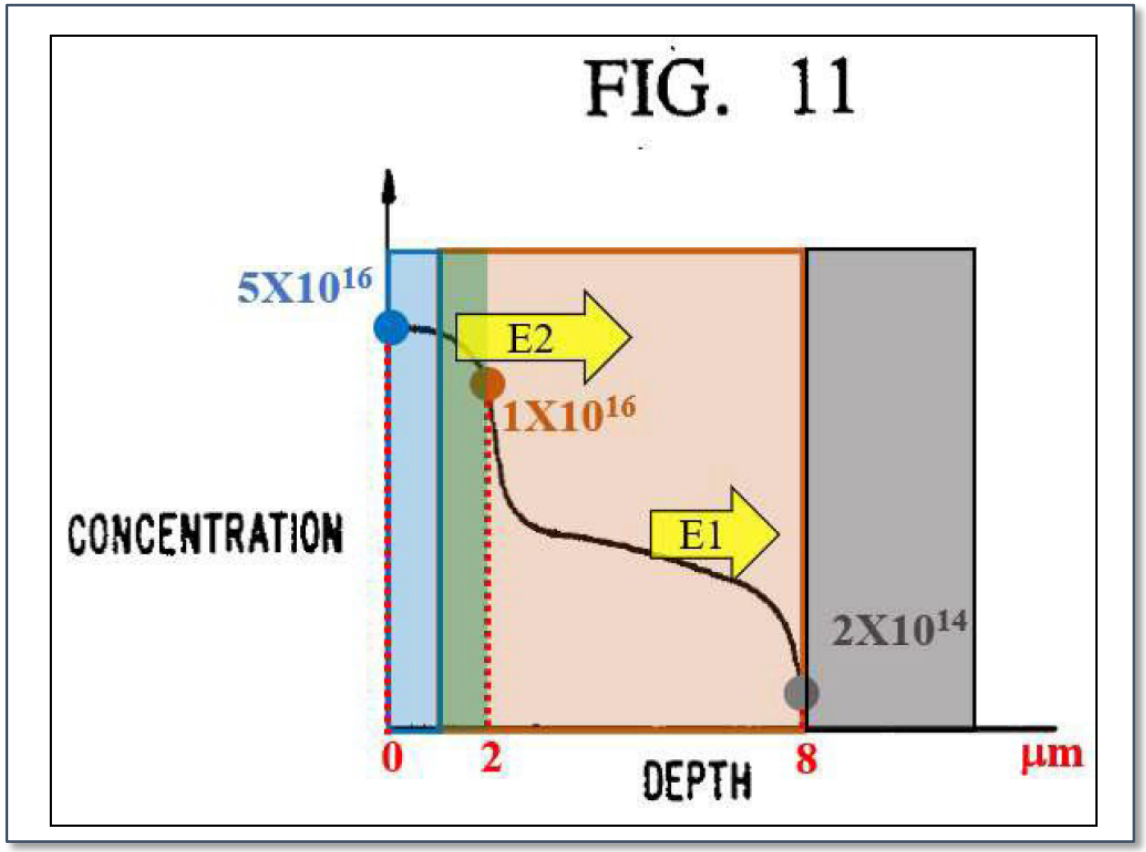
graded-dopant profile, including the profile in the well region, is set once the device has been fabricated and does not change, making the profile (and any resulting electric field) static, as described in §VIII.A.1.f.

Payne's Figure 11 is further annotated below to show the exemplary first static unidirectional electric drift field ("E1") present in a deep portion of the SDL (discussed in §VIII.A.1.f), and a different, exemplary second static unidirectional electric drift field ("E2") present in the well region disposed in the SDL. Ex.1003, ¶¶116-117; *see also* n.6.



Ex.1005, FIG. 11. Moreover, E1 and E2 are illustrated as electric fields having different magnitudes, to reflect the different local slopes (gradients) of the graded-

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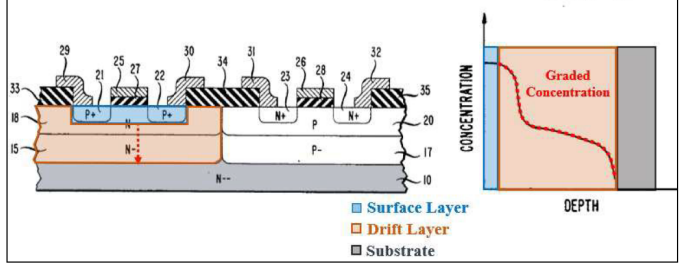
-00017: Petition [1] at 35

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed there is no electric field where the dopant concentration is flat.

Graded-dopant concentration – The '195 Patent admits that graded-dopant concentrations were known, Ex.1001, 2:13-15, FIG. 1 ("Prior Art"), and that it was known to grade the dopant concentration in CMOS devices to affect the movement of minority carriers. *Id.*, 1:34-2:5, FIGS. 3(a)-3(d) (all "Prior art"). Payne's SDL has a graded-dopant concentration extending between the surface layer and the substrate. Ex.1003 ¶89. Payne explains that the "impurity profile in both tubs [15/17] thereby has the general shape illustrated in FIG. 11" which exhibits "[t]he major advantage" of a "***high-low implant profile***." Ex.1005, 2:38-41, 5:14-17, 5:56-57. Payne's Figure 11 (below right) illustrates the dopant concentration measured along the red dotted line in Figure 10 (below left), which starts at the bottom of the surface layer (blue) and extends to the substrate (grey). As shown below, Payne discloses a downward-sloping graded-dopant concentration in the SDL (tan) associated with Payne's PMOS transistor (left).[5]

FIG. 11



Ex.1005, FIGS. 10-11. Dr. Banerjee has annotated Figure 11 to reflect exemplary

-00017: Petition [1] at 19-20

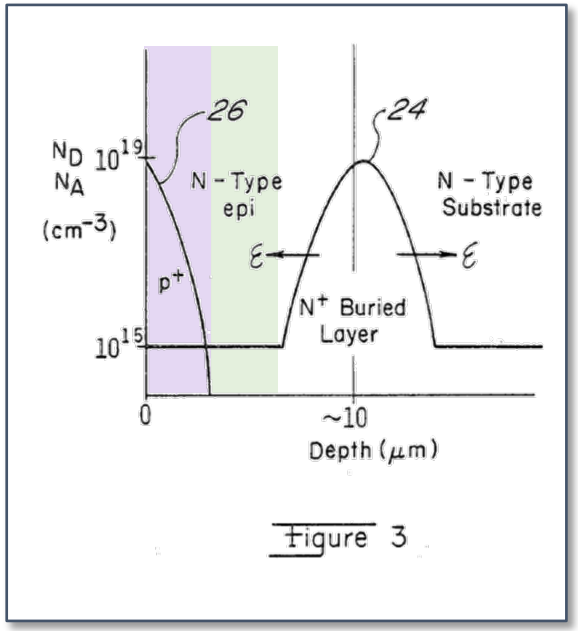


Figure 3

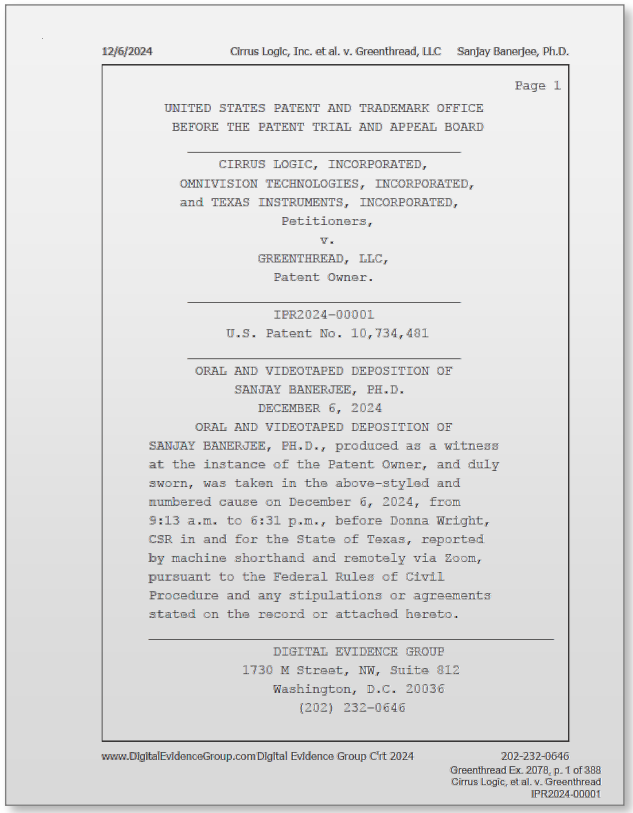
-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

Q. My question is about the flat section to the right of line 26 before it goes up.
A. Okay.
Q. Would there be an electric field in that flat region?
A. There should not be any built-in electric fields in that flat region.
Q. Why not?
A. Because the doping concentration isn't changing as a function of depth.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 260:2-13

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed that when the doping concentration is constant, there is no electric field present in that region.



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UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INCORPORATED,
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and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,481

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

ORAL AND VIDEOTAPED DEPOSITION OF SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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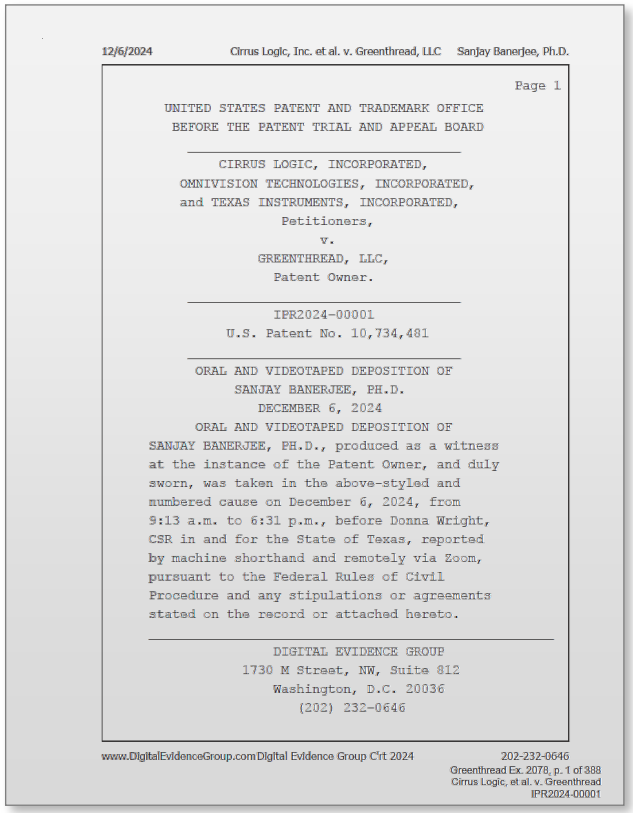
Greenthread Ex. 2078, p. 1 of 388
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19 Q. (BY MR. WHITEHURST) So it's
20 your testimony today that wherever the doping
21 concentration is constant, there would not be
22 a built-in electric field in those sections,
1 correct?
2 MR. PAUL: Objection to form.
3 THE WITNESS: Yeah, the doping
4 concentration is constant or a
5 substantial region. It would not lead
6 to built-in electric fields.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 214:19-215:6

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed that when the doping concentration is constant in the "active region," there is no electric field in the "active region."



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerjee, Ph.D.

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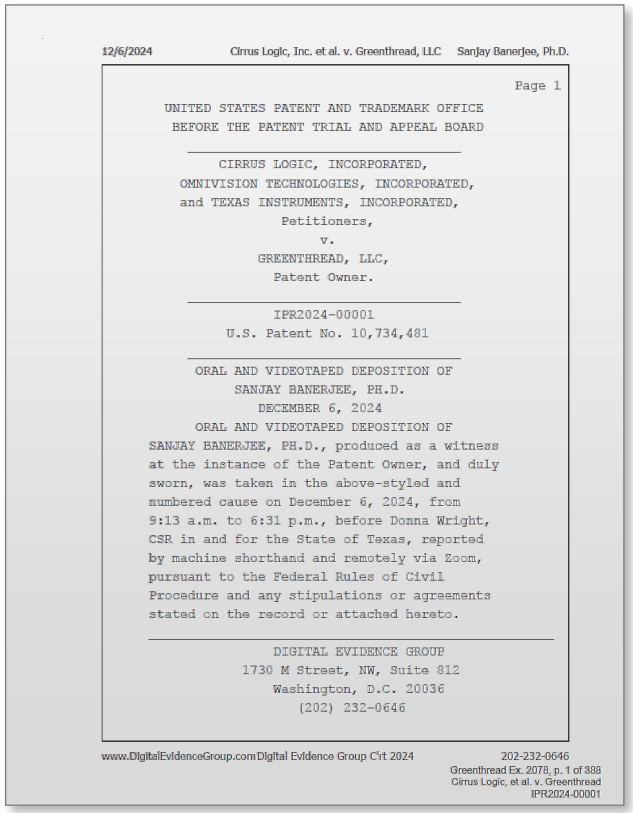
11 Q. If the doping profile is
12 constant in the active region, would you
13 agree that there is no built-in electric
14 field in the active region?
15 MR. PAUL: Objection,
16 foundation. Scope.
17 THE WITNESS: Can you point me
18 to a figure in Kawagoe of the prior
19 art?

20 Q. (BY MR. WHITEHURST) Do you
21 understand my question?
22 A. I think there is a substantial
1 region in the active region where the doping
2 profile was constant that would not have a
3 nonzero built-in electric field in that
4 region. But it has to be over a reasonable
5 landscape, which is known as a screening
6 lane, by the way.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 215:11-216:6

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed that when the doping concentration is constant in the "channel region," there is no electric field due to the doping concentration.



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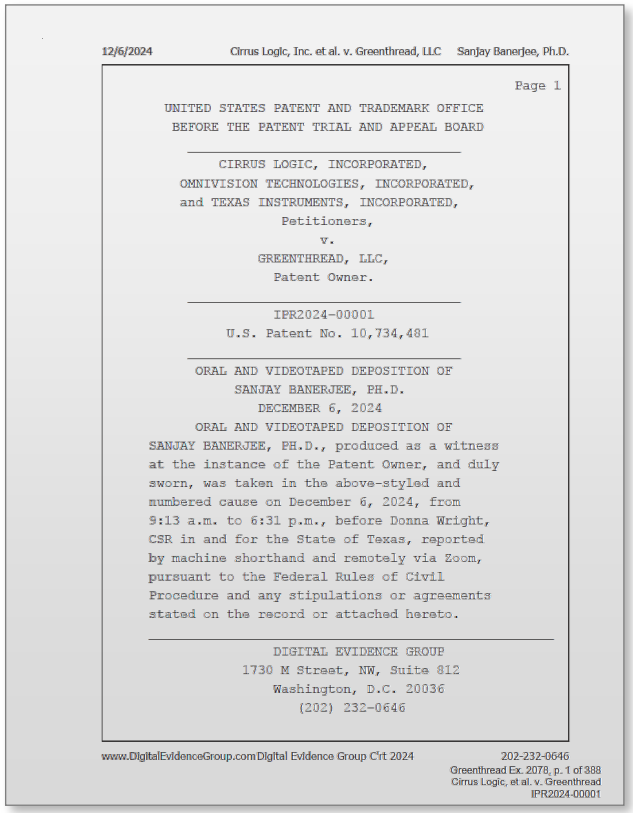
17 Q. If the doping profile is
18 constant in the middle of the channel region
19 in the downward direction, then there will be
20 no electric field in the active region; isn't
21 that right?
22 MR. PAUL: Objection,
1 foundation. Scope.
2 THE WITNESS: There would be no
3 built-in field due to the doping
4 gradient and the other factors in the
5 transistor --

6 Q. (BY MR. WHITEHURST) So there
7 would be no built-in electric field due to
8 the doping profile, correct?
9 A. There would be no built-in
10 electric field in the middle of the channel
11 as a function of depth if the doping
12 concentration did not vary as a function of
13 depth in the middle of the channel. But
14 there's other structures that can also
15 cause built-in electric fields.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 218:17-219:15

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee testified that other structures, like the gate and gate oxide, can create electric fields in the "active region."



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U.S. Patent No. 10,734,481

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

ORAL AND VIDEOTAPED DEPOSITION OF SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

Q. If the doping profile is constant in the middle of the channel region in the downward direction, then there will be no electric field in the active region; isn't that right?

MR. PAUL: Objection, foundation. Scope.

THE WITNESS: There would be no built-in field due to the doping gradient and the other factors in the transistor --

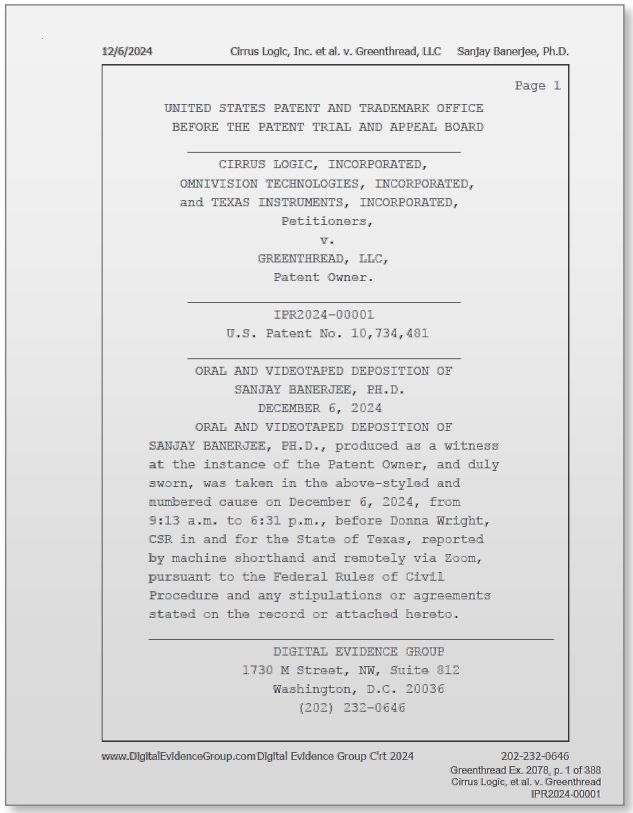
Q. (BY MR. WHITEHURST) So there would be no built-in electric field due to the doping profile, correct?

A. There would be no built-in electric field in the middle of the channel as a function of depth if the doping concentration did not vary as a function of depth in the middle of the channel. But there's other structures that can also cause built-in electric fields.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 218:17-219:15

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed that where the doping profile is uniform or constant, there is no electric field.



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerjee, Ph.D.

Page 1

UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INCORPORATED,
OMNIVISION TECHNOLOGIES, INCORPORATED,
and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,481

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Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

16 Q. When you looked at the doping
17 profile or the different prior art
18 references, did you look to see whether the
19 doping profile was uniform in certain
20 regions?
21 A. Yes.
22 Q. And would you agree that where
1 it is uniform, there would be no electric
2 field due to the doping profile?
3 A. Yes, if the doping
4 concentration was constant or a substantial
5 region, there would be no built-in electric
6 fields because of the doping gradient.

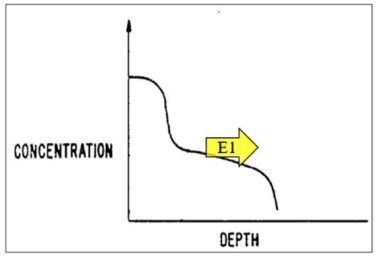
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 236:16-237:6

-00017: PO Resp. [45] at 1-4, 7-16, 25; PO Sur-Reply [59] at 1-7. 10, 14-20

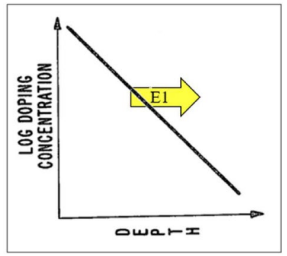
4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed that an electric field that does <u>not</u> start in the "surface layer," does <u>not</u> move carriers from the "surface layer."

Thus, according to Jastrzebski, Kamins, Applicant, and PO, Payne's profile generates a (first) "built-in" static unidirectional electric drift field (illustrated by the yellow arrow labelled "E1" below left) that aids the movement of minority carriers from the surface layer to the substrate.[6] Ex.1003, ¶¶103-105.



Ex.1005, FIG. 11



Ex.1010, FIG. 1b

generates a (first) "built-in" static unidirectional electric drift field (illustrated by the yellow arrow labelled "E1" below left) that aids the movement of minority carriers from the surface layer to the substrate.[6] Ex.1003, ¶¶103-105.

[6] The Ground I figures depict electric fields in N-wells, *e.g.*, Payne's nested N-wells 15/18. §§VIII.A.1.f-g. The electric fields would be pointing in the opposite direction in Payne's nested P-wells. In both cases, these electric fields result from the downward-sloping graded dopant concentrations in Payne's N-wells and P-wells

- 27 -

-00017: Petition [1] at 27-28

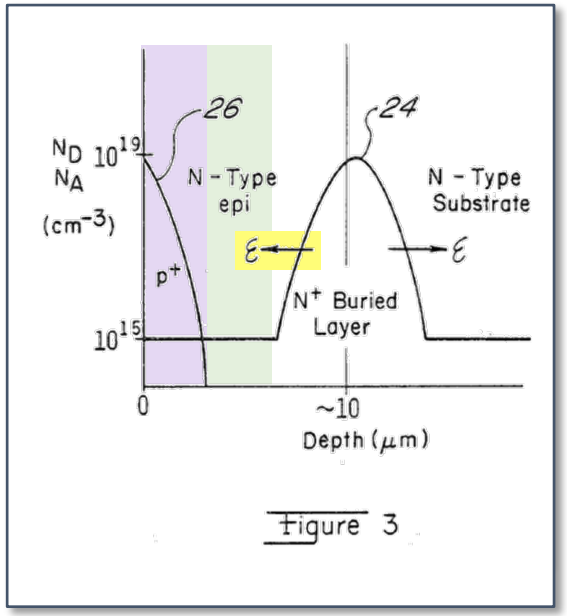


Figure 3

16	THE WITNESS: Yes, that
17	electric field doesn't extend all the
18	way to the surface. Therefore, there
19	cannot be any drift velocity of the
20	holes due to that electric field.
21	And, furthermore, even if it
22	did extend to the surface, it points
1	in the wrong direction and will cause
2	the holes to move via drift towards
3	the surface. But, remember, there is
4	always an opposing diffusion part.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 266:16-267:4

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed that an electric field that does not start in the "surface layer," does not move carriers from the "surface layer."

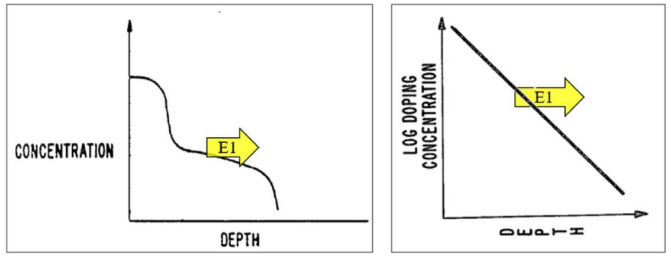
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Figures 2 and 5-
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¶101; Ex.1005,
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[6] The Ground I figures depict electric fields in N-wells, *e.g.*, Payne's nested N-wells 15/18. §§VIII.A.1.f-g. The electric fields would be pointing in the opposite direction in Payne's nested P-wells. In both cases, these electric fields result from the downward-sloping graded dopant concentrations in Payne's N-wells and P-wells

- 27 -

Thus, according to Jastrzebski, Kamins, Applicant, and PO, Payne's profile generates a (first) "built-in" static unidirectional electric drift field (illustrated by the yellow arrow labelled "E1" below left) that aids the movement of minority carriers from the surface layer to the substrate.[6] Ex.1003, ¶¶103-105.



Ex.1005, FIG. 11

Ex.1010, FIG. 1b

-00017: Petition [1] at 27-28

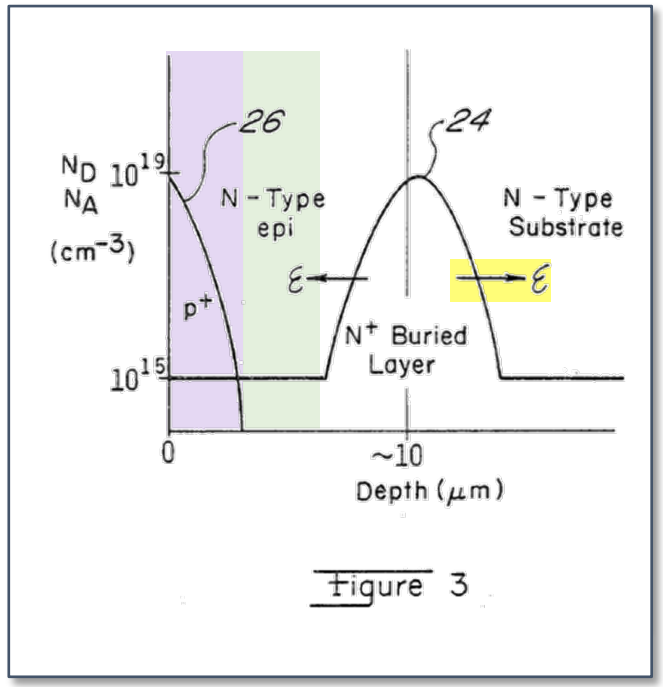


Figure 3

16 THE WITNESS: That electric
17 field points in the current direction.
18 It enabled holes to drift towards the
19 substrate, but it is too far away from
20 the active region, and therefore will
21 not have any impact in terms of drift
22 motion of the holes on the active
1 region towards the substrate.
2 Q. (BY MR. WHITEHURST) Now,
3 because the electric field shown to the right
4 of ten microns is too far from the surface in
5 the active region, it will not aid movement
6 of holes from the surface or the active
7 region to the substrate?
8 MR. PAUL: Objection to form.
9 Scope.
10 THE WITNESS: Will not aid
11 movement from the surface to the
12 substrate of the holes in the active
13 region due to the drift mechanism.

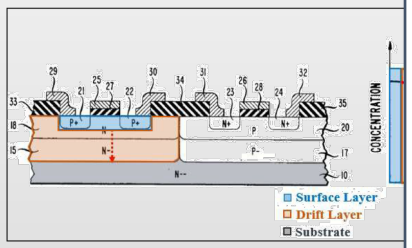
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 268:3-269:13

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners identify a PMOS transistor in an N-well.

f. **Element [1.5]: "said drift layer f… static unidirectional electric dr… movement of minority carriers fr… to said substrate; and"**

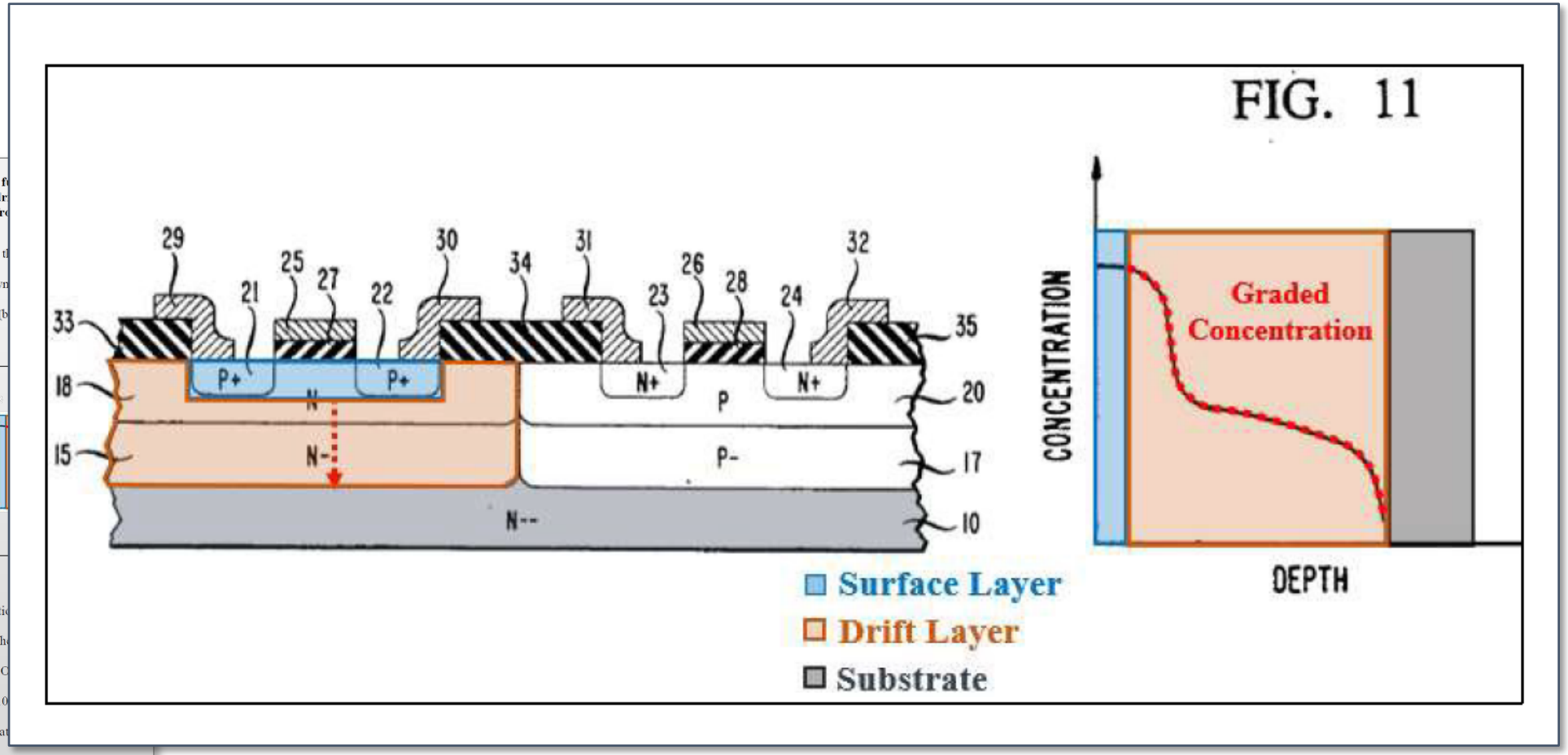
Payne discloses or, at a minimum, renders obvious t… ¶¶94-107. As shown below, Payne's SDL (tan) has a down… dopant concentration extending between the surface layer (b… (grey). §VIII.A.1.e.



Ex.1005, FIGS. 10-11.

Payne's downward-sloping graded-dopant concentrati… of minority carriers from the surface layer to the substrate to th… Applicant relied on the prior art and admitted to the Patent C… movement would occur under the same scenario. Ex.10… prosecution, Applicant represented to the Patent Office that… graded-dopant concentration was known in the prior art to create an "inherent 'built-…

- 22 -



-00017: Petition [1] at 22

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- For a PMOS transistor in an N-well, Petitioners identify "holes" as the "minority carrier."

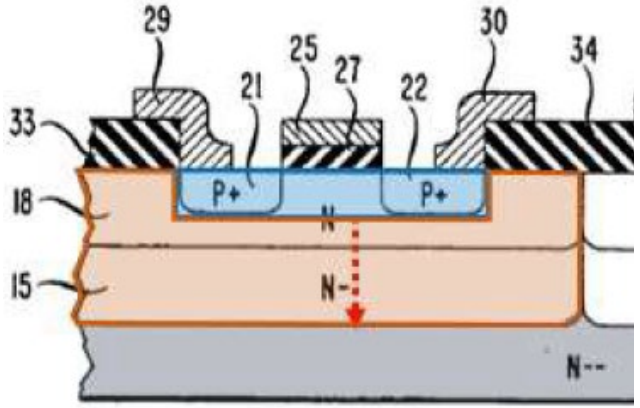
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yellow arrow labelled "E1" below left) that aids the movement of minority carriers from the surface layer to the substrate.[6] Ex.1003, ¶¶103-105.

[6] The Ground I figures depict electric fields in N-wells, *e.g.*, Payne's nested N-wells 15/18. §§VIII.A.1.f-g. The electric fields would be pointing in the opposite direction in Payne's nested P-wells. In both cases, these electric fields result from the downward-sloping graded dopant concentrations in Payne's N-wells and P-wells

- 27 -

[6] The Ground I figures depict electric fields in N-wells, *e.g.*, Payne's nested N-wells 15/18. §§VIII.A.1.f-g. The electric fields would be pointing in the opposite direction in Payne's nested P-wells. In both cases, these electric fields result from the downward-sloping graded dopant concentrations in Payne's N-wells and P-wells and aid the movement of minority carriers (holes in N-wells, electrons in P-wells) downward to the substrate. *Id.*; Ex.1003, ¶¶105-106.

-00017: Petition [1] at 27-28 n. 6



-00017: Petition [1] at 22

-00017: Ex. 2057, ¶¶35-37; PO Resp. [45] at 4, 7-16; Ex. 1063, 25:6-26:1, 142:16-22; 149:9-151:9; Ex. 2078, 293:5-294:8; PO Sur-Reply [59] at 1, 3-5, 6-7. 10, 14-20

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

- For a PMOS transistor, the "minority carriers" are electrons, not holes.

Moreover
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Figures 2
is static—
¶101; Ex.
regions a
Applicant
like Appli
is created
Ex.1002, 318 (citing Ex.1009, 2:15-16, 2:64-3:2, 1:38-46, 3:8-11 and Ex.1002, 302-03), 333 (same).

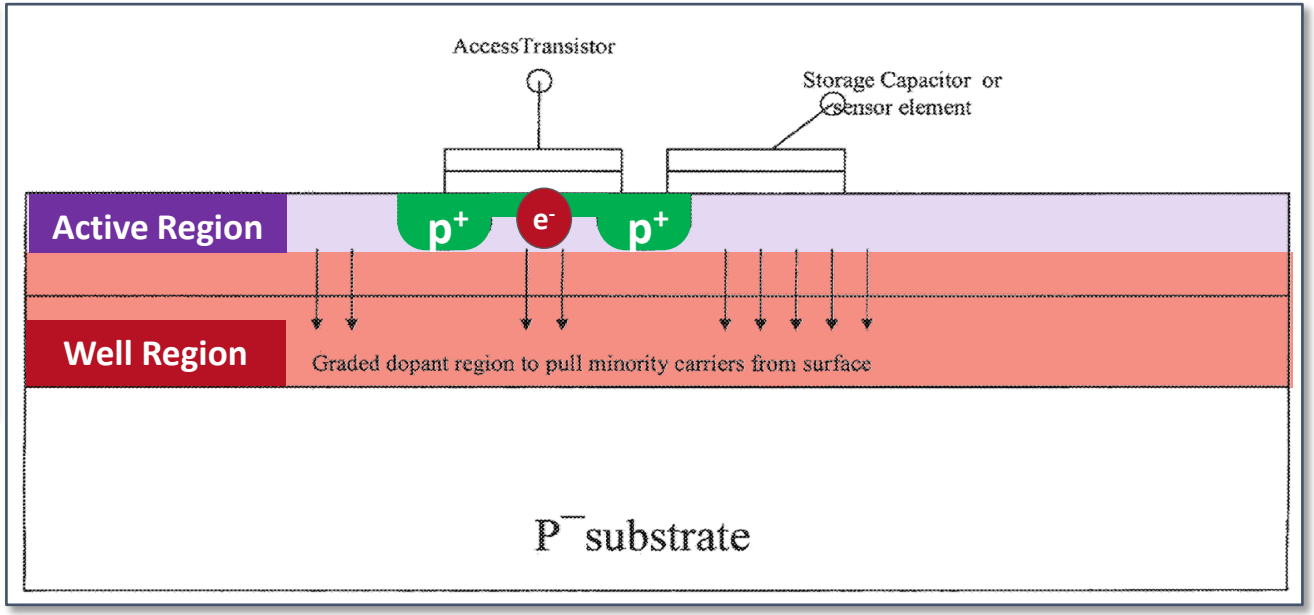
Thus, according to Jastrzebski, Kamins, Applicant, and PO, Payne's profile generates a (first) "built-in" static unidirectional electric drift field (illustrated by the yellow arrow labelled "E1" below left) that aids the movement of minority carriers from the surface layer to the substrate.[6] Ex.1003, ¶¶103-105.

[6] The Ground I figures depict electric fields in N-wells, *e.g.*, Payne's nested N-wells 15/18. §§VIII.A.1.f-g. The electric fields would be pointing in the opposite direction in Payne's nested P-wells. In both cases, these electric fields result from the downward-sloping graded dopant concentrations in Payne's N-wells and P-wells

- 27 -

[6] The Ground I figures depict electric fields in N-wells, *e.g.*, Payne's nested N-wells 15/18. §§VIII.A.1.f-g. The electric fields would be pointing in the opposite direction in Payne's nested P-wells. In both cases, these electric fields result from the downward-sloping graded dopant concentrations in Payne's N-wells and P-wells and aid the movement of minority carriers (holes in N-wells, electrons in P-wells) downward to the substrate. *Id.*; Ex.1003, ¶¶105-106.

-00017: Petition [1] at 27-28 n. 6



-00017: Ex. 1001 ('195 pat.) at Fig. 5B

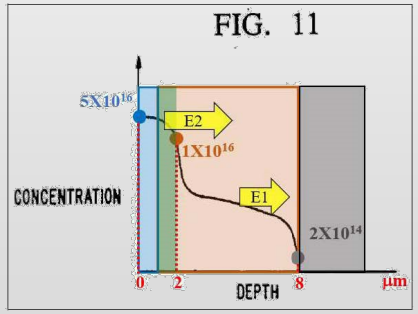
-00017: Ex. 2057, ¶¶35-37; PO Resp. [45] at 4, 7-16; Ex. 1063, 25:6-26:1, 142:16-22; 149:9-151:9; Ex. 2078, 293:5-294:8; PO Sur-Reply [59] at 1, 3-5, 6-7. 10, 14-20

4. Payne Does Not Move "Minority Carriers" from the "Surface Layer"

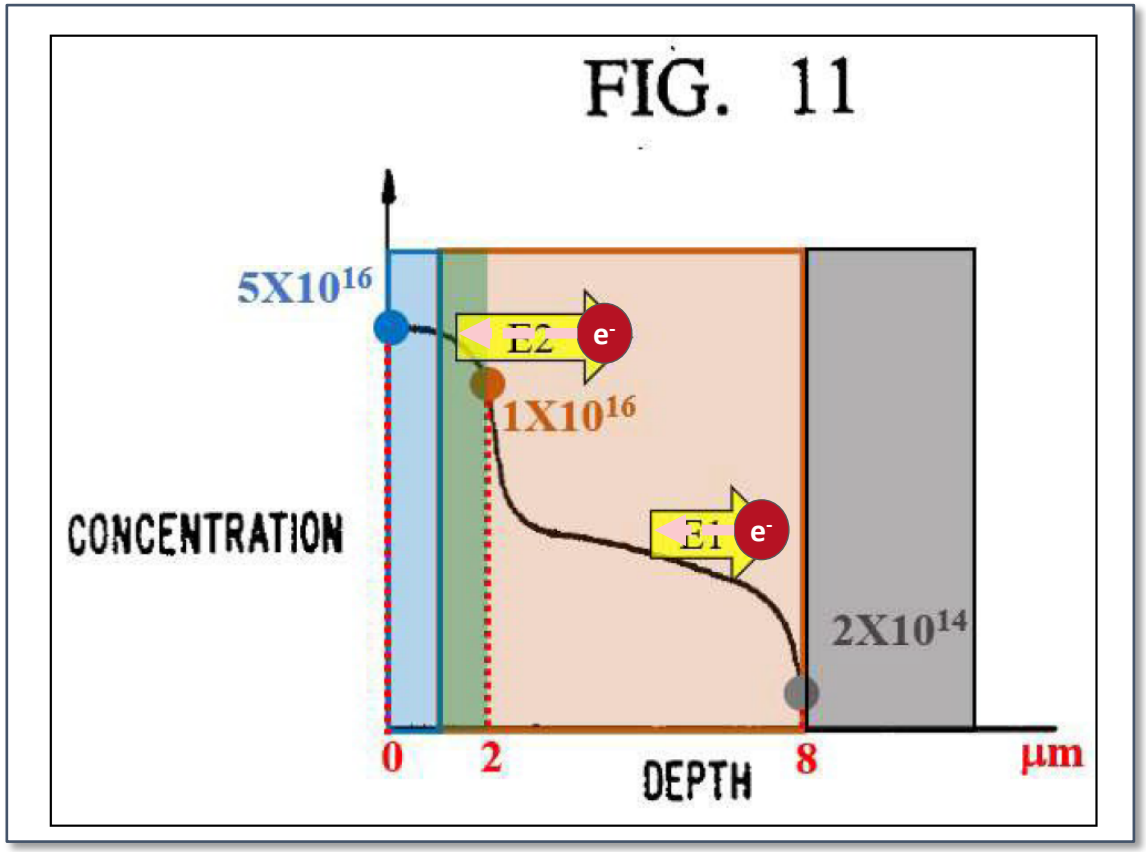
- Petitioners identified two electric fields that will <u>not</u> move electrons from the surface layer.

graded-dopant profile, including the profile in the well region, is set once the device has been fabricated and does not change, making the profile (and any resulting electric field) static, as described in §VIII.A.1.f.

Payne's Figure 11 is further annotated below to show the exemplary first static unidirectional electric drift field ("E1") present in a deep portion of the SDL (discussed in §VIII.A.1.f), and a different, exemplary second static unidirectional electric drift field ("E2") present in the well region disposed in the SDL. Ex.1003, ¶¶116-117; *see also* n.6.



Ex.1005, FIG. 11. Moreover, E1 and E2 are illustrated as electric fields having different magnitudes, to reflect the different local slopes (gradients) of the graded-



-00017: Petition [1] at 35

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. **Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
5. **Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
6. Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
7. The "movement of carriers" depends on the sum of all of the fields in the "surface layer."
8. Petitioners have the burden to analyze all of the fields in the "surface layer."
9. Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- Onoda <u>never</u> mentions carriers, much less moving minority carriers from the surface.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INC.;
OMNIVISION TECHNOLOGIES, INC.; AND
AMS SENSORS USA INC.,
Petitioner,

v.

GREENTHREAD, LLC,
Patent Owner.

Case No. IPR2024-00017
Patent No. 8,421,195

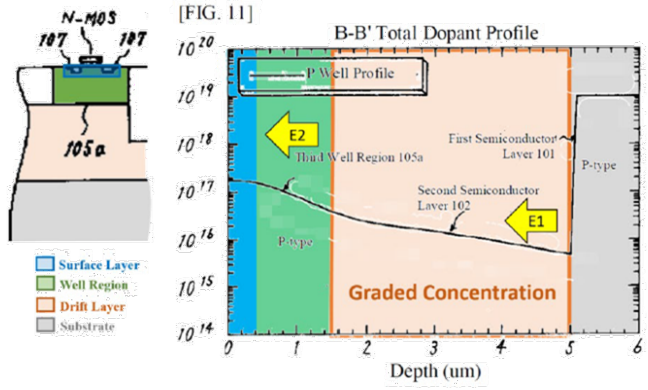
PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 8,421,195

UNDER 35 U.S.C. §§ 312 AND 37 C.F.R. § 42.104

f. Element [1.5]: "said drift layer further having a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and"

Onoda discloses this element. Ex.1003, ¶¶168-172. As discussed above with regard to element [1.4], Onoda discloses a SDL (tan) having a downward-sloping dopant concentration extending between the surface layer (blue—*i.e.*, starting at the 0 µm depth level) and the substrate (grey, starting at the 5 µm depth level). §VIII.B.1.e.

The below annotation of Onoda's Figure 11 depicts the exemplary first static unidirectional electric drift field ("E1") described in Section X.A.1.f, at a depth corresponding to Onoda's second semiconductor layer 102 (tan).



Ex.1042, FIG. 11, [0041], [0046], [0047], [0052]; Fig. 3 (excepted).

Thus, given Applicant's repeated representations to the Office and the Jastrzebski and Kamins cited art relied on by Applicant—such a downward-sloping graded-dopant concentration creates a "built-in" unidirectional electric drift field to aid the movement of minority carriers from the surface layer to the substrate. Ex.1003, ¶¶170-172; §VIII.A.1.f.[8]

Such a profile is created "through ion implantation techniques and thermal diffusion techniques" and thus the profile (and any resulting electric drift field) is static—it is set once the CMOS device has been fabricated and does not change afterwards. Ex.1003, ¶171. As discussed in Section VIII.A.1.f, Applicant described "static" similarly during prosecution. Ex.1002, 318 (citing Ex.1009), 333 (same).

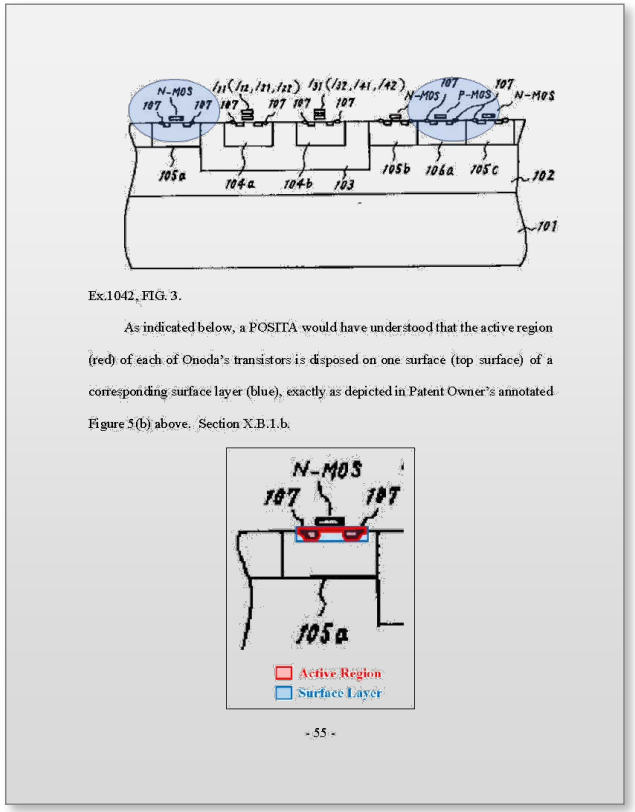
Accordingly, Onoda satisfies element [1.5] under PO's plain-meaning constructions. Ex.1033; Ex.1003, ¶¶172. Onoda's graded-dopant concentration is downward-sloping over the entire single drift layer (tan)—in fact, from the top of the silicon/surface layer (blue) to the bottom of the SDL—and thus, according to PO (and in light of Applicant's representations to the Patent Office), creates a static unidirectional electric drift field that aids the movement of minority carriers from the surface layer to the substrate. Ex.1003, ¶172.

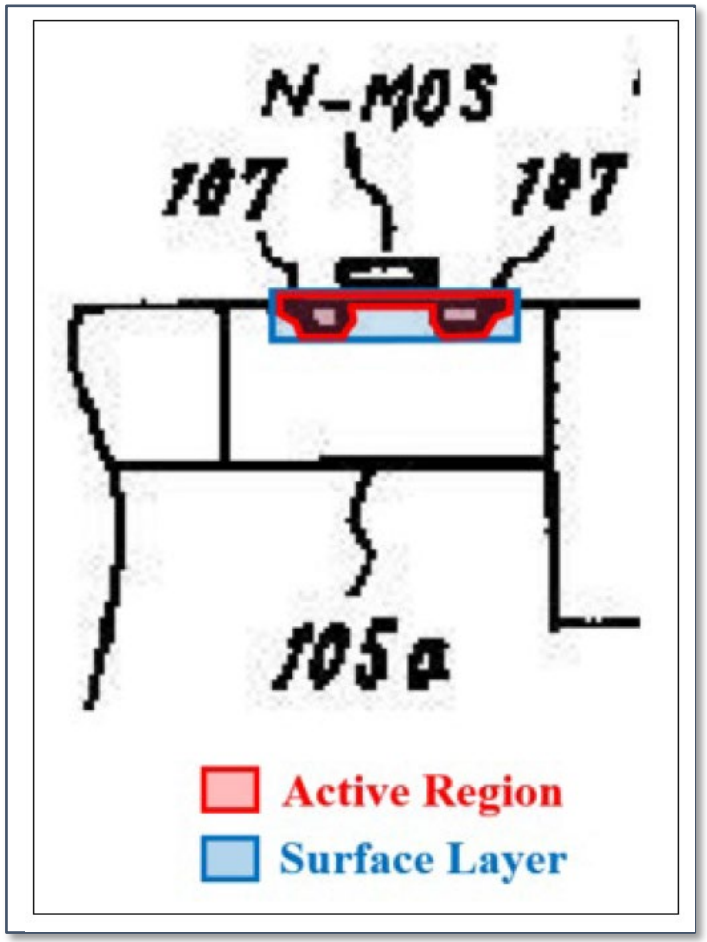
-00017: Petition [1] at 66-68

-00017: PO Resp. [45] at 13-16; PO Sur-Reply [59] at 14-15

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners identify the "active region" in the "surface layer."

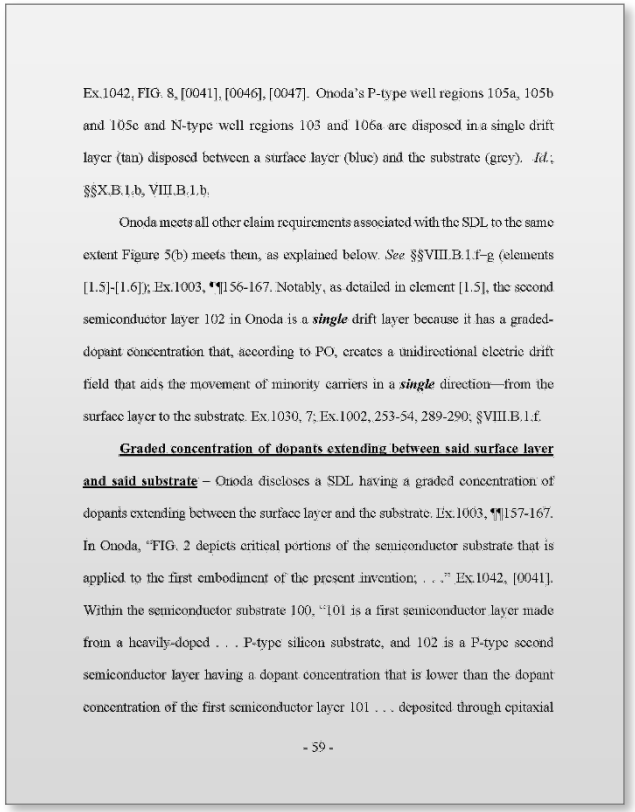




-00017: Petition [1] at 55

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners identify a "graded dopant concentration" <u>between</u> the surface layer and the substrate.



Ex.1042, FIG. 8, [0041], [0046], [0047]. Onoda's P-type well regions 105a, 105b and 105c and N-type well regions 103 and 106a are disposed in a single drift layer (tan) disposed between a surface layer (blue) and the substrate (grey). *Id.*; §§X.B.1.b, VIII.B.1.b.

Onoda meets all other claim requirements associated with the SDL to the same extent Figure 5(b) meets them, as explained below. *See* §§VIII.B.1.f–g (elements [1.5]-[1.6]); Ex.1003, ¶¶156-167. Notably, as detailed in element [1.5], the second semiconductor layer 102 in Onoda is a ***single*** drift layer because it has a graded-dopant concentration that, according to PO, creates a unidirectional electric drift field that aids the movement of minority carriers in a ***single*** direction—from the surface layer to the substrate. Ex.1030, 7; Ex.1002, 253-54, 289-290; §VIII.B.1.f.

Graded concentration of dopants extending between said surface layer and said substrate – Onoda discloses a SDL having a graded concentration of dopants extending between the surface layer and the substrate. Ex.1003, ¶¶157-167. In Onoda, "FIG. 2 depicts critical portions of the semiconductor substrate that is applied to the first embodiment of the present invention; . . ." Ex.1042, [0041]. Within the semiconductor substrate 100, "101 is a first semiconductor layer made from a heavily-doped . . . P-type silicon substrate, and 102 is a P-type second semiconductor layer having a dopant concentration that is lower than the dopant concentration of the first semiconductor layer 101 . . . deposited through epitaxial

- 59 -

Graded concentration of dopants extending between said surface layer and said substrate – Onoda discloses a SDL having a graded concentration of dopants extending between the surface layer and the substrate. Ex.1003, ¶¶157-167. In Onoda, "FIG. 2 depicts critical portions of the semiconductor substrate that is applied to the first embodiment of the present invention; . . ." Ex.1042, [0041]. Within the semiconductor substrate 100, "101 is a first semiconductor layer made from a heavily-doped . . . P-type silicon substrate, and 102 is a P-type second semiconductor layer having a dopant concentration that is lower than the dopant concentration of the first semiconductor layer 101 . . . deposited through epitaxial

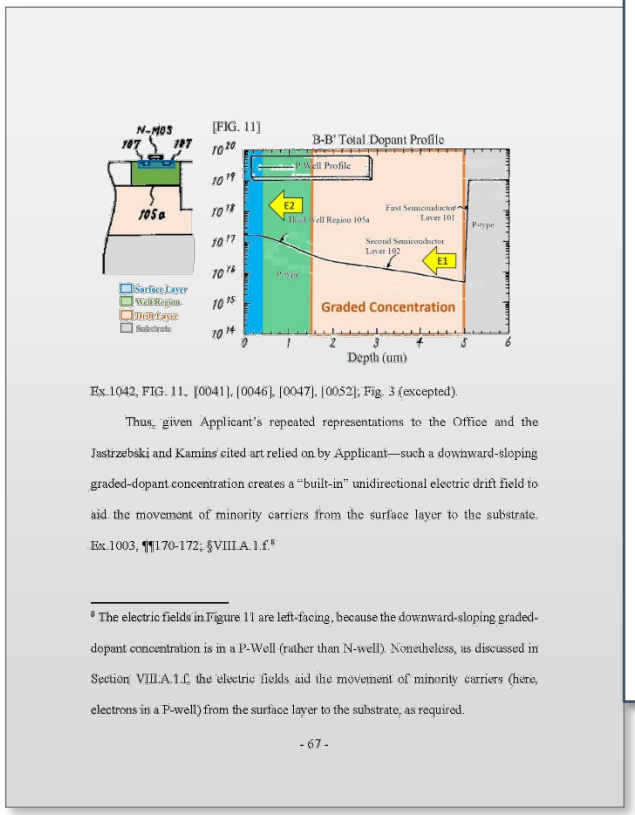
-00017: Petition [1] at 59

-00017: PO Resp. [45] at 1-4, 7-16, 25; PO Sur-Reply [59] at 1-7. 10, 14-20

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- The dopant concentration is <u>flat</u> in the "surface layer."

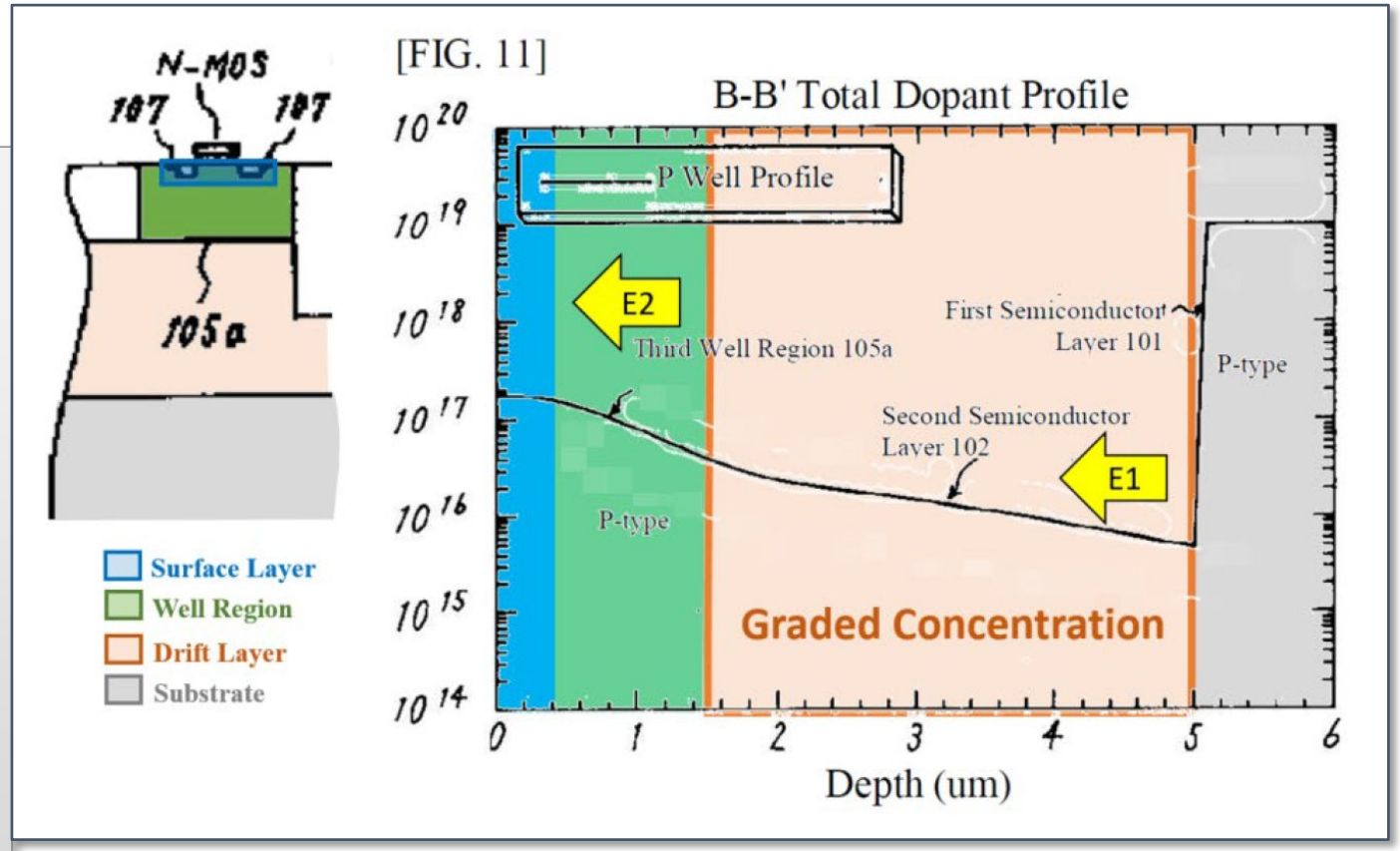


Ex.1042, FIG. 11, [0041], [0046], [0047], [0052]; Fig. 3 (excepted).

Thus, given Applicant's repeated representations to the Office and the Jastrzebski and Kamins cited art relied on by Applicant—such a downward-sloping graded-dopant concentration creates a "built-in" unidirectional electric drift field to aid the movement of minority carriers from the surface layer to the substrate. Ex.1003, ¶¶170-172; §VIII.A.1.f.[8]

[8] The electric fields in Figure 11 are left-facing, because the downward-sloping graded-dopant concentration is in a P-Well (rather than N-well). Nonetheless, as discussed in Section VIII.A.1.f, the electric fields aid the movement of minority carriers (here, electrons in a P-well) from the surface layer to the substrate, as required.

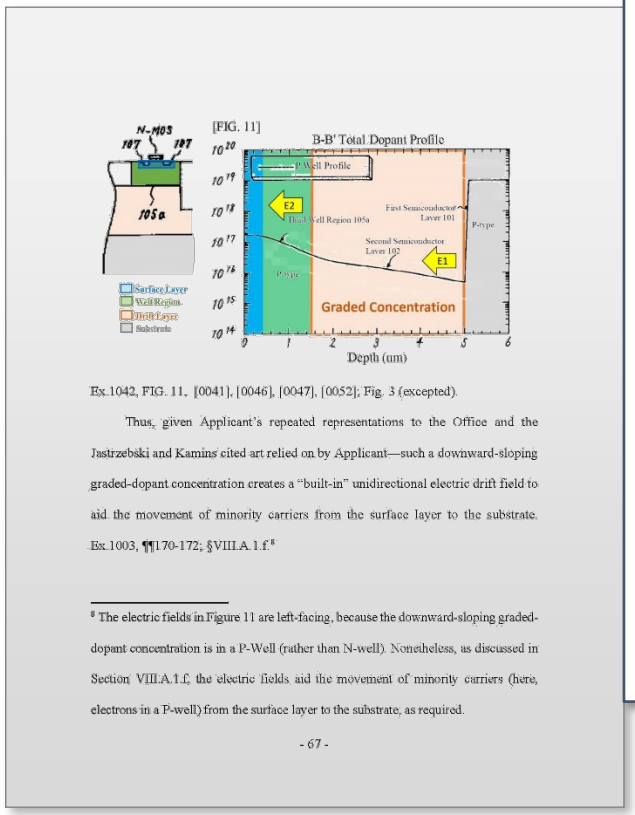
- 67 -



-00017: Petition [1] at 67

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners identify electric fields that do <u>not</u> start in the surface layer.

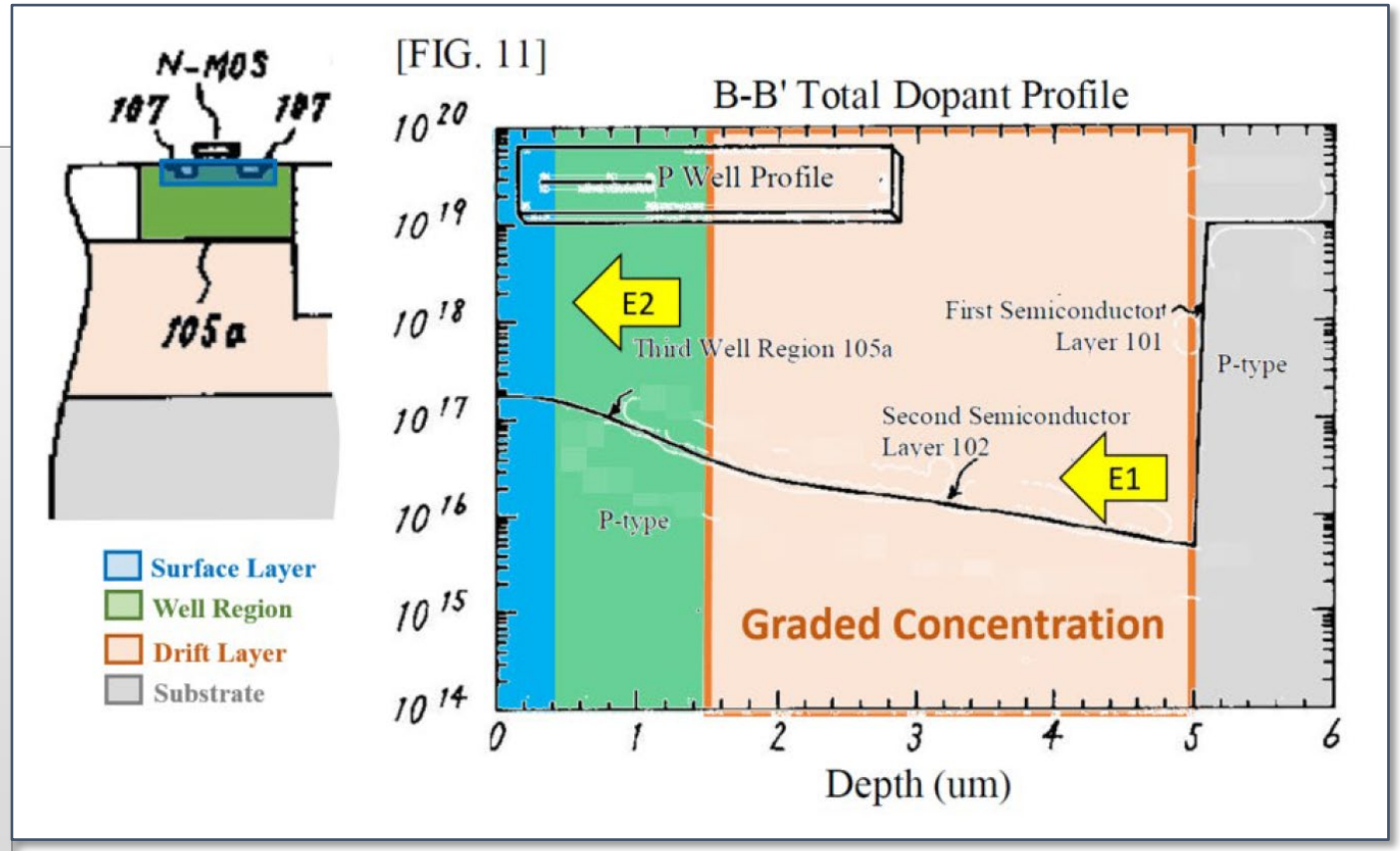


Ex.1042, FIG. 11, [0041], [0046], [0047], [0052]; Fig. 3 (excepted).

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[8] The electric fields in Figure 11 are left-facing, because the downward-sloping graded-dopant concentration is in a P-Well (rather than N-well). Nonetheless, as discussed in Section VIII.A.1.f, the electric fields aid the movement of minority carriers (here, electrons in a P-well) from the surface layer to the substrate, as required.

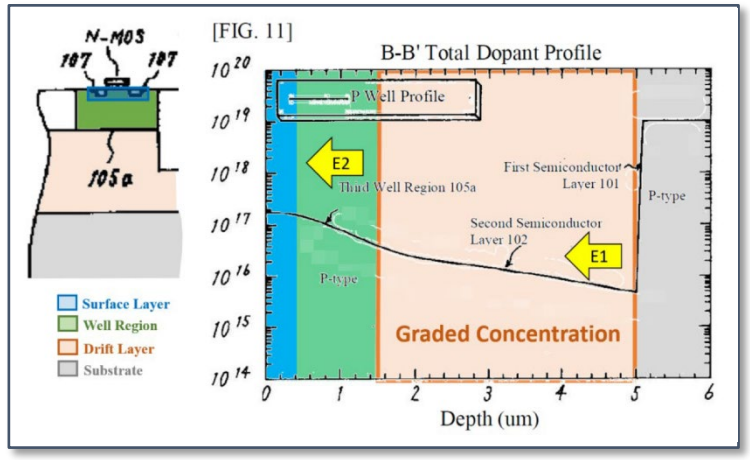
- 67 -



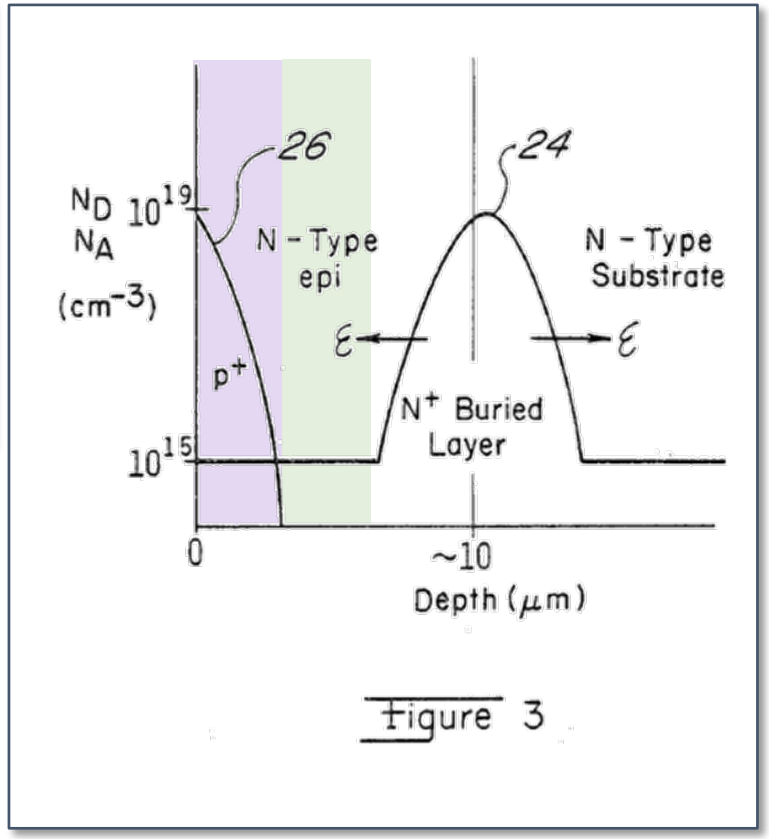
-00017: Petition [1] at 67

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed there is no electric field where the dopant concentration is flat.



-00017: Petition [1] at 67



-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

Q. My question is about the flat section to the right of line 26 before it goes up.

A. Okay.

Q. Would there be an electric field in that flat region?

A. There should not be any built-in electric fields in that flat region.

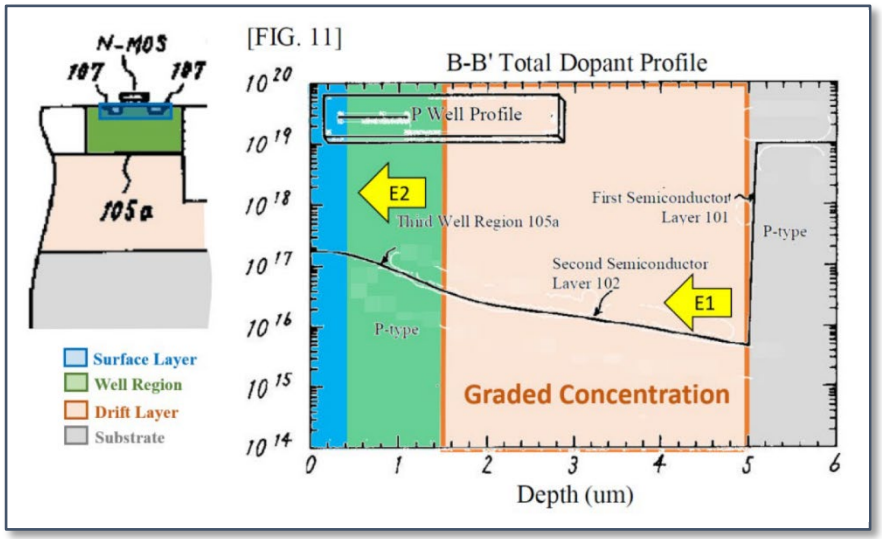
Q. Why not?

A. Because the doping concentration isn't changing as a function of depth.

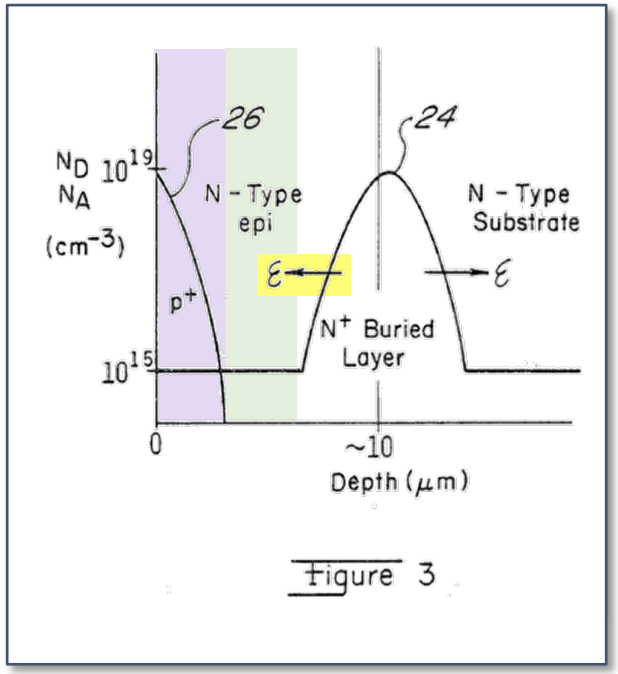
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 260:2-13

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed that an electric field that does not start in the "surface layer," does not move carriers from the "surface layer."



-00017: Petition [1] at 67



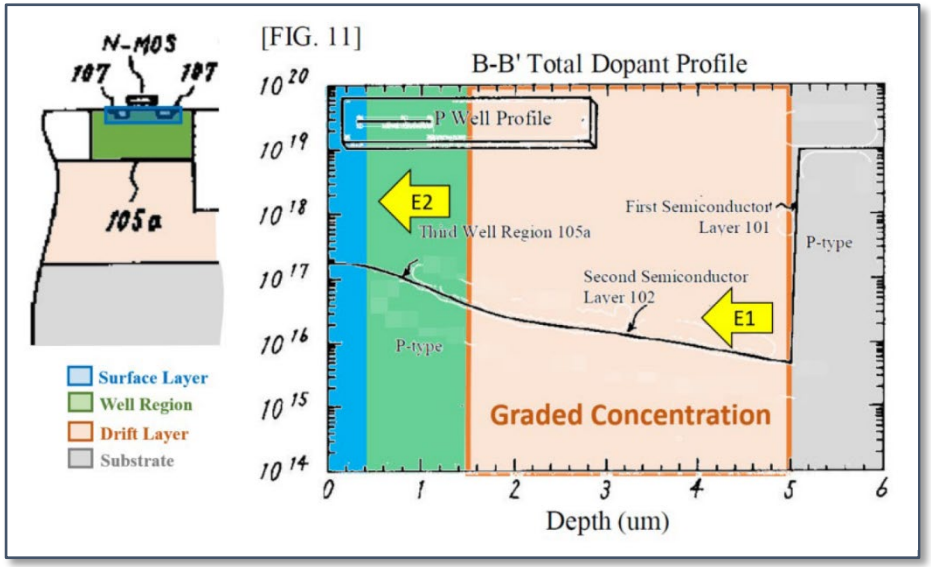
-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

16 THE WITNESS: Yes, that
17 electric field doesn't extend all the
18 way to the surface. Therefore, there
19 cannot be any drift velocity of the
20 holes due to that electric field.
21 And, furthermore, even if it
22 did extend to the surface, it points
1 in the wrong direction and will cause
2 the holes to move via drift towards
3 the surface. But, remember, there is
4 always an opposing diffusion part.

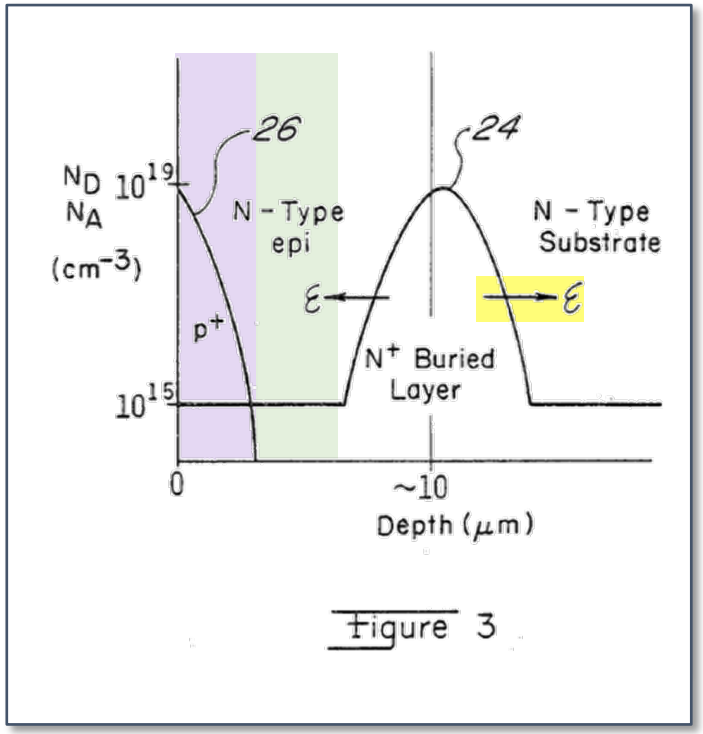
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 266:16-267:4

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- Dr. Banerjee confirmed that an electric field that does not start in the "surface layer," does not move carriers from the "surface layer."



-00017: Petition [1] at 67



-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

THE WITNESS: That electric field points in the current direction. It enabled holes to drift towards the substrate, but it is too far away from the active region, and therefore will not have any impact in terms of drift motion of the holes on the active region towards the substrate.

Q. (BY MR. WHITEHURST) Now, because the electric field shown to the right of ten microns is too far from the surface in the active region, it will not aid movement of holes from the surface or the active region to the substrate?

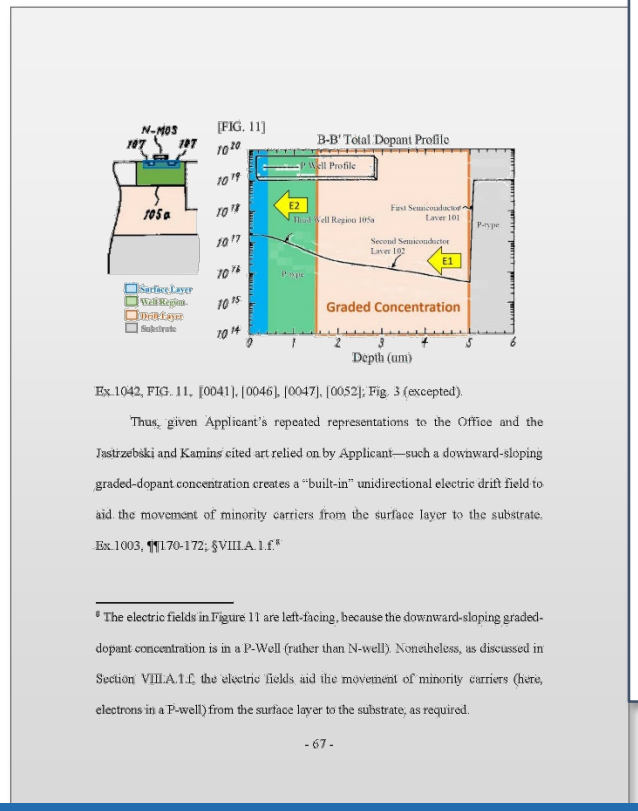
MR. PAUL: Objection to form. Scope.

THE WITNESS: Will not aid movement from the surface to the substrate of the holes in the active region due to the drift mechanism.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 268:3-269:13

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners identify an NMOS transistor in a P-well.

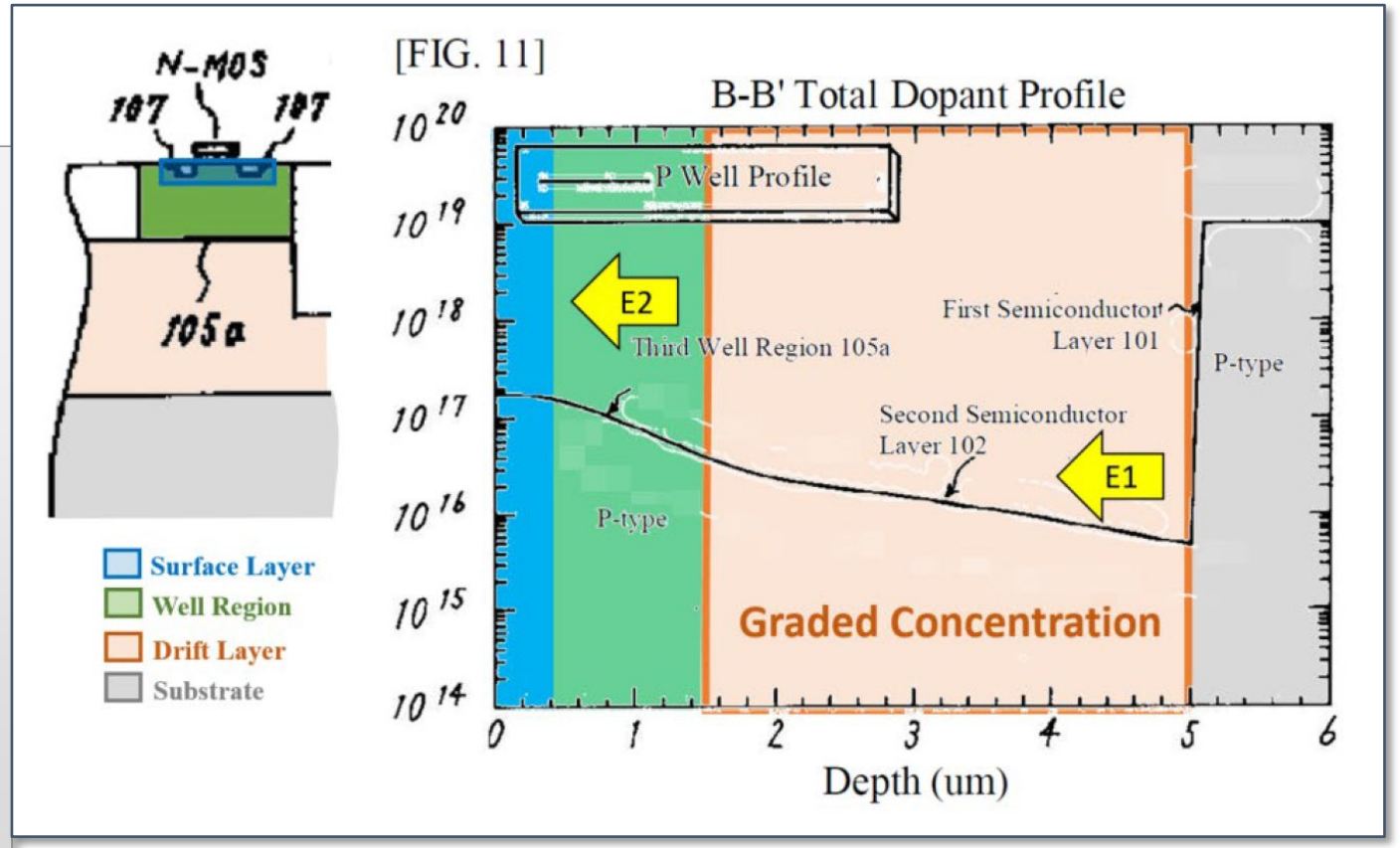


Ex.1042, FIG. 11, [0041], [0046], [0047], [0052]; Fig. 3 (excepted).

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[8] The electric fields in Figure 11 are left-facing, because the downward-sloping graded-dopant concentration is in a P-Well (rather than N-well). Nonetheless, as discussed in Section VIII.A.1.f, the electric fields aid the movement of minority carriers (here, electrons in a P-well) from the surface layer to the substrate, as required.

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-00017: Petition [1] at 67

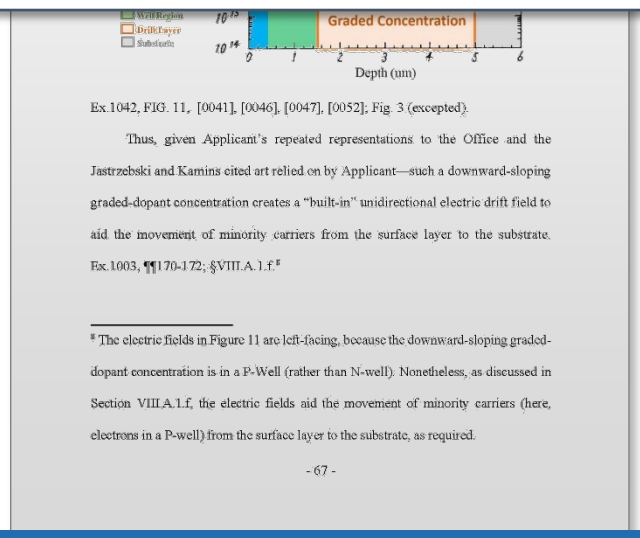
-00017: Ex. 2057, ¶¶35-37; PO Resp. [45] at 4, 7-16; Ex. 1063, 25:6-26:1, 142:16-22; 149:9-151:9; Ex. 2078, 293:5-294:8; PO Sur-Reply [59] at 1, 3-5, 6-7. 10, 14-20

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- For an NMOS transistor in a P-well, Petitioners identify "electrons" as the "minority carrier."

[8] The electric fields in Figure 11 are left-facing, because the downward-sloping graded-dopant concentration is in a P-Well (rather than N-well). Nonetheless, as discussed in Section VIII.A.1.f, the electric fields aid the movement of minority carriers (here, electrons in a P-well) from the surface layer to the substrate, as required.

-00017: Petition [1] at 67 n. 8

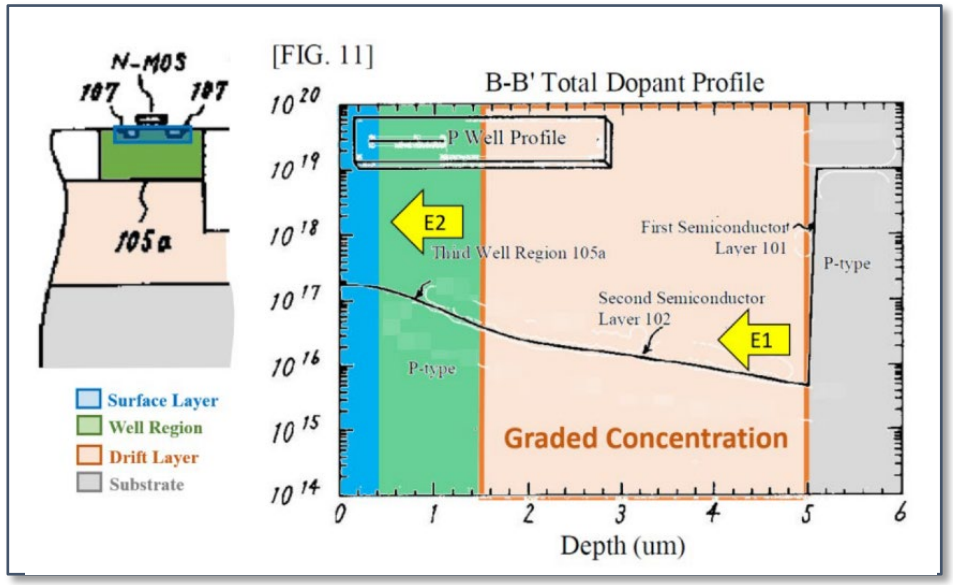

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-00017: Ex. 2057, ¶¶35-37; PO Resp. [45] at 4, 7-16; Ex. 1063, 25:6-26:1, 142:16-22; 149:9-151:9; Ex. 2078, 293:5-294:8; PO Sur-Reply [59] at 1, 3-5, 6-7. 10, 14-20



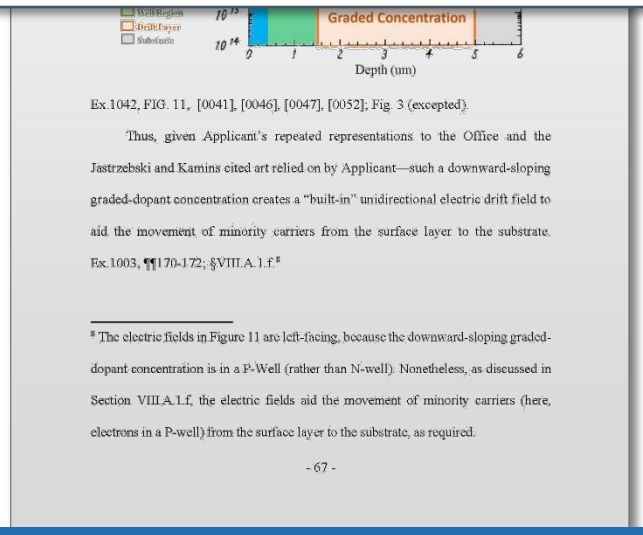
-00017: Petition [1] at 67

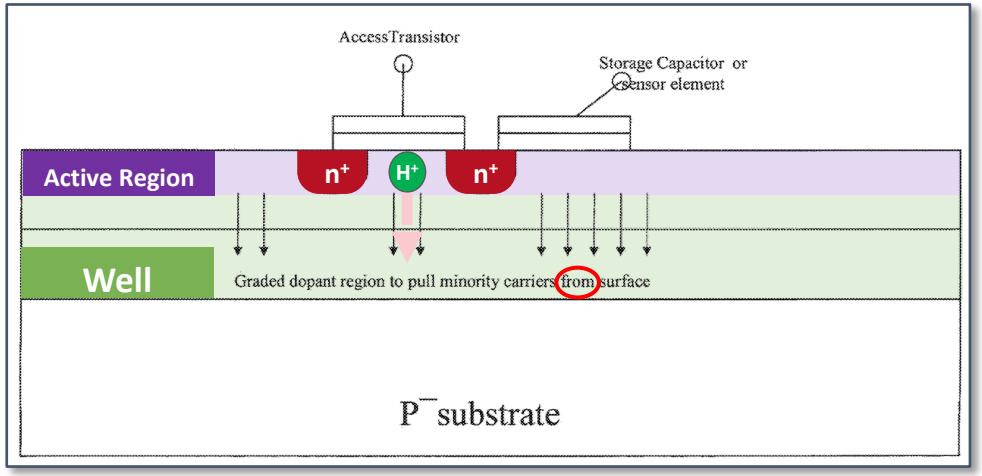
5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- For an NMOS transistor, the "minority carriers" are holes, not electrons.

[8] The electric fields in Figure 11 are left-facing, because the downward-sloping graded-dopant concentration is in a P-Well (rather than N-well). Nonetheless, as discussed in Section VIII.A.1.f, the electric fields aid the movement of minority carriers (here, electrons in a P-well) from the surface layer to the substrate, as required.

-00017: Petition [1] at 67 n. 8



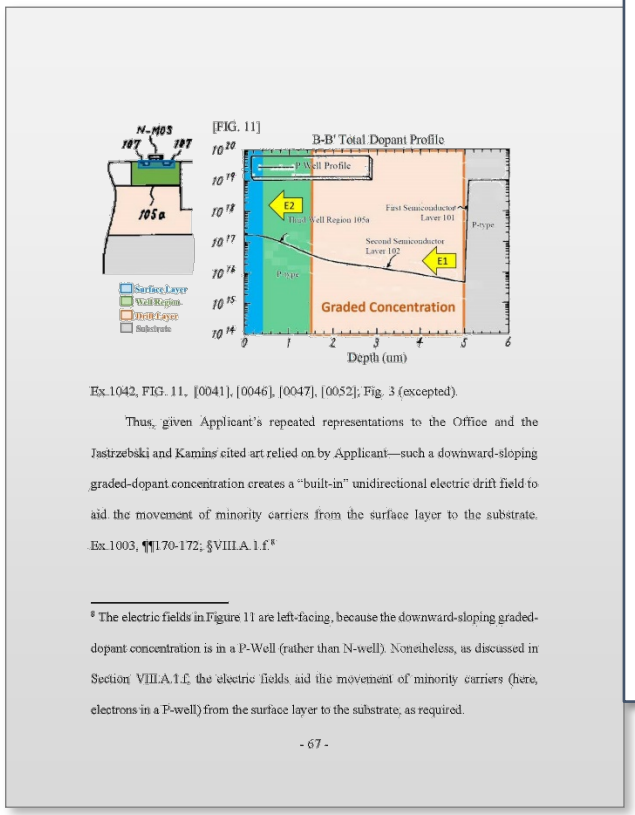


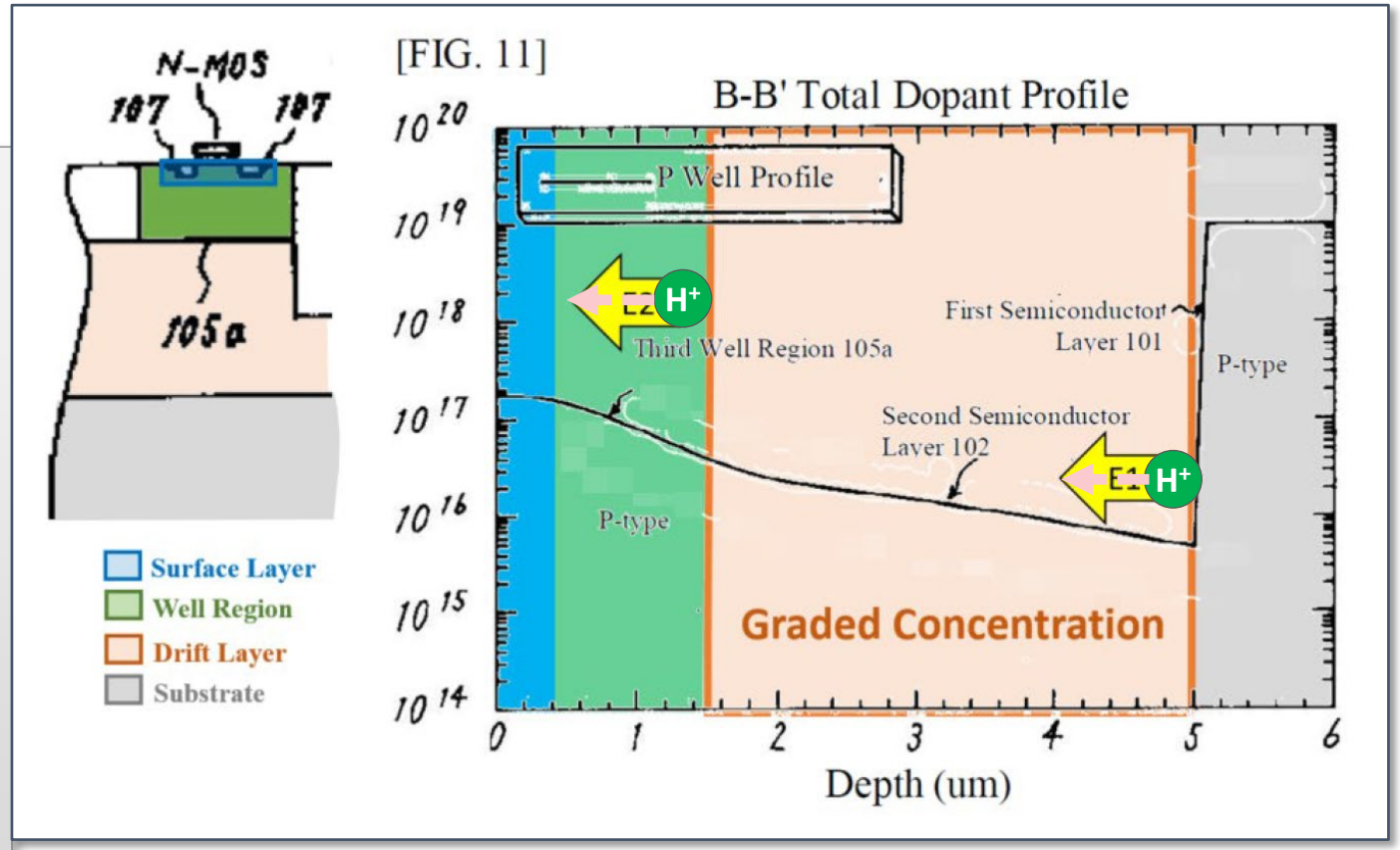
-00017: Ex. 1001 ('481 pat.) at Fig. 5B

-00017: Ex. 2057, ¶¶35-37; PO Resp. [45] at 4, 7-16; Ex. 1063, 25:6-26:1, 142:16-22; 149:9-151:9; Ex. 2078, 293:5-294:8; PO Sur-Reply [59] at 1, 3-5, 6-7. 10, 14-20

5. Onoda Does Not Move "Minority Carriers" from the "Surface Layer"

- Petitioners identified two electric fields that will <u>not</u> move holes from the surface layer.





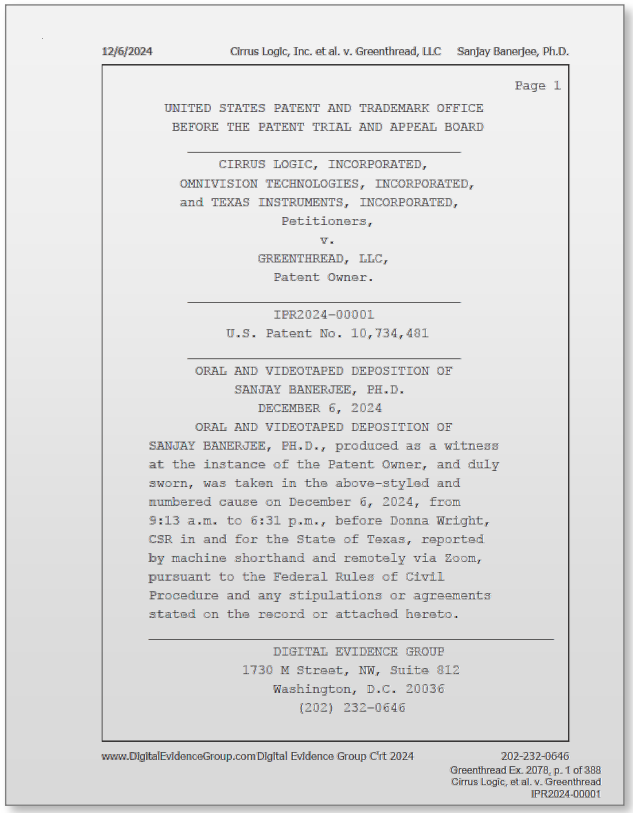
-00017: Petition [1] at 67

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. **Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
5. **Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
6. **Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).**
7. The "movement of carriers" depends on the sum of all of the fields in the "surface layer."
8. Petitioners have the burden to analyze all of the fields in the "surface layer."
9. Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

6. Carriers in the Surface Layer are Affected by Numerous Fields

- Dr. Banerjee testified that "carrier movement" depends on a "number of factors."



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OMNIVISION TECHNOLOGIES, INCORPORATED,
and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,481

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

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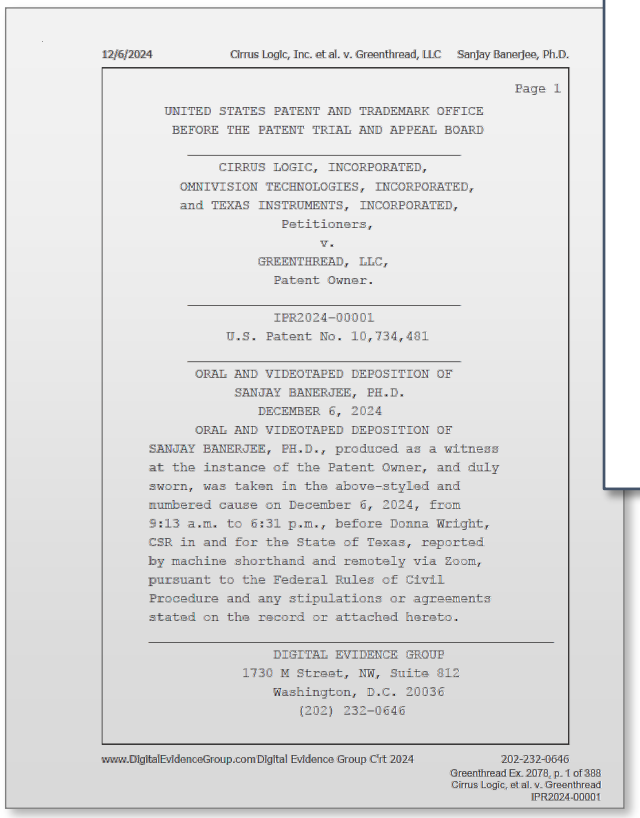
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18 So it sounds like to determine
19 movement of an electron in a semiconductor,
20 you have to look at a number of factors,
21 correct?
22 A. Yes.
1 MR. PAUL: Objection to form.
2 Q. (BY MR. WHITEHURST) What are
3 some of the factors you have to look at?
4 A. Well, as I mentioned, there's
5 three broad categories of forces. The

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 80:18-81:5

6. Carriers in the Surface Layer are Affected by Numerous Fields

- Dr. Banerjee testified that "carrier movement" depends on "externally applied forces" and "built-in electric fields."



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19 Q. The second category of force
20 that you would have to look at is externally
21 applied forces or a built-in electric field.
22 Did I get that correct?
1 A. Yes.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 83:19-84:1

6. Carriers in the Surface Layer are Affected by Numerous Fields

- Dr. Banerjee testified that the gate and gate oxide create fields that affect the movement of carriers in the active region (or surface layer).

How can the gate oxide create a built-in electric field even without an external voltage?

A. A gate oxide can attract charges and that can cause an electric field to be created in the semiconductor channel.

But that's not the subject of this patent. This patent is dealing with built-in electric fields due to doping gradients in the channel.

Q. But you agree that both the gate and the gate oxide can create electric fields in the active region, even when an external voltage is not applied, right?

MR. PAUL: Objection to form.

THE WITNESS: Yeah, the gate and gate oxide can create fields in the channel, even without external voltages.

Q. (BY MR. WHITEHURST) And the electric fields created by the gate and the gate oxide will affect the net electric field, right?

A. Yes. But, once again, that's not the subject matter of these patents.

Q. And you already testified today that the net electric field affects the net movement.

Do you recall that?

MR. PAUL: Objection to form.

THE WITNESS: Yes, electric field does affect net movement.

Q. (BY MR. WHITEHURST) So this means that the electric field created by the gate and the gate oxide will affect the net electric field and the net carrier movement, correct?

MR. PAUL: Objection to form.

THE WITNESS: The gate composition and the gate oxide composition can create built-in electric fields.

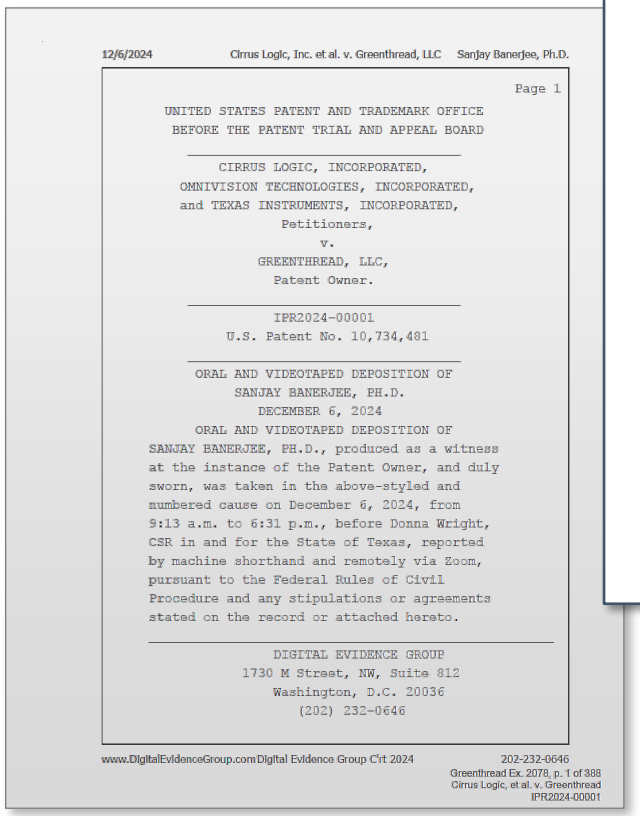
Q. (BY MR. WHITEHURST) And you didn't calculate the magnitude for the electric field due to the gate or the gate oxide, did you?

A. No one can, unless you give me specific information.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 222:4-224:7

6. Carriers in the Surface Layer are Affected by Numerous Fields

- Dr. Banerjee testified that "carrier movement" also depends on "temperature gradients."



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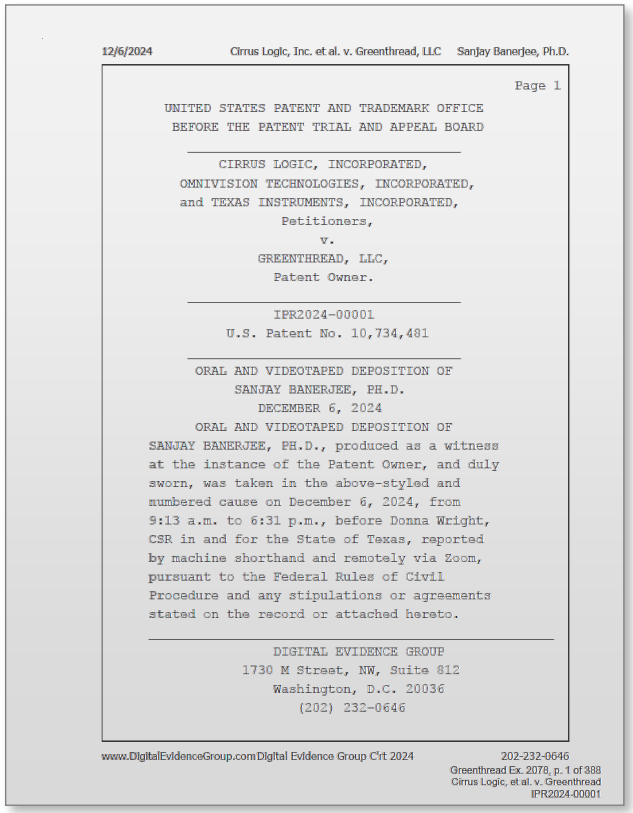
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11 Q. Can you think of any other
12 category 2 forces?
13 A. Yes. I could apply temperature
14 gradients where the temperature is not the
15 same throughout and that can give you what
16 are called thermoelectric effects.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 138:11-16

6. Carriers in the Surface Layer are Affected by Numerous Fields

- Dr. Banerjee testified that "carrier movement" also depends on "magnetic fields."



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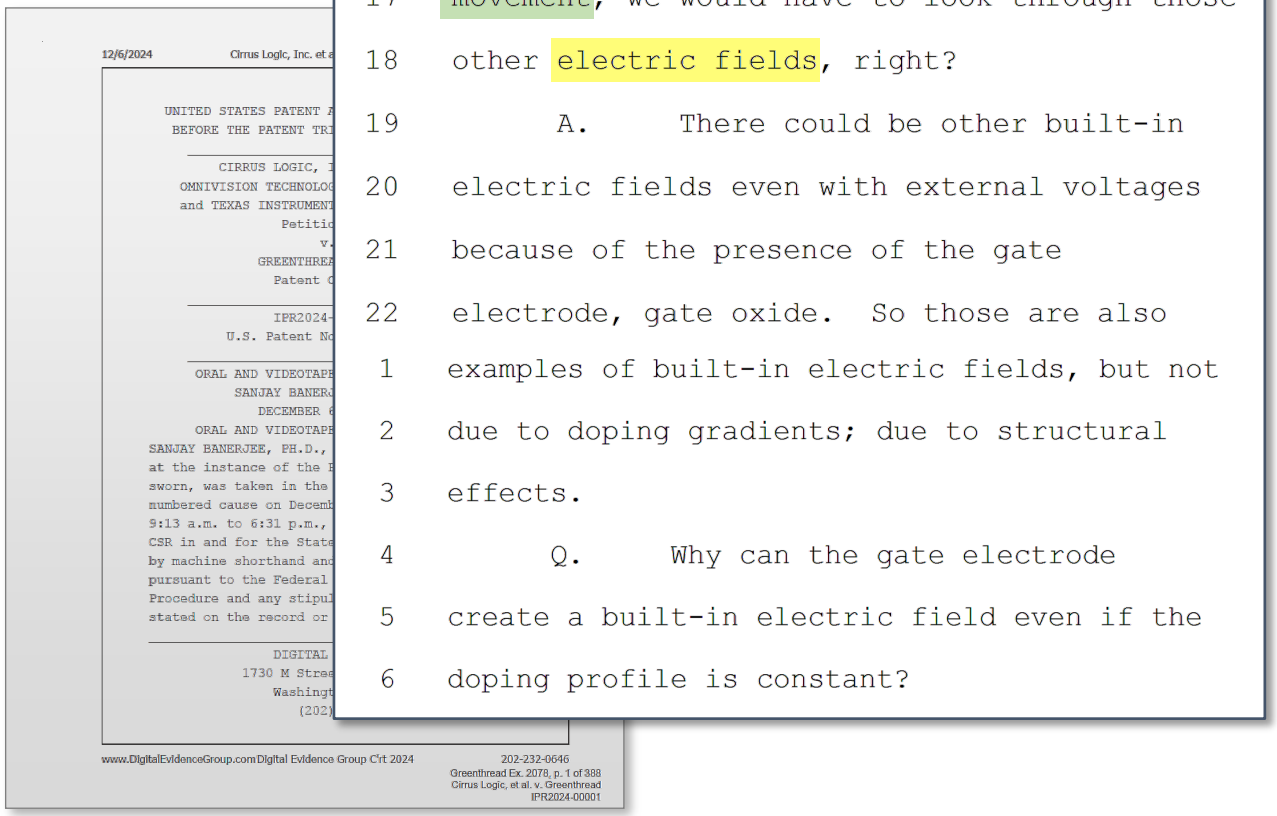
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11 Q. (BY MR. WHITEHURST) What is
12 the Hall effect?
13 A. The Hall effect happens when
14 you apply a magnetic field, say in the
15 vertical direction, and you apply and you
16 have the velocity of the particles in the
17 horizontal direction. That will create a
18 force in the mutually perpendicular
19 direction, so in the depth direction away
20 from me. And that's known as the Hall
21 effect.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 140:11-21

6. Carriers in the Surface Layer are Affected by Numerous Fields

- Dr. Banerjee testified that in order to determine movement you have to look at all of the fields.



16 Q. And in order to determine net
17 movement, we would have to look through those
18 other electric fields, right?
19 A. There could be other built-in
20 electric fields even with external voltages
21 because of the presence of the gate
22 electrode, gate oxide. So those are also
1 examples of built-in electric fields, but not
2 due to doping gradients; due to structural
3 effects.
4 Q. Why can the gate electrode
5 create a built-in electric field even if the
6 doping profile is constant?

7 A. It can because a gate electrode
8 in general will have different electronic
9 properties than the channel. And the
10 property that I'm talking about is known as
11 the work function, which is defined as the
12 energy between the forming level and the
13 vacuum level, the vacuum level being a
14 reference to potential energy.
15 In general, the work function
16 in the gate would be different from the work
17 function in the semiconductor in the channel.
18 That can also cause built-in fields in the
19 channel. But that's not really the subject
20 of this patent --

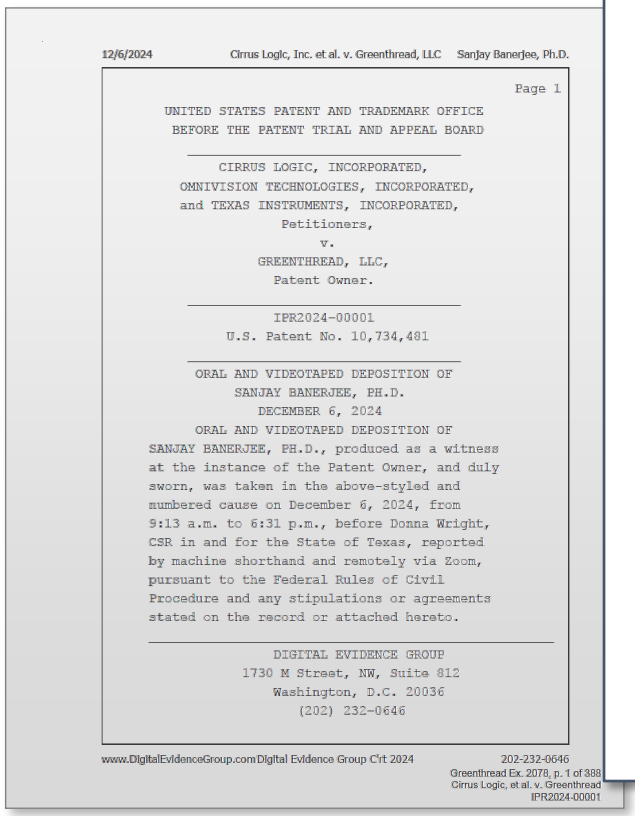
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 219:16-220:20

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. **Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
5. **Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
6. **Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).**
7. **The "movement of carriers" depends on the sum of all of the fields in the "surface layer."**
8. Petitioners have the burden to analyze all of the fields in the "surface layer."
9. Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

7. Movement of Carriers Depends on the Vector Sum

- Dr. Banerjee testified that the “movement of carriers” depends on the “vector sum.”



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerjee, Ph.D.

Page 1

UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INCORPORATED,
OMNIVISION TECHNOLOGIES, INCORPORATED,
and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,481

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

ORAL AND VIDEOTAPED DEPOSITION OF SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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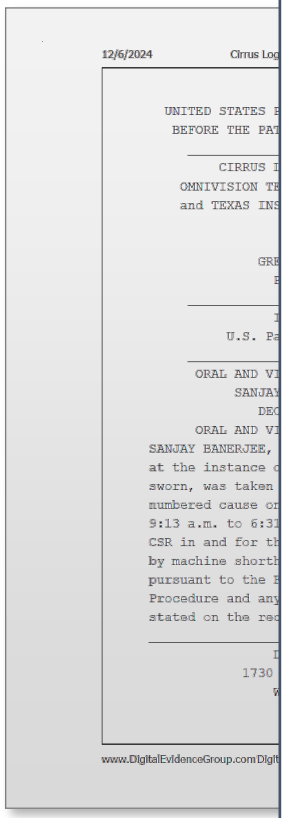
Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

15 Q. When you're trying to determine
16 net motion, you want to look at the vector
17 sum of all of the different fields, correct?
18 A. Yes.
19 Q. Because the vector sum
20 determines the net movement, correct?
21 MR. PAUL: Objection, form.
22 THE WITNESS: Yes.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 183:15-22

7. Movement of Carriers Depends on the Vector Sum

- Dr. Banerjee testified that the "movement of carriers" depends on the "vector sum."


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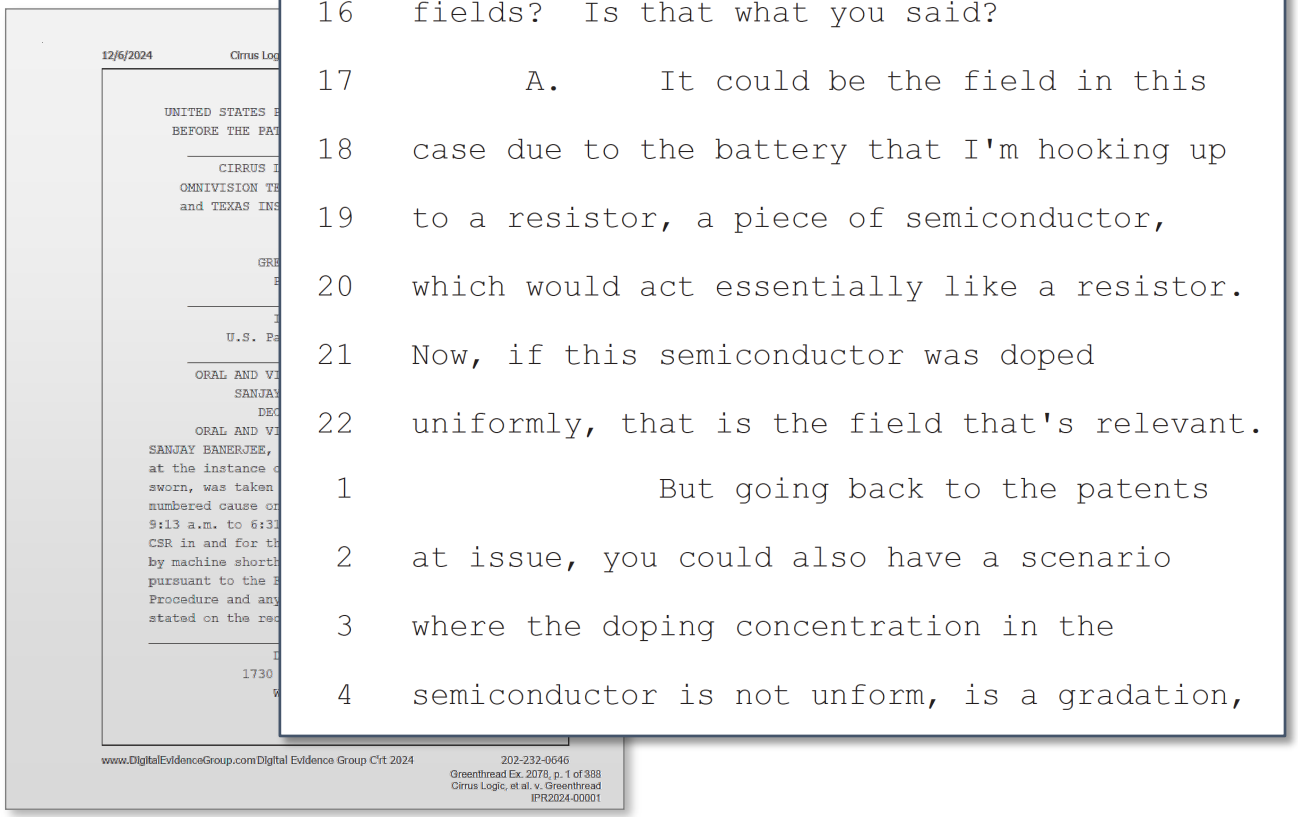
18 Q. (BY MR. WHITEHURST) So when
19 we're looking at an electron in a
20 semiconductor, we could have multiple forces
21 acting on it?
22 MR. PAUL: Objection to form.
1 THE WITNESS: Well, as I told
2 you, you have the three broad
3 categories of forces, but now focusing
4 on the second category, which are
5 externally applied forces or built-in
6 forces due to doping gradients, those
7 could also have multiple components to
8 it and you have to take the vector
9 sum.

10 Q. (BY MR. WHITEHURST) So when
11 you have multiple forces, you have to look at
12 the vector sum?
13 A. To get the net motion, yes.
14 Q. So in order to determine the
15 net motion, you have to look at the vector
16 sum?
17 A. In order to --
18 MR. PAUL: Objection to form.
19 THE WITNESS: In order to look
20 at the net motion, you have to look at
21 the vector sum. But then the net

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 113:18-114:21

7. Movement of Carriers Depends on the Vector Sum

- Dr. Banerjee testified that the “movement of carriers” depends on the “vector sum.”



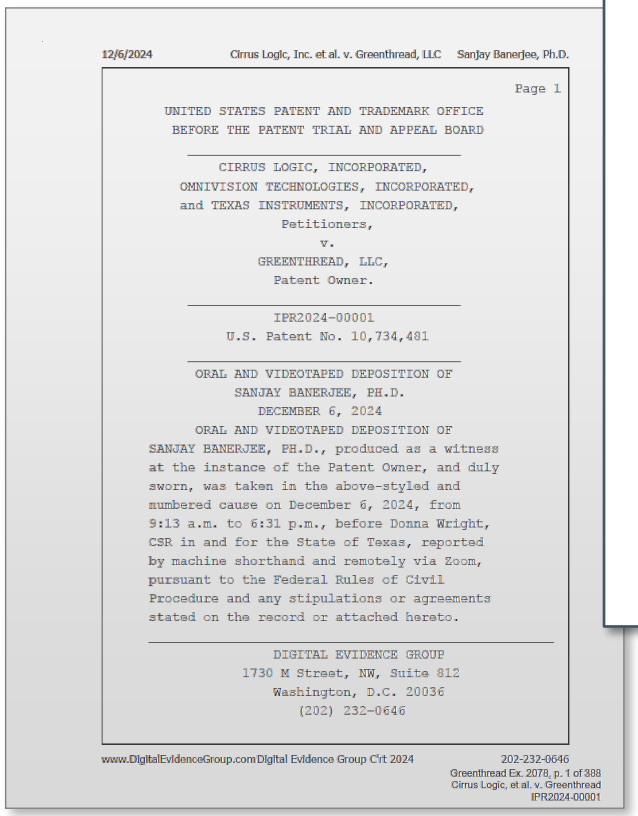
15 Q. So there could be multiple
16 fields? Is that what you said?
17 A. It could be the field in this
18 case due to the battery that I'm hooking up
19 to a resistor, a piece of semiconductor,
20 which would act essentially like a resistor.
21 Now, if this semiconductor was doped
22 uniformly, that is the field that's relevant.
1 But going back to the patents
2 at issue, you could also have a scenario
3 where the doping concentration in the
4 semiconductor is not unform, is a gradation,

5 and that self-generates additional electric
6 fields, which would be superimposed on the
7 externally applied electric fields due to the
8 battery. You either do a vector sum of the
9 built-in static electric fields to the doping
10 gradient, as well as the externally applied
11 fields, which can change from, you know, one
12 situation to the other, depending on, you
13 know, where I'm hooking up the battery,
14 magnitude of the voltage, et cetera, et
15 cetera.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 109:15-110:15

7. Movement of Carriers Depends on the Vector Sum

- Dr. Banerjee testified that the "movement of carriers" depends on the "vector sum."



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerjee, Ph.D.

Page 1

UNITED STATES PATENT AND TRADEMARK OFFICE
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IPR2024-00001
U.S. Patent No. 10,734,481

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Q. But we agree that net movement will depend on the vector sum, right?

MR. PAUL: Objection to form.

THE WITNESS: Net movement as in drift velocity would depend on the vector sum.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 251:3-8

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. **Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
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7. **The "movement of carriers" depends on the sum of all of the fields in the "surface layer."**
8. **Petitioners have the burden to analyze all of the fields in the "surface layer."**
9. Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

8. Petitioners Have the Burden to Analyze the Electric Fields



"In *Magnum Oil*, we soundly rejected the idea of shifting even the burden of *production* from the petitioner to the patent owner once the Board institutes an IPR where 'the patentee's position is that the patent challenger failed to meet its burden of proving obviousness.' … We therefore reject [petitioners'] suggestion that the patent owner's failure to put forth rebuttal evidence regarding the substance of the references' disclosures in any way limited the Board's ability to device for itself what the references would teach or suggest to a [POSITA]."

Fanduel, Inc. v. Interactive Games LLC,
966 F.3d 1334, 1341-42 (Fed. Cir. 2020) (cleaned up)

8. Petitioners Have the Burden to Analyze the Electric Fields

- Because the Prior Art does not expressly teach moving minority carriers from the "surface layer," Petitioners have the burden to:
  - identify an electric field that is in the correct location (*i.e.*, starts in the "surface layer")
  - identify an electric field that points in the correct direction
  - analyze the gate, gate oxide, and other fields in the "surface layer"


IN THE UNITED STATES PATENT AND TRADE

BEFORE THE PATENT TRIAL AND APPE

CIRRUS LOGIC, INC.;
OMNIVISION TECHNOLOGIES, INC.;
AMS SENSORS USA INC.,
Petitioner,

v.

GREENTHREAD, LLC,
Patent Owner.

Case No. IPR2024-00017
Patent No. 8,421,195

PETITION FOR *INTER PARTES* REVIEW OF U.
8,421,195

UNDER 35 U.S.C. §§ 312 AND 37 C.F.R.

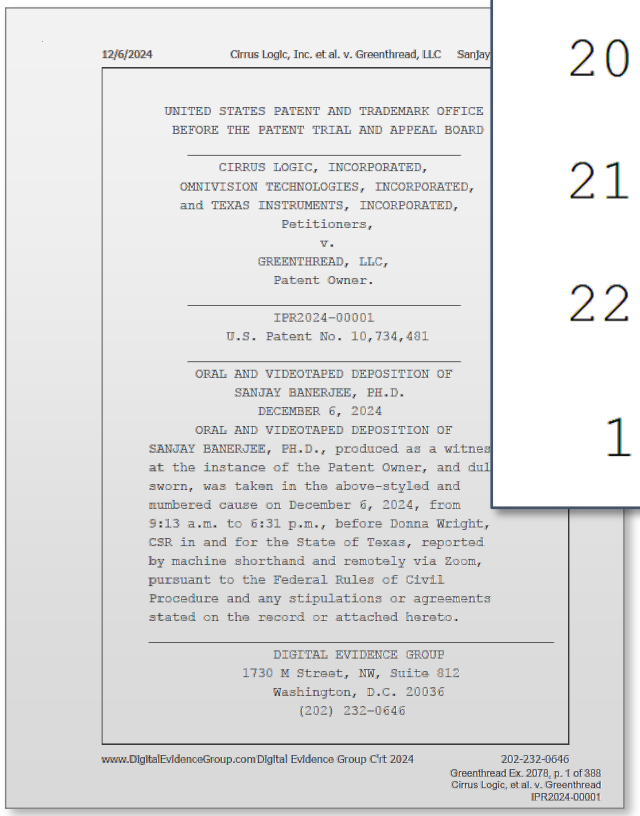
> In the absence of any teaching of the claim limitation in the prior art, Petitioners have two options: 1) they can read "aid carrier movement from the first surface" out of the claim or 2) they can argue that any "graded dopant concentration" in the active region will "aid carrier movement." Both options fail.

-00017: PO Response [45] at 2

-00017: PO Resp. [45] at 7-13; PO Sur-Reply [59] at 3-11

8. Petitioners Have the Burden to Analyze the Electric Fields

- Dr. Banerjee admitted that he did not calculate the magnitude for any of the electric fields.



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay

UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INCORPORATED,
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IPR2024-00001

19 When you were analyzing the
20 prior art references, you never calculated
21 the magnitude for any of the electric fields,
22 correct?

1 A. I did not calculate those.

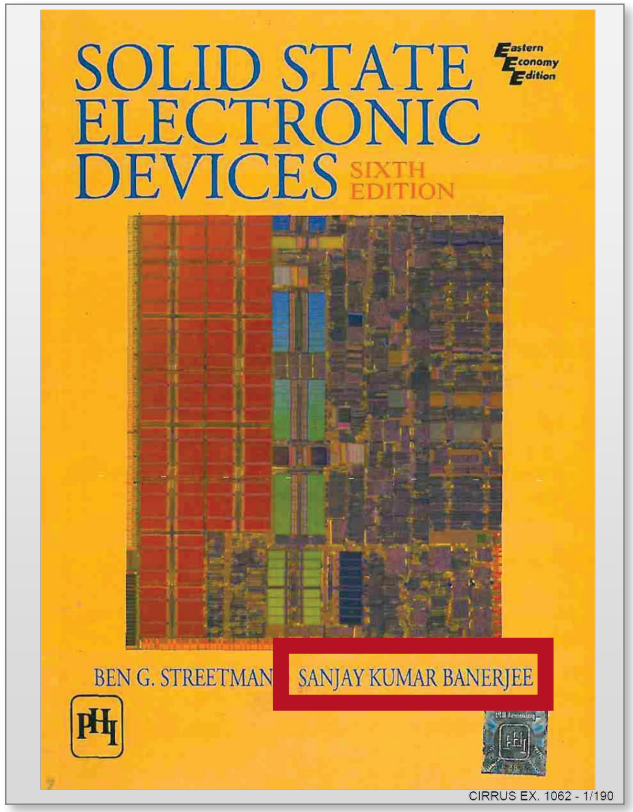
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 212:19-213:1

-00017: PO Sur-Reply [59] at 5, 22

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

8. Petitioners Have the Burden to Analyze the Electric Fields

- Dr. Banerjee's 2005 textbook states that an electric field may be insufficient to alter the movement of an electron.



If an electric field $\mathscr{E}_x$ is applied in the x-direction, each electron experiences a net force $-q\mathscr{E}_x$ from the field. This force may be insufficient to alter appreciably the random path of an individual electron; the effect when averaged over all the electrons, however, is a net motion of the group in the $-x$-direction (Fig. 3-20b). If p_x is the x-component of the total momentum of the group, the force of the field on the n electrons/cm^3 is

$$-nq\mathscr{E}_x = \left.\frac{dp_x}{dt}\right|_{\text{field}} \qquad (3\text{-}29)$$

-00017: Ex. 1062A (Streetman & Banerjee Textbook) at 99

8. Petitioners Have the Burden to Analyze the Electric Fields

- Cirrus Logic's VP of Technology, Mr. Warrick, confirmed that a graded concentration does not necessarily "aid carrier movement."

Q. (BY MR. MATICH) Can you tell me if the gradient there would aid carrier movement downward?
MR. LIDDELL: Objection, form.
THE WITNESS: I cannot tell you that.
Q. (BY MR. MATICH) Why not?
A. I don't have an understanding of what the benefit of that gradient would be or the degradation of that gradient.

-00017: Ex. 2056 (Warrick Dep. Tr.) at 95:2-9

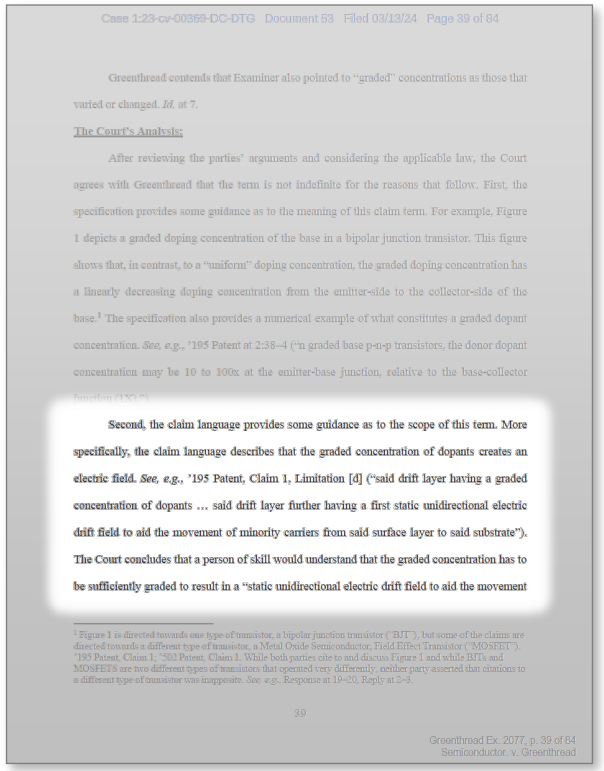
Q. And you can't tell me -- but can you tell me the -- leaving aside intent for a moment, you can't tell me what the effect of that gradient is?
A. No.
MR. LIDDELL: Objection, form.
Q. (BY MR. MATICH) Okay. And why not?
A. I don't know -- I don't -- you know, I don't have a knowledge of why that would be -- or the effect of that diffused grading here.
Q. Is -- is that because there's other things that might affect carrier movement besides the gradient?
A. Yes.

-00017: Ex. 2056 at 96:1-13

-00017: PO Resp. [45] at 7, 14-15; PO Sur-Reply [59] at 8

8. Petitioners Have the Burden to Analyze the Electric Fields

- WDTX ruled that a graded concentration does not necessarily "aid the movement of minority carriers."
- The dopants must be "sufficiently graded" in order to "aid the movement."


Case 1:23-cv-00369-DC-DTG Document 53 Filed 03/13/24 Page 39 of 84

Greenthread contends that Examiner also pointed to "graded" concentrations as those that varied or changed. *Id.* at 7.

The Court's Analysis:

After reviewing the parties' arguments and considering the applicable law, the Court agrees with Greenthread that the term is not indefinite for the reasons that follow. First, the specification provides some guidance as to the meaning of this claim term. For example, Figure 1 depicts a graded doping concentration of the base in a bipolar junction transistor. This figure shows that, in contrast, to a "uniform" doping concentration, the graded doping concentration has a linearly decreasing doping concentration from the emitter-side to the collector-side of the base.[1] The specification also provides a numerical example of what constitutes a graded dopant concentration. *See, e.g.*, '195 Patent at 2:38–4 ("n graded base p-n-p transistors, the donor dopant concentration may be 10 to 100x at the emitter-base junction, relative to the base-collector

Second, the claim language provides some guidance as to the scope of this term. More specifically, the claim language describes that the graded concentration of dopants creates an electric field. *See, e.g.*, '195 Patent, Claim 1, Limitation [d] ("said drift layer having a graded concentration of dopants … said drift layer further having a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate"). The Court concludes that a person of skill would understand that the graded concentration has to be sufficiently graded to result in a "static unidirectional electric drift field to aid the movement

[1] Figure 1 is directed towards one type of transistor, a bipolar junction transistor ("BJT"), but some of the claims are directed towards a different type of transistor, a Metal Oxide Semiconductor, Field Effect Transistor ("MOSFET"). '195 Patent, Claim 1; '502 Patent, Claim 1. While both parties cite to and discuss Figure 1 and while BJTs and MOSFETs are two different types of transistors that operated very differently, neither party asserted that citations to a different type of transistor was inapposite. *See, e.g.*, Response at 19–20, Reply at 2–3.

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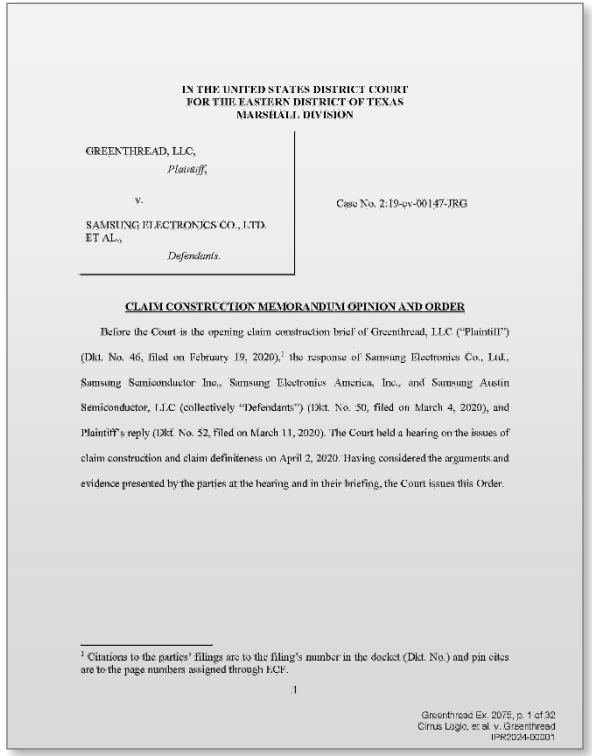
Greenthread Ex. 2077, p. 39 of 84
Semiconductor. v. Greenthread

Second, the claim language provides some guidance as to the scope of this term. More specifically, the claim language describes that the graded concentration of dopants creates an electric field. *See, e.g.*, '195 Patent, Claim 1, Limitation [d] ("said drift layer having a graded concentration of dopants … said drift layer further having a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate"). The Court concludes that a person of skill would understand that the graded concentration has to be sufficiently graded to result in a "static unidirectional electric drift field to aid the movement of minority carriers." This establishes a minimum graded concentration of dopants, *i.e.*, a graded concentration of dopants that is below this minimum will not aid in the movement of minority carriers and thus is not a graded concentration.

-00017: Ex. 2074 (WDTX Order) at 39-40

8. Petitioners Have the Burden to Analyze the Electric Fields

- EDTX ruled that carrier movement depends on the direction and <u>magnitude</u> of the slope.



IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

GREENTHREAD, LLC,
Plaintiff,

v.

SAMSUNG ELECTRONICS CO., LTD. ET AL.,
Defendants.

Case No. 2:19-cv-00147-JRG

CLAIM CONSTRUCTION MEMORANDUM OPINION AND ORDER

Before the Court is the opening claim construction brief of Greenthread, LLC ("Plaintiff") (Dkt. No. 46, filed on February 19, 2020),[1] the response of Samsung Electronics Co., Ltd., Samsung Semiconductor Inc., Samsung Electronics America, Inc., and Samsung Austin Semiconductor, LLC (collectively "Defendants") (Dkt. No. 50, filed on March 4, 2020), and Plaintiff's reply (Dkt. No. 52, Filed on March 11, 2020). The Court held a hearing on the issues of claim construction and claim definiteness on April 2, 2020. Having considered the arguments and evidence presented by the parties at the hearing and in their briefing, the Court issues this Order.

[1] Citations to the parties' filings are to the filing's number in the docket (Dkt. No.) and pin cites are to the page numbers assigned through ECF.

1

Greenthread Ex. 2075, p. 1 of 32
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

'195 Patent File Wrapper April 17, 2012 Response Pursuant to 37 CFR 1.114 Amendment E at 6–7, Dkt. No. 50-12 at 59–60. Taken in context, that the direction of the electrical field and the carrier movement "depends solely on the slope of the graded concentration of dopant" does not mandate that the slope must be only increasing or only decreasing to maintain a unidirectional drift field. For example, the slope has both a direction and a magnitude and Defendant suggests that the direction of the drift electric field depends solely on ***the direction*** of the slope of the graded concentration of dopant. This is not justified by the prosecution history statements that Defendant cites. In fact, the *Grove* reference cited by the patentee in the above-quoted statement includes Figure 7.13 (reproduced and annotated below) which depicts a dopant concentration that both increases and decreases in the "graded base region" that provides an "electric field . . . of such direction as to aid the motion of injected holes." A.S. Grove, *Physics and Technology of Semiconductor Devices* 224–25 (1967), Dkt. No. 50-13 at 22–23. In other words, the patentee cited

-00017: Ex. 2075 (EDTX Order) at 15

8. Petitioners Have the Burden to Analyze the Electric Fields

- EDTX already rejected Petitioners' prosecution history argument.

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

'195 Patent File Wrapper April 17, 2012 Response Pursuant to 37 CFR 1.114 Amendment E at 6–7, Dkt. No. 50-12 at 59–60. Taken in context, that the direction of the electrical field and the carrier movement "depends solely on the slope of the graded concentration of dopant" does not mandate that the slope must be only increasing or only decreasing to maintain a unidirectional drift field. For example, the slope has both a direction and a magnitude and Defendant suggests that the direction of the drift electric field depends solely on ***the direction*** of the slope of the graded concentration of dopant. This is not justified by the prosecution history statements that Defendant cites. In fact, the *Grove* reference cited by the patentee in the above-quoted statement includes Figure 7.13 (reproduced and annotated below) which depicts a dopant concentration that both increases and decreases in the "graded base region" that provides an "electric field . . . of such direction as to aid the motion of injected holes." A.S. Grove, *Physics and Technology of Semiconductor Devices* 224–25 (1967), Dkt. No. 50-13 at 22–23. In other words, the patentee cited

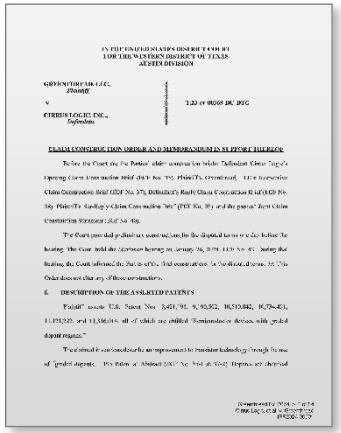
-00017: Ex. 2075 (EDTX Order) at 15

Applicant respectfully disagrees with this position because (as previously argued by Applicant) a unidirectional drift (electric) field necessarily affects all the present minority carriers in the same way – moving all minority carriers in the same direction because of the unidirectional drift due to the existence of the electric field. *See* "Physics and Technology of Semiconductor Devices," A.S. Grove, pp. 224-225, John Wiley and Sons, Inc., New York, 1st Edition 1967 ("This same electric field will then be of such direction as to aid the motion of injected holes. Thus the injected minority carriers will now move not only by diffusion but also by drift due to the existence of this electric field."). Depending on the particular slope of the graded concentration of dopant, all minority carriers are either swept "down" (from the surface layer to the substrate) or "up" (from the substrate to the surface layer). *See* Applicant's Figs. 5(b) and 5(c).

-00017: Ex. 1016 ('195 Prosecution History) at 289

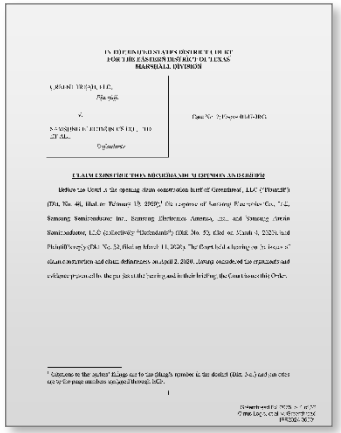
8. Petitioners Have the Burden to Analyze the Electric Fields

- WDTX and EDTX agreed that the slope must be sufficiently graded.



The Court concludes that a person of skill would understand that the graded concentration has to be sufficiently graded to result in a "static unidirectional electric drift field to aid the movement of minority carriers." This establishes a minimum graded concentration of dopants, *i.e.*, a graded concentration of dopants that is below this minimum will not aid in the movement of minority carriers and thus is not a graded concentration.

-00017: Ex. 2074 (WDTX Order) at 39-40



For example, the slope has both a direction and a magnitude and Defendant suggests that the direction of the drift electric field depends solely on ***the direction*** of the slope of the graded concentration of dopant. This is not justified by the prosecution history statements that Defendant cites. In fact, the *Grove* reference cited by the patentee in the above-quoted statement includes

-00017: Ex. 2075 (EDTX Order) at 15

8. Petitioners Have the Burden to Analyze the Electric Fields



"A petitioner may not rely on a vague, generic, and/or meandering petition and later fault the Board for failing to understand what the petition really meant …. Ultimately, it is the petitioner's burden to present a clear argument."

Netflix, Inc. v. DivX, LLC, 84 F.4th 1371, 1377 (Fed. Cir. 2023)

8. Petitioners Have the Burden to Analyze the Electric Fields



"That the '803 patent itself does not describe how to implement pixels of varying sizes in a passive-matrix display does not help the Petitioner here, because in this proceeding it is **Petitioner who bears the burden of proof and who needs to show a reasonable expectation of success in accomplishing what it proposes**."

Mianyang Boe Optoelectronics Tech. Co. v. Samsung Display Co., IPR2023-00987, Paper 46 at 37 (PTAB Jan. 6, 2025) (emphasis added)

8. Petitioners Have the Burden to Analyze the Electric Fields

Where the "[p]etitioner does not meet its burden to show obviousness," the Board's "determination is reinforced by consideration of Patent Owner's counterarguments."

Intel Corp. v. Besang Inc., IPR2023-00991, Paper 39 at 32 (PTAB Dec. 11, 2024)

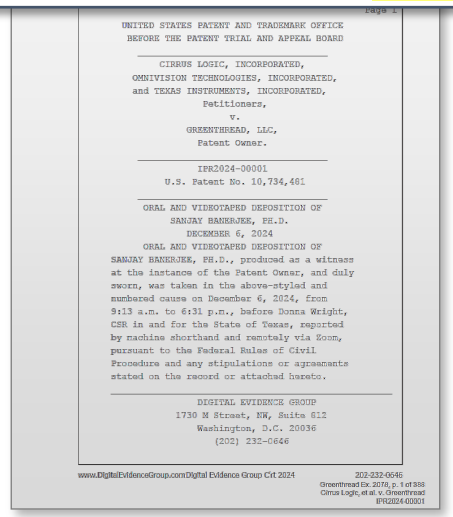
Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. **Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
5. **Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
6. **Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).**
7. **The "movement of carriers" depends on the sum of all of the fields in the "surface layer."**
8. **Petitioners have the burden to analyze all of the fields in the "surface layer."**
9. **Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."**
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

9. Dr. Banerjee Did Not Analyze the Electric Fields in the References

- Dr. Banerjee admitted that he did not calculate the magnitude for any of the electric fields.

19 When you were analyzing the
20 prior art references, you never calculated
21 the magnitude for any of the electric fields,
22 correct?
1 A. I did not calculate those.


UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

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Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

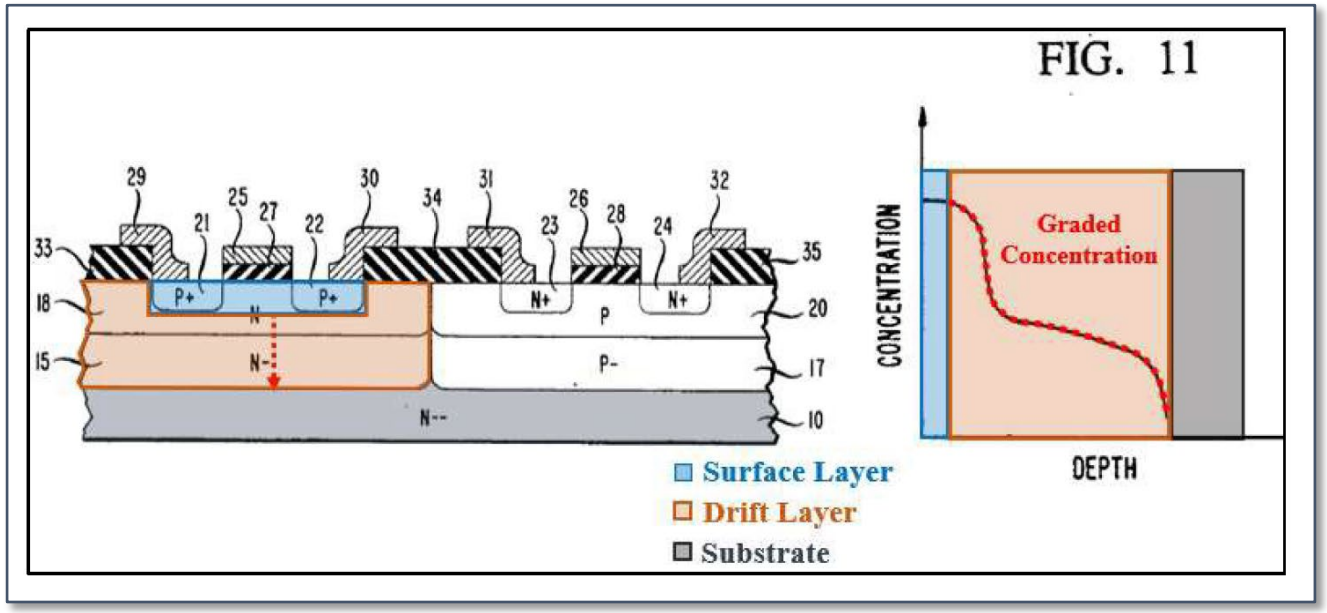
IPR2024-00001
U.S. Patent No. 10,734,461

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

ORAL AND VIDEOTAPED DEPOSITION OF SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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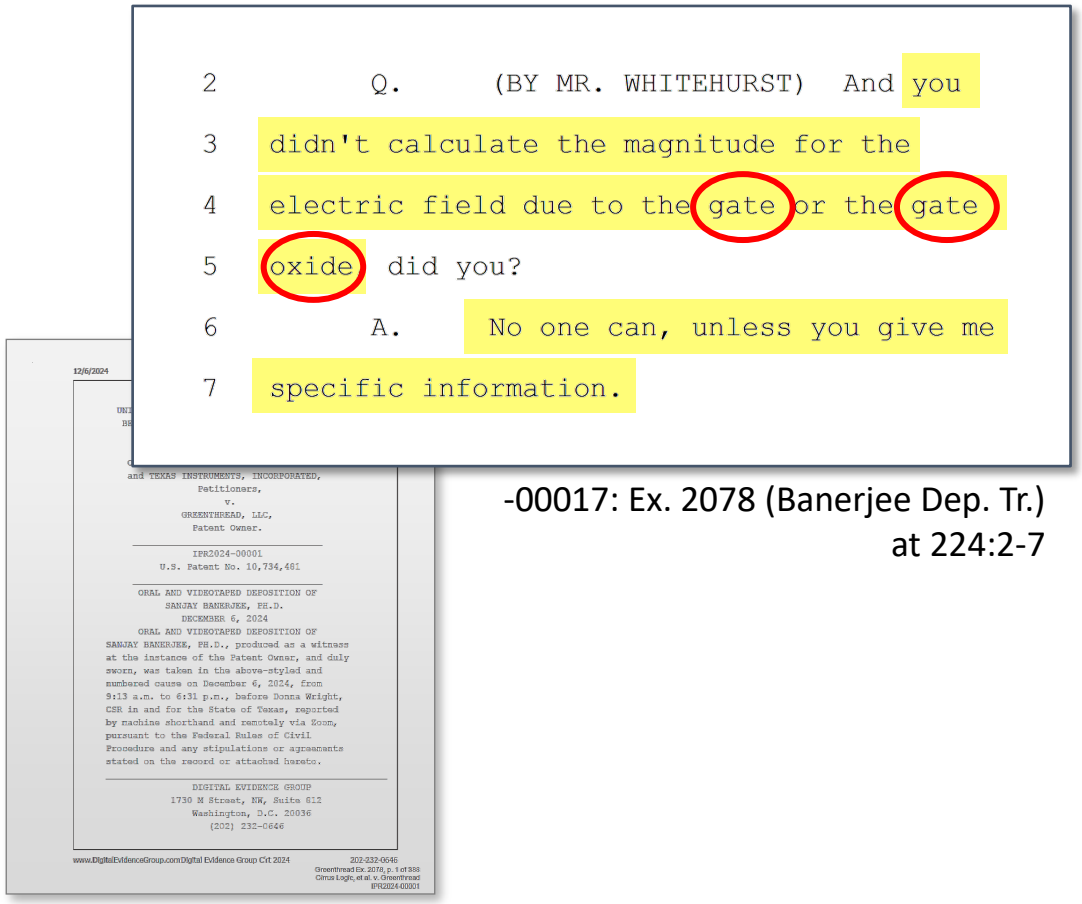
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 212:19-213:1



-00017: Ex. 1005 (Payne) at Figs. 10-11

9. Dr. Banerjee Did Not Analyze the Electric Fields in the References

- Dr. Banerjee did not analyze any of the electric fields in Payne's surface layer.



2 Q. (BY MR. WHITEHURST) And you
3 didn't calculate the magnitude for the
4 electric field due to the gate or the gate
5 oxide did you?
6 A. No one can, unless you give me
7 specific information.

12/6/2024

and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

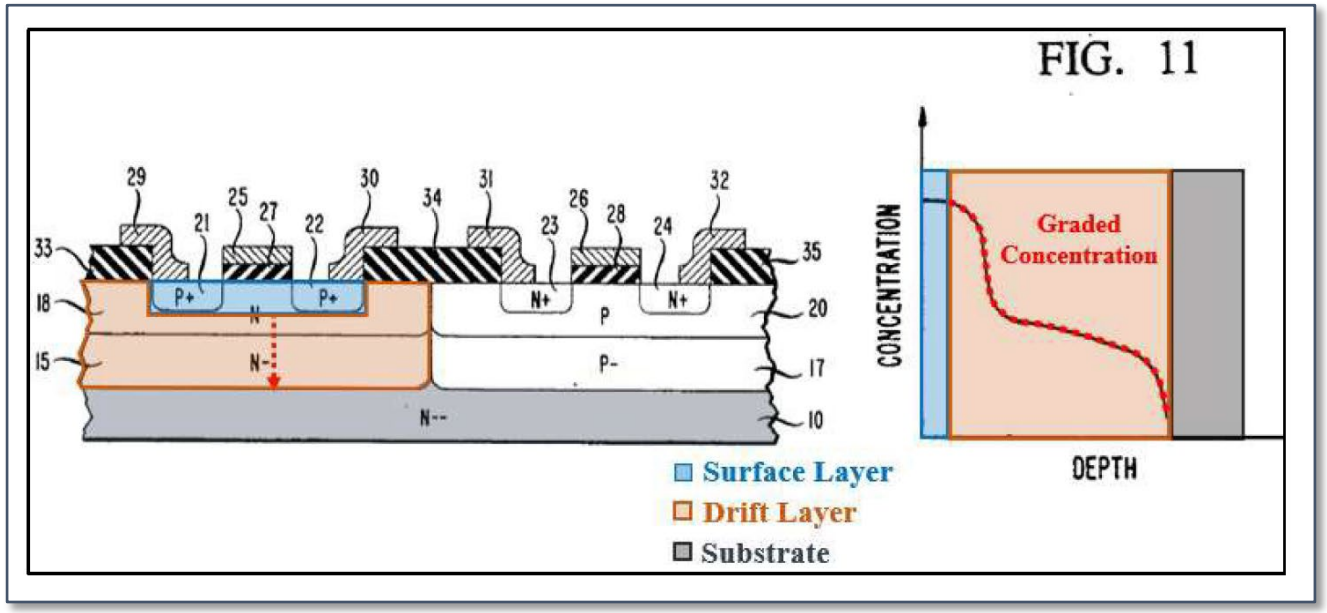
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Greenthread Ex. 2078, p. 1 of 388
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IPR2024-00001

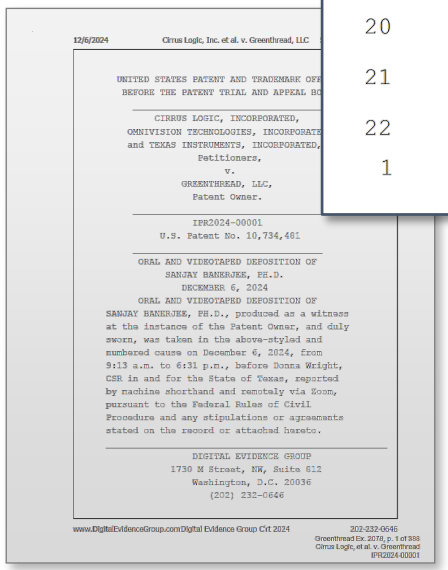
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 224:2-7



-00017: Ex. 1005 (Payne) at Figs. 10-11

9. Dr. Banerjee Did Not Analyze the Electric Fields in the References

- Dr. Banerjee confirmed that the net effect of these electric fields determine the movement of the electron.


12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC

UNITED STATES PATENT AND TRADEMARK OFF
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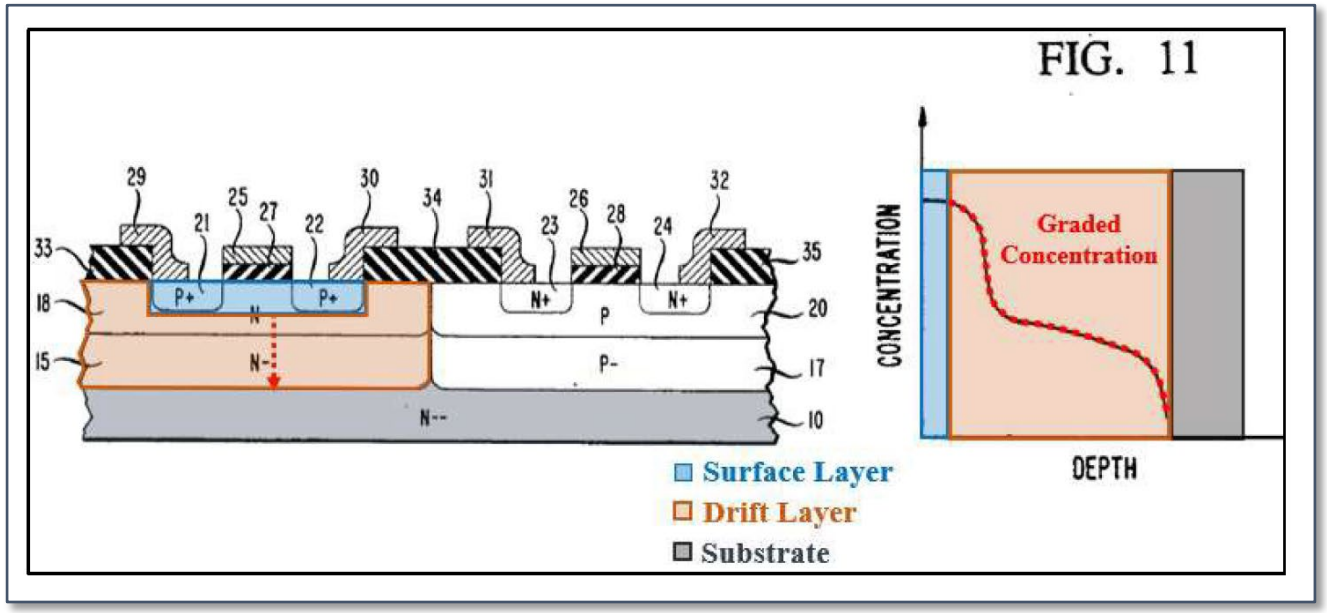
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Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

14 Q. (BY MR. WHITEHURST) So this
15 means that the electric field created by the
16 gate and the gate oxide will affect the net
17 electric field and the net carrier movement,
18 correct?
19 MR. PAUL: Objection to form.
20 THE WITNESS: The gate
21 composition and the gate oxide
22 composition can create built-in
1 electric fields.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 223:14-224:1



-00017: Ex. 1005 (Payne) at Figs. 10-11

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. **Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
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8. **Petitioners have the burden to analyze all of the fields in the "surface layer."**
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10. **Petitioners' prosecution-related arguments are incorrect.**
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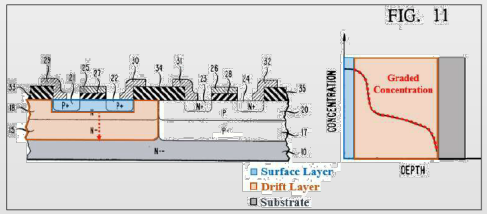
10. Petitioners' Prosecution-Related Arguments are Incorrect

- Payne does not mention an electric field in the "surface layer," and Petitioners have not identified such a field.

f. Element [1.5]: "said drift layer further having a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and"

Payne discloses or, at a minimum, renders obvious this element. Ex.1003, ¶¶94-107. As shown below, Payne's SDL (tan) has a downward-sloping graded-dopant concentration extending between the surface layer (blue) and the substrate (grey). §VIII.A.1.e.

FIG. 11



Ex.1005, FIGS. 10-11.

Payne's downward-sloping graded-dopant concentration aids the movement of minority carriers from the surface layer to the substrate to the same extent to which Applicant relied on the prior art and admitted to the Patent Office that such carrier movement would occur under the same scenario. Ex.1003, ¶¶95-99. During prosecution, Applicant represented to the Patent Office that a downward-sloping graded-dopant concentration was known in the prior art to create an "inherent 'built-

- 22 -

Payne's downward-sloping graded-dopant concentration aids the movement of minority carriers from the surface layer to the substrate to the same extent to which Applicant relied on the prior art and admitted to the Patent Office that such carrier movement would occur under the same scenario. Ex.1003, ¶¶95-99. During prosecution, Applicant represented to the Patent Office that a downward-sloping graded-dopant concentration was known in the prior art to create an "inherent 'built-in' unidirectional electric field" that moves carriers deep into the substrate (while an upward-sloping concentration, not at issue in Payne, would move those carriers in the opposite direction towards the surface):

> [T]he graded dopant concentration itself creates a ***'built-in' electrical field*** that forces the movement of carriers into a particular direction, whereby ***the 'direction' of the electrical field and the resulting direction of the carrier movement depends solely on the slope of the graded concentration of dopant.***

-00017: Petition [1] at 22-23

-00017: PO Resp. [45] at 9-12; PO Sur-Reply [59] at 14-15

10. Petitioners' Prosecution-Related Arguments are Incorrect

- For the electric field, Petitioners rely entirely on a misreading of a claim construction brief and the prosecution history.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INC.;
OMNIVISION TECHNOLOGIES, INC.; AND
AMS SENSORS USA INC.,
Petitioner,

v.

GREENTHREAD, LLC,
Patent Owner.

Case No. IPR2024-00017
Patent No. 8,421,195

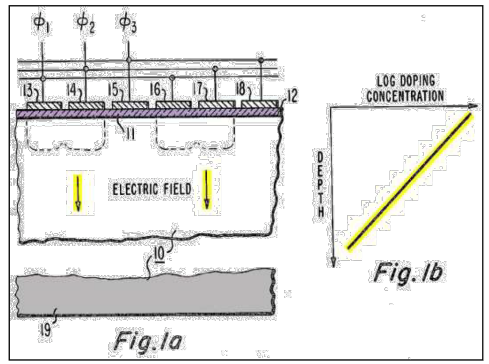
PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 8,421,195

UNDER 35 U.S.C. §§ 312 AND 37 C.F.R. § 42.104

Payne's downward-sloping graded-dopant concentration aids the movement of minority carriers from the surface layer to the substrate to the same extent to which Applicant relied on the prior art and admitted to the Patent Office that such carrier movement would occur under the same scenario. Ex.1003, ¶¶95-99. During prosecution, Applicant represented to the Patent Office that a downward-sloping graded-dopant concentration was known in the prior art to create an "inherent 'built-in' unidirectional electric field" that moves carriers deep into the substrate (while an upward-sloping concentration, not at issue in Payne, would move those carriers in the opposite direction towards the surface):

> [T]he graded dopant concentration itself creates a ***'built-in' electrical field*** that forces the movement of carriers into a particular direction, whereby ***the 'direction' of the electrical field and the resulting direction of the carrier movement depends solely on the slope of the graded concentration of dopant.***

Ex.1002, 289-290 (underlining in original); Ex.1003, ¶¶95-96. Applicant further represented that "a unidirectional drift (electric) field necessarily affects ***all*** the present ***minority*** carriers in the same way…. Depending on the particular slope of the graded concentration of dopant, ***all minority*** carriers are either ***swept*** 'down' … or 'up…'" Ex.1002, 289. Applicant cited Jastrzebski in support. *Id.*, 290. In Jastrzebski, the graded-dopant concentration is "decreasing with depth" from the top surface 11 (purple) of the substrate 10, as shown in Figure 1b below. Ex.1010, 5:14-22. Jastrzebski teaches that this downward-sloping graded-dopant concentration creates an electric drift field that "force[s] most of the charge carriers … ***deep into the substrate***[.]" *Id.*, 5:14-22; *id.*, 2:27-32 ("This is done by creating a field, such as a drift field, in the semiconductor substrate to ***sweep minority charge carriers…into the bulk [substrate], away from the electrode-bearing surface of the substrate.***").

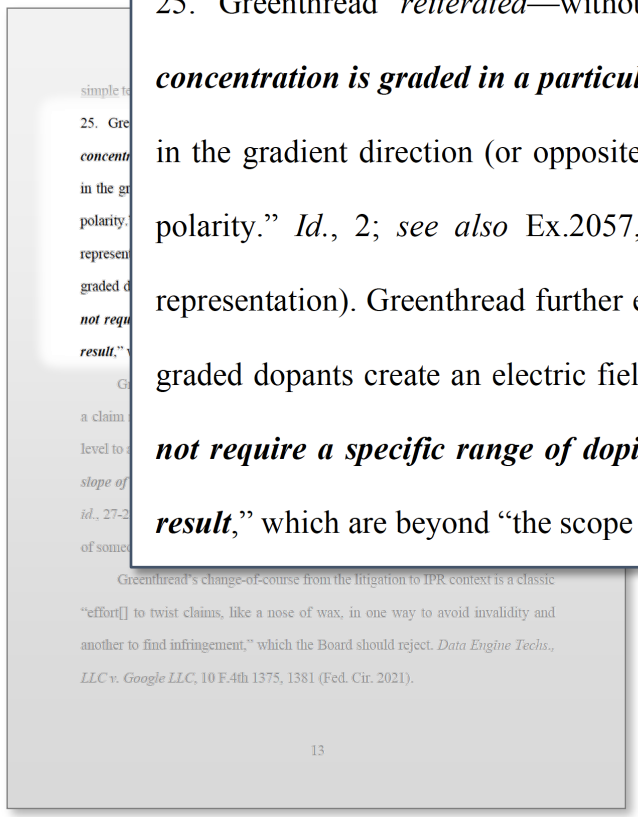


Ex.1010, FIGS. 1a-1b.

-00017: Petition [1] at 22-24

10. Petitioners' Prosecution-Related Arguments are Incorrect

- Greenthread did not say: all "graded dopant concentrations" will move carriers from the "surface layer."
- Greenthread said: the electric field must move the carriers from the surface layer.



25. Greenthread *reiterated*—without qualification—that "***[w]hen the dopant concentration is graded in a particular direction, other charge carriers will move*** in the gradient direction (or opposite direction) depending on the charge carrier's polarity." *Id.*, 2; *see also* Ex.2057, ¶33 (Dr. Glew providing the ***exact same*** representation). Greenthread further explained, "[w]hile the claims require that the graded dopants create an electric field that aids movement of the carriers, they ***do not require a specific range of doping***, a particular doping field, ***or a particular result***," which are beyond "the scope of Dr. Rao's invention." Ex. 1020, 28.

-00017: Pet. Reply [54] at 13

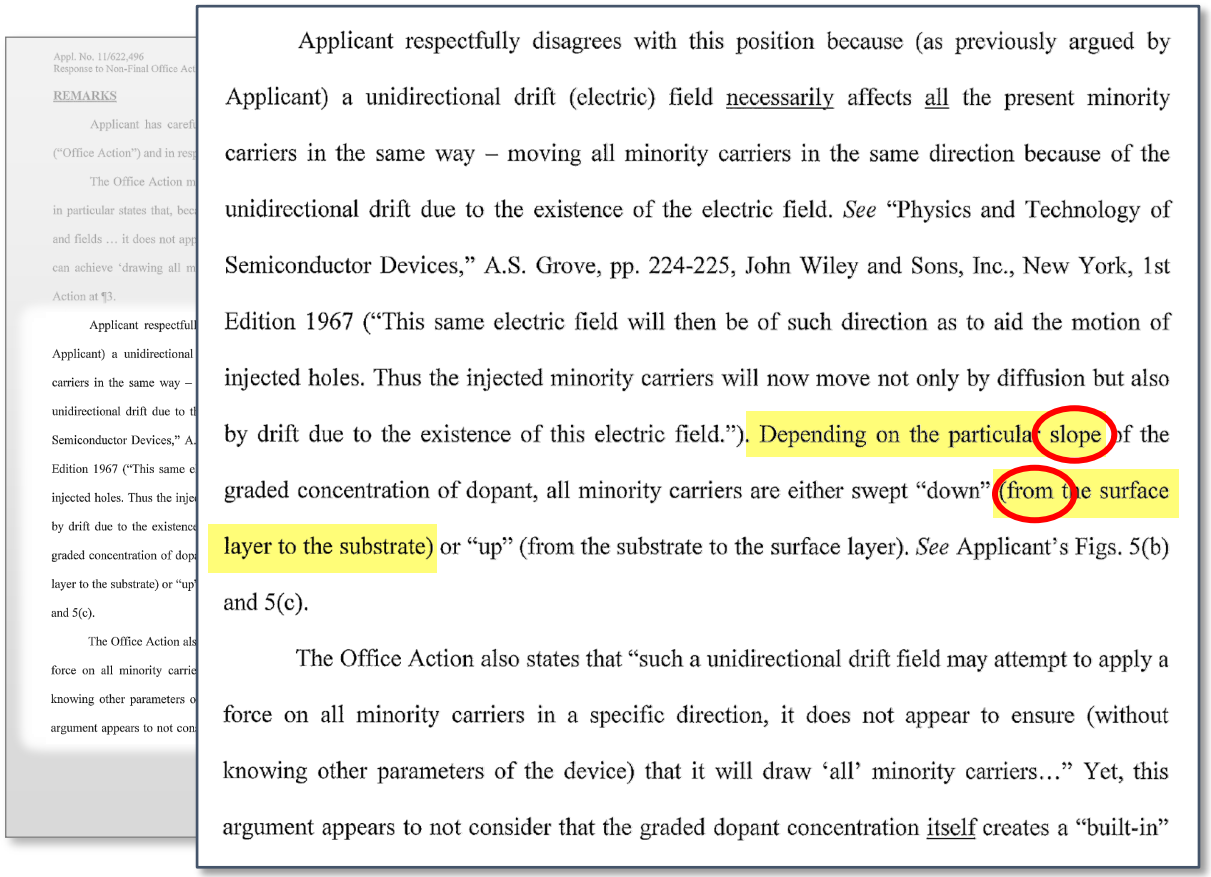
is clear on its face, and the intrinsic record confirms what is claimed. The claim specifies the graded dopants create an electric field that aids movement of the carriers away from the surface layer. Defendants assert that the specification does not provide guidance on how to assess or measure carrier movement. This is not true. The claims and the specification make clear that the electric field must move the carriers in a particular direction (from the surface layer to the substrate). Whether the carrier movement has a particular speed or acceleration is beyond the scope of the claim, as long as it meets the other limitations of the claim.

-00017: Ex. 1020 (Greenthread's Brief) at 29

-00017: PO Resp. [45] at 9-12; PO Sur-Reply [59] at 14-15

10. Petitioners' Prosecution-Related Arguments are Incorrect

- Greenthread did not say: all "graded dopant concentrations" will move carriers from the "surface layer."
- Greenthread said: the electric field must move the carriers from the surface layer.



Applicant respectfully disagrees with this position because (as previously argued by Applicant) a unidirectional drift (electric) field necessarily affects all the present minority carriers in the same way – moving all minority carriers in the same direction because of the unidirectional drift due to the existence of the electric field. *See* "Physics and Technology of Semiconductor Devices," A.S. Grove, pp. 224-225, John Wiley and Sons, Inc., New York, 1st Edition 1967 ("This same electric field will then be of such direction as to aid the motion of injected holes. Thus the injected minority carriers will now move not only by diffusion but also by drift due to the existence of this electric field."). Depending on the particular slope of the graded concentration of dopant, all minority carriers are either swept "down" (from the surface layer to the substrate) or "up" (from the substrate to the surface layer). *See* Applicant's Figs. 5(b) and 5(c).

The Office Action also states that "such a unidirectional drift field may attempt to apply a force on all minority carriers in a specific direction, it does not appear to ensure (without knowing other parameters of the device) that it will draw 'all' minority carriers…" Yet, this argument appears to not consider that the graded dopant concentration itself creates a "built-in"

electrical field that forces the movement of carriers into a particular direction, whereby the "direction" of the electrical field and the resulting direction of the carrier movement depends solely on the slope of the graded concentration of dopant. With regard to the existence of a "built-in" electric field created by a graded dopant density, *see*, e.g., Jastrzebski (US 4,481,522) col. 5, lines 11-13 (cited in Office Action). Applicant respectfully submits that this inherent "built-in" unidirectional electric field is the additional parameter for ensuring that all minority carriers are being moved in one direction and which parameter the Office Action deemed to be missing from the disclosure.

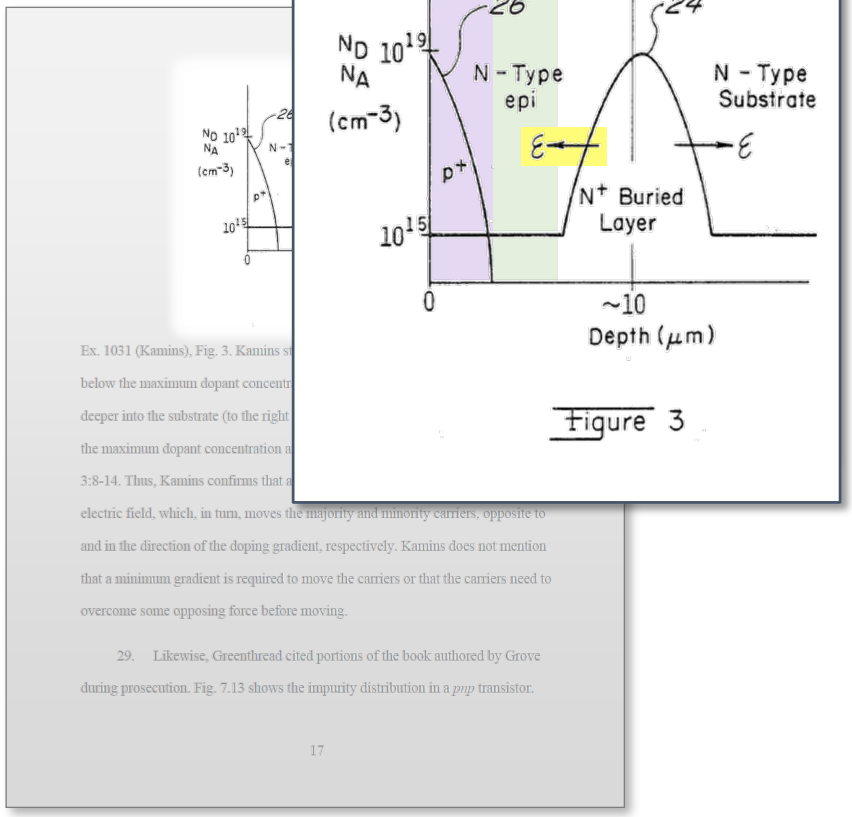
-00017: Ex. 1016 ('195 Prosecution History) at 289-290

-00017: PO Resp. [45] at 9-12; PO Sur-Reply [59] at 14-15

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

10. Petitioners' Prosecution-Related Arguments are Incorrect

- Dr. Banerjee confirmed that a "built in" field cannot move carriers <u>from</u> the "surface," unless it is in the <u>correct location</u> and it points in the <u>correct direction</u>.



Ex. 1031 (Kamins), Fig. 3. Kamins st
below the maximum dopant concentr
deeper into the substrate (to the right
the maximum dopant concentration a
3:8-14. Thus, Kamins confirms that a
electric field, which, in turn, moves the majority and minority carriers, opposite to
and in the direction of the doping gradient, respectively. Kamins does not mention
that a minimum gradient is required to move the carriers or that the carriers need to
overcome some opposing force before moving.

29. Likewise, Greenthread cited portions of the book authored by Grove during prosecution. Fig. 7.13 shows the impurity distribution in a *pnp* transistor.

17

Q. (BY MR. WHITEHURST) So the electric field shown in Figure 3 that points in an upward direction will not aid movement of holes from the surface or the active region to the substrate for two reasons: One, because the electric field does not extend to the surface or the active region; and, two, because holes move in the same direction of the electric field.

Did I get that right?

MR. PAUL: Objection to form. Scope.

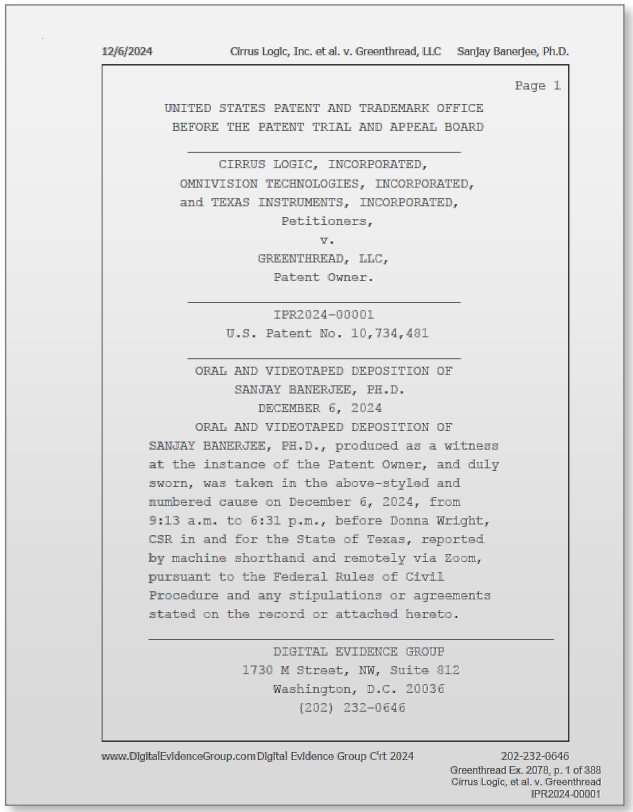
THE WITNESS: Yes, that electric field doesn't extend all the way to the surface. Therefore, there cannot be any drift velocity of the holes due to that electric field.

And, furthermore, even if it did extend to the surface, it points in the wrong direction and will cause the holes to move via drift towards the surface. But, remember, there is always an opposing diffusion part.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 266:4-267:4

10. Petitioners' Prosecution-Related Arguments are Incorrect

- Dr. Banerjee confirmed that in order for an "electric field" to aid movement <u>from</u> the "active region" (or surface layer) you have to know the <u>direction</u> and <u>location</u> of the electric field.



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerjee, Ph.D.

Page 1

UNITED STATES PATENT AND TRADEMARK OFFICE
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Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,481

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Greenthread Ex. 2078, p. 1 of 388
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14 So when you're trying to
15 determine whether an electric field will aid
16 carrier movement from the active region to
17 the substrate, you have to know more than
18 just the direction of the electric field.
19 You also need to know where the electric
20 field starts.
21 Did I get that right?
22 MR. PAUL: Objection to form.
1 THE WITNESS: Yes, you need to
2 know the direction and the spatial
3 location where the electric field is
4 existing in order to determine the
5 drift motion.
6 Q. (BY MR. WHITEHURST) And why do
7 you need to know the specific location of the
8 electric field?

9 A. Because this collective
10 ensemble is the center of gravity, or a part,
11 if you will, of this collective ensemble of
12 holes, it's sensitive to the direction,
13 magnitude, and whether there is a nonzero
14 electric field in that center point of this
15 ensemble, if you will.
16 Q. And I think we agree if the
17 electric field starts or ends below the
18 active region, it will not aid carrier
19 movement from the active region?
20 A. If the electric field isn't
21 present in the active region, it will not aid
22 carrier movement via the drift mechanism for
1 this ensemble of failures in the active
2 region.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 272:14-274:2

10. Petitioners' Prosecution-Related Arguments are Incorrect

- Dr. Banerjee also confirmed that other fields affect the movement of carriers in the surface layer.

How can the gate oxide create a built-in electric field even without an external voltage?

A. A gate oxide can attract charges and that can cause an electric field to be created in the semiconductor channel.

But that's not the subject of this patent. This patent is dealing with built-in electric fields due to doping gradients in the channel.

Q. But you agree that both the gate and the gate oxide can create electric fields in the active region, even when an external voltage is not applied, right?

MR. PAUL: Objection to form.

THE WITNESS: Yeah, the gate and gate oxide can create fields in the channel, even without external voltages.

Q. (BY MR. WHITEHURST) And the electric fields created by the gate and the gate oxide will affect the net electric field, right?

A. Yes. But, once again, that's not the subject matter of these patents.

Q. And you already testified today that the net electric field affects the net movement.

Do you recall that?

MR. PAUL: Objection to form.

THE WITNESS: Yes, electric field does affect net movement.

Q. (BY MR. WHITEHURST) So this means that the electric field created by the gate and the gate oxide will affect the net electric field and the net carrier movement, correct?

MR. PAUL: Objection to form.

THE WITNESS: The gate composition and the gate oxide composition can create built-in electric fields.

Q. (BY MR. WHITEHURST) And you didn't calculate the magnitude for the electric field due to the gate or the gate oxide, did you?

A. No one can, unless you give me specific information.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 222:4-224:7

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. **Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
5. **Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
6. **Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).**
7. **The "movement of carriers" depends on the sum of all of the fields in the "surface layer."**
8. **Petitioners have the burden to analyze all of the fields in the "surface layer."**
9. **Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."**
10. **Petitioners' prosecution-related arguments are incorrect.**
11. **Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.**
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

11. “Brownian Motion” is New Argument

Patent Owner argues Petitioner raises new arguments in its Reply that we should not consider, citing the Federal Circuit’s holding in *Wasica Fin. GmbH v. Cont’l Auto. Sys. Inc.*, 853 F.3d 1272, 1286 (Fed. Cir. 2017), that a petitioner cannot “cure the petition’s deficiencies in its subsequent briefing.” Sur-reply 4. We find this argument persuasive.

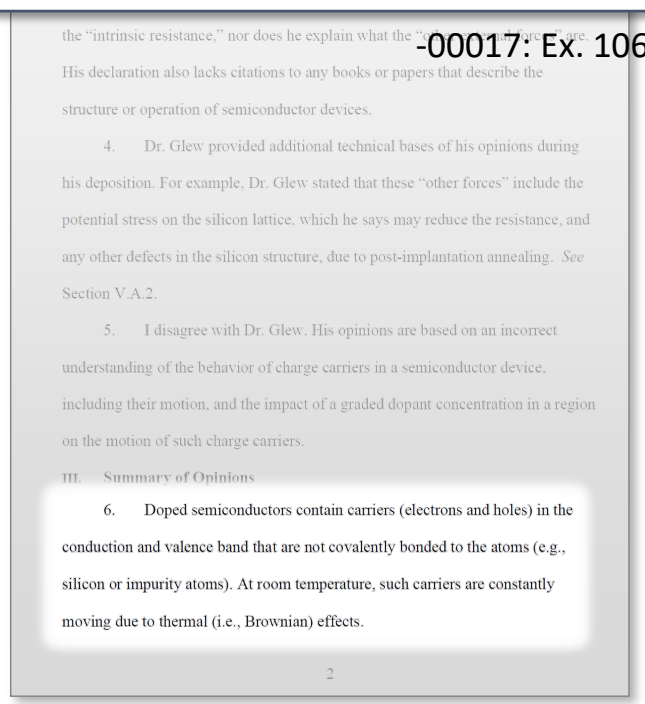
Satco Products, Inc. v. Seoul Semiconductor Co., Ltd., IPR2020-00146, Paper 44 at 20 (PTAB June 25, 2021)

“Brownian Motion” is Not Relevant

- “Brownian Motion” is “random” motion with “zero net displacement.”

6. Doped semiconductors contain carriers (electrons and holes) in the conduction and valence band that are not covalently bonded to the atoms (e.g., silicon or impurity atoms). At room temperature, such carriers are constantly moving due to thermal (i.e., Brownian) effects.

-00017: Ex. 1060 at ¶ 6


the "intrinsic resistance," nor does he explain what the "[illegible]" are.
His declaration also lacks citations to any books or papers that describe the structure or operation of semiconductor devices.

4. Dr. Glew provided additional technical bases of his opinions during his deposition. For example, Dr. Glew stated that these "other forces" include the potential stress on the silicon lattice, which he says may reduce the resistance, and any other defects in the silicon structure, due to post-implantation annealing. *See* Section V.A.2.

5. I disagree with Dr. Glew. His opinions are based on an incorrect understanding of the behavior of charge carriers in a semiconductor device, including their motion, and the impact of a graded dopant concentration in a region on the motion of such charge carriers.

III. Summary of Opinions

6. Doped semiconductors contain carriers (electrons and holes) in the conduction and valence band that are not covalently bonded to the atoms (e.g., silicon or impurity atoms). At room temperature, such carriers are constantly moving due to thermal (i.e., Brownian) effects.

2

19. In an *n*-type silicon, the conduction electrons are essentially free particles because they are not associated with any particular lattice or donor site. Same is true for holes in a *p*-type semiconductor. Though the carriers are bound to the atoms at low temperature, the bonds are very weak and thermal energy breaks the bonds at room temperature. Importantly, these carriers are not stationary, but are constantly moving in random paths, due to thermal effects, in all directions reaching speeds of about 10^7 cm/second at room temperature. (“***The electrons in the semiconductor are therefore moving rapidly in all directions***). Ex.1063 (Sze), p. 48. The “motion of an individual electron may be visualized as a succession of random scattering from collisions with [vibrating] lattice atoms, impurity atoms and other scattering centers,” as illustrated in Fig. 1(a) below (the electron is annotated in blue). Ex. 1063 (Sze), p. 48.

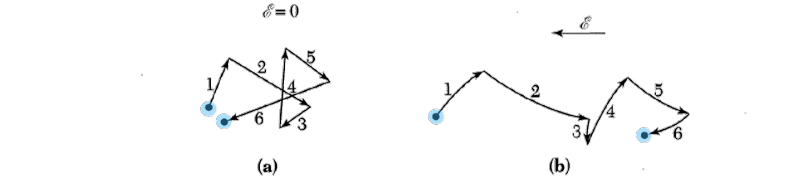


Fig. 1 Schematic path of an electron in a semiconductor. (*a*) Random thermal motion. (*b*) Combined motion due to random thermal motion and an applied electric field.

Ex. 1061 (Sze), 48 (annotated). *See also* Ex. 1062 (Streetman) Fig. 3-20 at 98. The random motion of electrons leads to zero net displacement of a group of electrons over a sufficiently long period of time. The average distance between collisions is called *mean free path*, and the average time between collisions is called *mean free time* τ_c. Ex. 1061 (Sze), 48. *See also* Ex. 1062 (Streetman) at 98-99.

-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 19

11. “Brownian Motion” is Not Relevant

- “Brownian Motion” is “random thermal motion.”

Q. Can we refer to this as random thermal motion?
A. Yes.
Q. Can we refer to this as Brownian motion?
A. Yes.
Q. Can we refer to this as random motion?
A. Yes, a random thermal motion.

SANJAY BANERJEE, PH.D., produced as a witness at the instance of the [illegible], duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
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-00017: Ex. 2078 at 196:3-11

Q. And shown here in Figure 1(a), we see this random motion going from one to two to three to four to five to six.
Do you see that?
A. Yes.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 197:16-20

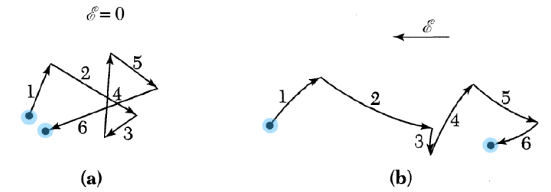


Fig. 1 Schematic path of an electron in a semiconductor. (*a*) Random thermal motion. (*b*) Combined motion due to random thermal motion and an applied electric field.

-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 19

11. "Brownian Motion" is Not Relevant

- The claims require "carrier movement" <u>from</u> the "surface layer," <u>not</u> "random thermal motion."

US 8,421,195

1. A CMOS Semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of said surface layer;
a single drift layer disposed between the other surface of said surface layer and said substrate, said drift layer having a graded concentration of dopants extending between said surface layer and said substrate, said drift layer further having a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and
at least one well region disposed in said single drift layer, said well region having a graded concentration of dopants and a second static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate.

-00017: Ex. 1001 ('195 pat.) at 4:13-29

US 9,190,502

7. A semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of said surface layer;
a single drift layer disposed between the other surface of said surface layer and said substrate, said drift layer having a graded concentration of dopants generating a first static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate; and
at least one well region disposed in said single drift layer, said well region having a graded concentration of dopants generating a second static unidirectional electric drift field to aid the movement of minority carriers from said surface layer to said substrate.

-00018: Ex. 1001 ('502 pat.) at 4:52-67

US 11,121,222

44. A CMOS Semiconductor device comprising:
a surface layer;
a substrate;
an active region including a source and a drain, disposed on one surface of the surface layer;
a single drift layer disposed between the other surface of the surface layer and the substrate, the drift layer having a graded concentration of dopants extending between the surface layer and the substrate, the drift layer further having a first static unidirectional electric drift field to aid the movement of carriers from the surface layer to an area of the substrate where there are no active regions; and
at least one well region disposed in the single drift layer, the well region having a graded concentration of dopants and a second static unidirectional electric drift field to aid the movement of carriers from the surface layer to the area of the substrate where there are no active regions.

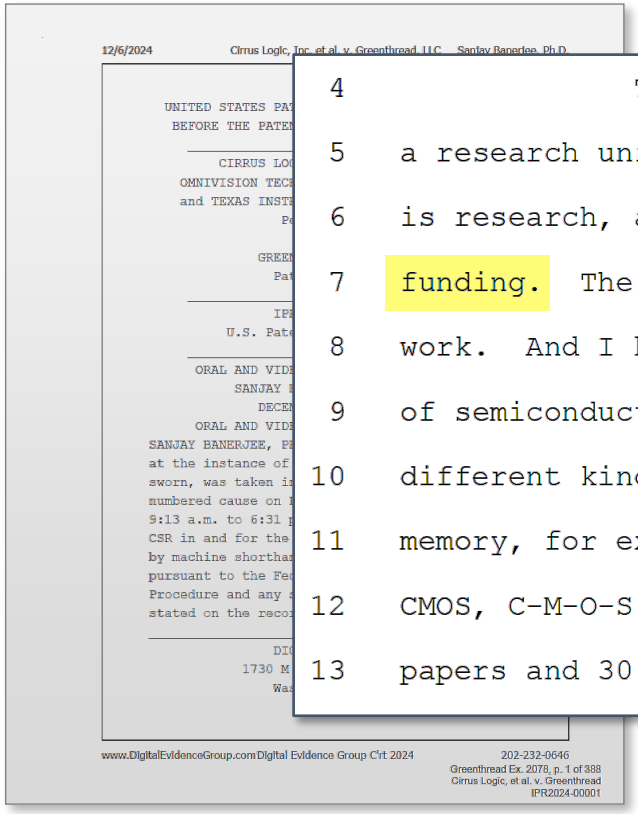
-00021: Ex. 1001 ('222 pat.) at 8:21-39

Overview of Issues

1. **The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.**
2. **The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."**
3. **Dr. Banerjee confirmed the "electric field" must start in the "surface layer."**
4. **Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
5. **Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."**
6. **Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).**
7. **The "movement of carriers" depends on the sum of all of the fields in the "surface layer."**
8. **Petitioners have the burden to analyze all of the fields in the "surface layer."**
9. **Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."**
10. **Petitioners' prosecution-related arguments are incorrect.**
11. **Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.**
12. **Dr. Banerjee's credibility issues**
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

12. Dr. Banerjee's Relationship with Petitioner TI

- Dr. Banerjee depends on research funding from private companies for his career advancement.
- To him, this is "more important than being a good teacher."



4 The main role of a professor in
5 a research university, as you probably know,
6 is research, actually bringing in research
7 funding. The graduate students do the hard
8 work. And I have worked on different kinds
9 of semiconductor devices, transistors,
10 different kinds of memories, including flash
11 memory, for example, other kinds of memory,
12 CMOS, C-M-O-S. I believe I have over 1,200
13 papers and 30 patents on these topics.

-00017: Ex. 2078 at 29:4-13

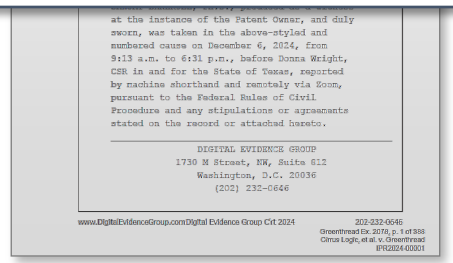
18 When did you -- when did it
19 become part of your job to secure research
20 funding?
21 A. From day one. I mean, if you
22 do not bring in research funding, you do not
1 get tenure at research universities. They
2 kick you out in six years. So that's
3 probably more important than being a good
4 teacher.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 29:18-30:4

12. Dr. Banerjee's Relationship with Petitioner TI

- Dr. Banerjee has two active private industry grants.
- Only one was disclosed to the Board on his CV.

13 Q. What other companies besides
14 Intel have you received directed funding
15 from?
16 A. I currently have direct funding
17 from Texas Instruments, Samsung. I think
18 currently those are the only two that are
19 active.

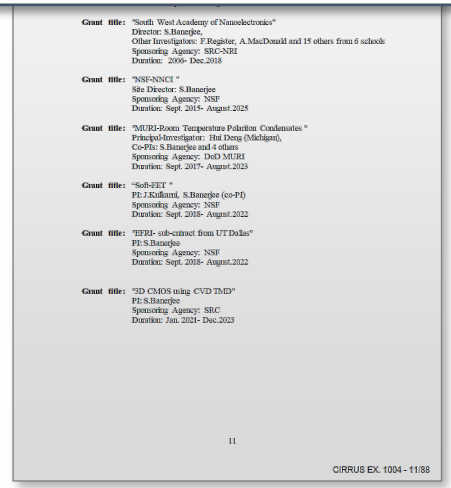

at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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IPR2024-00001

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 44:13-19

Grant title: "NSF-NNCI "
Site Director: S.Banerjee
Sponsoring Agency: NSF
Duration: Sept. 2015- August.2025


Grant title: "South West Academy of Nanoelectronics"
Director: S.Banerjee,
Other Investigators: T.Register, A.MacDonald and 15 others from 6 schools
Sponsoring Agency: SRC-NRI
Duration: 2006- Dec.2018

Grant title: "NSF-NNCI "
Site Director: S.Banerjee
Sponsoring Agency: NSF
Duration: Sept. 2015- August.2025

Grant title: "MURI-Room Temperature Pollution Condensates "
Principal-Investigator: Hui Deng (Michigan),
Co-PIs: S.Banerjee and 4 others
Sponsoring Agency: DoD MURI
Duration: Sept. 2017- August.2023

Grant title: "Soft-EET "
PI: J.Kolliamil, S.Banerjee (co-PI)
Sponsoring Agency: NSF
Duration: Sept. 2018- August.2022

Grant title: "EFRI- sub-cntract from UT Dallas"
PI: S.Banerjee
Sponsoring Agency: NSF
Duration: Sept. 2018- August.2022

Grant title: "3D CMOS using CVD TMD"
PI: S.Banerjee
Sponsoring Agency: SRC
Duration: Jan. 2021- Dec.2023

11

CIRRUS EX. 1004 - 11/88

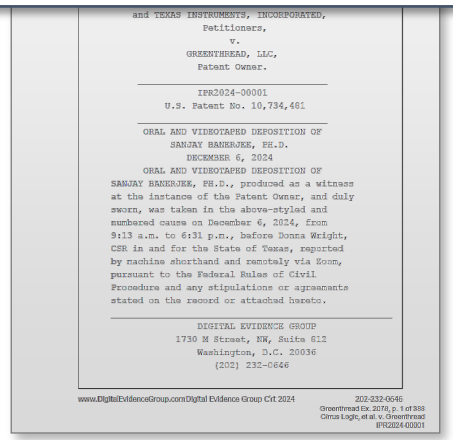
-00017: Ex. 1004 (Banerjee CV) at pg. 11

12. Dr. Banerjee's Relationship with Petitioner TI

- Dr. Banerjee has received substantial funding from Texas Instruments and plans to pursue more.

10 I got funding from Texas
11 Instruments. In fact, I have funding from
12 them now. I probably got funding from
13 Samsung. In the past, I had funding from
14 Micron, Intel. I'm trying to think. I think
15 those are some of the immediate ones.

-00017: Ex. 2078 at 37:10-15



and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,461

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

ORAL AND VIDEOTAPED DEPOSITION OF SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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Cirrus Logic, et al. v. Greenthread
IPR2024-00001

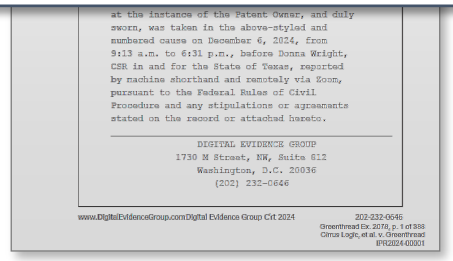
11 Q. So you are currently receiving
12 funding from Texas Instruments?
13 A. That's correct.
14 Q. And what is Texas Instruments'
15 funding you to do?
16 A. Work on transistors, thin film
17 transistors, the modeling of them.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 46:11-17

12. Dr. Banerjee's Relationship with Petitioner TI

- Dr. Banerjee has received substantial funding from Texas Instruments and plans to pursue more.

22 Q. (BY MR. WHITEHURST) When did
1 Texas Instruments begin funding you?
2 A. This latest financial funding
3 started, I think, in April of this year.
4 Q. And how much have they paid you
5 since April of this year?
6 A. It's a small amount, something
7 like $90,000; 80-, 90,000.


at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

-00017: Ex. 2078 at 46:22-47:7

15 Q. Are you hoping to get future
16 funding from TI?
17 A. I'm always hoping to get
18 funding from everybody.
19 Q. And why are you hoping to get
20 funding from everybody?
21 A. That's how you pay your
22 graduate students, your postdoctoral fellows.
1 Your lab collapses if you don't have money.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 49:15-50:1

12. Dr. Banerjee's Relationship with Petitioner TI

- Texas Instruments is joined as a Petitioner in 4 out of 7 IPR proceedings involving Cirrus Logic/OmniVision.

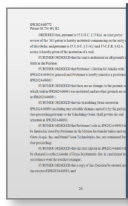
CIRRUS LOGIC, INC.;
OMNIVISION TECHNOLOGIES, INC.; AND
TEXAS INSTRUMENTS INCORPORATED,
Petitioner,

v.

GREENTHREAD, LLC,
Patent Owner.

IPR2024-00017*
Patent 10,734,195 B2

-00017: Paper 52, pg. 15



FURTHER ORDERED that the case caption in IPR2024-00001 shall be changed to reflect joinder of Texas Instruments, Inc. as a petitioner in accordance with the attached example;

-00001: Paper 52, pg. 20



FURTHER ORDERED that the case caption in IPR2024-00017 shall be changed to reflect joinder of Texas Instruments Incorporated as a petitioner in accordance with the attached example;

-00017: Paper 52, pg. 13



FURTHER ORDERED that the case caption in IPR2024-00018 shall be modified to reflect Petitioner's joinder in accordance with the attached example.

-00018: Paper 51, pg. 18



FURTHER ORDERED that the case caption in IPR2024-00019 shall be changed to reflect joinder of Texas Instruments Incorporated as a petitioner in accordance with the attached example;

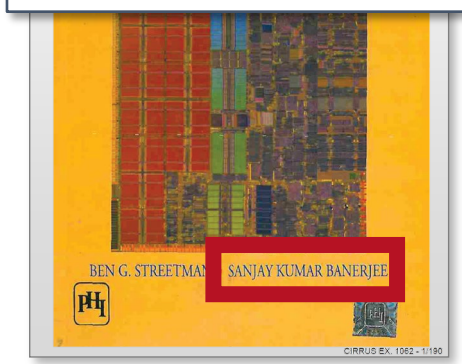
-00019: Paper 51, pg. 21

12. Dr. Banerjee's Relationship with Petitioner TI

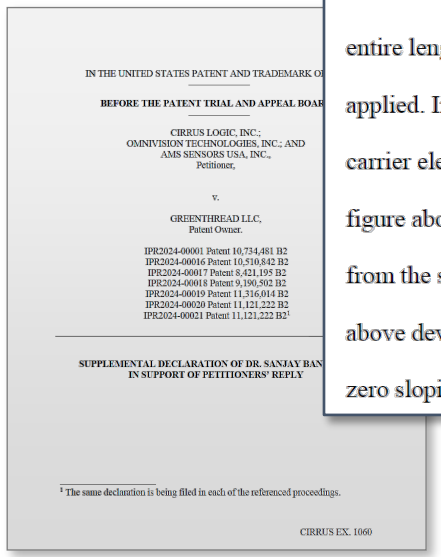
- Dr. Banerjee's current opinions are inconsistent with his earlier 2005 textbook.

If an electric field $\mathscr{E}_x$ is applied in the x-direction, each electron experiences a net force $-q\mathscr{E}_x$ from the field. This force may be insufficient to alter appreciably the random path of an individual electron; the effect when averaged over all the electrons, however, is a net motion of the group in the $-x$-direction (Fig. 3-20b). If p_x is the x-component of the total momentum of the group, the force of the field on the n electrons/cm^3 is

$$-nq\mathscr{E}_x = \left.\frac{dp_x}{dt}\right|_{\text{field}} \qquad (3\text{-}29)$$



-00017: Ex. 1062A (Streetman & Banerjee Textbook) at 99

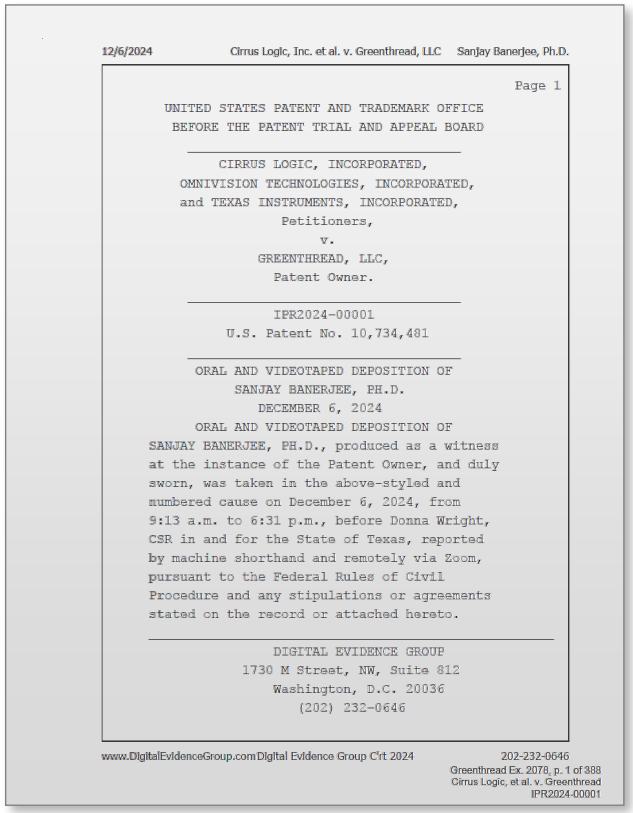


25. Of course, in the absence of *externally* applied voltages or electric field, there cannot be any *net* movement of either the electrons or holes. Thus, in this case, the diffusion of carriers in one direction *must* be counterbalanced by movement of carriers in the opposite direction. Such a movement is called ***drift***, which occurs due to the static electric field Ɛ shown by the red arrow. The static electric field Ɛ is self-generated due to the decrease in the acceptor impurity concentration from the surface into the substrate. The electric field Ɛ spans the entire length for which the slope is monotonically decreasing and is not *externally* applied. In the figure above, the electric field Ɛ will aid the movement of minority carrier electrons from the surface to the substrate (depicted as Electron Drift in figure above, and—conversely will aid the movement of majority carrier holes from the substrate to the surface (depicted as Hole Drift in figure above). In the above device, ***carrier drift will necessarily occur*** by virtue of the graded (i.e., non-zero sloping) dopant concentration, and the resulting electric field Ɛ. Ex. 1061

-00017: Ex. 1060 (Banerjee Supp. Decl.) at ¶25

12. Improper Witness Coaching

- Dr. Banerjee agreed that coaching during breaks is not allowed.



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerjee, Ph.D.

Page 1

UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INCORPORATED,
OMNIVISION TECHNOLOGIES, INCORPORATED,
and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,481

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024
ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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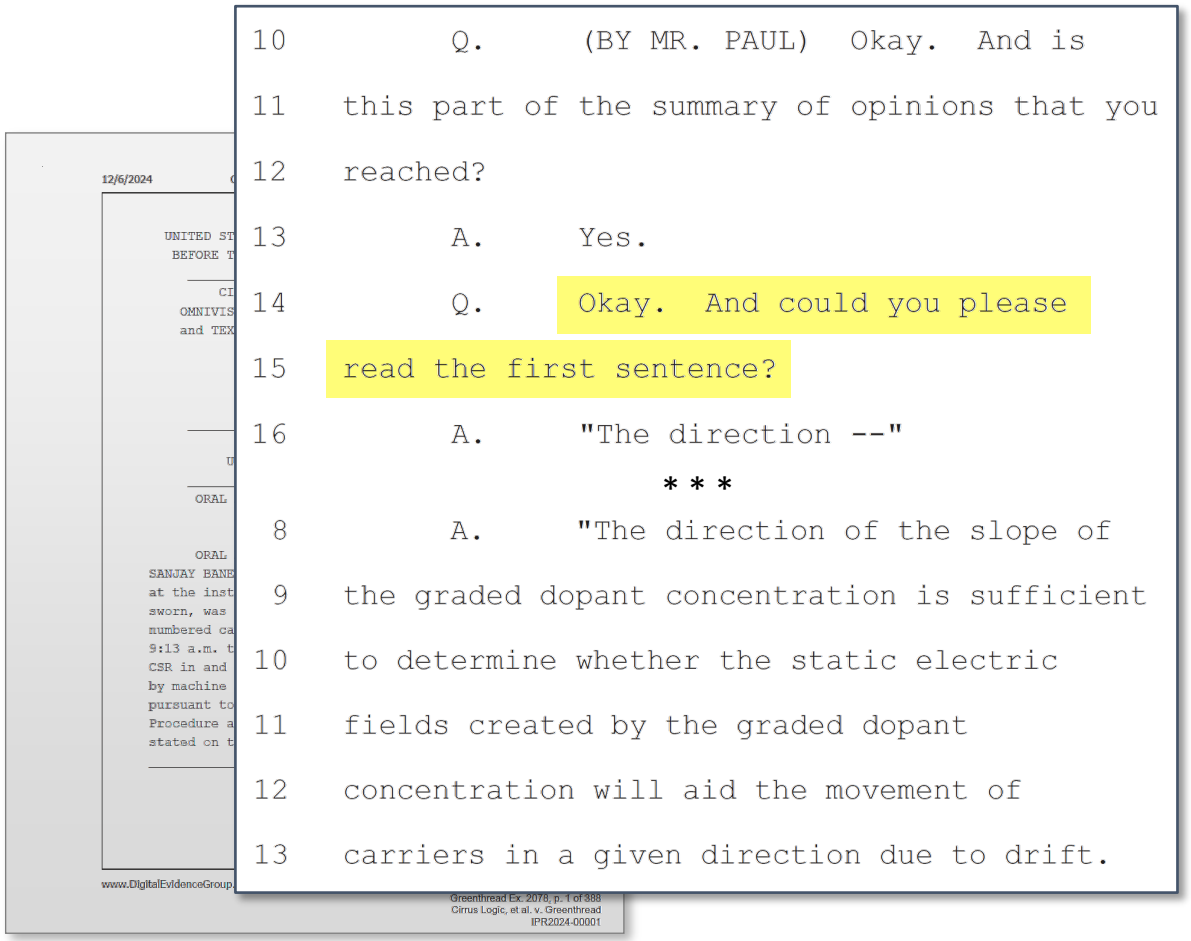
Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

12 Q. So you know how the procedure
13 works. I'm not going to go over all of that
14 now. But you know that under the rules for
15 these IPR proceedings, you're not allowed to
16 talk to anybody during the breaks about your
17 testimony.
18 Do you understand that rule?
19 A. Yes.
20 Q. And do you intend to comply
21 with that rule today?
22 A. Yes.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 7:12-22

12. Improper Witness Coaching

- After cross examination, Petitioners' counsel asked a series of leading questions to elicit "yes" or "no" answers.



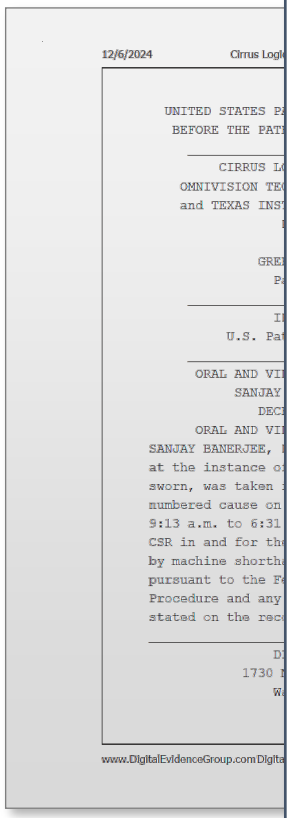
10 Q. (BY MR. PAUL) Okay. And is
11 this part of the summary of opinions that you
12 reached?
13 A. Yes.
14 Q. Okay. And could you please
15 read the first sentence?
16 A. "The direction --"
* * *
8 A. "The direction of the slope of
9 the graded dopant concentration is sufficient
10 to determine whether the static electric
11 fields created by the graded dopant
12 concentration will aid the movement of
13 carriers in a given direction due to drift.

14 The carriers (holes or electrons) in the
15 conduction band are in constant motion, and
16 the static electric field causes them to
17 drift. At equilibrium (i.e., when the device
18 is off), there cannot be a net movement of
19 carriers. As a result, the movement of
20 carriers due to drift in one direction is
21 compensated by diffusion of those carriers in
22 the opposite direction."
1 Q. And do you agree with the --
2 are these your opinions?
3 A. Yes.
4 Q. And do you stand by them?

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 313:10-16; 314:8-315:4

12. Improper Witness Coaching

- Dr. Banerjee testified that he conferred with four attorneys during the 40-minute break.



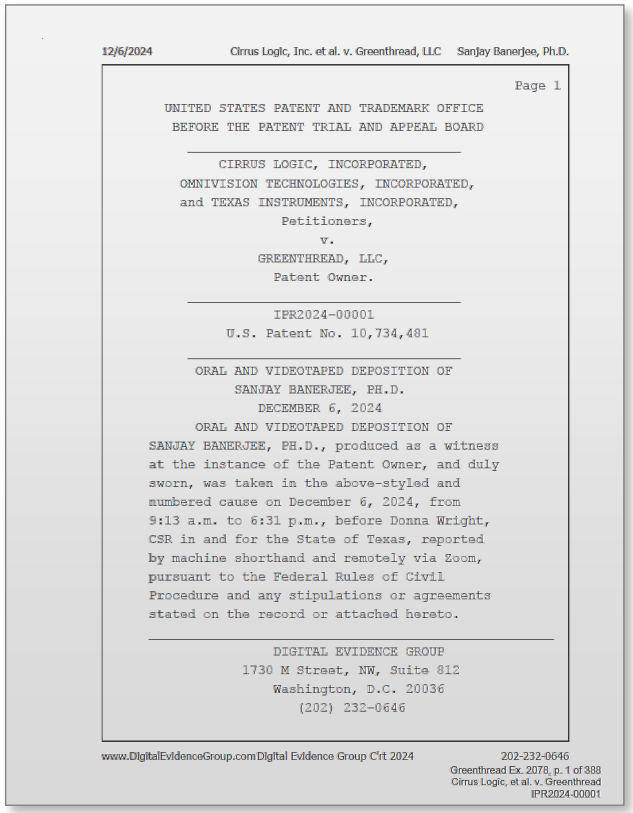
17 Q. I don't normally do this, but
18 this is rather extraordinary. You and your
19 attorneys took a 40-minute break. During
20 that 40-minute break, at any time did you
21 meet with any of the attorneys or other
22 persons sitting at the table with you now?
1 A. Yes.
2 Q. Which of the attorneys sitting
3 at the table did you meet with during the
4 40-minute break? If you can please identify
5 them by name on the record.
6 A. I met with counsel, Raj Paul
7 and Anupam Sharma, and I believe Kent Cooper
8 was also there and Emre.

9 Q. Did you speak with anybody on
10 the phone?
11 A. I did not.
12 Q. Did you speak with anybody
13 other than the attorneys sitting at the table
14 with you?
15 A. I did not.
16 Q. Did you meet with the four
17 attorneys -- how many attorneys did you meet
18 with?
19 A. I believe there are four in the
20 room.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 337:17-338:20

12. Improper Witness Coaching

- Dr. Banerjee testified that he conferred with four attorneys during the 40-minute break.



12/6/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerjee, Ph.D.

Page 1

UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INCORPORATED,
OMNIVISION TECHNOLOGIES, INCORPORATED,
and TEXAS INSTRUMENTS, INCORPORATED,
Petitioners,
v.
GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001
U.S. Patent No. 10,734,481

ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

ORAL AND VIDEOTAPED DEPOSITION OF SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure and any stipulations or agreements stated on the record or attached hereto.

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9 Q. What's your best approximation
10 of how long you met with the attorneys during
11 the 40-minute break?
12 MR. PAUL: Objection to the
13 relevance of this.
14 THE WITNESS: Probably 20
15 minutes or so because I took a bio
16 break, Raj Paul took a bio break. And
17 for some time, I was walking around in
18 the corridor and they were talking
19 amongst themselves. So maybe half the
20 time.

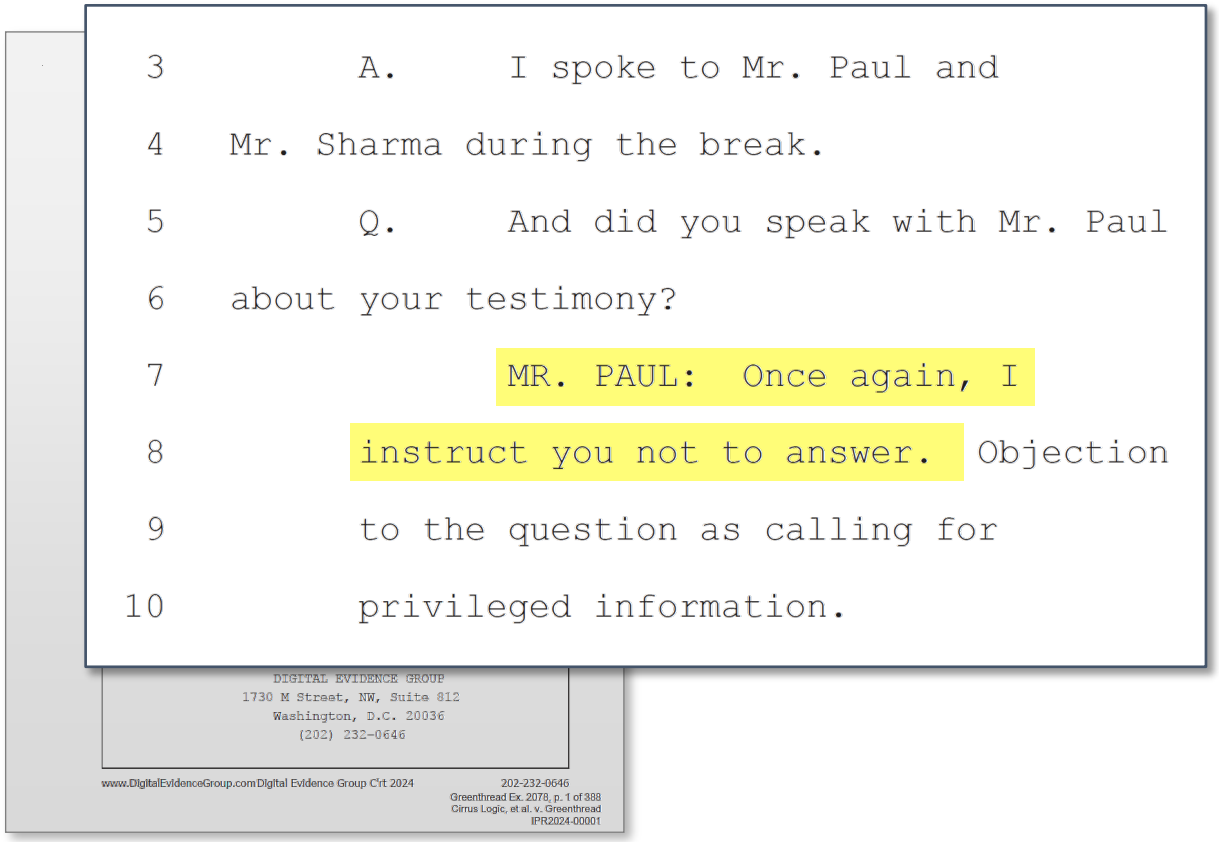
-00017: Ex. 2078 (Banerjee Dep. Tr.) at 339:9-20

-00017: PO Sur-Reply [59] at 14

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

12. Improper Witness Coaching

- Dr. Banerjee was instructed not to answer questions regarding his discussions with the four attorneys during the 40-minute break.



A. I spoke to Mr. Paul and Mr. Sharma during the break.

Q. And did you speak with Mr. Paul about your testimony?

MR. PAUL: Once again, I instruct you not to answer. Objection to the question as calling for privileged information.

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Q. (BY MR. WHITEHURST) Dr. Banerjee, are you going to follow your attorney's advice?

A. Yes.

Q. And you are going to refuse to answer my question whether you spoke with Mr. Paul about your testimony?

A. I'm going to follow my attorney's advice.

-00017: Ex. 2078 (Banerjee Dep. Tr.) at 344:3-19

12. Improper Witness Coaching

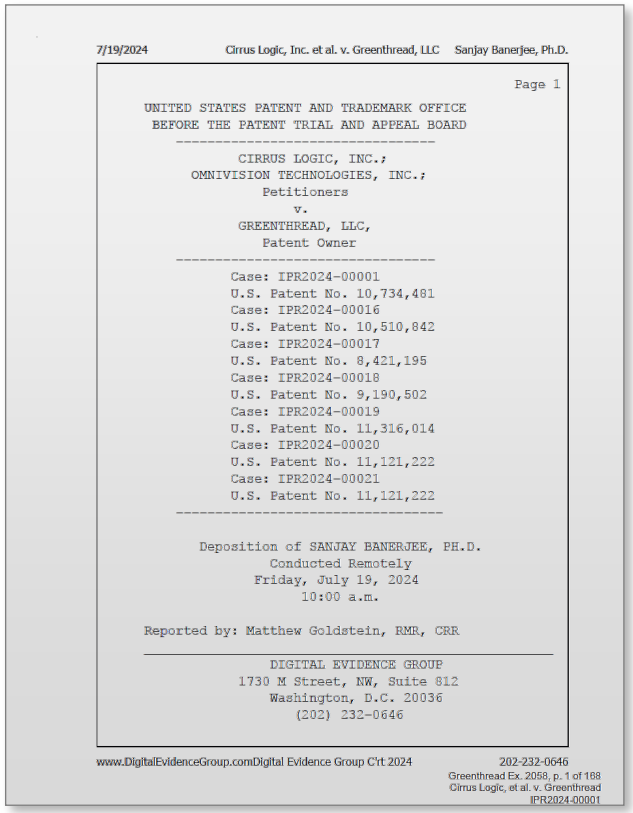


"In general, there are problems associated with off-the-record discussions between counsel for a party and a witness testifying on behalf of a party taking place during any recess after conclusion of cross-examination and before and redirect. … There are inherent difficulties for an opponent to uncover the nature of any conversation during a recess. As a result, ***when recess conversations occur a party runs a risk that the Board may find that there was witness coaching and may exclude or give little, or no, weight to the testimony of a coached witness***."

Flir Systems, Inc. v. Leak Surveys, Inc., IPR2014-00411, Paper 45 at 7 (PTAB Feb. 10, 2015)

12. Petitioners' Replicated Expert Declaration

- Dr. Banerjee testified that he was unsure if the Board could determine his contributions to his own declaration.



7/19/2024 Cirrus Logic, Inc. et al. v. Greenthread, LLC Sanjay Banerjee, Ph.D.

Page 1

UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INC.;
OMNIVISION TECHNOLOGIES, INC.;
Petitioners
v.
GREENTHREAD, LLC,
Patent Owner

Case: IPR2024-00001
U.S. Patent No. 10,734,481
Case: IPR2024-00016
U.S. Patent No. 10,510,842
Case: IPR2024-00017
U.S. Patent No. 8,421,195
Case: IPR2024-00018
U.S. Patent No. 9,190,502
Case: IPR2024-00019
U.S. Patent No. 11,316,014
Case: IPR2024-00020
U.S. Patent No. 11,121,222
Case: IPR2024-00021
U.S. Patent No. 11,121,222

Deposition of SANJAY BANERJEE, PH.D.
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Friday, July 19, 2024
10:00 a.m.

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IPR2024-00001

11 When the judges read paragraph 71 of
12 your declaration, how are they to know which
13 portions you have verified and which portions you
14 have not verified and instead relied on your
15 attorneys for?

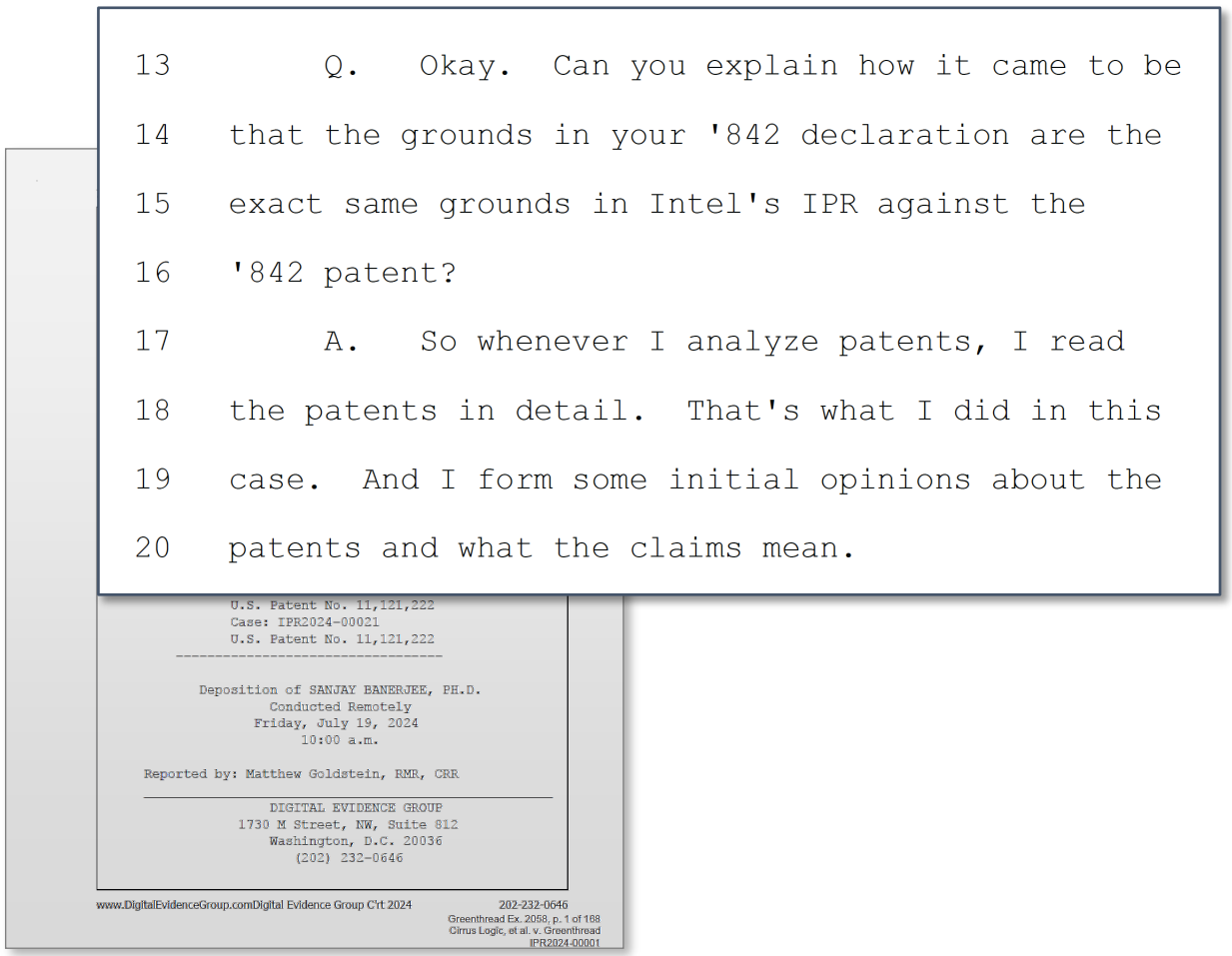
* * *

18 Q. And I would remind you, sir, that you
19 are under oath.
20 A. I don't know how they could tell. As
21 far as technical opinions regarding the validity
22 of the claims, I do stand by those opinions. I
1 think that's most important.

-00017: Ex. 2058 (Banerjee Dep. Tr.) at 125:11-126:1

12. Petitioners' Replicated Expert Declaration

- Dr. Blalock admitted to replicating Dr. Travis Blalock's prior report.



13 Q. Okay. Can you explain how it came to be
14 that the grounds in your '842 declaration are the
15 exact same grounds in Intel's IPR against the
16 '842 patent?
17 A. So whenever I analyze patents, I read
18 the patents in detail. That's what I did in this
19 case. And I form some initial opinions about the
20 patents and what the claims mean.

U.S. Patent No. 11,121,222
Case: IPR2024-00021
U.S. Patent No. 11,121,222

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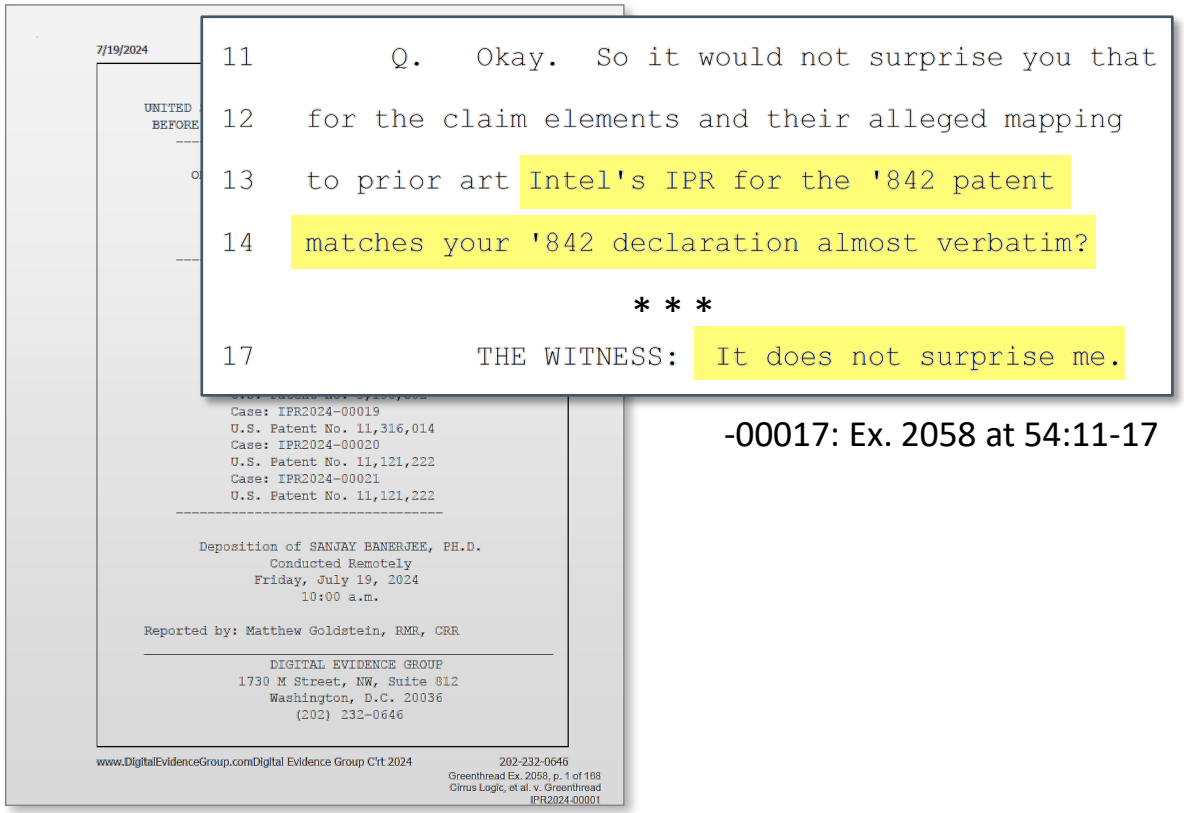
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21 And in this case, the attorneys had
22 given me copies of the cited prior art. So I read
1 through those in detail, also. And I formed my
2 opinion about the validity or invalidity of the
3 various claims in the '842 patent. And that's
4 what's captured in my report.
5 I was given a copy of the Blalock
6 report. I reviewed that. And I saw that in this
7 case, I believe many or all of my conclusions were
8 consistent with what Dr. Blalock had written. So
9 that's why I didn't see any point in reinventing
10 the wheel. So that's why there's similarities.

-00017: Ex. 2058 (Banerjee Dep. Tr.) at 53:13-54:10

12. Petitioners' Replicated Expert Declaration

- Dr. Banerjee was not surprised that his "analysis" matches the previous declaration almost verbatim.
- The two declarations include substantially identical excerpts.



7/19/2024

UNITED
BEFORE

Case: IPR2024-00019
U.S. Patent No. 11,316,014
Case: IPR2024-00020
U.S. Patent No. 11,121,222
Case: IPR2024-00021
U.S. Patent No. 11,121,222

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11 Q. Okay. So it would not surprise you that
12 for the claim elements and their alleged mapping
13 to prior art Intel's IPR for the '842 patent
14 matches your '842 declaration almost verbatim?

* * *

17 THE WITNESS: It does not surprise me.

-00017: Ex. 2058 at 54:11-17

13 Q. Okay. Well, if we were to do a
14 line-by-line comparison here, would it surprise
15 you to find substantially identical lines and
16 sentences in paragraphs in Dr. Blalock's
17 declarations and your declarations?

* * *

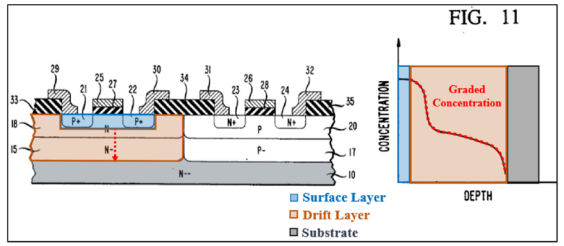
19 THE WITNESS: No, it did not surprise
20 me. Just as I told you, I read the patents, I
21 read the prior art, came to my opinions, then I
22 read Dr. Blalock's report and I agreed with any or
1 all of the statements he made in his reports. I
2 did not -- I saw no point in, you know,
3 reinventing the wheel and new language. So
4 wherever it was appropriate, I incorporated
5 sentences or paragraphs.

-00017: Ex. 2058 (Banerjee Dep. Tr.) at 57:13-58:5

12. Petitioners' Replicated Expert Declaration

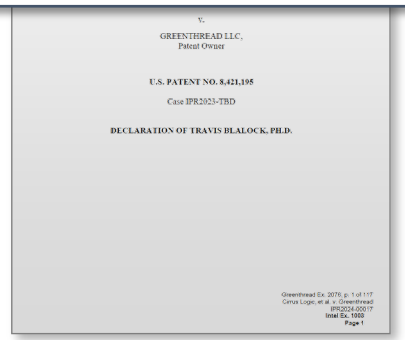
- Dr. Banerjee's declaration essentially matches the prior expert's declaration.

94. In my opinion, Payne discloses or, at a minimum, renders obvious this element. As shown below, Payne's single drift layer (tan) has a downward-sloping graded-dopant concentration extending between the surface layer (blue) and the substrate (grey). Section X.A.1.e.



Ex. 1005, FIGS. 10-11.

95. Payne's downward-sloping graded-dopant concentration aids the movement of minority carriers from the surface layer to the substrate to the same extent to which Applicant relied on the prior art and admitted to the Patent Office that such carrier movement would occur under the same scenario. During


v.
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Patent Owner
U.S. PATENT NO. 8,421,195
Case IPR2023-TBD
DECLARATION OF TRAVIS BLALOCK, PH.D.

prosecution, Applicant represented to the Patent Office that a downward-sloping graded-dopant concentration was known in the prior art to create an "inherent 'built-in' unidirectional electric field" that moves carriers deep into the substrate (while an upward-sloping concentration, not at issue in Payne, would move those carriers in the opposite direction towards the surface):

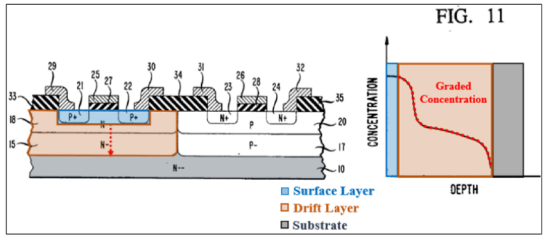
> [T]he graded dopant concentration itself creates a ***'built-in' electrical field*** that forces the movement of carriers into a particular direction, whereby ***the 'direction' of the electrical field and the resulting direction of the carrier movement depends solely on the slope of the graded concentration of dopant.***

Ex. 1002, 289-290 (underlining in original).

96. Applicant further represented that "a unidirectional drift (electric) field necessarily affects ***all*** the present minority carriers in the same way…. Depending on the particular slope of the graded concentration of dopant, ***all*** minority carriers are either ***swept*** 'down' … or 'up…'" Ex. 1002, 289. Applicant cited Jastrzebski in support. *Id.*, 290. In Jastrzebski, the graded-dopant concentration is "decreasing with depth" from the top surface 11 (purple) of the substrate 10, as shown in Figure 1b below. Ex. 1010, 5:14-22.

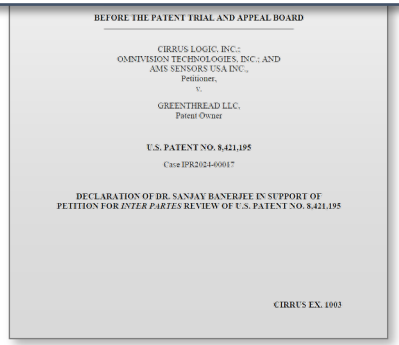
-00017: Ex. 2076 (Prior Blalock Decl.) at ¶¶ 94-96

94. In my opinion, Payne discloses or, at a minimum, renders obvious this element. As shown below, Payne's single drift layer (tan) has a downward-sloping graded-dopant concentration extending between the surface layer (blue) and the substrate (grey). Section X.A.1.e.



Ex. 1005, FIGS. 10-11.

95. Payne's downward-sloping graded-dopant concentration aids the movement of minority carriers from the surface layer to the substrate to the same extent to which Applicant relied on the prior art and admitted to the Patent Office that such carrier movement would occur under the same scenario. During


BEFORE THE PATENT TRIAL AND APPEAL BOARD
CIRRUS LOGIC, INC.;
OMNIVISION TECHNOLOGIES, INC.; AND
AMS SENSORS USA INC.,
Petitioner,
v.
GREENTHREAD LLC,
Patent Owner
U.S. PATENT NO. 8,421,195
Case IPR2024-00017
DECLARATION OF DR. SANJAY BANERJEE IN SUPPORT OF
PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 8,421,195
CIRRUS EX. 1003

prosecution, Applicant represented to the Patent Office that a downward-sloping graded-dopant concentration was known in the prior art to create an "inherent 'built-in' unidirectional electric field" that moves carriers deep into the substrate (while an upward-sloping concentration, not at issue in Payne, would move those carriers in the opposite direction towards the surface):

> [T]he graded dopant concentration itself creates a ***'built-in' electrical field*** that forces the movement of carriers into a particular direction, whereby ***the 'direction' of the electrical field and the resulting direction of the carrier movement depends solely on the slope of the graded concentration of dopant.***

Ex. 1002, 289-290 (underlining in original).

96. Applicant further represented that "a unidirectional drift (electric) field necessarily affects ***all*** the present minority carriers in the same way…. Depending on the particular slope of the graded concentration of dopant, ***all*** minority carriers are either swept 'down' … or 'up…'" Ex. 1002, 289. Applicant cited Jastrzebski in support. *Id.*, 290. In Jastrzebski, the graded-dopant concentration is "decreasing with depth" from the top surface 11 (purple) of the substrate 10, as shown in Figure 1b below. Ex. 1010, 5:14-22.

-00017: Ex. 1003 (Banerjee Decl.) at ¶¶ 94-96

12. Petitioners' Replicated Expert Declaration

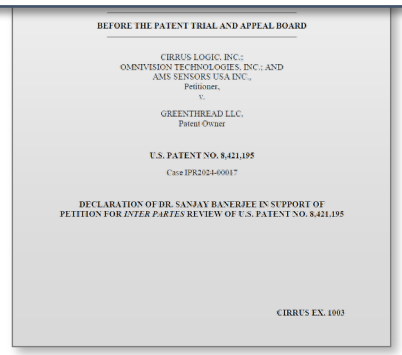
- Dr. Banerjee even copied minute details from the prior declaration.
- Dr. Banerjee allegedly conducted the exact same "internet search" as Dr. Blalock.

69. *Silicon Processing For The VLSI Era* by Stanley Wolf is a four volume textbook related to semiconductor devices, with particular focus on CMOS devices. Exs. 1008A-D. I am familiar with the Wolf textbook. An internet search for this textbook title limited to the ".edu" domain yields over 800 results. Thus, it is clearly used as a teaching resource in engineering courses in many, many universities and is widely cited in scientific works.


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-00017: Ex. 2076 (Prior Blalock Decl.) at ¶ 69

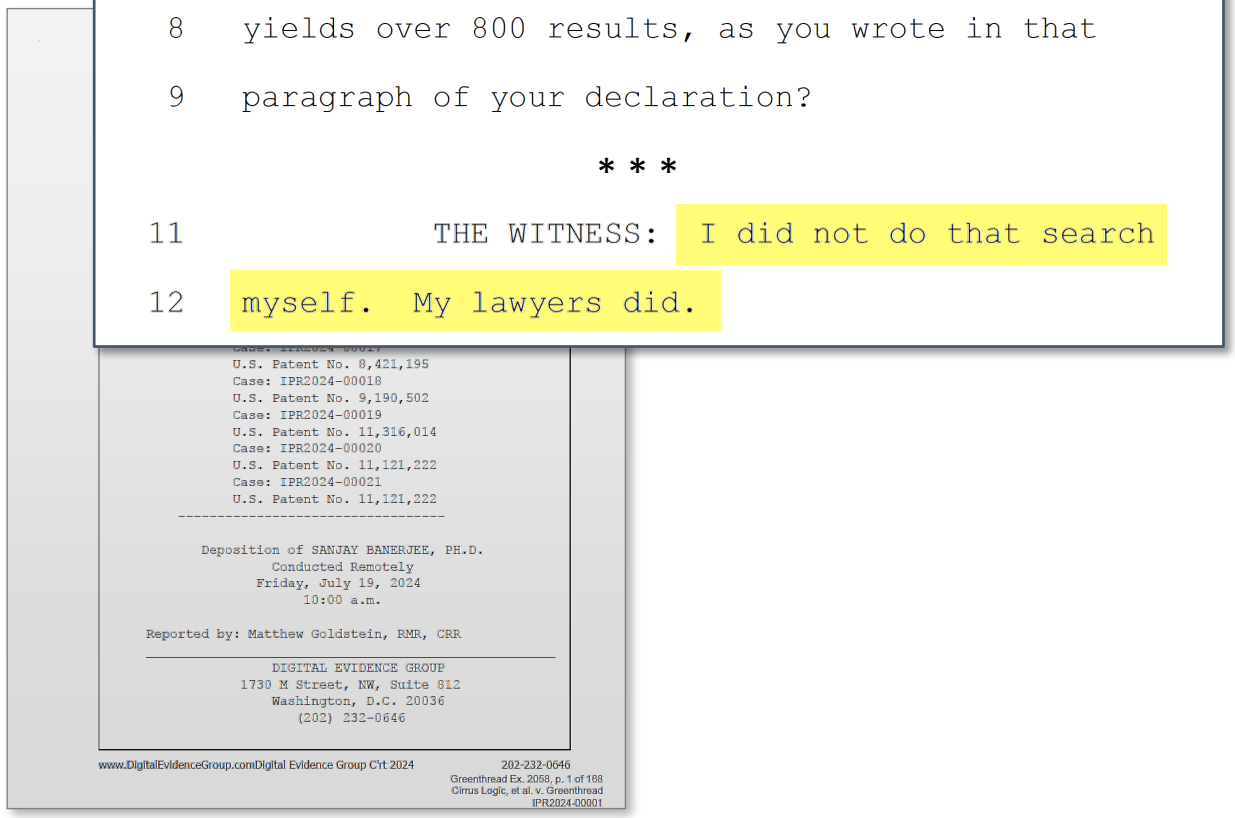
71. *Silicon Processing For The VLSI Era* by Stanley Wolf is a four volume textbook related to semiconductor devices, with particular focus on CMOS devices. Exs. 1008A-D. I am familiar with the Wolf textbook. An internet search for this textbook title limited to the ".edu" domain yields over 800 results. Thus, it is clearly used as a teaching resource in engineering courses in many, many universities and is widely cited in scientific works.


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AMS SENSORS USA INC.,
Petitioner,
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GREENTHREAD LLC,
Patent Owner
U.S. PATENT NO. 8,421,195
Case IPR2024-00017
DECLARATION OF DR. SANJAY BANERJEE IN SUPPORT OF
PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 8,421,195
CIRRUS EX. 1003

-00017: Ex. 1003 (Banerjee Decl.) at ¶ 71

12. Petitioners' Replicated Expert Declaration

- Dr. Banerjee admitted he did not conduct the search for the "well-known" Wolf reference.



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Case: IPR2024-00018
U.S. Patent No. 9,190,502
Case: IPR2024-00019
U.S. Patent No. 11,316,014
Case: IPR2024-00020
U.S. Patent No. 11,121,222
Case: IPR2024-00021
U.S. Patent No. 11,121,222

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7 Q. How do you know that the Internet search
8 yields over 800 results, as you wrote in that
9 paragraph of your declaration?

* * *

11 THE WITNESS: I did not do that search
12 myself. My lawyers did.

14 Q. And you did not verify if that sentence
15 is accurate?

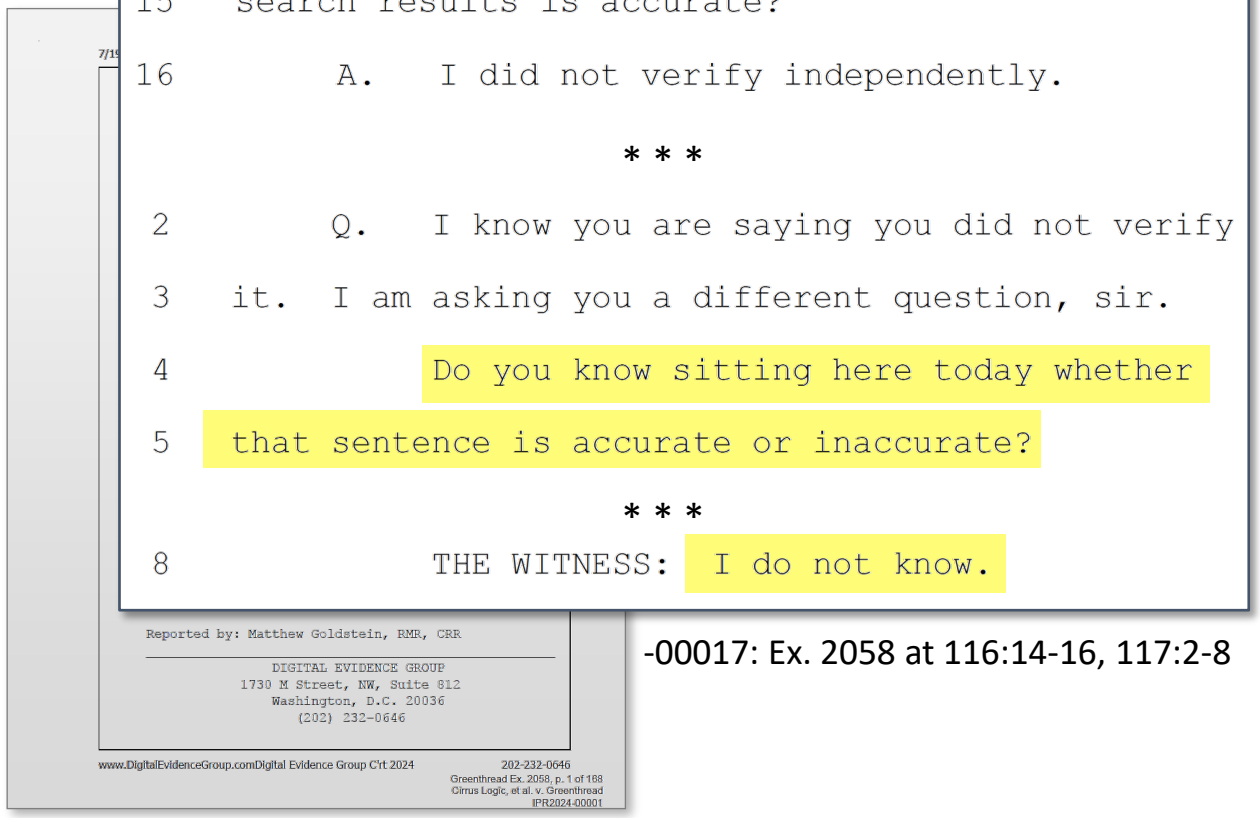
* * *

17 THE WITNESS: No, I did not. But as I
18 told you, I have used Wolf as a reference for many
19 years when I teach my graduate course, as do my
20 colleagues at other top-tier universities. So
21 independent of this, I feel that Wolf is a good
22 encyclopedic reference.

-00017: Ex. 2058 (Banerjee Dep. Tr.) at 114:7-22

12. Petitioners' Replicated Expert Declaration

- Dr. Banerjee could <u>not</u> verify the accuracy of relevant portions of his declaration.



14 Q. Do you know if the sentence about 800
15 search results is accurate?
16 A. I did not verify independently.
* * *
2 Q. I know you are saying you did not verify
3 it. I am asking you a different question, sir.
4 Do you know sitting here today whether
5 that sentence is accurate or inaccurate?
* * *
8 THE WITNESS: I do not know.

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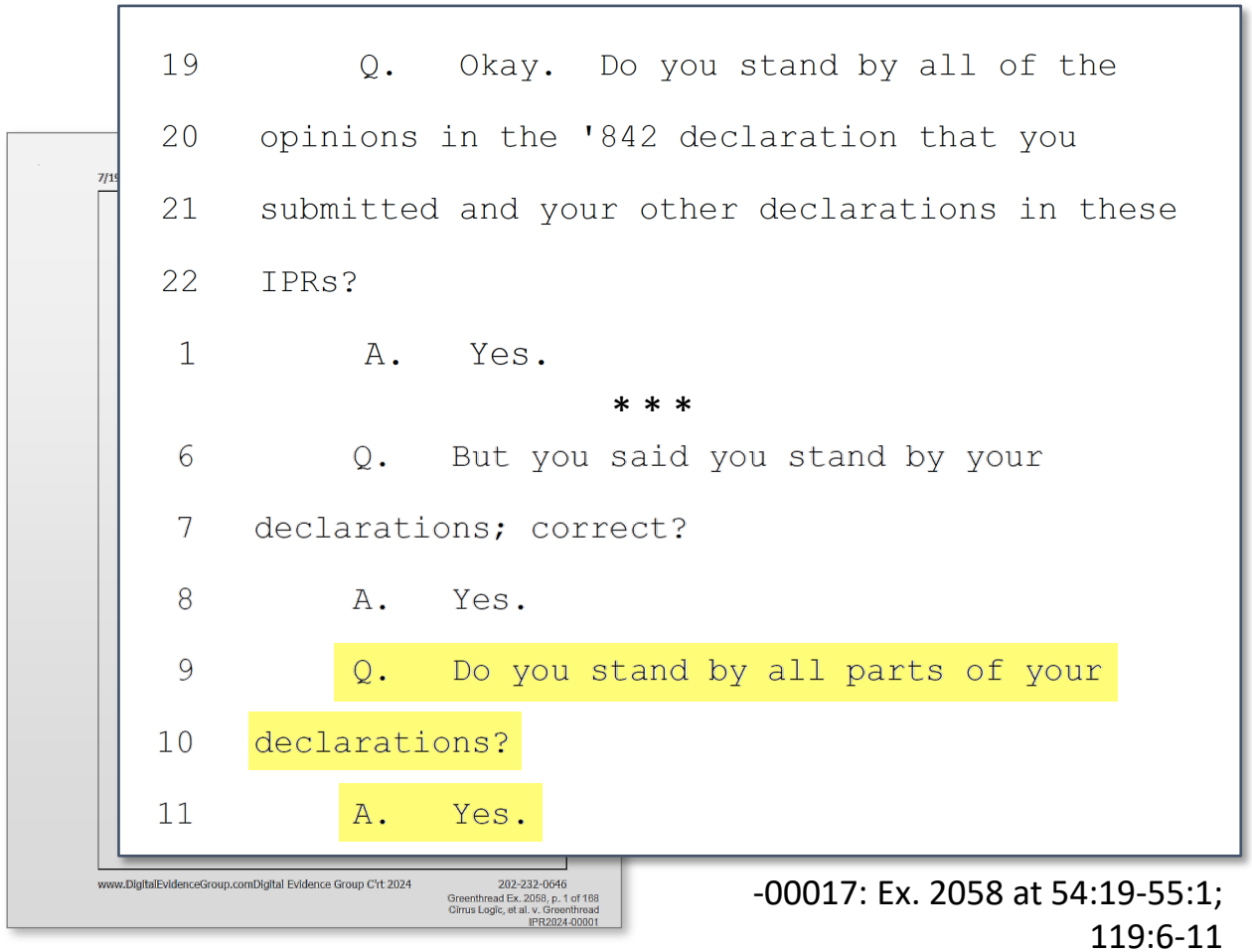
-00017: Ex. 2058 at 116:14-16, 117:2-8

20 Q. Instead, you used the sentence that
21 Dr. Blalock used and that perhaps your attorneys
22 gave you, which you have not verified and you do
1 not even know right now if it is accurate;
2 correct?
* * *
4 THE WITNESS: I cannot attest to the
5 accuracy of the number 800 search results.

-00017: Ex. 2058 (Banerjee Dep. Tr.) at 122:20-123:5

12. Petitioners' Replicated Expert Declaration

- Dr. Banerjee changed his testimony to state that he only verified "substantive matters."



19 Q. Okay. Do you stand by all of the
20 opinions in the '842 declaration that you
21 submitted and your other declarations in these
22 IPRs?
1 A. Yes.
* * *
6 Q. But you said you stand by your
7 declarations; correct?
8 A. Yes.
9 Q. Do you stand by all parts of your
10 declarations?
11 A. Yes.

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-00017: Ex. 2058 at 54:19-55:1; 119:6-11

12 Q. How can you stand by parts of your
13 declarations if you relied on your counsel and did
14 not independently verify them?
* * *
16 THE WITNESS: I definitely verified what
17 I regard as substantive matters. The thing that
18 you mentioned about 800 citations to Wolf is a
19 peripheral issue. I'm very familiar with Wolf as
20 a reliable textbook, independent of that.

-00017: Ex. 2058 (Banerjee Dep. Tr.) at 122:20-123:5

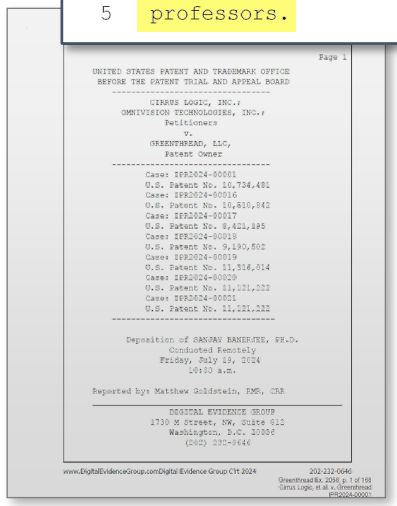
12. Petitioners' Replicated Expert Declaration

- At first, Dr. Banerjee relied upon the Internet search to demonstrate his familiarity with Wolf.
- Later, Dr. Banerjee testified that the "main basis" for his familiarity was prior use of the book.

19 Q. In paragraph 71, you mentioned an
20 Internet search; right?
21 A. Yes.
22 Q. Why did you write in that paragraph
1 about an Internet search for the Wolf textbook?

* * *

3 THE WITNESS: It demonstrates that Wolf
4 is a well-respected reference used by many
5 professors.


UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD
CIRRUS LOGIC, INC.,
OMNIVISION TECHNOLOGIES, INC.,
Petitioners
v.
GREENTHREAD, LLC,
Patent Owner
Deposition of SANJAY BANERJEE, PH.D.
Conducted Remotely
Friday, July 19, 2024
Reported by: Matthew Goldstein, RMR, CRR
DIGITAL EVIDENCE GROUP
1730 M Street, NW, Suite 812
Washington, D.C. 20036
(202) 232-0646

-00017: Ex. 2058 at 113:19-114:5

8 Q. Did you include the sentence about 800
9 results to help bolster the point that Wolf is
10 clearly used as a teaching resource in many, many
11 universities and widely cited in scientific works?

* * *

13 THE WITNESS: In the case of Wolf, my
14 main basis for my opinion that it's a reliable
15 reference is the fact that I've used it for many
16 years in my graduate course at the university
17 where we talk about CMOS device fabrication. So
18 that's my primary basis for the opinion. This
19 800 number is sort of the cherry on top, if you
20 will.

-00017: Ex. 2058 at 120:8-20

22 Q. But the part that's below the cherry,
1 your main basis, you didn't put that in your
2 declaration; did you?

* * *

4 THE WITNESS: I did not use the phrase
5 "cherry on top" with respect to the 800 number in
6 the declaration.
7 BY MR. JAIRAM:
8 Q. I'm not asking about the phrase. I'm
9 saying, what you just now characterized as your
10 main basis for your opinion, the fact that you
11 used it for many years allegedly in your graduate
12 course at the university, that is not mentioned in
13 your declaration -- or any of your declarations;
14 is it?

* * *

17 THE WITNESS: I do not mention that
18 explicitly. That's kind of implicit in the
19 statement I'm familiar with the Wolf textbook.
20 But I could have been specific, I guess.

-00017: Ex. 2058 (Banerjee Dep. Tr.) at 120:22-121:20

Overview of Issues

1. The Claims require "movement of carriers" from the "surface layer," where the "active region" is located.
2. The '195 and '502 Claims require "movement of minority carriers" from the "surface layer."
3. Dr. Banerjee confirmed the "electric field" must start in the "surface layer."
4. Payne does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."
5. Onoda does not disclose "movement of carriers" and "movement of minority carriers" from the "surface layer."
6. Dr. Banerjee confirmed that carriers in the "surface layer" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
7. The "movement of carriers" depends on the sum of all of the fields in the "surface layer."
8. Petitioners have the burden to analyze all of the fields in the "surface layer."
9. Dr. Banerjee testified that he did not analyze any of the fields in the "surface layer."
10. Petitioners' prosecution-related arguments are incorrect.
11. Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
12. Dr. Banerjee's credibility issues
13. Greenthread's licensing agreements provide substantial evidence of objective indicia of non-obviousness.

13. Objective Indicia of Non-Obviousness



"Objective evidence of nonobviousness … may often be the most probative and cogent evidence in the record. It may often establish that an invention appearing to have been obvious in light of the prior art was not."

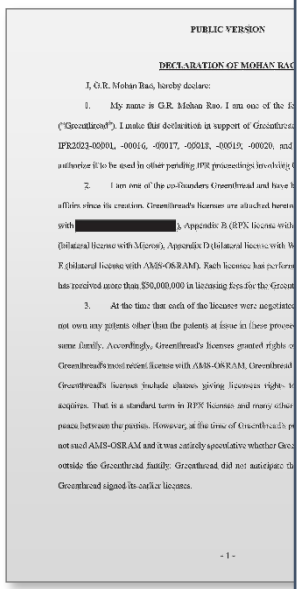
* * *

"[L]icenses with companies under no apparent threat of litigation" are especially probative of non-obviousness.

Transocean Offshore Deepwater Drilling, Inc. v. Maersk Drilling USA, Inc., 699 F.3d 1340, 1349, 1353 (Fed. Cir. 2012)

13. Objective Indicia of Non-Obviousness

- Two semiconductor companies took licenses without any threat of litigation.
- There is no evidence that these companies took a license to save litigation costs.
- The license was for the entire patent family and all of the patents involved graded dopant concentrations.



4. Greenthread has never threatened litigation—implicitly, explicitly, or otherwise—against [redacted] or any of their affiliates.

5. In 2020, after Greenthread sued [redacted] for infringing Greenthread's patents, RPX Corp. ("RPX") approached Greenthread to negotiate a license on behalf of some of its members, including [redacted] and [redacted]. Greenthread and RPX negotiated a license to RPX (Appendix A) which gave RPX the right to sublicense those companies to the Greenthread family of patents and which I understand RPX did in fact grant to them.

-00017: Ex. 2072 (Dr. Rao Decl.) at 2

13. Objective Indicia of Non-Obviousness

- Intel, Sony, Micron, and Western Digital also licensed the patents.

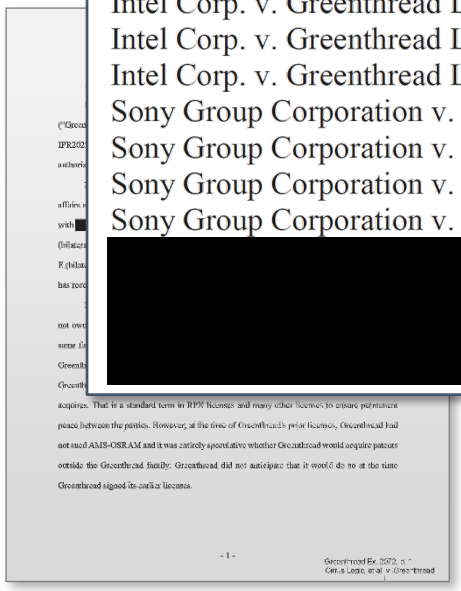


EXHIBIT E

LICENSEE NULLITY PROCEEDINGS AND LICENSOR LITIGATIONS

Greenthread, LLC v. Intel Corporation, 22-cv-02001-JR (D. Or.)

[redacted]

Intel Corp. v. Greenthread LLC, IPR2023-00260
Intel Corp. v. Greenthread LLC, IPR2023-00308
Intel Corp. v. Greenthread LLC, IPR2023-00386
Intel Corp. v. Greenthread LLC, IPR2023-00420
Intel Corp. v. Greenthread LLC, IPR2023-00541
Intel Corp. v. Greenthread LLC, IPR2023-00548
Intel Corp. v. Greenthread LLC, IPR2023-00552
Sony Group Corporation v. Greenthread LLC, IPR2023-00324
Sony Group Corporation v. Greenthread LLC,IPR2023-00325
Sony Group Corporation v. Greenthread LLC,IPR2023-00375
Sony Group Corporation v. Greenthread LLC,IPR2023-00376

[redacted]

-00017: Ex. 2072 at 55

EXHIBIT D – LITIGATION

Greenthread, LLC v. Micron Technology, Inc. et al., 23-cv-00333 (D. Del.)

-00017: Ex. 2072 at 81

EXHIBIT D – LITIGATION

Greenthread, LLC v. Western Digital Corporation et al., 1:23-cv-00326-RGA (D. Del.)

-00017: Ex. 2072 at 101

GREENTHREAD-AMS-OSRAM SETTLEMENT

EXHIBIT D – LITIGATION and IPRs

Greenthread, LLC v. OSRAM GmbH et al., 2:23-cv-00179-JRG (E.D. Tex.)

IPR2024-00001, IPR2024-00016, IPR2024-00017, IPR2024-00018, IPR2024-00019, IPR2024-00020, IPR2024-00021 and all other proceedings challenging the validity of a Licensed Patent.

-00017: Ex. 2072 (Dr. Rao Decl.) at 122