Demonstratives of Patent Owner Greenthread, LLC

IPR2024-00001 (’481 patent)
IPR2024-00016 (’842 patent)
IPR2024-00019 (’014 patent)
IPR2024-00020 (’222 patent)

USPTO Patent Trial and Appeal Board

Oral Hearing: January 28, 2025

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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Overview of Issues

- The Challenged Claims require "carrier movement" from the "active region."
- Dr. Banerjee confirmed that the "electric field" must start in the "active region."
- Petitioners did not identify an electric field, much less an electric field that starts in the "active region."
- Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
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- Petitioners have the burden to analyze all of the fields in the "active region."
- Dr. Banerjee testified that he did not analyze any of the fields in the "active region."
  - Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."
  - The graded dopant concentration is "uniform" in Wieczorek's "active region."
- Petitioners' prosecution-related arguments are incorrect.
- Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
- Kawagoe does not meet the "second doping type" limitation.
- Petitioners' expert declaration and testimony are untrustworthy.
  - Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.
  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

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- **The Challenged Claims require "carrier movement" from the "active region."**
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  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

Aid Carrier Movement from the Active Region

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

US 10,734,481

1. A semiconductor device, comprising:
a substrate of a first doping type at a first doping level having first and second surfaces;
a first active region disposed adjacent the first surface of the substrate with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region;
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first surface to the second surface of the substrate; and
at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid carrier movement from the first surface to the second surface of the substrate.

-00001: Ex. 1001 ('481 pat.) at 4:50-5:3

US 10,510,842

1. A semiconductor device, comprising:
a substrate of a first doping type at a first doping level having first and second surfaces;
a first active region disposed adjacent the first surface of the substrate with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region; and
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first surface to the second surface of the substrate.

-00016: Ex. 1001 ('842 pat.) at 4:45-60

US 11,316,014

1. An electronic system, the system comprising:
at least one semiconductor device, the at least one semiconductor device including:
a substrate of a first doping type at a first doping level having a surface;
a first active region disposed adjacent the surface with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region;
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first and second active regions towards an area of the substrate where there are no active regions; and
at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid carrier movement from the surface towards the area of the substrate where there are no active regions, wherein at least some of the transistors form digital logic of the semiconductor device.

-00019: Ex. 1001 ('014 pat.) at 4:49-5:7

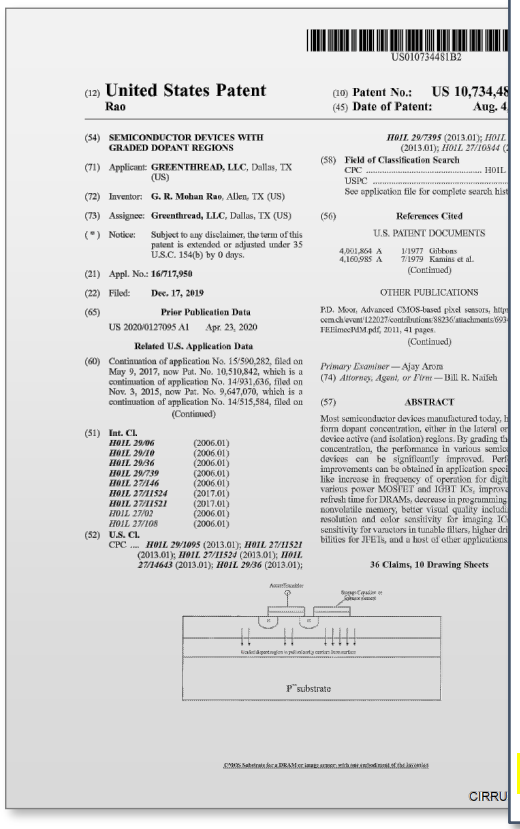
US 11,121,222

1. A VLSI semiconductor device, comprising:
a substrate of a first doping type at a first doping level having a surface;
a first active region disposed adjacent the surface with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region;
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first and second active regions towards an area of the substrate where there are no active regions; and
at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid carrier movement from the surface towards the area of the substrate where there are no active regions, wherein at least some of the transistors form digital logic of the VLSI semiconductor device.

-00020: Ex. 1001 ('222 pat.) at 4:38-62

Aid Carrier Movement from the Active Region

- Dr. Rao's specification discloses that "spurious minority carriers" interfere with the "active circuitry at the surface."



US010734481B2

(12) **United States Patent**
Rao

(10) **Patent No.: US 10,734,48**
(45) **Date of Patent: Aug. 4**

(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.: **16/717,950**

(22) Filed: **Dec. 17, 2019**

(65) **Prior Publication Data**

US 2020/0127095 A1 Apr. 23, 2020

Related U.S. Application Data

(60) Continuation of application No. 15/590,282, filed on May 9, 2017, now Pat. No. 10,510,842, which is a continuation of application No. 14/931,636, filed on Nov. 3, 2015, now Pat. No. 9,647,070, which is a continuation of application No. 14/515,584, filed on (Continued)

(51) **Int. Cl.**

H01L 29/06	(2006.01)
H01L 29/10	(2006.01)
H01L 29/36	(2006.01)
H01L 29/739	(2006.01)
H01L 27/146	(2006.01)
H01L 27/11524	(2017.01)
H01L 27/11521	(2017.01)
H01L 27/02	(2006.01)
H01L 27/108	(2006.01)

(52) **U.S. Cl.**
CPC ***H01L 29/1095*** (2013.01); ***H01L 27/11521*** (2013.01); ***H01L 27/11524*** (2013.01); ***H01L 27/14643*** (2013.01); ***H01L 29/36*** (2013.01);

H01L 29/7395 (2013.01); *H01L* (2013.01); *H01L 27/10844* (

(58) **Field of Classification Search**
CPC H01L
USPC .....
See application file for complete search hist

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4,160,985 A 7/1979 Kamins et al.
(Continued)

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FEIImecPDM.pdf, 2011, 41 pages.
(Continued)

Primary Examiner — Ajay Arora
(74) *Attorney, Agent, or Firm* — Bill R. Naifeh

(57) **ABSTRACT**

Most semiconductor devices manufactured today h
form dopant concentration, either in the lateral or
device active (and isolation) regions. By grading th
concentration, the performance in various semico
devices can be significantly improved. Parti
improvements can be obtained in application speci
like increase in frequency of operation for digit
various power MOSFET and IGBT ICs, improve
refresh time for DRAMs, decrease in programming
nonvolatile memory, better visual quality includi
resolution and color sensitivity for imaging IC
sensitivity for varactors in tunable filters, higher de
bilities for JFETs, and a host of other applications

36 Claims, 10 Drawing Sheets

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As illustrated in FIGS. **5**A, **5**B, and **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 ICs. These unwanted carriers can discharge dynamically-held "actively held high" nodes. In most cases, statically-held nodes (with V_{cc}) cannot be affected. Degradation of refresh time in DRAMs is one of the results, because the capacitor holds charge dynamically. Similarly, degradation of CMOS digital images in digital imaging ICs is another result of the havoc caused by minority carriers. Pixel and color resolution can be significantly enhanced in imaging ICs with the embodiments described herein. Creating "subterranean" 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 is described herein which creates a drift field to sweep these unwanted minority carriers from the active circuitry at the surface into the substrate in a monolithic die as quickly as

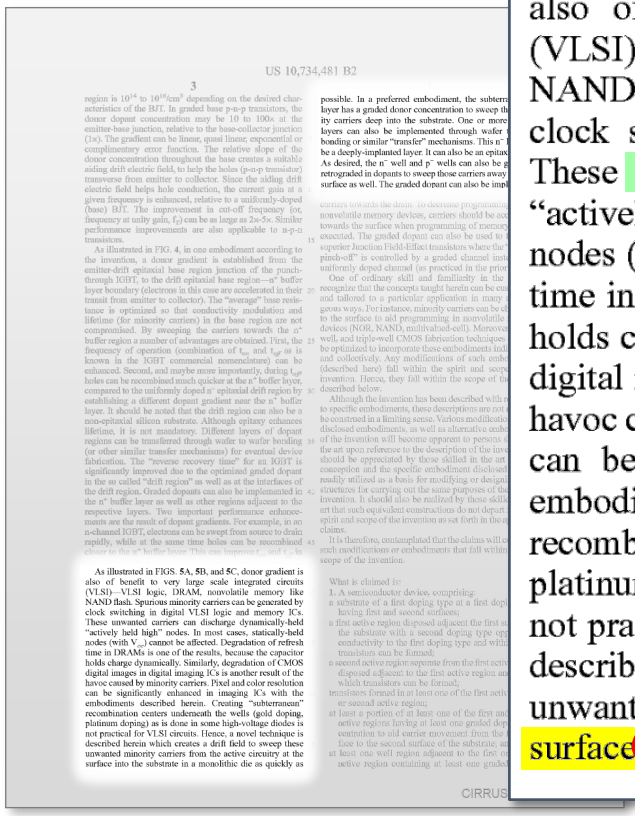
-00001: Ex. 1001 at 3:48-67

possible. In a preferred embodiment, the subterranean 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. As desired, the n^- well and p^- wells can also be graded or retrograded in dopants to sweep those carriers away from the surface as well. The graded dopant can also be implemented

-00001: Ex. 1001 ('481 pat.) at 4:1-9

Aid Carrier Movement from the Active Region

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



As illustrated in FIGS. **5**A, **5**B, and **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 ICs. These unwanted carriers can discharge dynamically-held "actively held high" nodes. In most cases, statically-held nodes (with V_{cc}) cannot be affected. Degradation of refresh time in DRAMs is one of the results, because the capacitor holds charge dynamically. Similarly, degradation of CMOS digital images in digital imaging ICs is another result of the havoc caused by minority carriers. Pixel and color resolution can be significantly enhanced in imaging ICs with the embodiments described herein. Creating "subterranean" 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 is described herein which creates a drift field to sweep these unwanted minority carriers from the active circuitry at the surface into the substrate in a monolithic die as quickly as

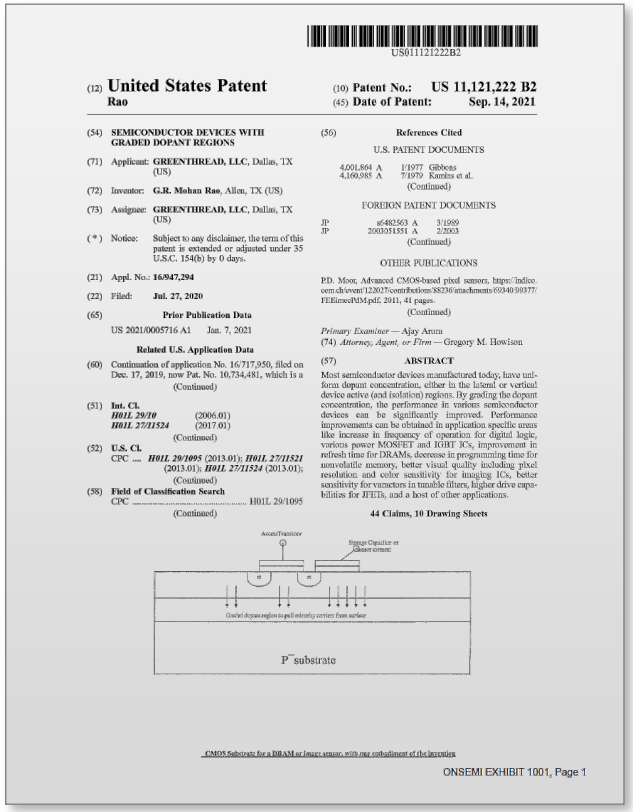
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-00001: Ex. 1001 ('481 pat.) at 4:1-9

Aid Carrier Movement 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**

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(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)

(56) **References Cited**

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4,001,864 A 1/1977 Gibbons
4,160,985 A 7/1979 Kamins et al.
(Continued)

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(Continued)

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(Continued)

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

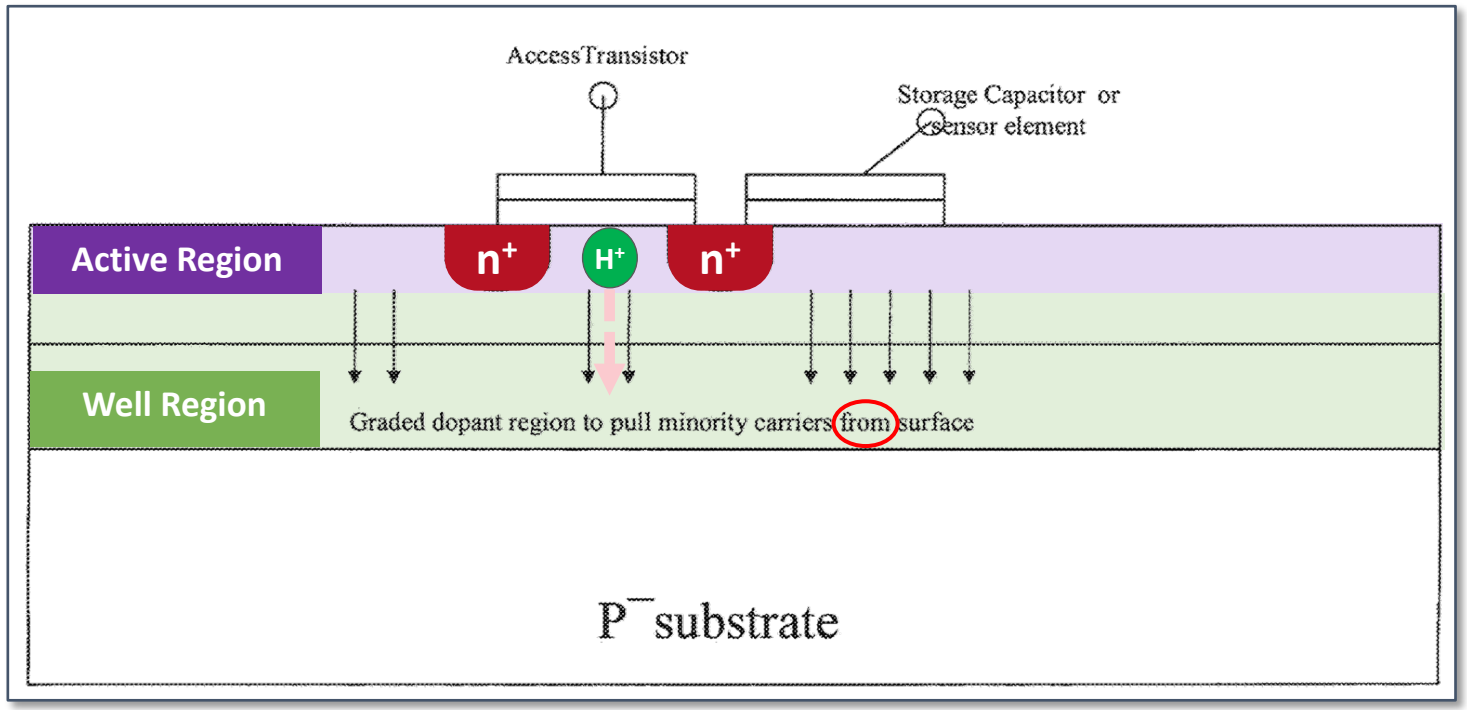
(57) **ABSTRACT**

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



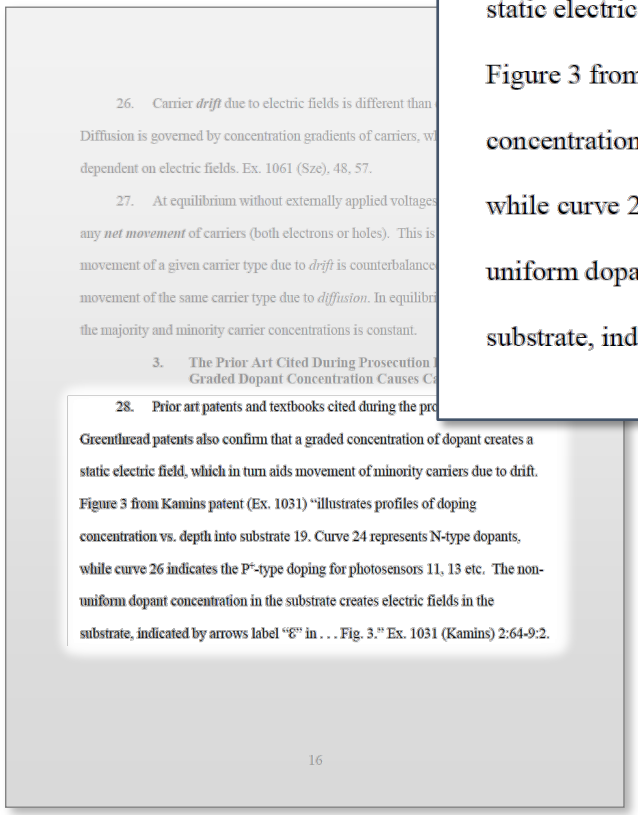
-00001: Ex. 1001 (’481 pat.) at Fig. 5B

Overview of Issues

- **The Challenged Claims require "carrier movement" from the "active region."**
- **Dr. Banerjee confirmed that the "electric field" must start in the "active region."**
- Petitioners did not identify an electric field, much less an electric field that starts in the "active region."
- Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
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  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

The Electric Field Must Start in the Active Region

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



26. Carrier *drift* due to electric fields is different than
Diffusion is governed by concentration gradients of carriers, wi
dependent on electric fields. Ex. 1061 (Sze), 48, 57.

27. At equilibrium without externally applied voltages
any *net movement* of carriers (both electrons or holes). This is
movement of a given carrier type due to *drift* is counterbalance
movement of the same carrier type due to *diffusion*. In equilibri
the majority and minority carrier concentrations is constant.

3. The Prior Art Cited During Prosecution
Graded Dopant Concentration Causes C

28. Prior art patents and textbooks cited during the pro
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.

16

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.

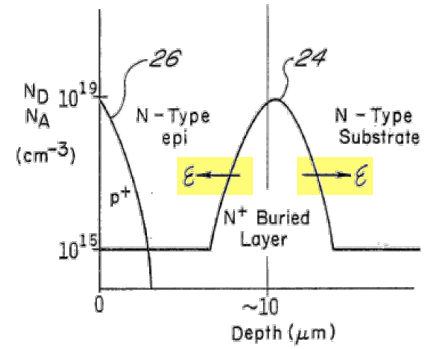


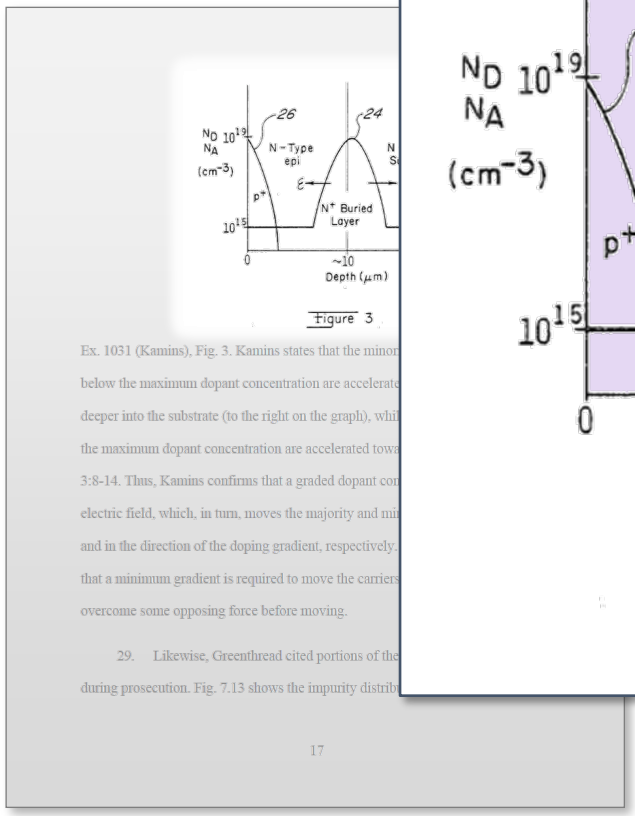
Figure 3

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.

-00001: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

The Electric Field Must Start in the Active Region

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



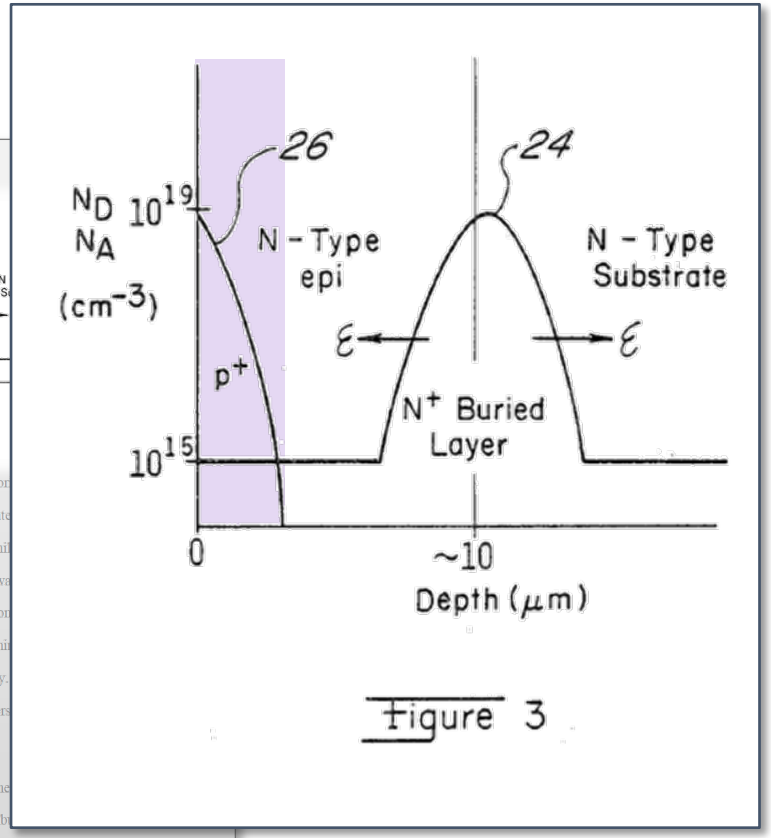


Figure 3

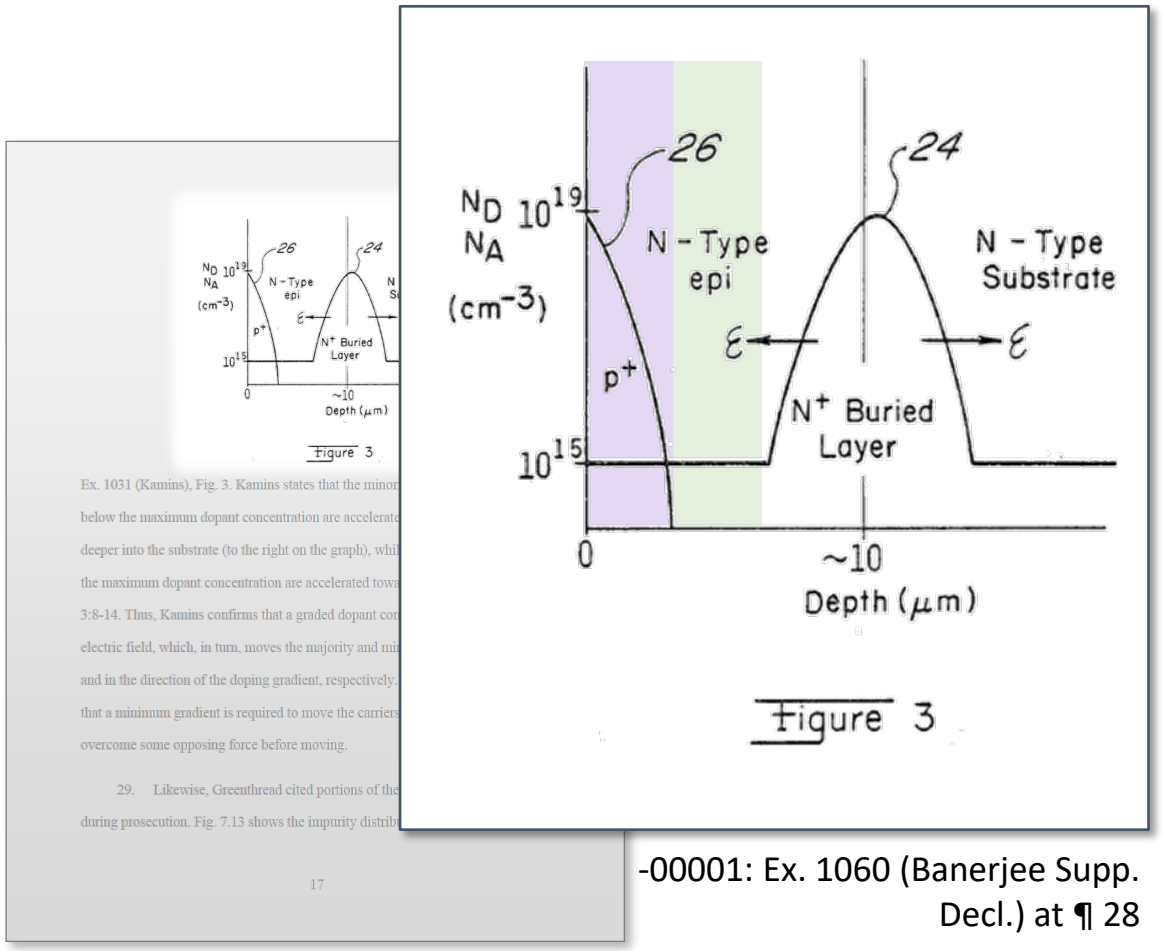
-00001: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 256:11-15

The Electric Field Must Start in the Active Region

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



-00001: 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.

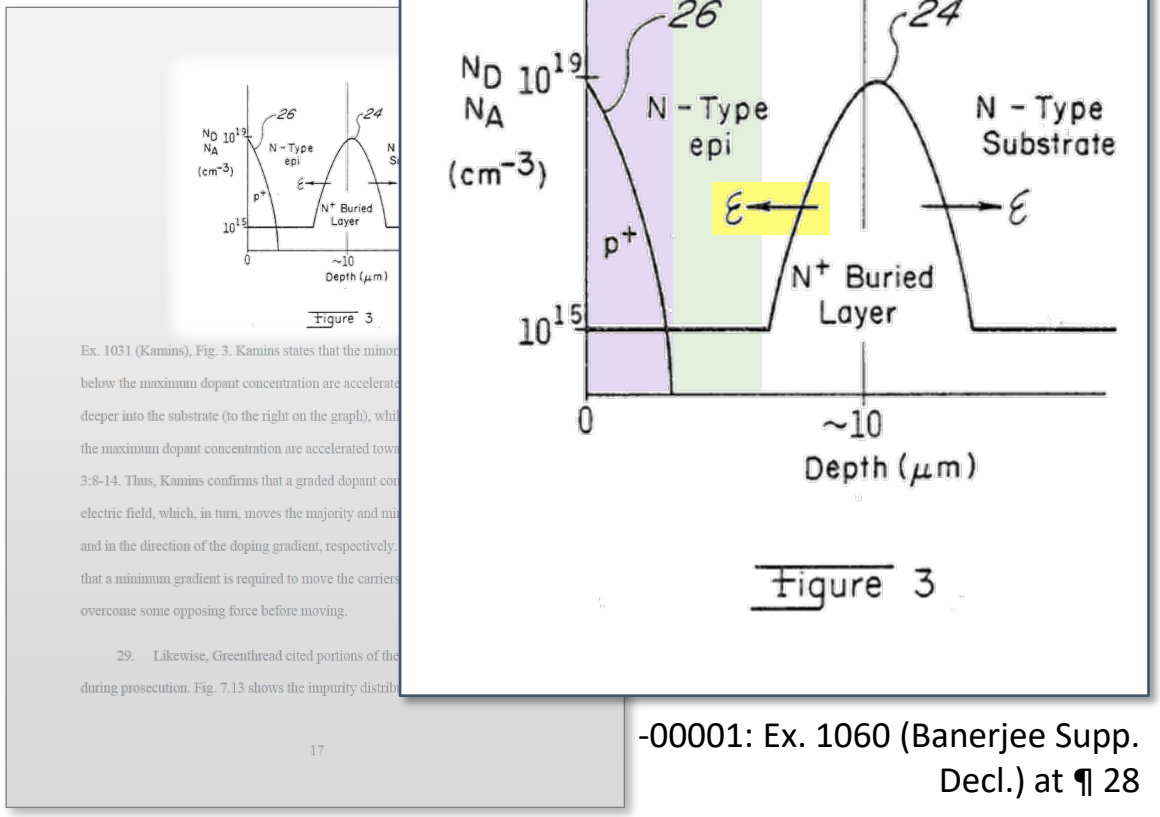
-00001: Ex. 2078 (Banerjee Dep. Tr.) at 260:2-13

-00001: PO Sur-Reply [63] at 14-15, 22

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

The Electric Field Must Start in the Active Region

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



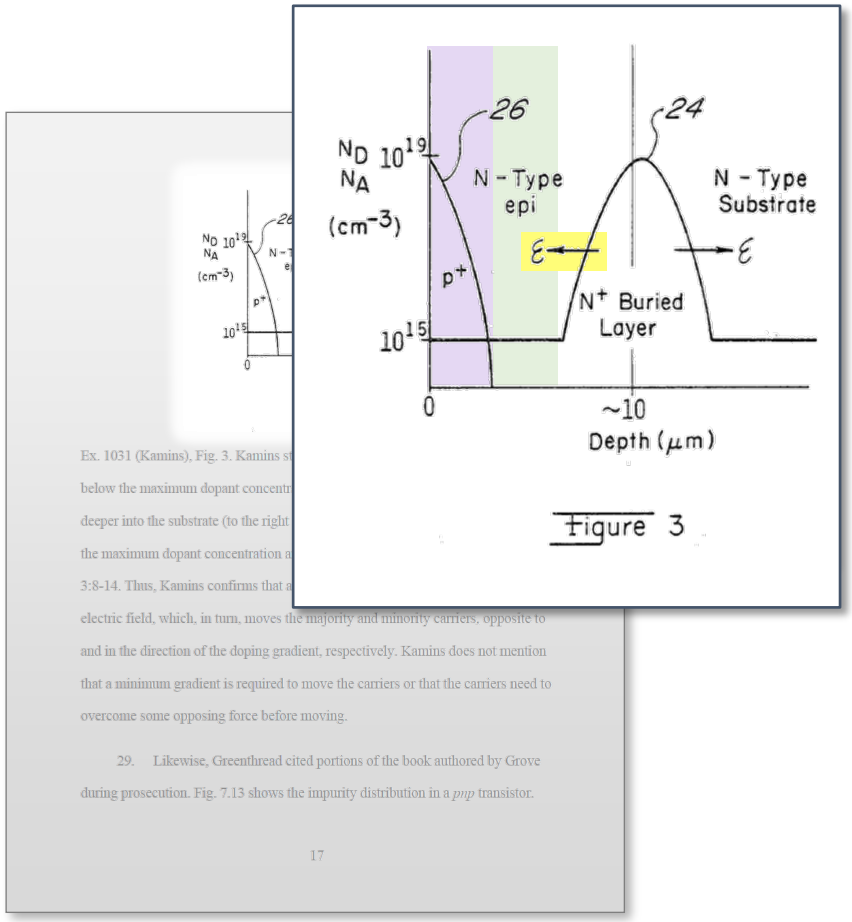
-00001: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 28

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 262:12-20

The Electric Field Must Start in the Active Region

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

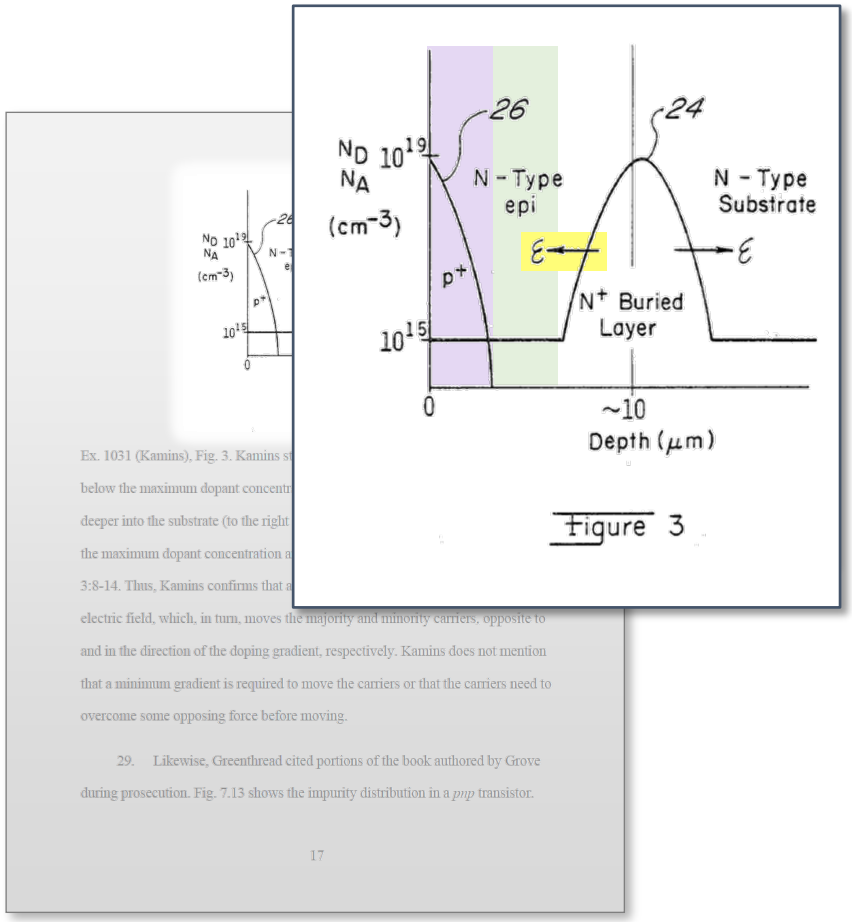
THE WITNESS: Yes, that electric field doesn't extend all the way to the surface. Therefore, there cannot be any drift velocity of the holes due to that electric field.

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 266:4-267:4

The Electric Field Must Start in the Active Region

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



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.

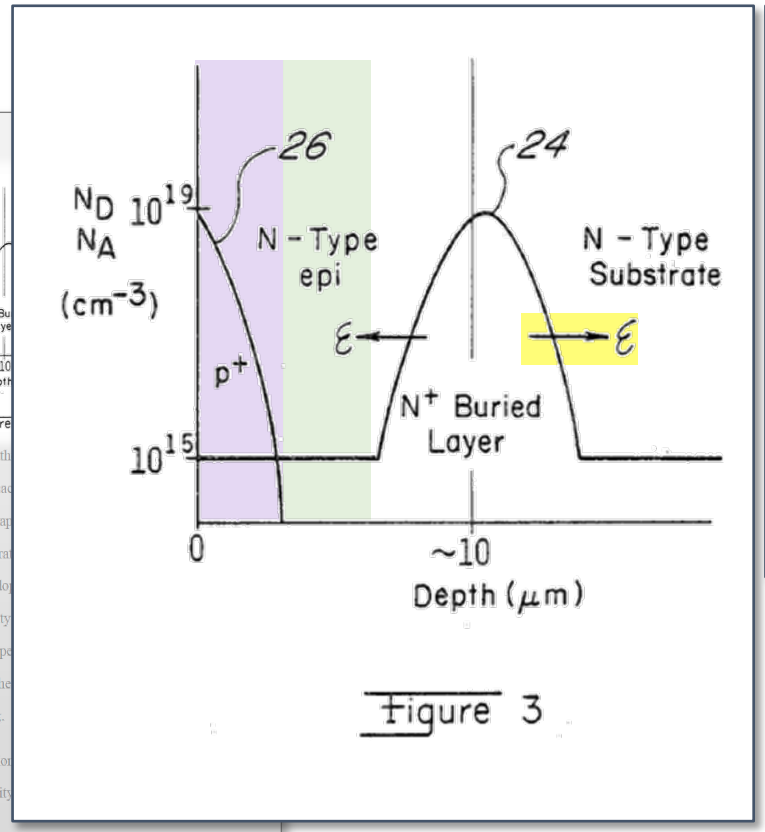
THE WITNESS: Yes, that electric field doesn't extend all the way to the surface. Therefore, there cannot be any drift velocity of the holes due to that electric field.

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 266:4-267:4

The Electric Field Must Start in the Active Region

- 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.



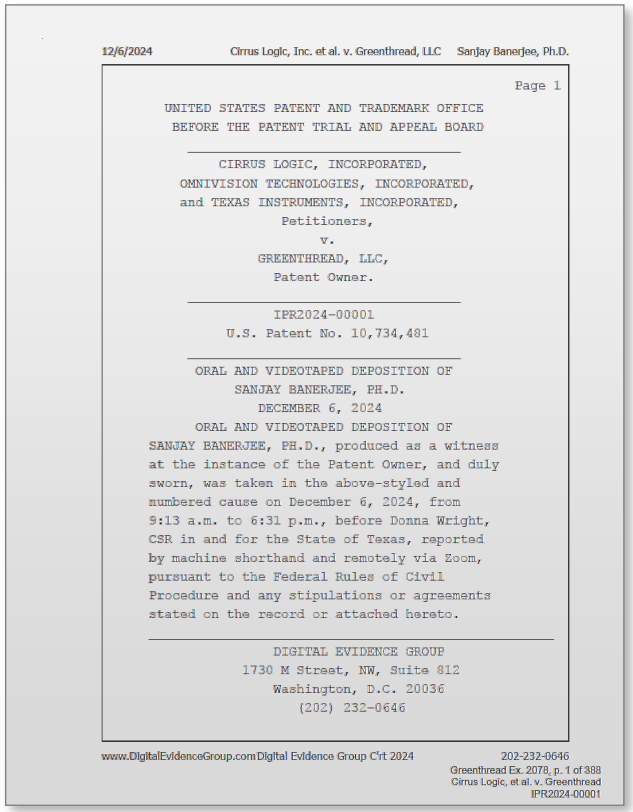
3	Q. (BY MR. WHITEHURST) Now, let's
4	stay with Figure 3, but turn to the electric
5	field that's to the right pointing in the
6	downward direction.
7	Do you see that?
8	A. Yes.
9	Q. Do you agree that the electric
10	field that's pointing in the downward
11	direction will not aid movement of holes from
12	the surface or the active region to the
13	substrate?
14	MR. PAUL: Objection to form.
15	Scope.

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 268:3-269:13

The Electric Field Must Start in the Active Region

- 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."



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.

DIGITAL EVIDENCE GROUP
1730 M Street, NW, Suite 812
Washington, D.C. 20036
(202) 232-0646

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 here 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.

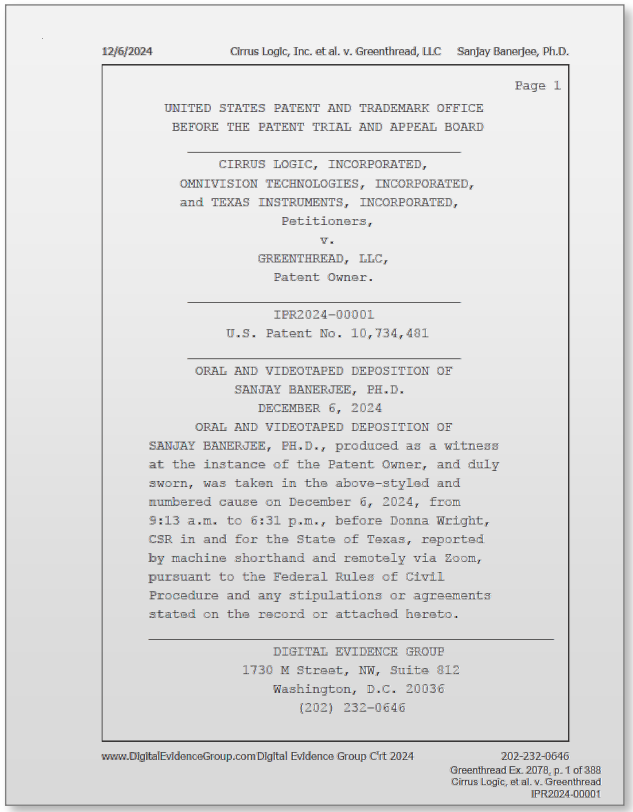
Q. And I think we agree if the electric field starts or ends below the active region, it will not aid carrier movement from the active region?

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 272:14-274:2

The Electric Field Must Start in the Active Region

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



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

CIRRUS LOGIC, INCORPORATED,
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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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 272:14-274:2

Overview of Issues

- **The Challenged Claims require "carrier movement" from the "active region."**
- **Dr. Banerjee confirmed that the "electric field" must start in the "active region."**
- **Petitioners did not identify an electric field, much less an electric field that starts in the "active region."**
- Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
- Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."
- Petitioners have the burden to analyze all of the fields in the "active region."
- Dr. Banerjee testified that he did not analyze any of the fields in the "active region."
  - Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."
  - The graded dopant concentration is "uniform" in Wieczorek's "active region."
- Petitioners' prosecution-related arguments are incorrect.
- Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
- Kawagoe does not meet the "second doping type" limitation.
- Petitioners' expert declaration and testimony are untrustworthy.
  - Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.
  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- Kawagoe does <u>not</u> mention moving carriers from the "active region."

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.

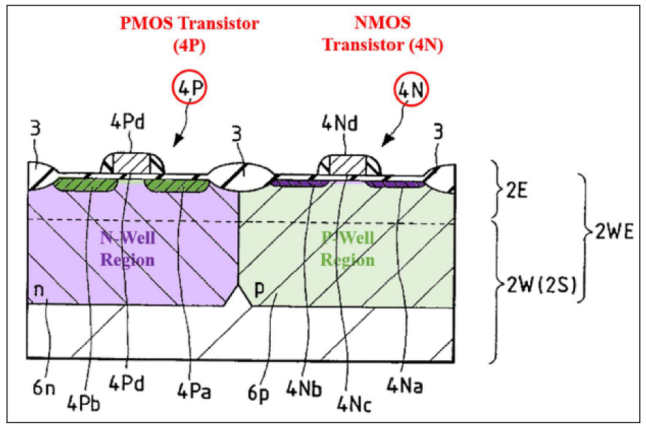
GREENTHREAD, LLC,
Patent Owner.

Case No. IPR2024-00001
Patent No. 10,734,481

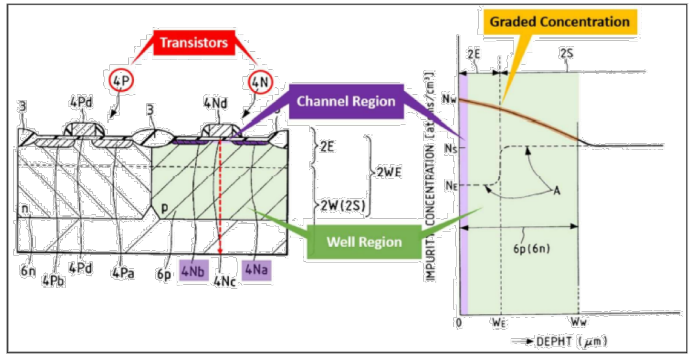
PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 10,734,481
UNDER 35 U.S.C. §§ 312 AND 37 C.F.R. § 42.104

A. Kawagoe

Kawagoe describes CMOS devices fabricated using twin-well CMOS technology and an epitaxial substrate, whereby the epitaxial layer can be doped at the same or lower level than the substrate body. Ex.1007, 3:32-38, 6:65- 7:3, 8:40-53, 15:13-17, 15:26-40. Kawagoe's figure below depicts a twin-well CMOS structure. Ex.1007, 15:26-40, 18:18-23.



Id., FIG. 23. Kawagoe further teaches that the well regions have a graded dopant concentration that decreases with depth, as illustrated in Figure 17 (corresponding to Figure 23). *Id.*, 14:46¬55, 15:62-16:40 ("p-well 6p and n-well 6n have their impurity concentrations ***gradually lowered*** in the depthwise direction ...").[6]



Id., FIGS. 17, 23. The graded dopant concentration reduces soft errors by sweeping unwanted carriers into the substrate body. *Id.*, 16:2-11 ("electrons produced by the α-ray are ***attracted to the substrate body 2S*** by that concentration gradient...so that the soft errors can be reduced.").

-00001: Petition [1] at 12-13

-00001: PO Resp. [45] at 9-12; PO Sur-Reply [63] at 14-15

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- Petitioners did <u>not</u> identify an electric field, much less an electric field starting in the active region.

f. Element[1.5]

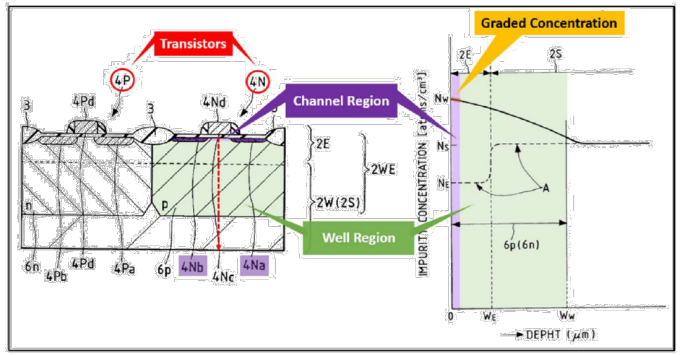
As illustrated the below annotation of Figure 23 (left), a channel region (light purple) formed at the top surface of the substrate connects source-drain regions 4Na/4Nb (purple) of transistor 4N. Ex.1008B, 298 ("A channel region in the semiconductor under the gate electrode separates the source and drain"), 300-301 ("When positive bias is applied to an NMOS transistor gate ... an *n*-type ***channel*** connects the ***source*** and ***drain*** regions"), FIG. 5-2; Ex.1007, 8:46-47 ("nMOS" is a shorthand for "n-channel MOS.FET"), 8:60-67, 14:46-55, 15:26-30, 15:37-40; Ex.1003, ¶85. PO does not dispute this. Ex.1020, 4 (the channel is "a thin layer below the surface" connecting the source and drain).

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X.A.1.c. Re
can be form
Ex.1020, 31
Kawa
means "a d
source and
Ex.1003, ¶8
Sections X.A.1.c-d.

f. Element[1.5]

As illustrated the below annotation of Figure 23 (left), a channel region (light purple) formed at the top surface of the substrate connects source-drain regions 4Na/4Nb (purple) of transistor 4N. Ex.1008B, 298 ("A channel region in the semiconductor under the gate electrode separates the source and drain"), 300-301 ("When positive bias is applied to an NMOS transistor gate ... an *n*-type ***channel*** connects the ***source*** and ***drain*** regions"), FIG. 5-2; Ex.1007, 8:46-47 ("nMOS" is a shorthand for "n-channel MOS.FET"), 8:60-67, 14:46-55, 15:26-30, 15:37-40; Ex.1003, ¶85. PO does not dispute this. Ex.1020, 4 (the channel is "a thin layer below the surface" connecting the source and drain).

28



Ex.1007, FIGS. 17, 23. Kawagoe's Figure 17 (above right) illustrates the doping concentration measured along the red dotted line in Figure 23 (above left), which starts from the top surface of the substrate (depth=0) and includes the doping profile in the channel region (light purple). *Id.*, 5:41-45. As Figure 17 shows, the dopant concentration is "gradually lowered in the depthwise direction ***from the principal surface*** (having an impurity concentration N_W) of the epitaxial layer 2E." *Id.*, 15:62-16:40; *see also id.*, 16:21-26 (N_W is the concentration at the well surface). The dopant concentration is thus graded in the channel region of transistor 4N, which is a portion of the first active region formed at "the principal surface" (top surface) of epitaxial layer 2E. Ex.1003, ¶86. Kawagoe's graded dopant concentration is in fact downward-sloping from the top surface of the substrate and all the way through the entire depth of the channel region (light purple) and the underlying well region (green)—from depth=0 at the top surface of the epitaxial substrate to beyond depth=W_W where W_W is the depth at the bottom of the p-well 6p. Ex. 1007, 15:32-36. While Figure 17 depicts the dopant concentration sloping at such a degree so as to level off at the at N_S (the dopant concentration of the substrate body) beyond the depth W_W, a POSITA would have appreciated that when the device of Figure 23 is implemented using a uniformly-doped substrate as in Embodiment 1, in which the doping levels of the epitaxial layer (N_E) and substrate body (N_S) are equal, the downward slope through the p-well 6p would have the same general profile but steeper than as depicted in Figure 17 above. Ex. 1003, ¶86.

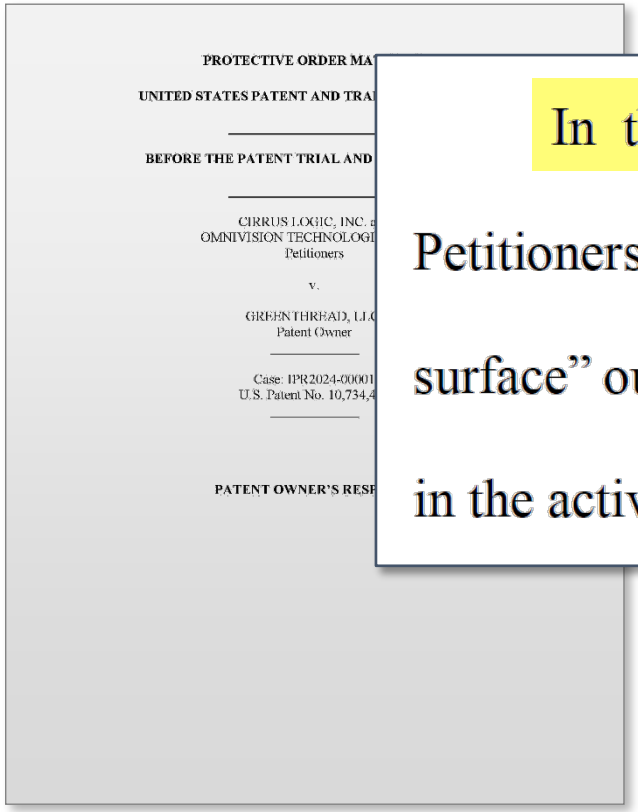
-00001: Petition [1] at 28-30

-00001: PO Resp. [45] at 9-12; PO Sur-Reply [63] at 14-15

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- Because Kawagoe does not expressly teach moving carriers from the "active region," Petitioners had the burden to identify an electric field in the "active region."


PROTECTIVE ORDER MA

UNITED STATES PATENT AND TRA

BEFORE THE PATENT TRIAL AND

CIRRUS LOGIC, INC. a
OMNIVISION TECHNOLOGI
Petitioners

v.

GREENTHREAD, LL
Patent Owner

Case: IPR2024-0000
U.S. Patent No. 10,734,4

PATENT OWNER'S RESP

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.

-00001: PO Response [45] at 2

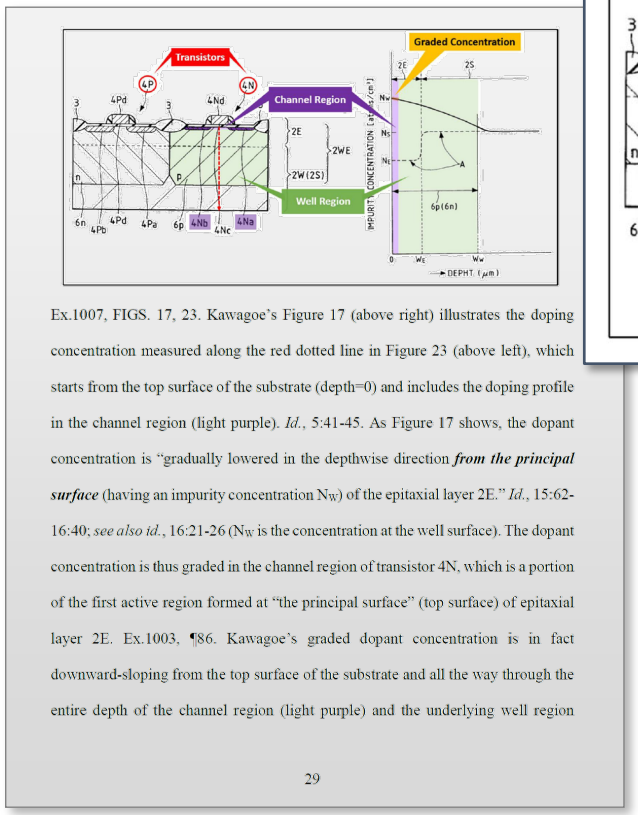
Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

An obviousness finding "is appropriate only when the reference discloses prior art that must *necessarily* include the unstated limitation."

Transclean Corp. v. Bridgewood Servs., Inc., 290 F.3d 1364, 1373 (Fed. Cir. 2002)

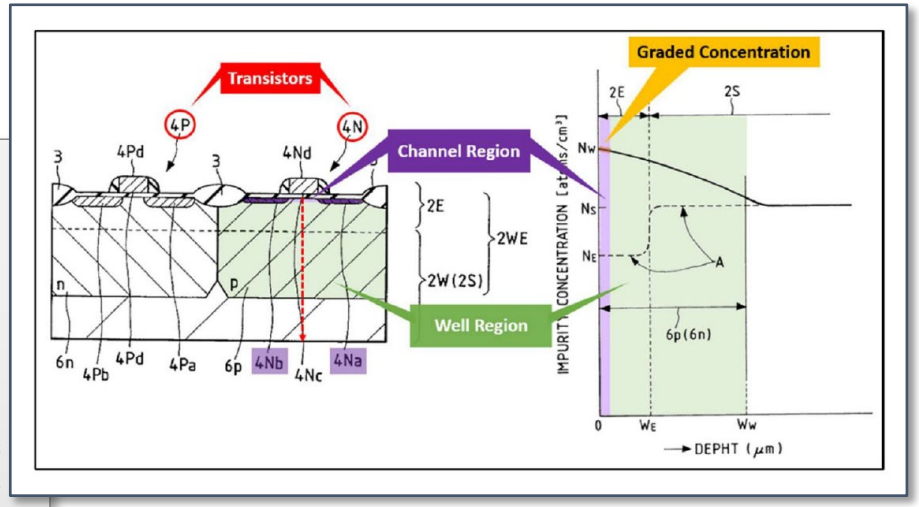
Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- As Dr. Banerjee explained, the electric field must point in the correct direction, otherwise it will not aid carrier movement from the active region.



Ex.1007, FIGS. 17, 23. Kawagoe's Figure 17 (above right) illustrates the doping concentration measured along the red dotted line in Figure 23 (above left), which starts from the top surface of the substrate (depth=0) and includes the doping profile in the channel region (light purple). *Id.*, 5:41-45. As Figure 17 shows, the dopant concentration is "gradually lowered in the depthwise direction ***from the principal surface*** (having an impurity concentration N_W) of the epitaxial layer 2E." *Id.*, 15:62-16:40; *see also id.*, 16:21-26 (N_W is the concentration at the well surface). The dopant concentration is thus graded in the channel region of transistor 4N, which is a portion of the first active region formed at "the principal surface" (top surface) of epitaxial layer 2E. Ex.1003, ¶86. Kawagoe's graded dopant concentration is in fact downward-sloping from the top surface of the substrate and all the way through the entire depth of the channel region (light purple) and the underlying well region

29



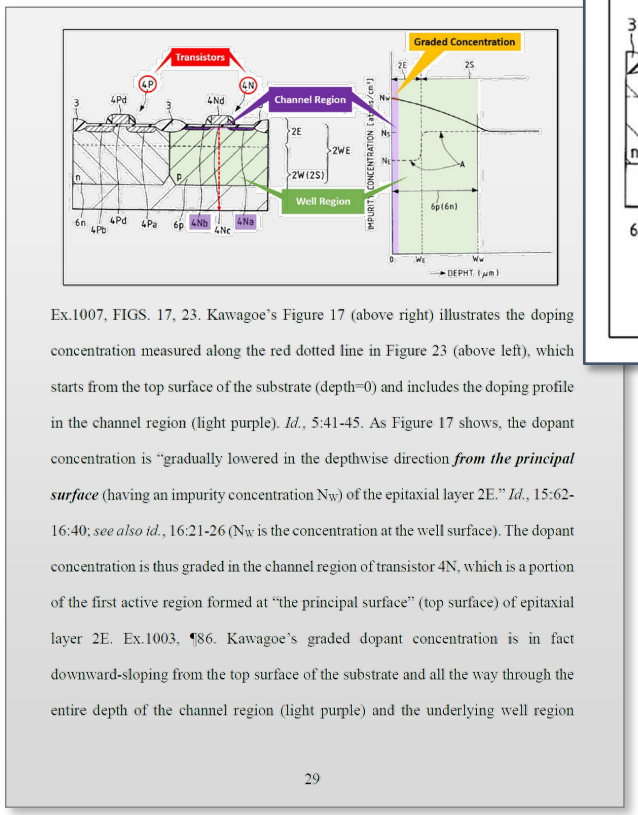
-00001: Petition [1] at 29

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 266:16-267:4

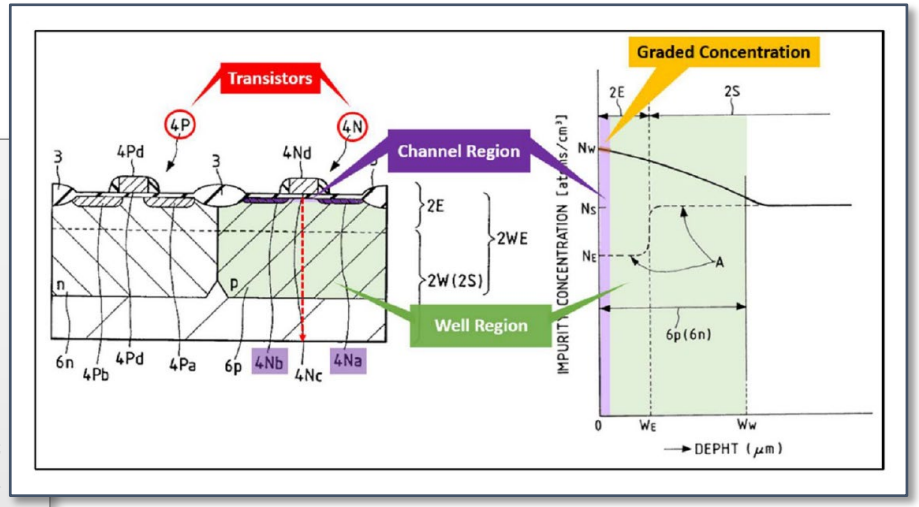
Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- As Dr. Banerjee explained, holes move in the same direction as the electric field, and electrons move in the opposite direction.



Ex.1007, FIGS. 17, 23. Kawagoe's Figure 17 (above right) illustrates the doping concentration measured along the red dotted line in Figure 23 (above left), which starts from the top surface of the substrate (depth=0) and includes the doping profile in the channel region (light purple). *Id.*, 5:41-45. As Figure 17 shows, the dopant concentration is "gradually lowered in the depthwise direction ***from the principal surface*** (having an impurity concentration N_W) of the epitaxial layer 2E." *Id.*, 15:62-16:40; *see also id.*, 16:21-26 (N_W is the concentration at the well surface). The dopant concentration is thus graded in the channel region of transistor 4N, which is a portion of the first active region formed at "the principal surface" (top surface) of epitaxial layer 2E. Ex.1003, ¶86. Kawagoe's graded dopant concentration is in fact downward-sloping from the top surface of the substrate and all the way through the entire depth of the channel region (light purple) and the underlying well region

29



-00001: Petition [1] at 29

22 And in the case of holes, that
1 drift velocity will be in the direction of
2 the electric field because holes have a
3 positive charge. Electrons, because they
4 have a negative charge, would move opposite
5 to the electric field.

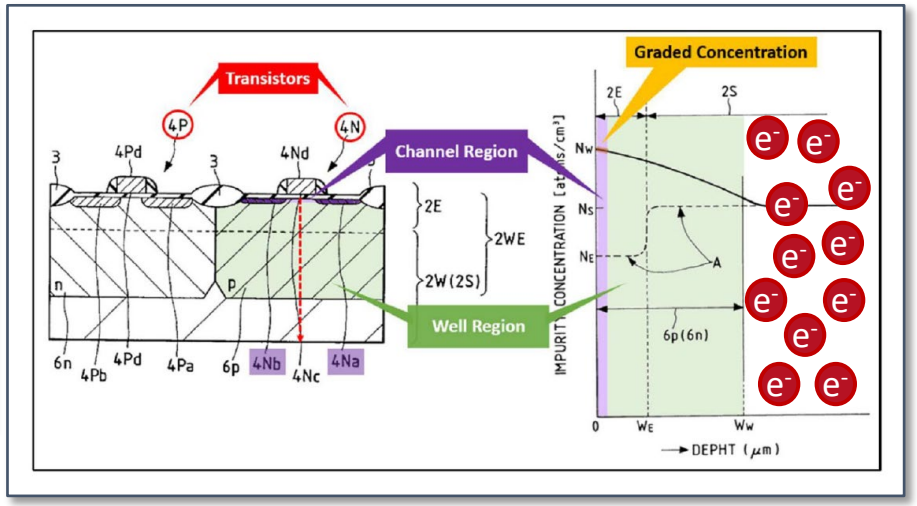
-00001: Ex. 2078 (Banerjee Dep. Tr.) at 104:22-105:5

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- Petitioners admit that the "electrons produced by the α-ray" are created below the wells.

10 Kawagoe also states that "electrons produced by the α-ray [are]... prevented from entering the p-well 6p ...." Ex. 1007, 16:7-9. This refers to electrons created by an α-ray in the substrate body below the wells, by far the largest volumetric region of any chip. Ex. 1003, ¶88; Ex. 1009, FIG. 2.

-00001: Petition [1] at 32



-00001: Petition [1] at 29

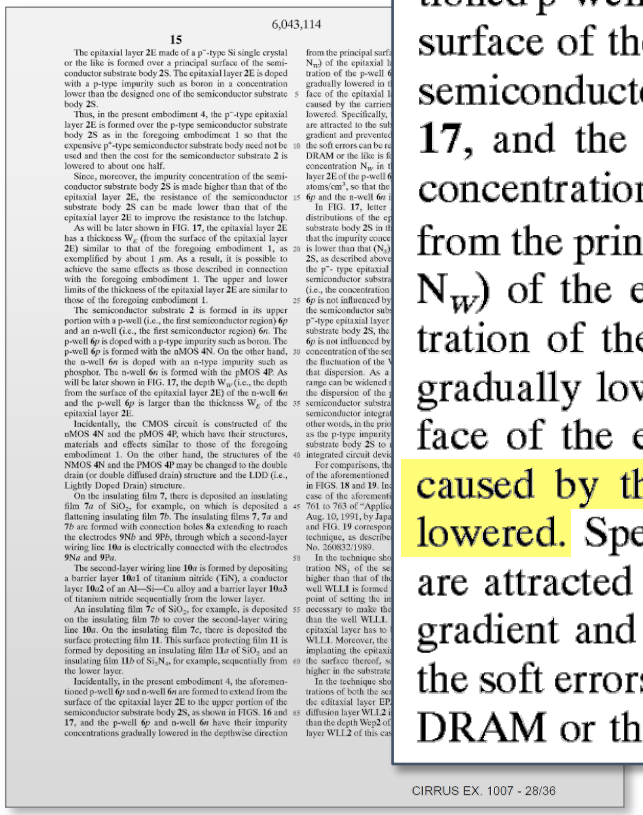
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32

-00001: PO Resp. [45] at 16-17; PO Sur-Reply [63] at 14-15

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- Kawagoe does <u>not</u> mention moving an electron from the "active region" (shaded purple).


6,043,114

15

The epitaxial layer 2E made of a p⁻-type Si single crystal or the like is formed over a principal surface of the semiconductor substrate body 2S. The epitaxial layer 2E is doped with a p-type impurity such as boron in a concentration lower than the designed one of the semiconductor substrate body 2S.

Thus, in the present embodiment 4, the p⁻-type epitaxial layer 2E is formed over the p-type semiconductor substrate body 2S as in the foregoing embodiment 1 so that the expensive p⁺-type semiconductor substrate body need not be used and then the cost for the semiconductor substrate 2 is lowered to about one half.

Since, moreover, the impurity concentration of the semiconductor substrate body 2S is made higher than that of the epitaxial layer 2E, the resistance of the semiconductor substrate body 2S can be made lower than that of the epitaxial layer 2E to improve the resistance to the latchup.

As will be later shown in FIG. 17, the epitaxial layer 2E has a thickness W_E (from the surface of the epitaxial layer 2E) similar to that of the foregoing embodiment 1, as exemplified by about 1 μm. As a result, it is possible to achieve the same effects as those described in connection with the foregoing embodiment 1. The upper and lower limits of the thickness of the epitaxial layer 2E are similar to those of the foregoing embodiment 1.

The semiconductor substrate 2 is formed in its upper portion with a p-well (i.e., the first semiconductor region) 6p and an n-well (i.e., the first semiconductor region) 6n. The p-well 6p is doped with a p-type impurity such as boron. The p-well 6p is formed with the nMOS 4N. On the other hand, the n-well 6n is doped with an n-type impurity such as phosphor. The n-well 6n is formed with the pMOS 4P. As will be later shown in FIG. 17, the depth W_W (i.e., the depth from the surface of the epitaxial layer 2E) of the n-well 6n and the p-well 6p is larger than the thickness W_E of the epitaxial layer 2E.

Incidentally, the CMOS circuit is constructed of the nMOS 4N and the pMOS 4P, which have their structures, materials and effects similar to those of the foregoing embodiment 1. On the other hand, the structures of the NMOS 4N and the PMOS 4P may be changed to the double drain (or double diffused drain) structure and the LDD (i.e., Lightly Doped Drain) structure.

On the insulating film 7, there is deposited an insulating film 7a of SiO_2, for example, on which is deposited a flattening insulating film 7b. The insulating films 7, 7a and 7b are formed with connection holes 8s extending to reach the electrodes 9Nb and 9Pb, through which a second-layer wiring line 10a is electrically connected with the electrodes 9Na and 9Pa.

The second-layer wiring line 10a is formed by depositing a barrier layer 10a1 of titanium nitride (TiN), a conductor layer 10a2 of an Al—Si—Cu alloy and a barrier layer 10a3 of titanium nitride sequentially from the lower layer.

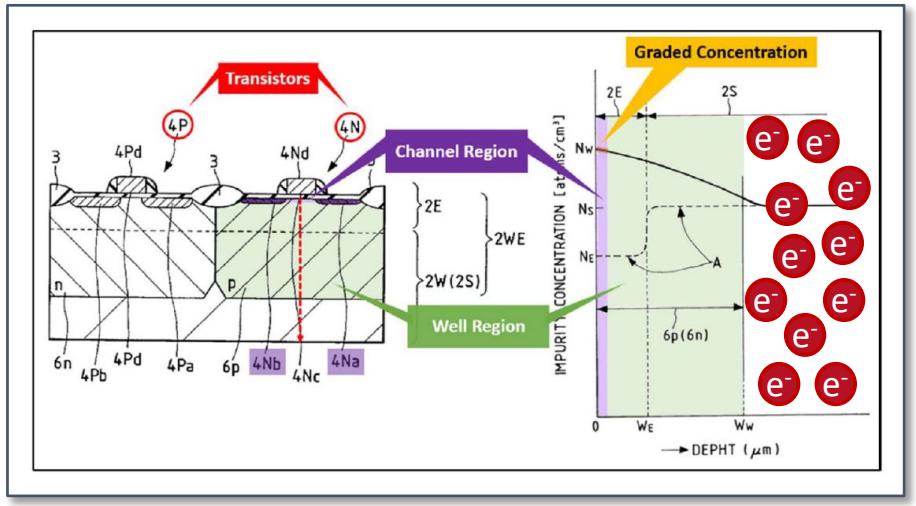
An insulating film 7c of SiO_2, for example, is deposited on the insulating film 7b to cover the second-layer wiring line 10a. On the insulating film 7c, there is deposited the surface protecting film 11. This surface protecting film 11 is formed by depositing an insulating film 11a of SiO_2 and an insulating film 11b of Si_3N_4, for example, sequentially from the lower layer.

Incidentally, in the present embodiment 4, the aforementioned p-well 6p and n-well 6n are formed to extend from the surface of the epitaxial layer 2E to the upper portion of the semiconductor substrate body 2S, as shown in FIGS. 16 and 17, and the p-well 6p and n-well 6n have their impurity concentrations gradually lowered in the depthwise direction

CIRRUS EX. 1007 - 28/36

Incidentally, in the present embodiment 4, the aforementioned p-well **6***p* and n-well **6***n* are formed to extend from the surface of the epitaxial layer **2**E to the upper portion of the semiconductor substrate body **2**S, as shown in FIGS. **16** and **17**, and the p-well **6***p* and n-well **6***n* have their impurity concentrations gradually lowered in the depthwise direction from the principal surface (having an impurity concentration N_W) of the epitaxial layer **2**E. Thus, the impurity concentration of the p-well **6***p* is given such a gradient that it is gradually lowered in the depthwise direction from the surface of the epitaxial layer **2**E, so that the influence to be caused by the carriers (or electrons) due to the α-ray is lowered. Specifically, the electrons produced by the α-ray are attracted to the substrate body **2**S by that concentration gradient and prevented from entering the p-well **6***p* so that the soft errors can be reduced in case the MIS memory of the DRAM or the like is formed in the p-well **6***p*. The impurity

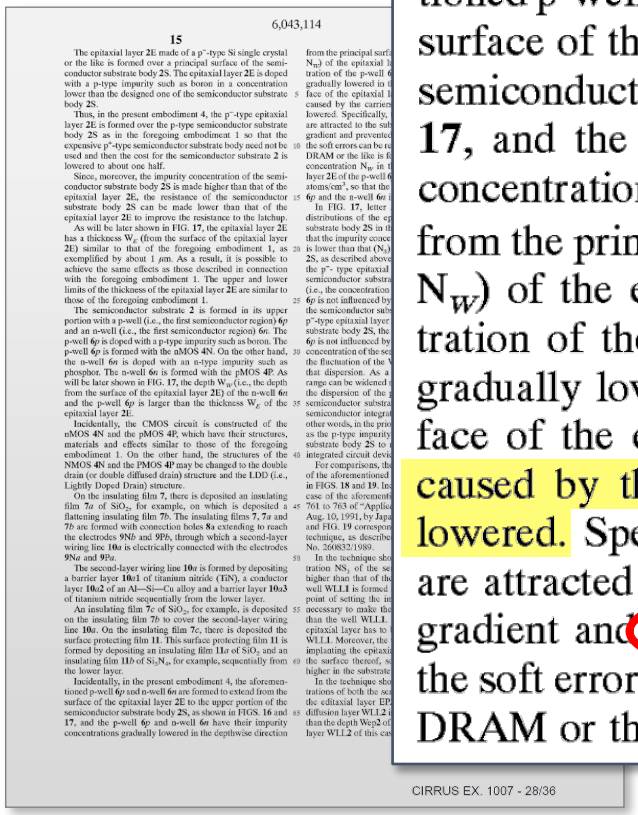
-00001: Ex. 1007 (Kawagoe) at 15:62-16:11



-00001: Petition [1] at 29

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- Kawagoe expressly says it "prevents" the electrons from "entering the p-well 6p" (shaded green).


6,043,114

15

The epitaxial layer 2E made of a p⁻-type Si single crystal or the like is formed over a principal surface of the semiconductor substrate body 2S. The epitaxial layer 2E is doped with a p-type impurity such as boron in a concentration lower than the designed one of the semiconductor substrate body 2S.

Thus, in the present embodiment 4, the p⁻-type epitaxial layer 2E is formed over the p-type semiconductor substrate body 2S as in the foregoing embodiment 1 so that the expensive p⁺-type semiconductor substrate body need not be used and then the cost for the semiconductor substrate 2 is lowered to about one half.

Since, moreover, the impurity concentration of the semiconductor substrate body 2S is made higher than that of the epitaxial layer 2E, the resistance of the semiconductor substrate body 2S can be made lower than that of the epitaxial layer 2E to improve the resistance to the latchup.

As will be later shown in FIG. 17, the epitaxial layer 2E has a thickness W_E (from the surface of the epitaxial layer 2E) similar to that of the foregoing embodiment 1, as exemplified by about 1 μm. As a result, it is possible to achieve the same effects as those described in connection with the foregoing embodiment 1. The upper and lower limits of the thickness of the epitaxial layer 2E are similar to those of the foregoing embodiment 1.

The semiconductor substrate 2 is formed in its upper portion with a p-well (i.e., the first semiconductor region) 6p and an n-well (i.e., the first semiconductor region) 6n. The p-well 6p is doped with a p-type impurity such as boron. The p-well 6p is formed with the nMOS 4N. On the other hand, the n-well 6n is doped with an n-type impurity such as phosphor. The n-well 6n is formed with the pMOS 4P. As will be later shown in FIG. 17, the depth W_W (i.e., the depth from the surface of the epitaxial layer 2E) of the n-well 6n and the p-well 6p is larger than the thickness W_E of the epitaxial layer 2E.

Incidentally, the CMOS circuit is constructed of the nMOS 4N and the pMOS 4P, which have their structures, materials and effects similar to those of the foregoing embodiment 1. On the other hand, the structures of the NMOS 4N and the PMOS 4P may be changed to the double drain (or double diffused drain) structure and the LDD (i.e., Lightly Doped Drain) structure.

On the insulating film 7, there is deposited an insulating film 7a of SiO_2, for example, on which is deposited a flattening insulating film 7b. The insulating films 7, 7a and 7b are formed with connection holes 8s extending to reach the electrodes 9Nb and 9Pb, through which a second-layer wiring line 10a is electrically connected with the electrodes 9Na and 9Pa.

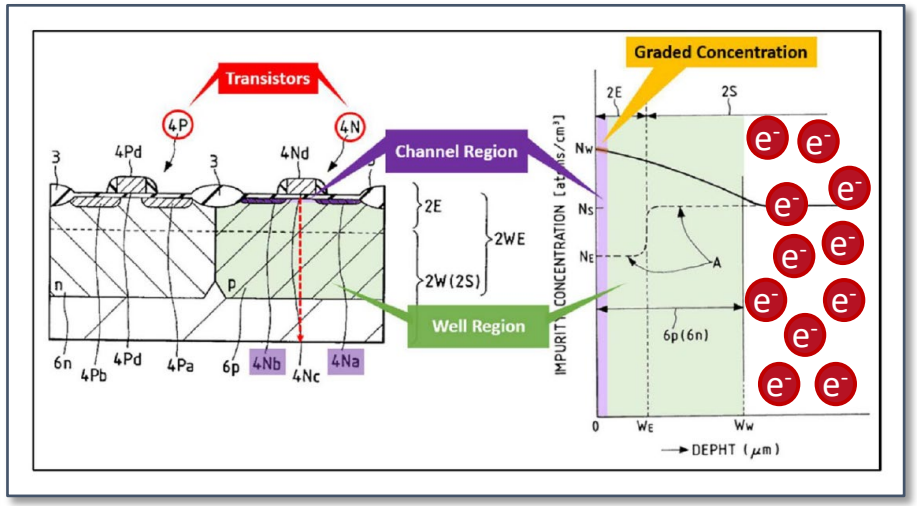
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CIRRUS EX. 1007 - 28/36

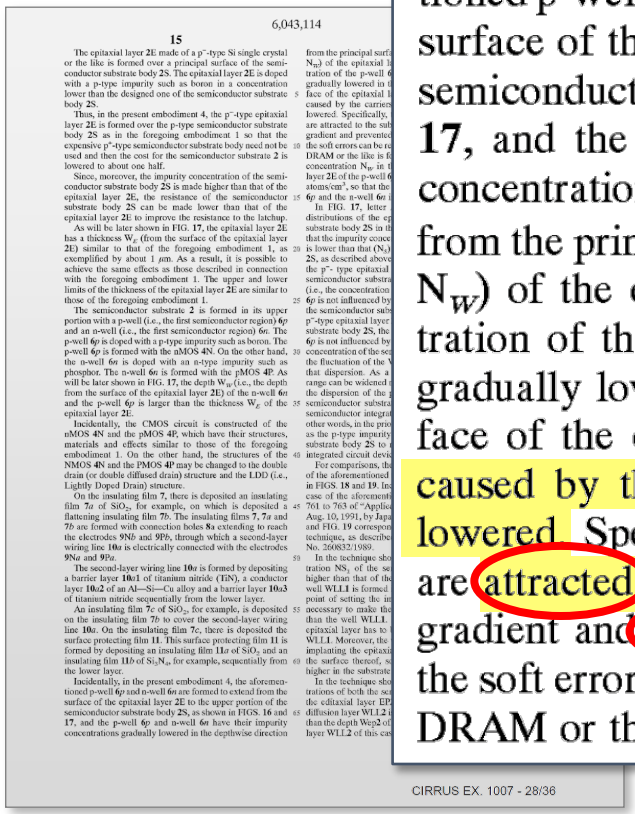
-00001: Ex. 1007 (Kawagoe) at 15:62-16:11



-00001: Petition [1] at 29

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- When Kawagoe says the electrons are "attracted to the substrate body 2S," it means the electrons stay in the substrate.


6,043,114

15

The epitaxial layer 2E made of a p⁻-type Si single crystal or the like is formed over a principal surface of the semiconductor substrate body 2S. The epitaxial layer 2E is doped with a p-type impurity such as boron in a concentration lower than the designed one of the semiconductor substrate body 2S.

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Incidentally, the CMOS circuit is constructed of the nMOS 4N and the pMOS 4P, which have their structures, materials and effects similar to those of the foregoing embodiment 1. On the other hand, the structures of the NMOS 4N and the PMOS 4P may be changed to the double drain (or double diffused drain) structure and the LDD (i.e., Lightly Doped Drain) structure.

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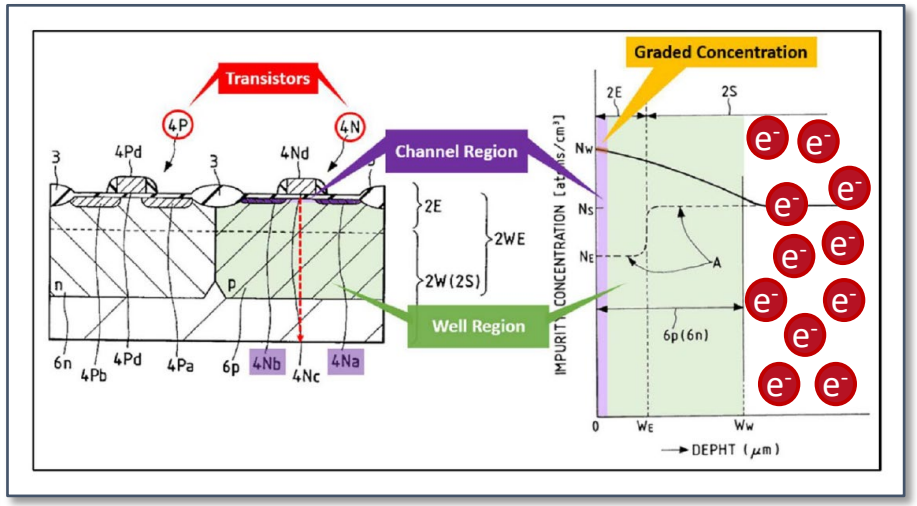
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CIRRUS EX. 1007 - 28/36

Incidentally, in the present embodiment 4, the aforementioned p-well **6***p* and n-well **6***n* are formed to extend from the surface of the epitaxial layer **2**E to the upper portion of the semiconductor substrate body **2**S, as shown in FIGS. **16** and **17**, and the p-well **6***p* and n-well **6***n* have their impurity concentrations gradually lowered in the depthwise direction from the principal surface (having an impurity concentration N_W) of the epitaxial layer **2**E. Thus, the impurity concentration of the p-well **6***p* is given such a gradient that it is gradually lowered in the depthwise direction from the surface of the epitaxial layer **2**E, so that the influence to be caused by the carriers (or electrons) due to the α-ray is lowered. Specifically, the electrons produced by the α-ray are attracted to the substrate body **2**S by that concentration gradient and prevented from entering the p-well **6***p* so that the soft errors can be reduced in case the MIS memory of the DRAM or the like is formed in the p-well **6***p*. The impurity

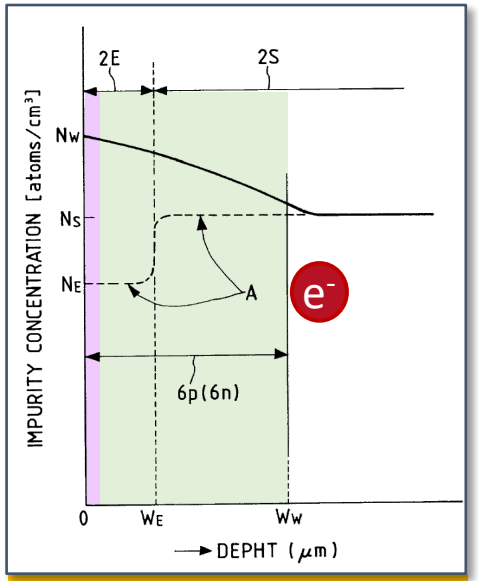
-00001: Ex. 1007 (Kawagoe) at 15:62-16:11



-00001: Petition [1] at 29

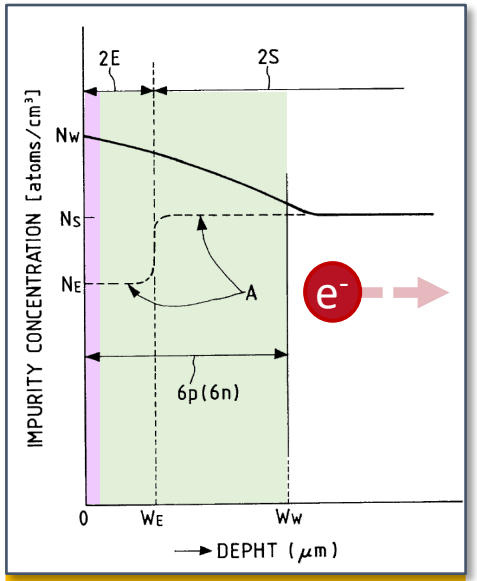
Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- Kawagoe does <u>not</u> disclose "aiding carrier movement" <u>from</u> the active region <u>to</u> the substrate.



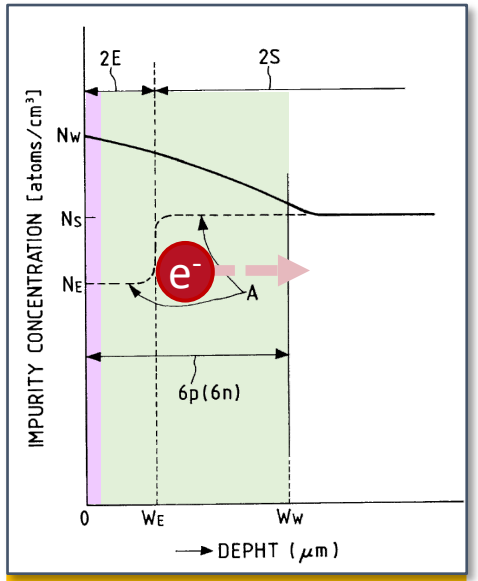
Scenario 1

SEU electron stays in substrate and never enters p-well



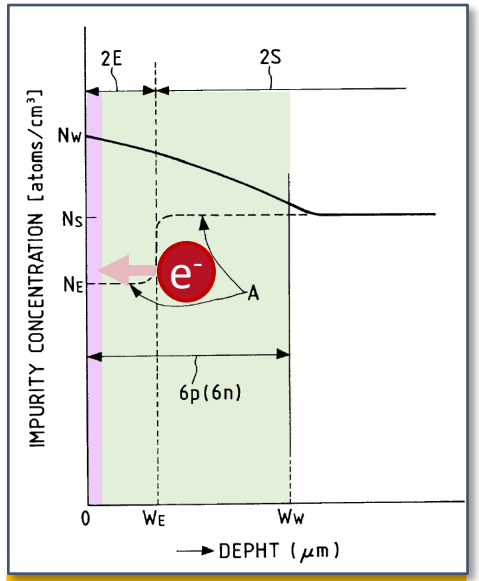
Scenario 2

SEU electron moves deeper into substrate



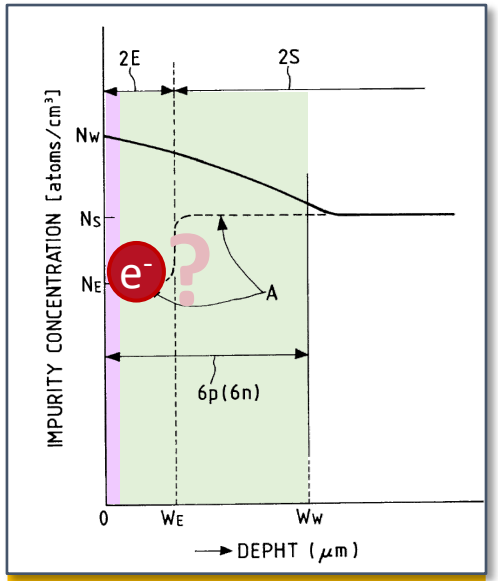
Scenario 3

SEU electron theoretically enters p-well contrary to Kawagoe specification



Scenario 4

SEU electron theoretically enters p-well contrary to Kawagoe specification

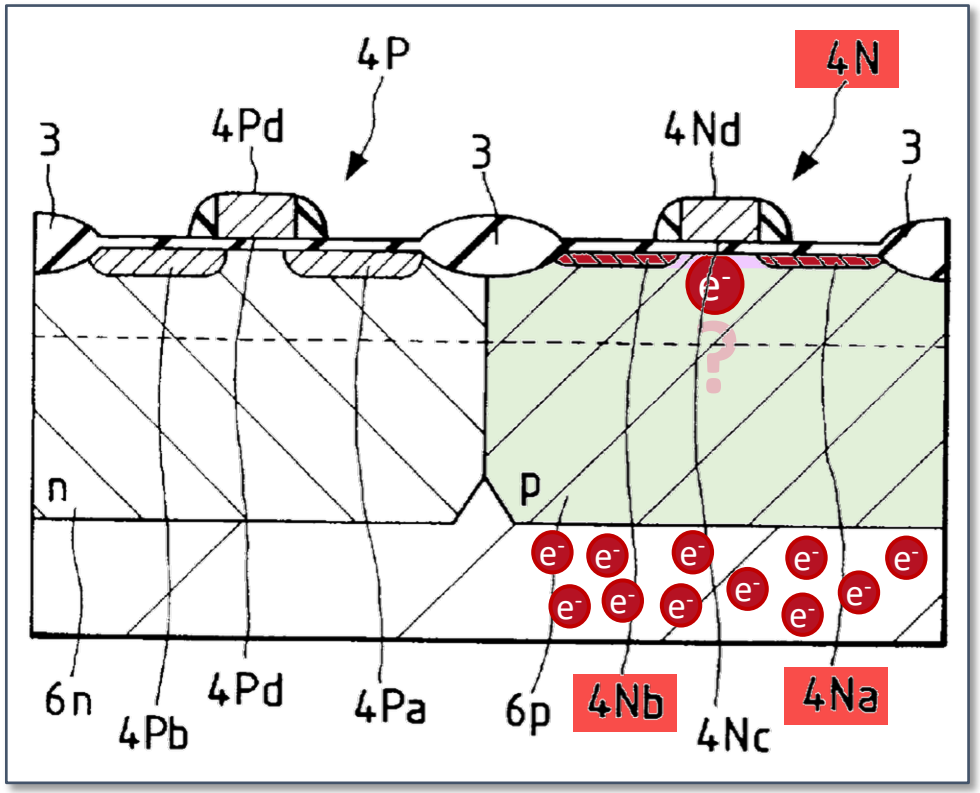


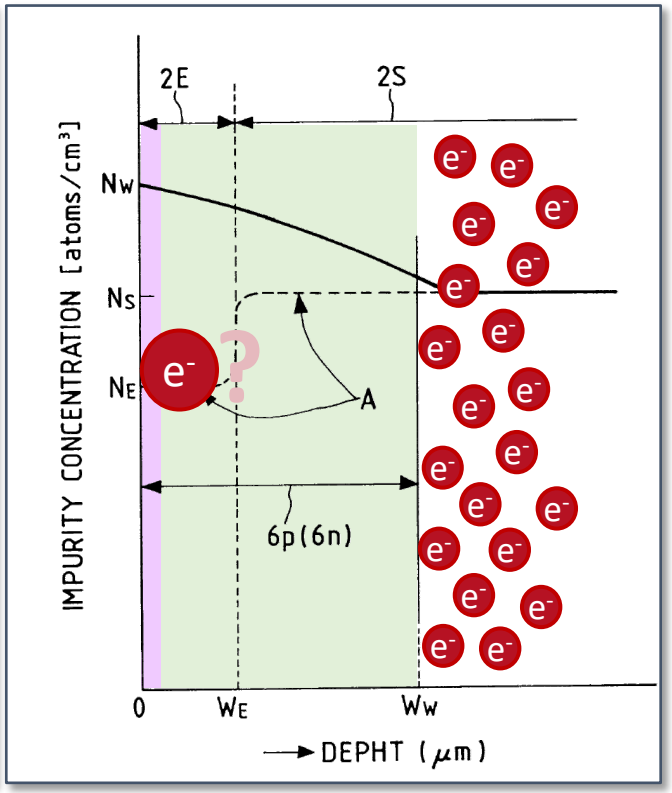
Scenario 5

SEU electrons are not in the active region

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- Kawagoe does <u>not</u> disclose "aiding carrier movement" <u>from</u> the active region <u>to</u> the substrate.



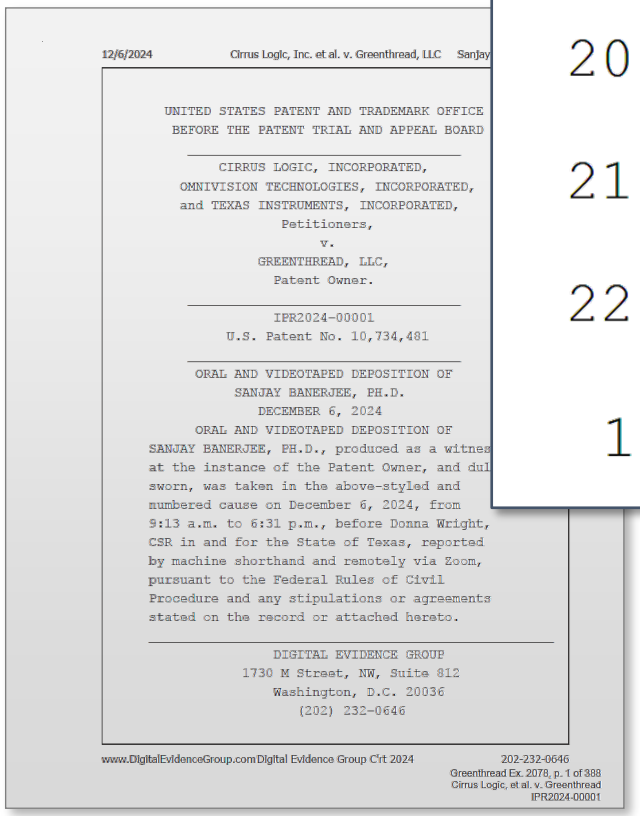


Scenario 5

SEU electrons are not in the active region

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- 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,
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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SANJAY BANERJEE, PH.D., produced as a witnes
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sworn, was taken in the above-styled and
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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,
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Procedure and any stipulations or agreements
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Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

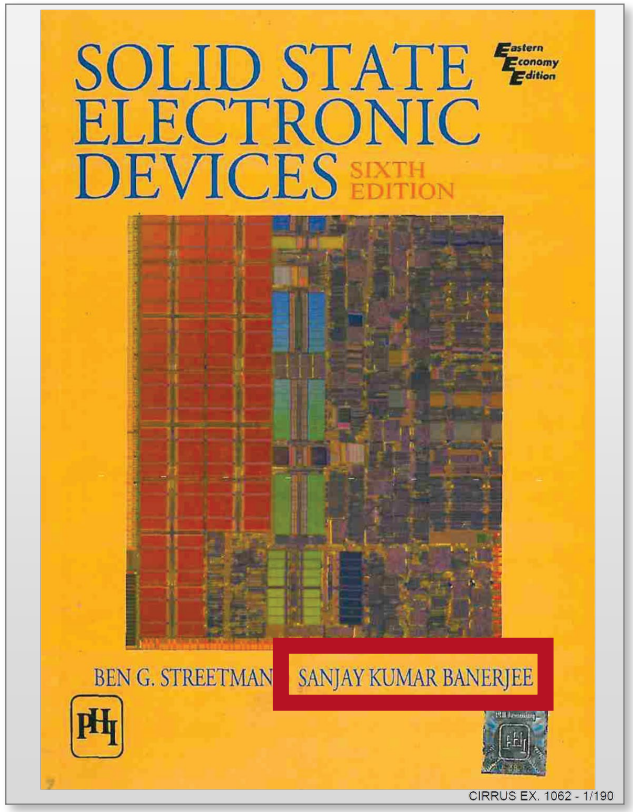
19 When you were analyzing the
20 prior art references, you never calculated
21 the magnitude for any of the electric fields,
22 correct?

1 A. I did not calculate those.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 212:19-213:1

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- 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

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

-00001: Ex. 1062A (Streetman & Banerjee Textbook) at 99

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- 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.

-00001: 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.

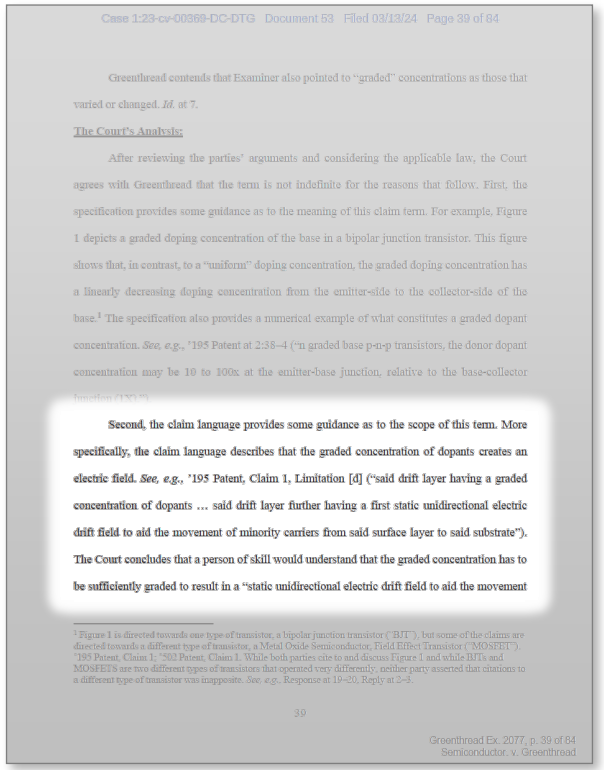
-00001: Ex. 2056 at 96:1-13

-00001: PO Resp. [45] at 7, 14-15; PO Sur-Reply [63] at 8

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

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



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.

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.

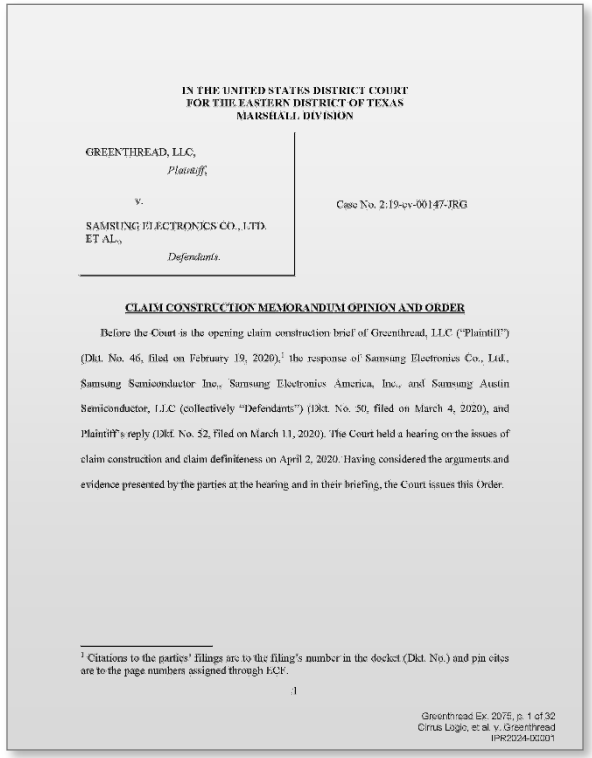
-00001: Ex. 2074 (WDTX Order) at 39-40

-00001: PO Resp. [45] at 9; PO Sur-Reply [63] at 9, 19-20

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- 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
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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

-00001: Ex. 2075 (EDTX Order) at 15

-00001: PO Resp. [45] at 9; PO Sur-Reply [63] at 9

Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- 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

-00001: 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).

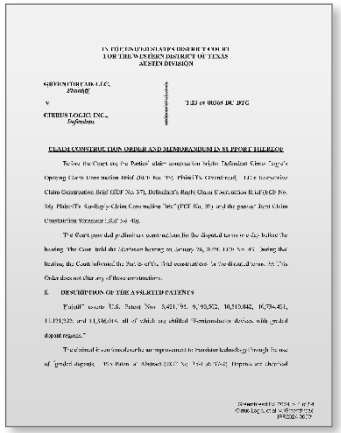
-00001: Ex. 1016 ('195 Prosecution History) at 289

-00001: PO Resp. [45] at 9; PO Sur-Reply [63] at 9

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

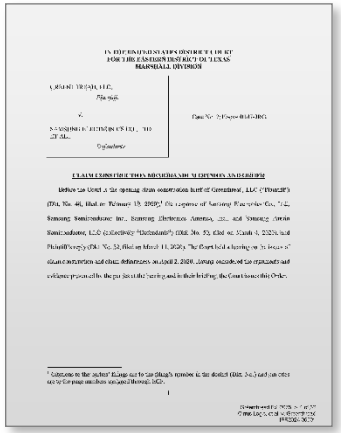
Petitioners Did Not Identify an Electric Field in Kawagoe's Active Region

- 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.

-00001: 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

-00001: Ex. 2075 (EDTX Order) at 15

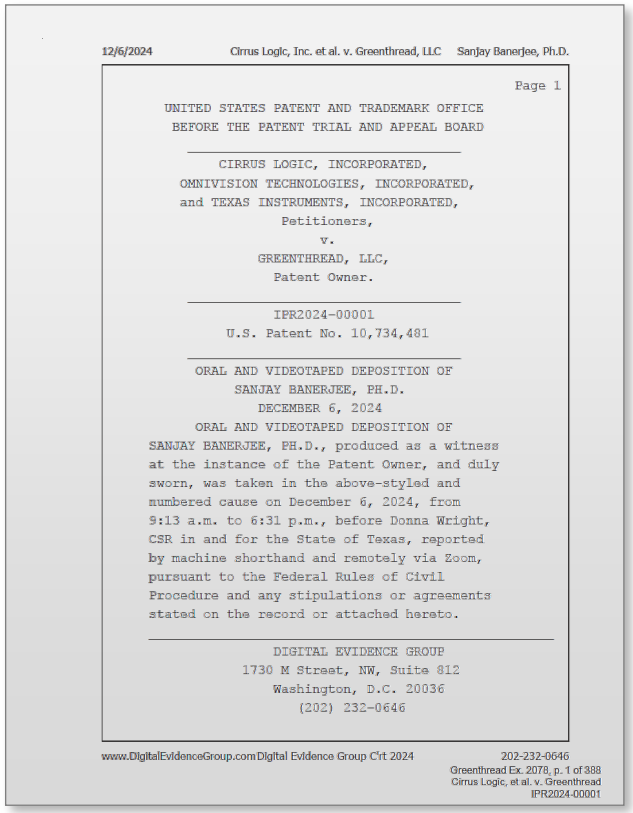
-00001: PO Resp. [45] at 9; PO Sur-Reply [63] at 9

Overview of Issues

- **The Challenged Claims require "carrier movement" from the "active region."**
- **Dr. Banerjee confirmed that the "electric field" must start in the "active region."**
- **Petitioners did not identify an electric field, much less an electric field that starts in the "active region."**
- **Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).**
- Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."
- Petitioners have the burden to analyze all of the fields in the "active region."
- Dr. Banerjee testified that he did not analyze any of the fields in the "active region."
  - Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."
  - The graded dopant concentration is "uniform" in Wieczorek's "active region."
- Petitioners' prosecution-related arguments are incorrect.
- Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
- Kawagoe does not meet the "second doping type" limitation.
- Petitioners' expert declaration and testimony are untrustworthy.
  - Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.
  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

Carriers in the "Active Region" are Affected by Numerous Fields

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



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GREENTHREAD, LLC,
Patent Owner.

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

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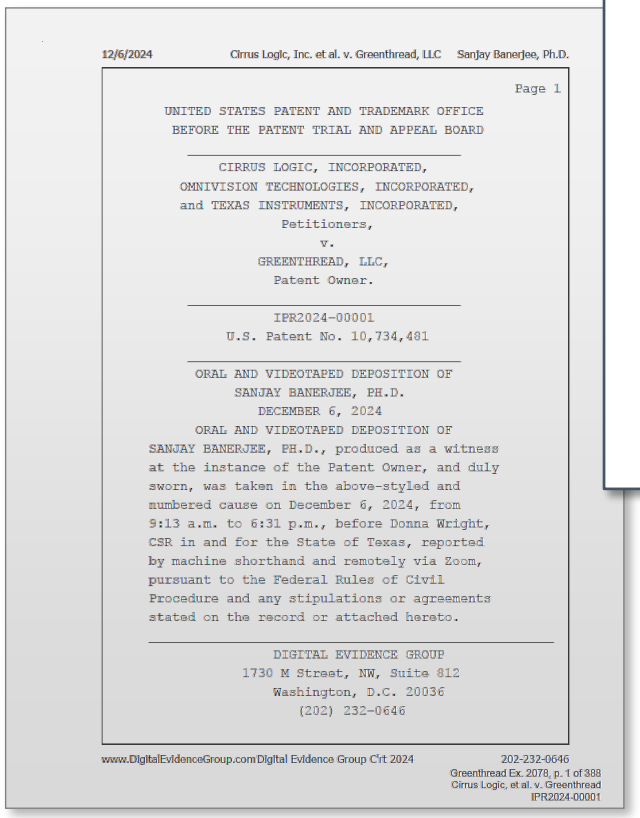
Greenthread Ex. 2078, p. 1 of 388
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IPR2024-00001

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

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 80:18-81:5

Carriers in the "Active Region" are Affected by Numerous Fields

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



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

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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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 83:19-84:1

Carriers in the "Active Region" 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.

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.

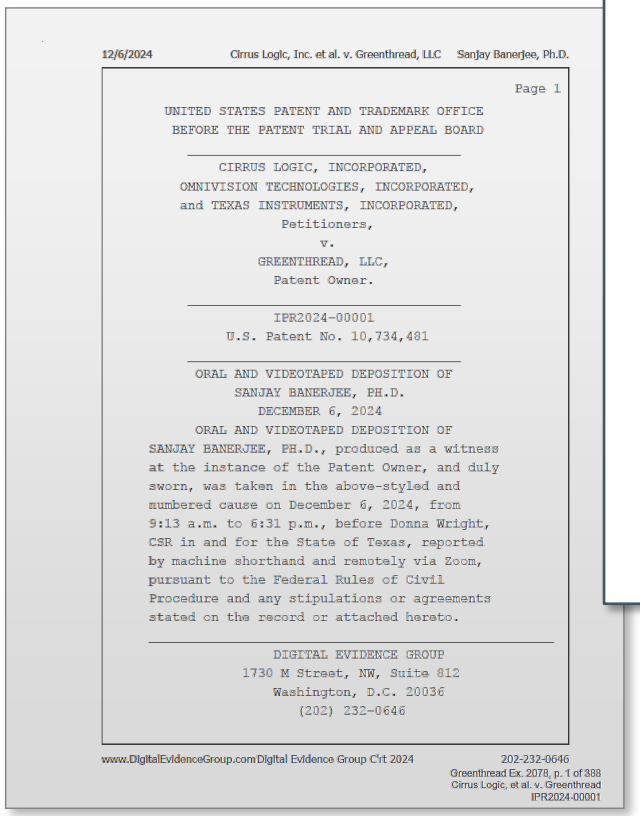
Q. (BY MR. WHITEHURST) And you didn't calculate the magnitude for the electric field due to the gate or the gate oxide, did you?

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

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 222:4-224:7

Carriers in the "Active Region" are Affected by Numerous Fields

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



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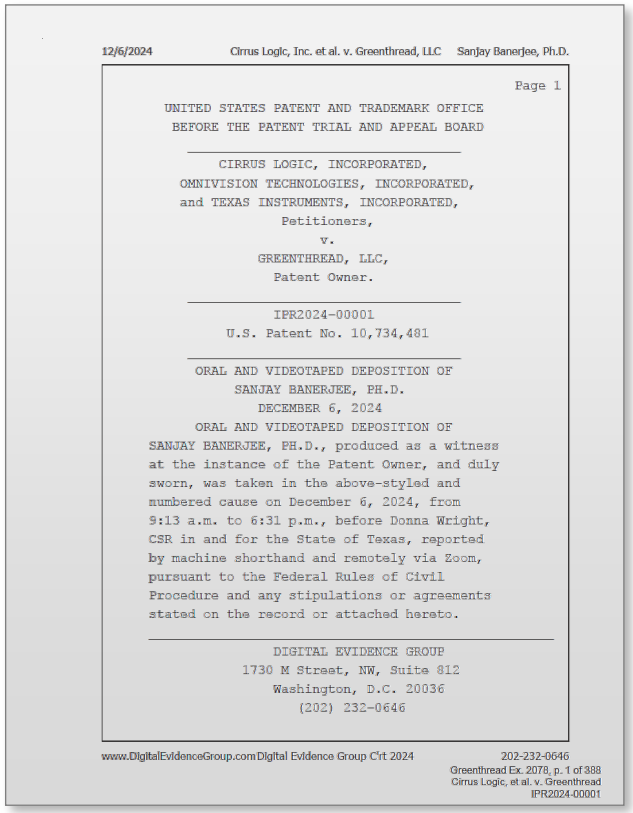
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11 Q. Can you think of any other
12 category 2 forces?
13 A. Yes. I could apply temperature
14 gradients where the temperature is not the
15 same throughout and that can give you what
16 are called thermoelectric effects.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 138:11-16

Carriers in the "Active Region" are Affected by Numerous Fields

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



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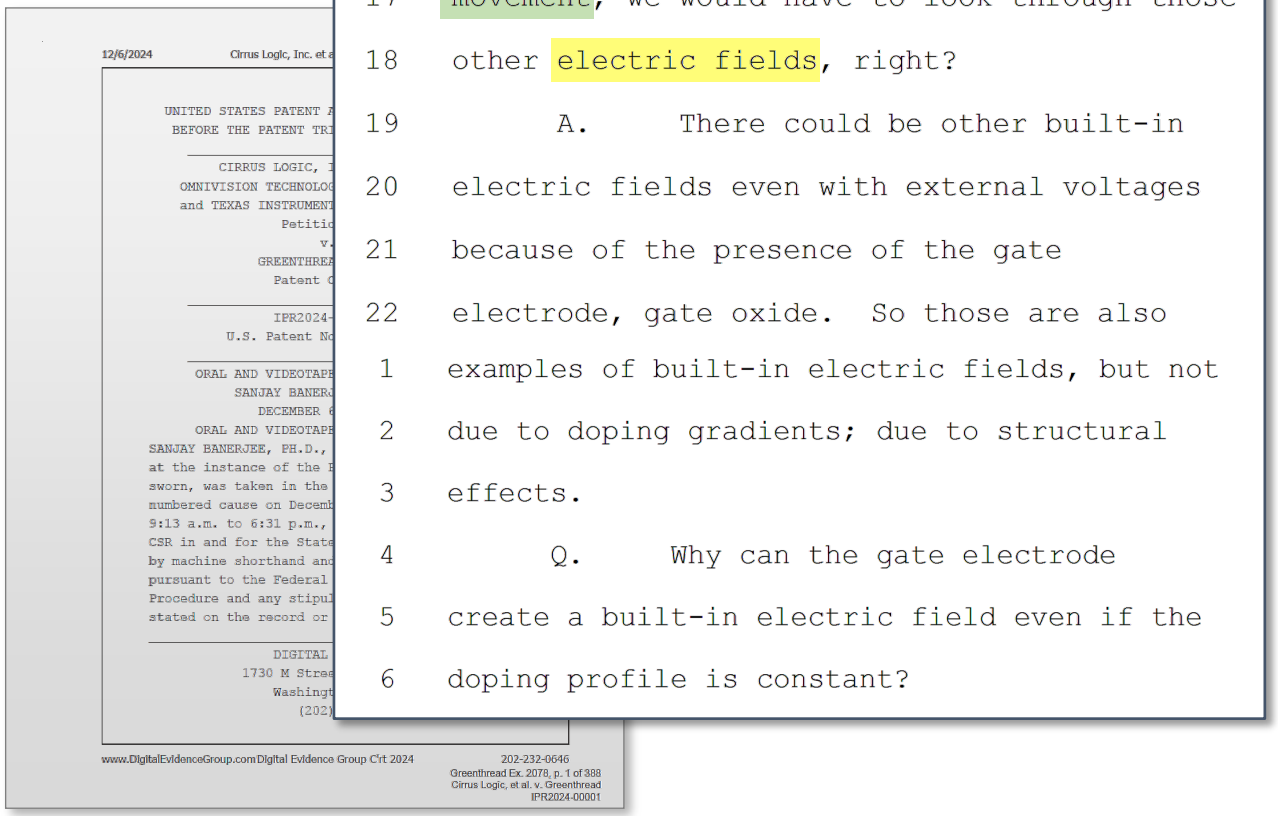
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11	Q. (BY MR. WHITEHURST) What is
12	the Hall effect?
13	A. The Hall effect happens when
14	you apply a magnetic field, say in the
15	vertical direction, and you apply and you
16	have the velocity of the particles in the
17	horizontal direction. That 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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 140:11-21

Carriers in the "Active Region" 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 --

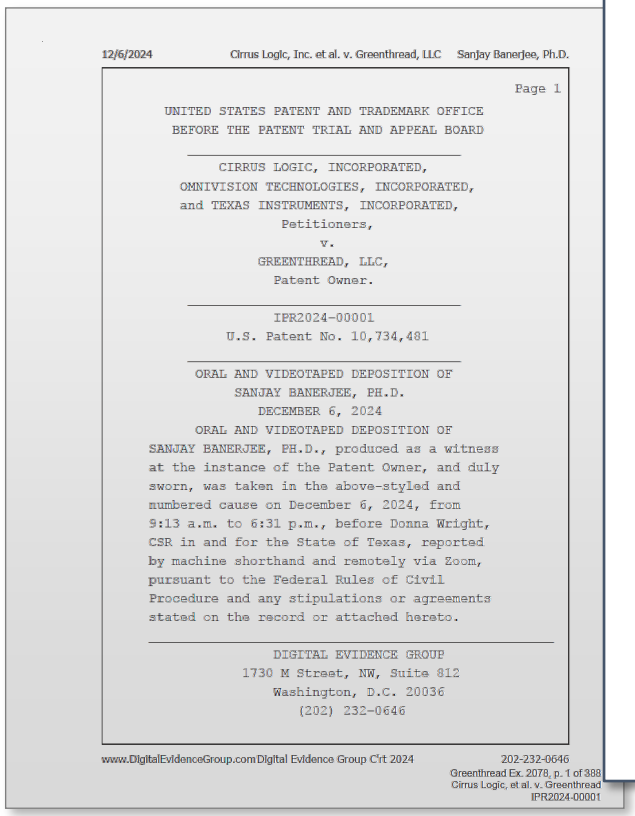
-00001: Ex. 2078 (Banerjee Dep. Tr.) at 219:16-220:20

Overview of Issues

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- **Dr. Banerjee confirmed that the "electric field" must start in the "active region."**
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- **Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."**
- Petitioners have the burden to analyze all of the fields in the "active region."
- Dr. Banerjee testified that he did not analyze any of the fields in the "active region."
  - Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."
  - The graded dopant concentration is "uniform" in Wieczorek's "active region."
- Petitioners' prosecution-related arguments are incorrect.
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Carrier Movement Depends on the Vector Sum

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



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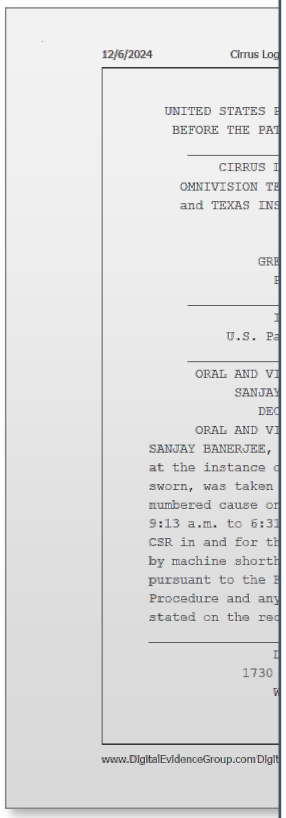
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15 Q. When you're trying to determine
16 net motion, you want to look at the vector
17 sum of all of the different fields, correct?
18 A. Yes.
19 Q. Because the vector sum
20 determines the net movement, correct?
21 MR. PAUL: Objection, form.
22 THE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

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 183:15-22

Carrier Movement Depends on the Vector Sum

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



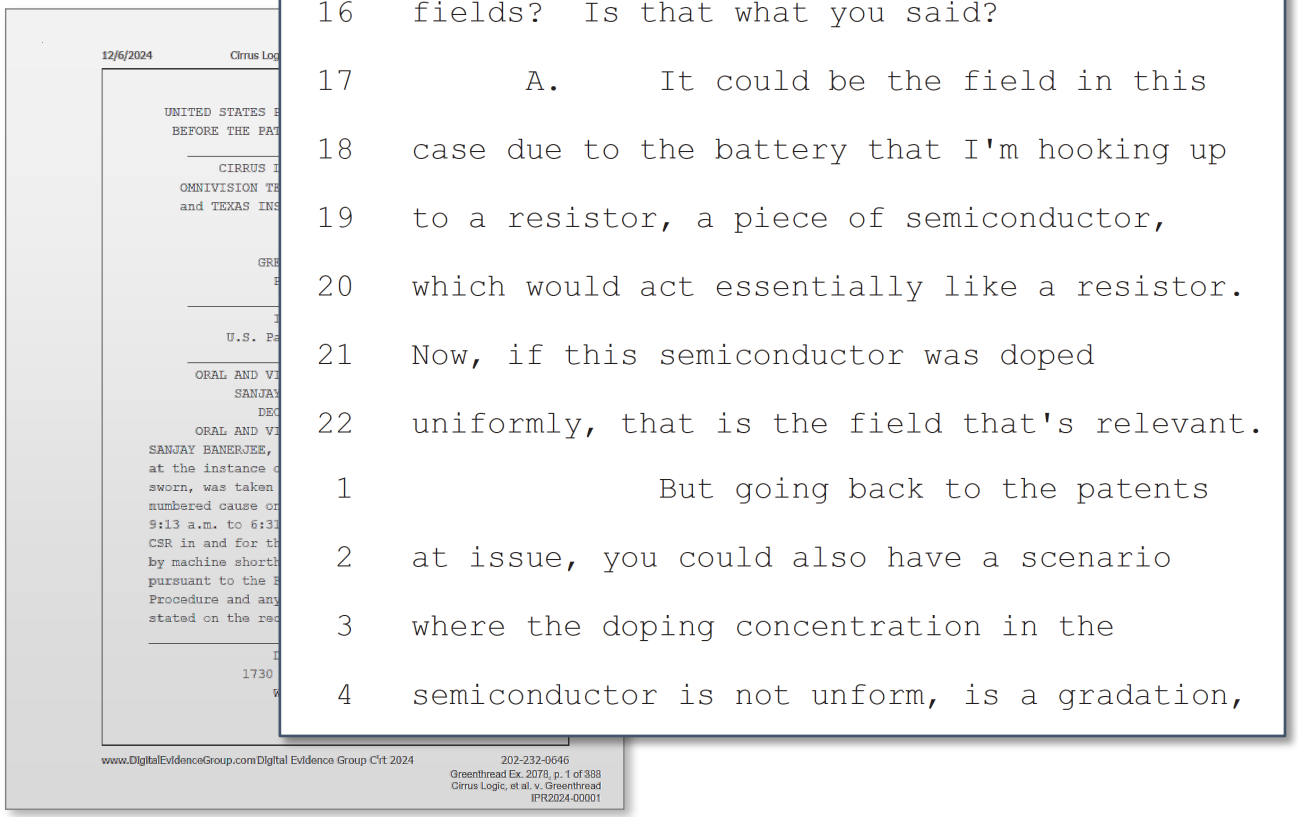
18 Q. (BY MR. WHITEHURST) So when
19 we're looking at an electron in a
20 semiconductor, we could have multiple forces
21 acting on it?
22 MR. PAUL: Objection to form.
1 THE WITNESS: Well, as I told
2 you, you have the three broad
3 categories of forces, but now focusing
4 on the second category, which 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

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 113:18-114:21

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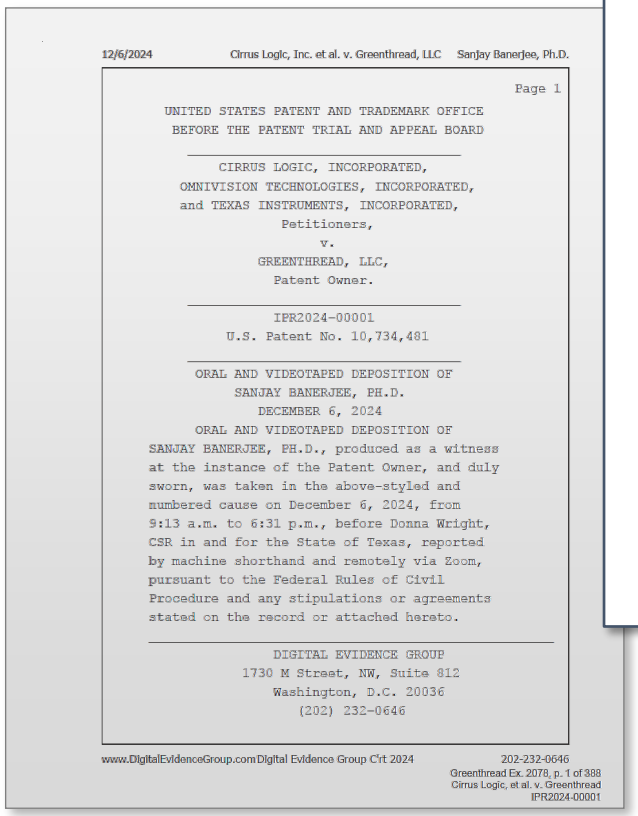
15 Q. So there could be multiple
16 fields? Is that what you said?
17 A. It could be the field in this
18 case due to the battery that I'm hooking up
19 to a resistor, a piece of semiconductor,
20 which would act essentially like a resistor.
21 Now, if this semiconductor was doped
22 uniformly, that 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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 109:15-110:15

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3 Q. But we agree that net movement
4 will depend on the vector sum, right?
5 MR. PAUL: Objection to form.
6 THE WITNESS: Net movement as
7 in drift velocity would depend on the
8 vector sum.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 251:3-8

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  - Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.
  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

Petitioners Have the Burden to Analyze the Electric Fields

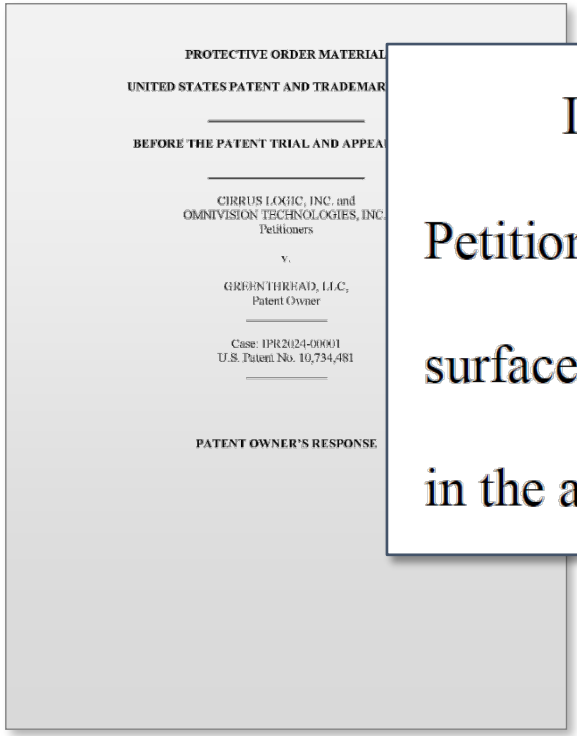


"In *Magnum Oil*, we soundly rejected the idea of shifting even the burden of *production* from the petitioner to the patent owner once the Board institutes an IPR where 'the patentee's position is that the patent challenger failed to meet its burden of proving obviousness.' … We therefore reject [petitioners'] 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)

Petitioners Have the Burden to Analyze the Electric Fields

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


PROTECTIVE ORDER MATERIAL

UNITED STATES PATENT AND TRADEMAR

BEFORE THE PATENT TRIAL AND APPEA

CIRRUS LOGIC, INC. and
OMNIVISION TECHNOLOGIES, INC.
Petitioners

v.

GREENTHREAD, LLC,
Patent Owner

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

PATENT OWNER'S RESPONSE

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.

-00001: PO Response [45] at 2

Petitioners Have the Burden to Analyze the Electric Fields

An obviousness finding "is appropriate only when the reference discloses prior art that must *necessarily* include the unstated limitation."

Transclean Corp. v. Bridgewood Servs., Inc.,, 290 F.3d 1364, 1373 (Fed. Cir. 2002)

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)

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)

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

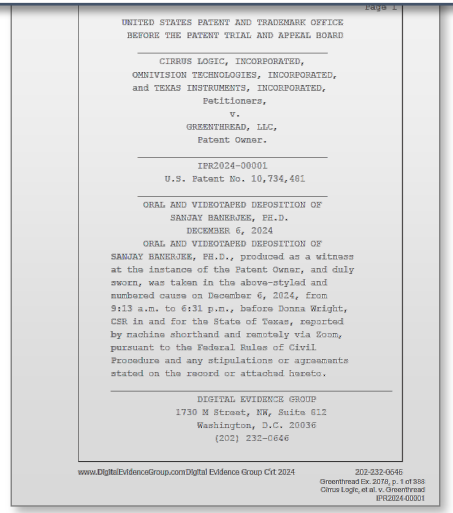
- **The Challenged Claims require "carrier movement" from the "active region."**
- **Dr. Banerjee confirmed that the "electric field" must start in the "active region."**
- **Petitioners did not identify an electric field, much less an electric field that starts in the "active region."**
- **Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).**
- **Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."**
- **Petitioners have the burden to analyze all of the fields in the "active region."**
- **Dr. Banerjee testified that he did not analyze any of the fields in the "active region."**
  - **Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."**
  - The graded dopant concentration is "uniform" in Wieczorek's "active region."
- Petitioners' prosecution-related arguments are incorrect.
- Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
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  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

Dr. Banerjee Did Not Analyze the Electric Fields in Kawagoe

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

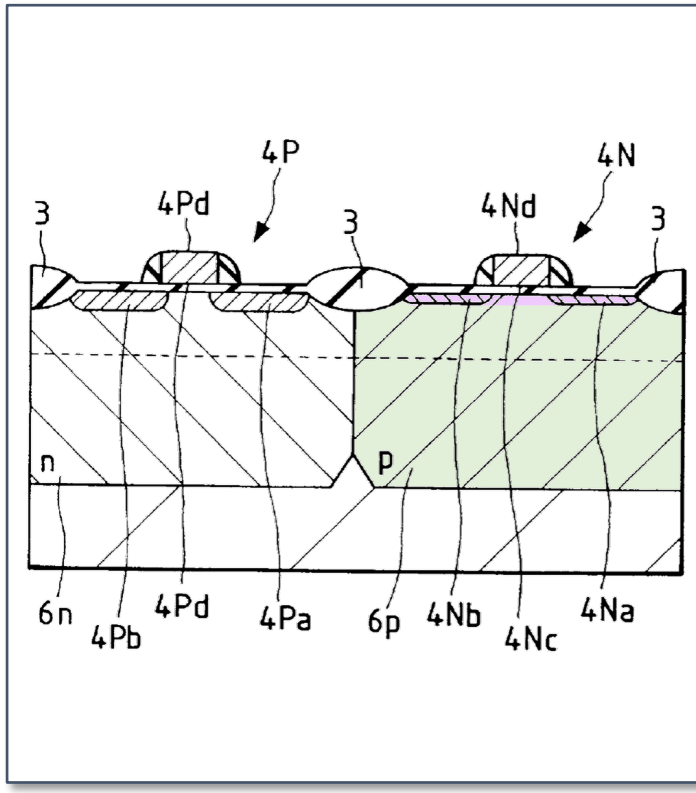
ORAL AND VIDEOTAPED DEPOSITION OF
SANJAY BANERJEE, PH.D.
DECEMBER 6, 2024

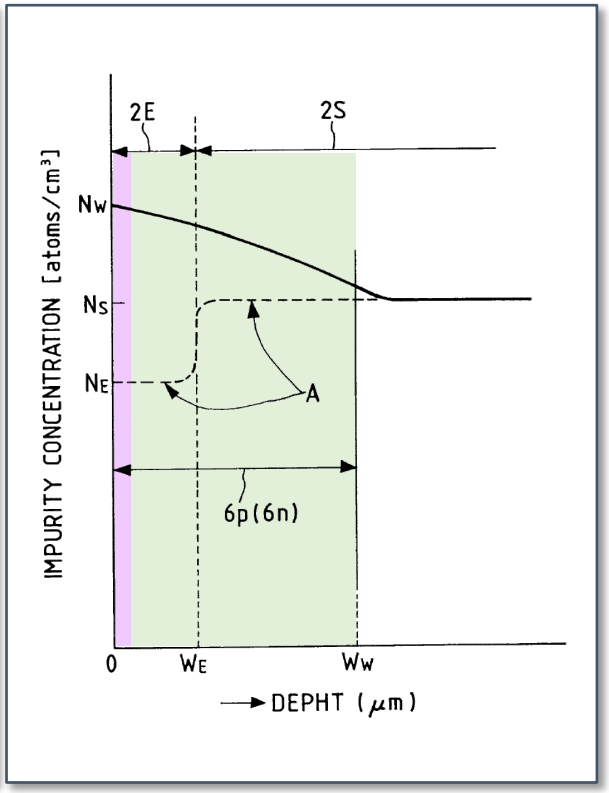
ORAL AND VIDEOTAPED DEPOSITION OF SANJAY BANERJEE, PH.D., produced as a witness at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine 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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Greenthread Ex. 2078, p. 1 of 388
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-00001: Ex. 2078 (Banerjee Dep. Tr.) at 212:19-213:1

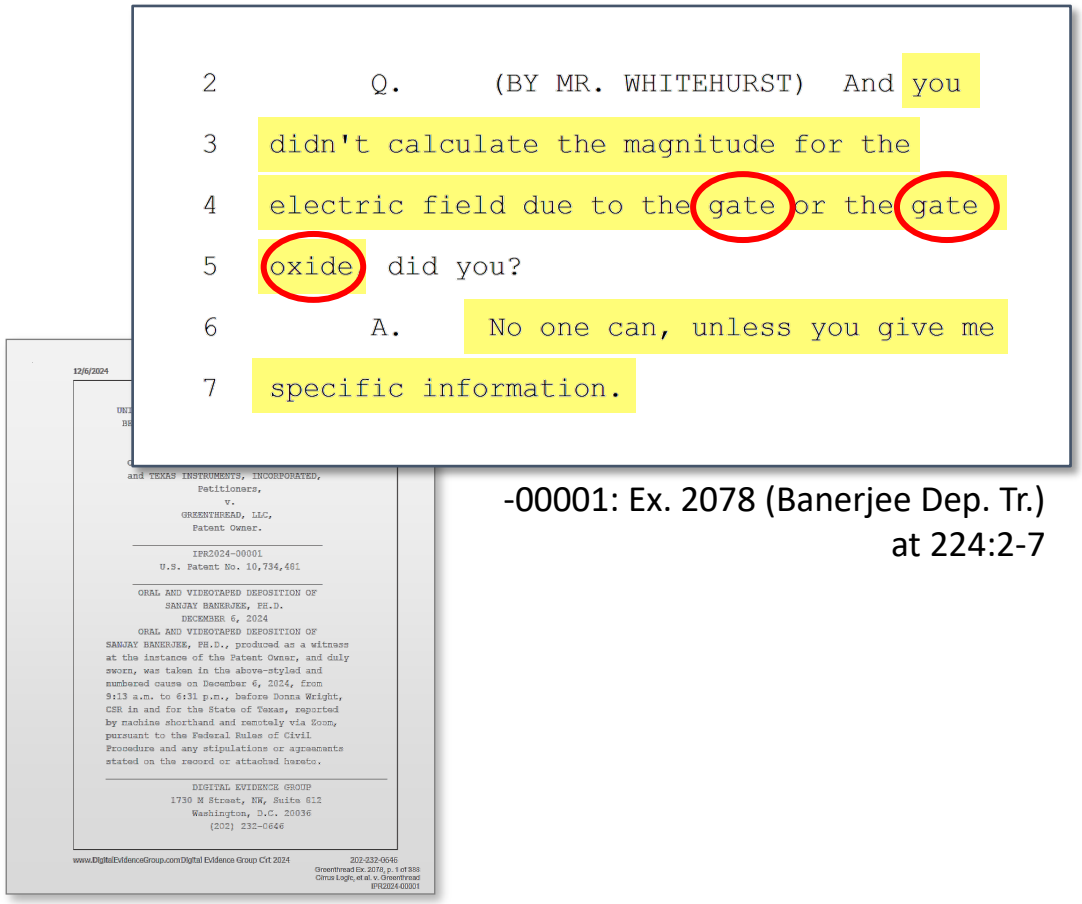




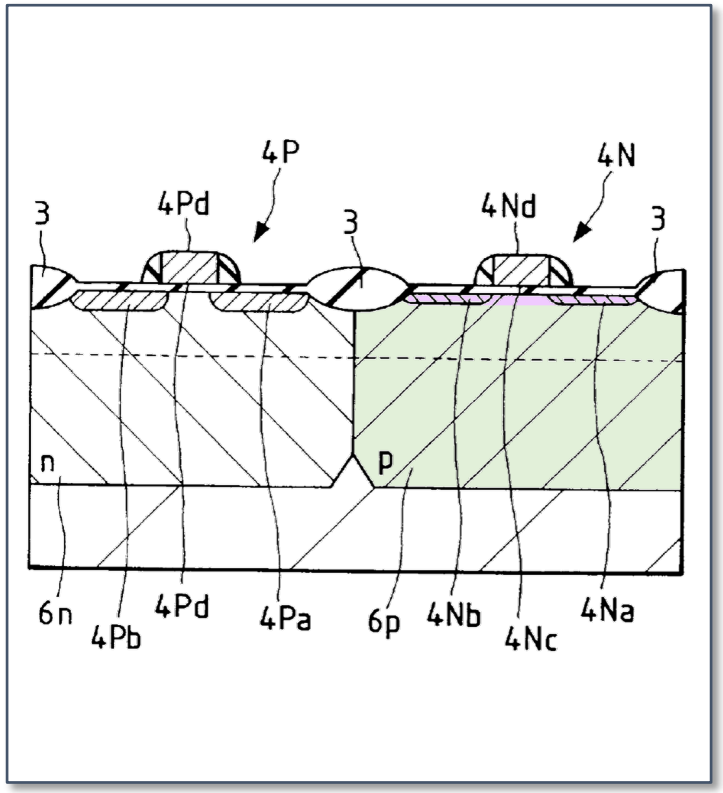
-00001: Ex. 1007 (Kawagoe) at Figs. 17, 23

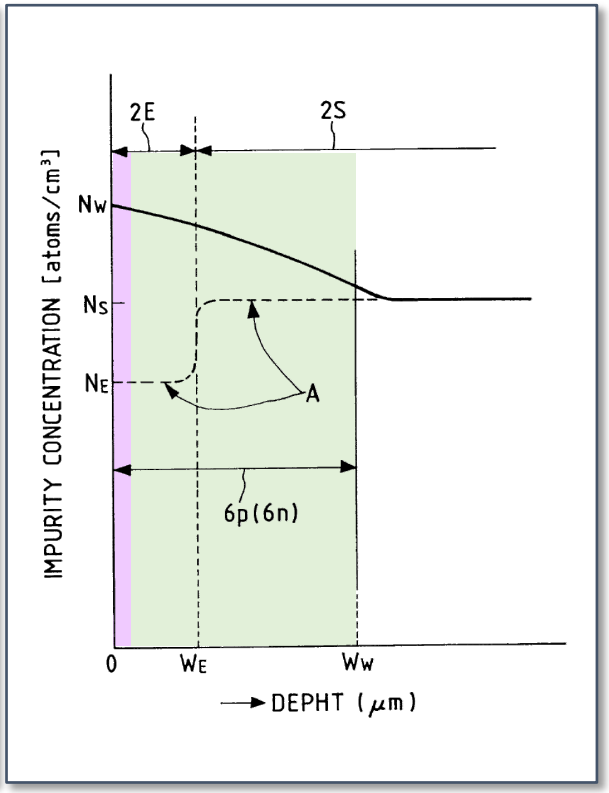
Dr. Banerjee Did Not Analyze the Electric Fields in Kawagoe

- Dr. Banerjee did not analyze any of the electric fields in Kawagoe's active region.



-00001: Ex. 2078 (Banerjee Dep. Tr.) at 224:2-7

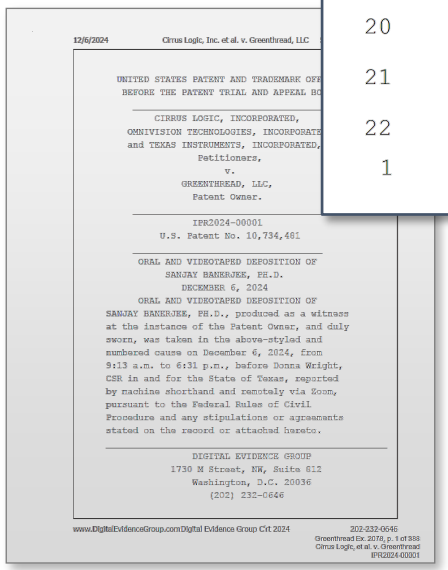




-00001: Ex. 1007 (Kawagoe) at Figs. 17, 23

Dr. Banerjee Did Not Analyze the Electric Fields in Kawagoe

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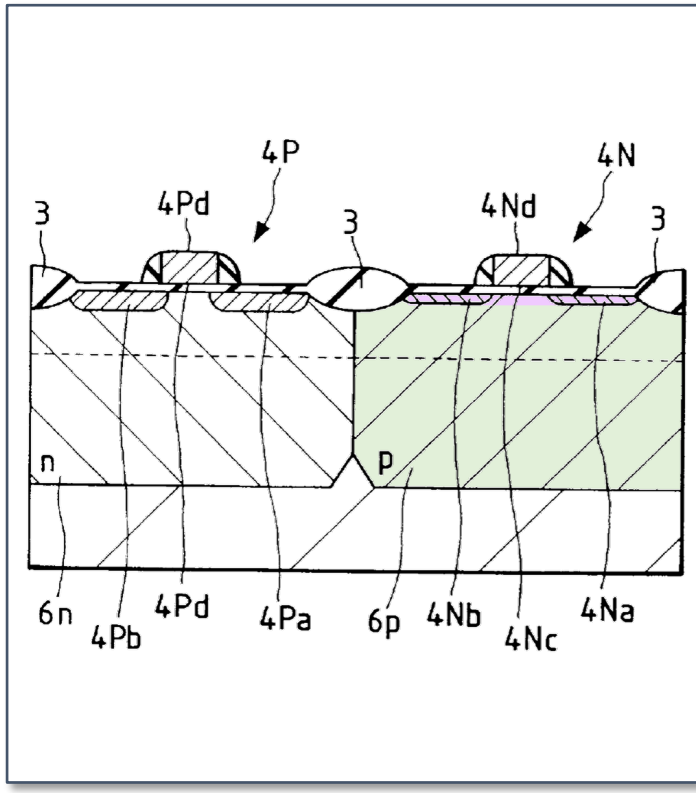
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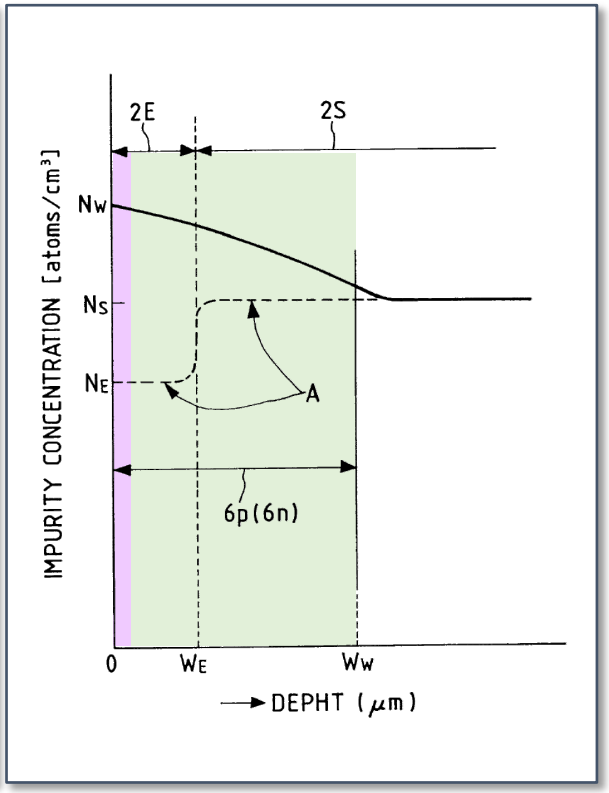
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Greenthread Ex. 2078, p. 1 of 388
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IPR2024-00001

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 223:14-224:1

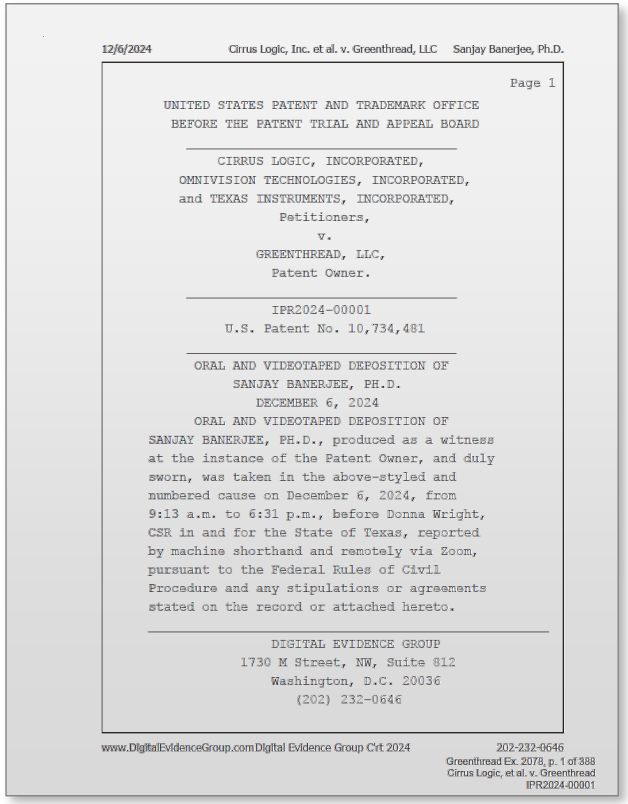




-00001: Ex. 1007 (Kawagoe) at Figs. 17, 23

Dr. Banerjee Did Not Analyze the Electric Fields in Kawagoe

- Dr. Banerjee admitted that he cannot determine the starting point of Kawagoe's electrons.



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

14 Q. (BY MR. WHITEHURST) So it's
15 your testimony today that when you look at
16 Figure 17 of Kawagoe, it's not possible to
17 determine the starting point for the ensemble
18 of electrons?
19 Did I get that right?
20 MR. PAUL: Objection, form.
21 Scope.
22 THE WITNESS: It's not possible
1 to find the starting point of any
2 individual electron ensemble or any
3 individual hole.

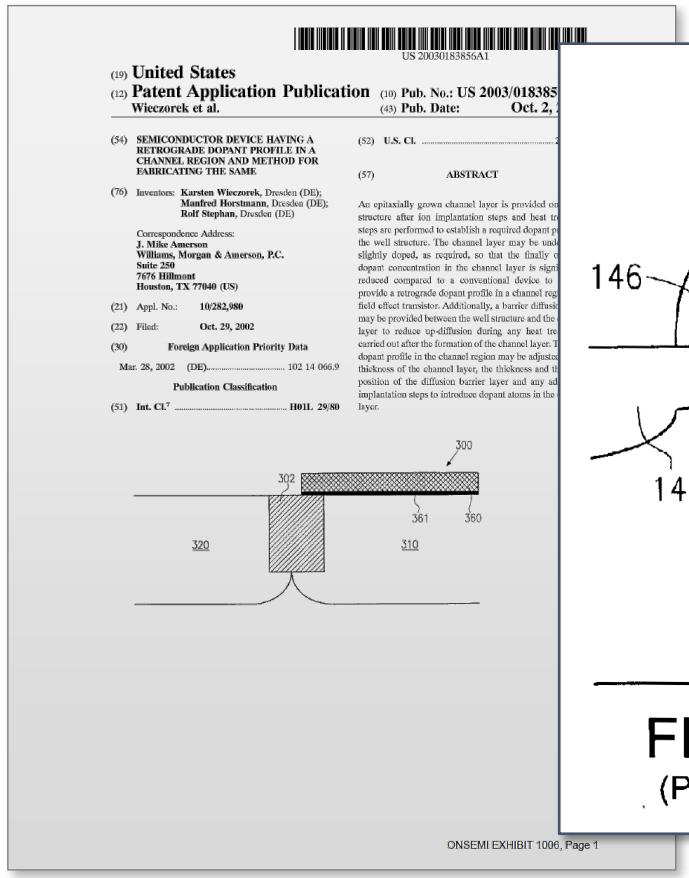
-00001: Ex. 2078 (Banerjee Dep. Tr.) at 241:14-242:3

Overview of Issues

- **The Challenged Claims require "carrier movement" from the "active region."**
- **Dr. Banerjee confirmed that the "electric field" must start in the "active region."**
- **Petitioners did not identify an electric field, much less an electric field that starts in the "active region."**
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  - **The graded dopant concentration is "uniform" in Wieczorek's "active region."**
- Petitioners' prosecution-related arguments are incorrect.
- Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
- Kawagoe does not meet the "second doping type" limitation.
- Petitioners' expert declaration and testimony are untrustworthy.
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  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

Wieczorek is Uniform in the Active Region

- Petitioners rely entirely on the following two figures.
- There is no evidence that carriers move from the surface to the substrate.


US 20030183856A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2003/018385

Wieczorek et al. (43) Pub. Date: Oct. 2,

(54) SEMICONDUCTOR DEVICE HAVING A RETROGRADE DOPANT PROFILE IN A CHANNEL REGION AND METHOD FOR FABRICATING THE SAME

(76) Inventors: Karsten Wieczorek, Dresden (DE); Manfred Horstmann, Dresden (DE); Rolf Stephan, Dresden (DE)

Correspondence Address:
J. Mike Amerson
Williams, Morgan & Amerson, P.C.
Suite 250
7676 Hillmont
Houston, TX 77040 (US)

(21) Appl. No.: 10/282,980

(22) Filed: Oct. 29, 2002

(30) Foreign Application Priority Data

Mar. 28, 2002 (DE)..... 102 14 066.9

Publication Classification

(51) Int. Cl.[7] H01L 29/80

(52) U.S. Cl. .....

(57) ABSTRACT

An epitaxially grown channel layer is provided on structure after ion implantation steps and heat tr steps are performed to establish a required dopant p the well structure. The channel layer may be und slightly doped, as required, so that the finally dopant concentration in the channel layer is signi reduced compared to a conventional device to provide a retrograde dopant profile in a channel reg field effect transistor. Additionally, a barrier diffusi may be provided between the well structure and the layer to reduce up-diffusion during any heat tre carried out after the formation of the channel layer. dopant profile in the channel region may be adjuste thickness of the channel layer, the thickness and t position of the diffusion barrier layer and any ad implantation steps to introduce dopant atoms in the layer.

ONSEMI EXHIBIT 1006, Page 1

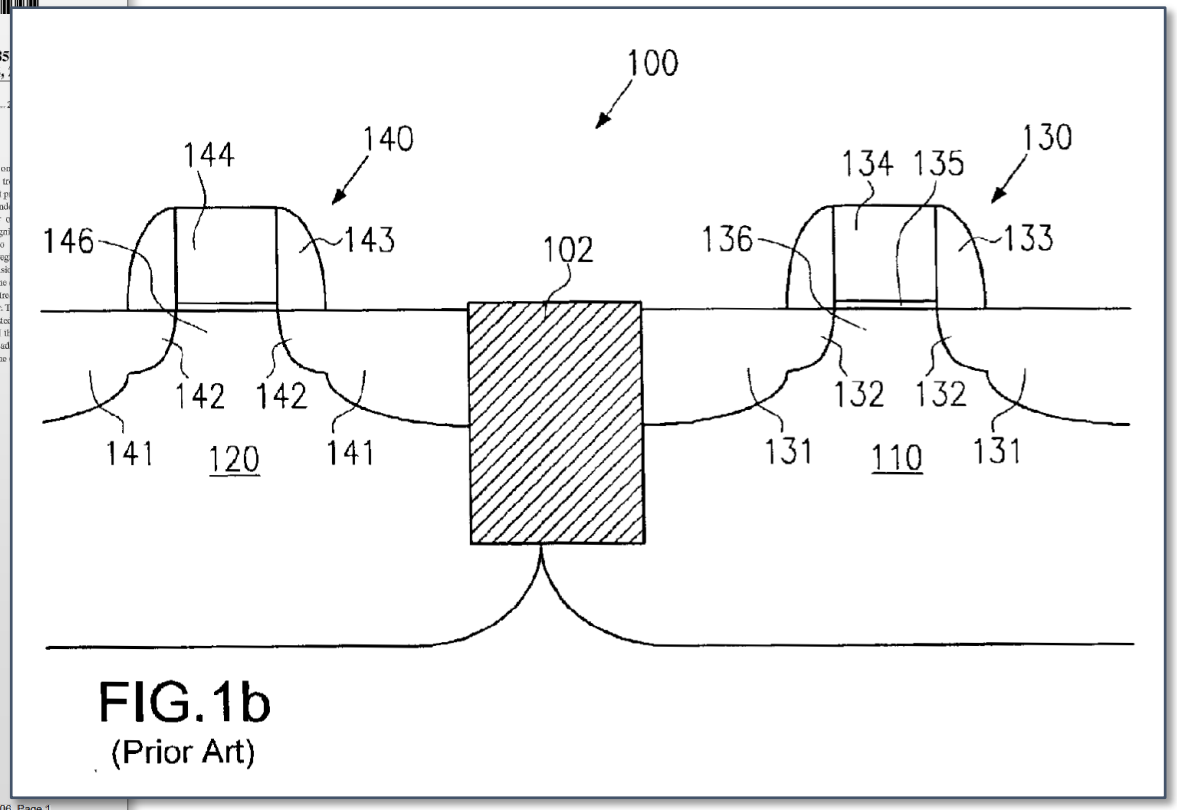


FIG.1b
(Prior Art)

-00001: Ex. 1006 (Wieczorek) at Fig. 1b

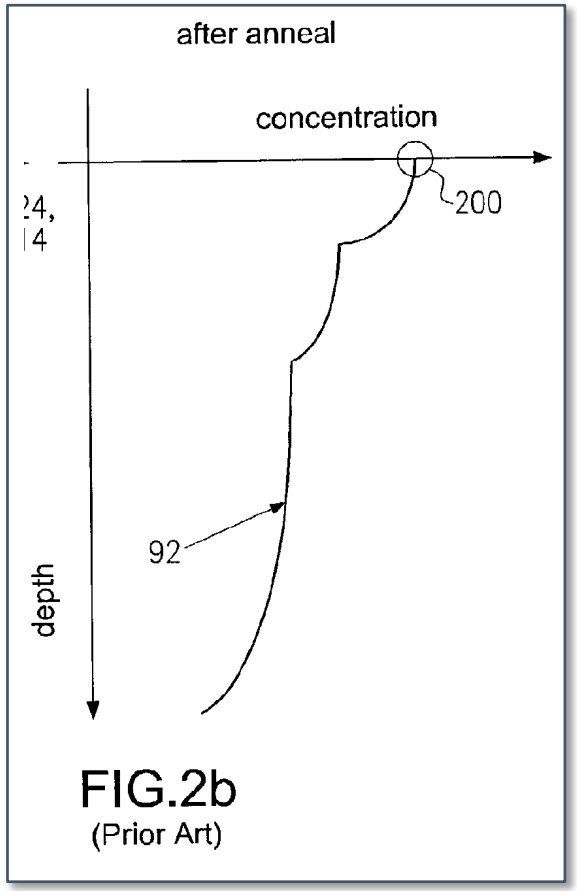
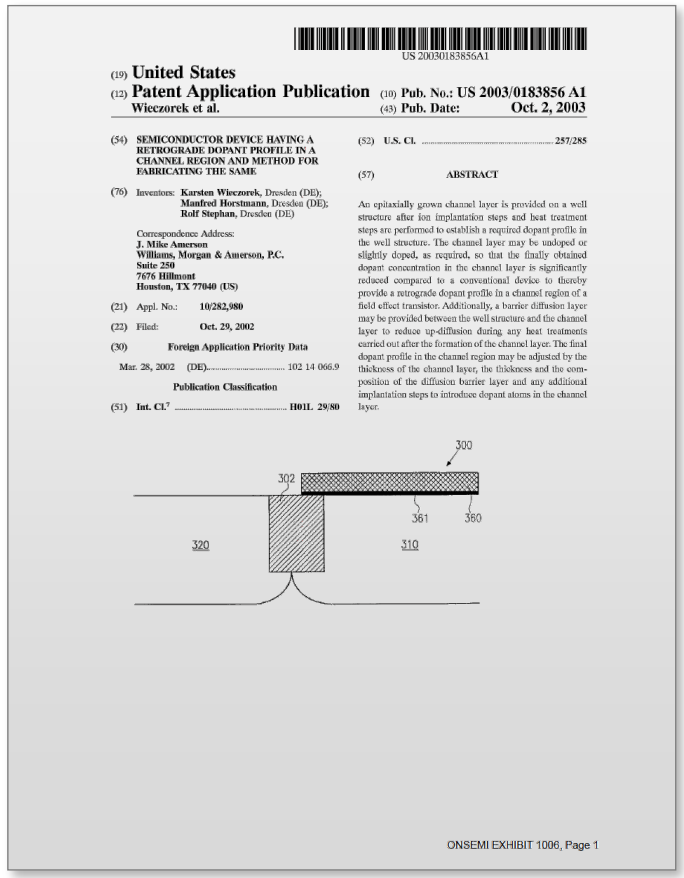


FIG.2b
(Prior Art)

-00001: Ex. 1006 at Fig. 2b

Wieczorek is Uniform in the Active Region

- Wieczorek does <u>not</u> mentions carriers, much less moving carriers from the surface to the substrate.



US 20030183856A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2003/0183856 A1**
Wieczorek et al. (43) **Pub. Date: Oct. 2, 2003**

(54) **SEMICONDUCTOR DEVICE HAVING A RETROGRADE DOPANT PROFILE IN A CHANNEL REGION AND METHOD FOR FABRICATING THE SAME**

(76) Inventors: **Karsten Wieczorek**, Dresden (DE); **Manfred Horstmann**, Dresden (DE); **Rolf Stephan**, Dresden (DE)

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Publication Classification

(51) **Int. Cl.**[7] **H01L 29/80**

(52) **U.S. Cl.** **257/285**

(57) **ABSTRACT**

An epitaxially grown channel layer is provided on a well structure after ion implantation steps and heat treatment steps are performed to establish a required dopant profile in the well structure. The channel layer may be undoped or slightly doped, as required, so that the finally obtained dopant concentration in the channel layer is significantly reduced compared to a conventional device to thereby provide a retrograde dopant profile in a channel region of a field effect transistor. Additionally, a barrier diffusion layer may be provided between the well structure and the channel layer to reduce up-diffusion during any heat treatments carried out after the formation of the channel layer. The final dopant profile in the channel region may be adjusted by the thickness of the channel layer, the thickness and the composition of the diffusion barrier layer and any additional implantation steps to introduce dopant atoms in the channel layer.

ONSEMI EXHIBIT 1006, Page 1

[0009] **FIG. 2***a* is a graph, in which the dopant concentration of the N-well structure **120** and the P-well structure **110** is depicted with respect to the depth in the respective well structures. In particular, it is evident from **FIG. 2***a* that the V_T implantation (**114**, **124**), indicated by the same reference number as the respective implantation portions, leads to a dopant concentration that significantly decreases at the vicinity of the surface of the semiconductor device **100**. That is, the dopant concentration immediately after the implantation process exhibits a desired retrograde dopant profile in the N-well structure **120** and the P-well structure **110** near the surface of the semiconductor device **100**, where, after completion of the device, a channel will form during operation of the device.

-00001: Ex. 1006 at [0009]

[0011] **FIG. 2***b* shows a corresponding graph with a typical dopant profile with respect to the depth of the respective well structure. Due to the up-diffusion of the dopant atoms during the heat treatment, the initially retrograde profile in the vicinity of the surface of the semiconductor device **100**, as indicated by reference number **200**, may have become substantially uniformly distributed.

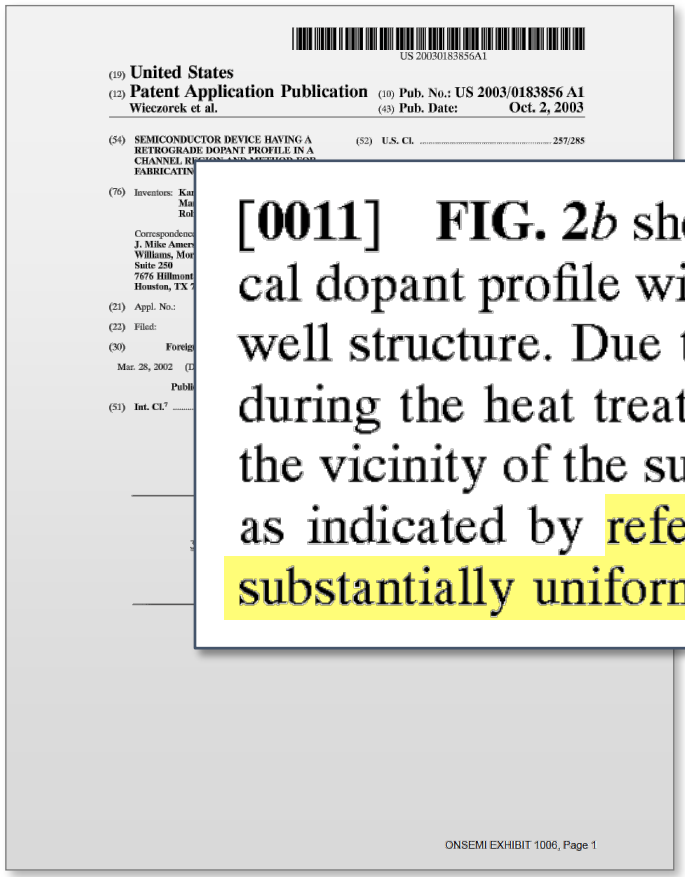
-00002: Ex. 1006 at [0011]

[0013] Typically, the N-channel transistor **130** and the P-channel transistor **140** are formed by the following processes. After the heat treatment, the gate insulation layer **135** is formed, wherein the gate insulation layer may be deposited by chemical vapor deposition (CVD), or, if an oxide layer is used, a rapid thermal furnace process or a conventional furnace oxidation process may be used. Since, commonly, elevated temperatures are involved in fabricating the gate insulation layer **135**, this process also contributes to a further diffusion of the dopants within the P-well structure **110** and the N-well structure **120**. Thereafter, polysilicon is deposited and patterned by sophisticated photolithography techniques to form the gate electrodes **134** and **144**. With a first implantation, the extensions **132** and **142** are defined, and, subsequently, the spacer elements **133**, **143** are formed and serve as an implantation mask during a subsequent implantation process for defining the source and drain regions **131**, **141**. Since a further heat treatment is necessary to activate the dopants within the regions **131**, **132** and **141**, **142** and to cure any crystal damage caused by the preceding implantation steps, the initial dopant concentration, as shown in **FIG. 2***a*, will be even more strongly affected so that, after the plurality of heat treatments, the actual dopant concentration will be represented by the graph shown in **FIG. 2***b*. In particular, it is thus very difficult to obtain or to maintain a retrograde dopant profile in the channel regions **136** and **146**, which would be desirable to achieve an improved carrier mobility therein.

-00001: Ex. 1006 (Wieczorek) at [0013]

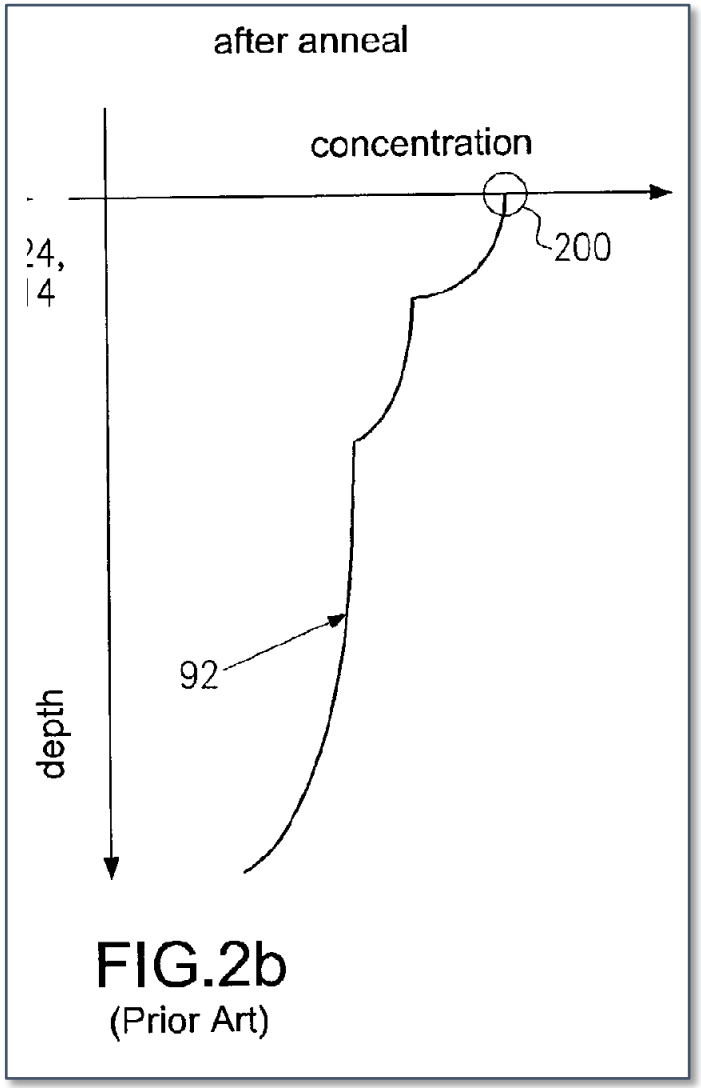
Wieczorek is Uniform in the Active Region

- Wieczorek says the gradient concentration may be uniform.



[0011] **FIG. 2*b*** shows a corresponding graph with a typical dopant profile with respect to the depth of the respective well structure. Due to the up-diffusion of the dopant atoms during the heat treatment, the initially retrograde profile in the vicinity of the surface of the semiconductor device **100**, as indicated by reference number **200**, may have become substantially uniformly distributed.

-00001: Ex. 1006 (Wieczorek) at [0011]



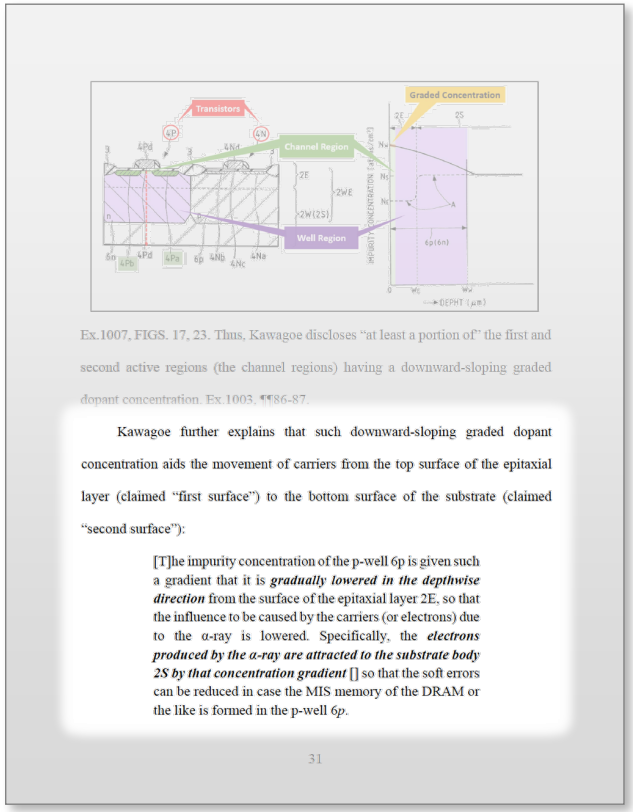
-00001: Ex. 1006 at Fig. 2b

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  - Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.
  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

Petitioners' Prosecution-Related Arguments are Incorrect

- Kawagoe does <u>not</u> mention an electric field in the "active region," and Petitioners have not identified such a field.



Ex.1007, FIGS. 17, 23. Thus, Kawagoe discloses "at least a portion of" the first and second active regions (the channel regions) having a downward-sloping graded dopant concentration. Ex.1003, ¶¶86-87.

Kawagoe further explains that such downward-sloping graded dopant concentration aids the movement of carriers from the top surface of the epitaxial layer (claimed "first surface") to the bottom surface of the substrate (claimed "second surface"):

> [T]he impurity concentration of the p-well 6p is given such a gradient that it is ***gradually lowered in the depthwise direction*** from the surface of the epitaxial layer 2E, so that the influence to be caused by the carriers (or electrons) due to the α-ray is lowered. Specifically, the ***electrons produced by the α-ray are attracted to the substrate body 2S by that concentration gradient*** [] so that the soft errors can be reduced in case the MIS memory of the DRAM or the like is formed in the p-well *6p*.

31

Kawagoe further explains that such downward-sloping graded dopant concentration aids the movement of carriers from the top surface of the epitaxial layer (claimed "first surface") to the bottom surface of the substrate (claimed "second surface"):

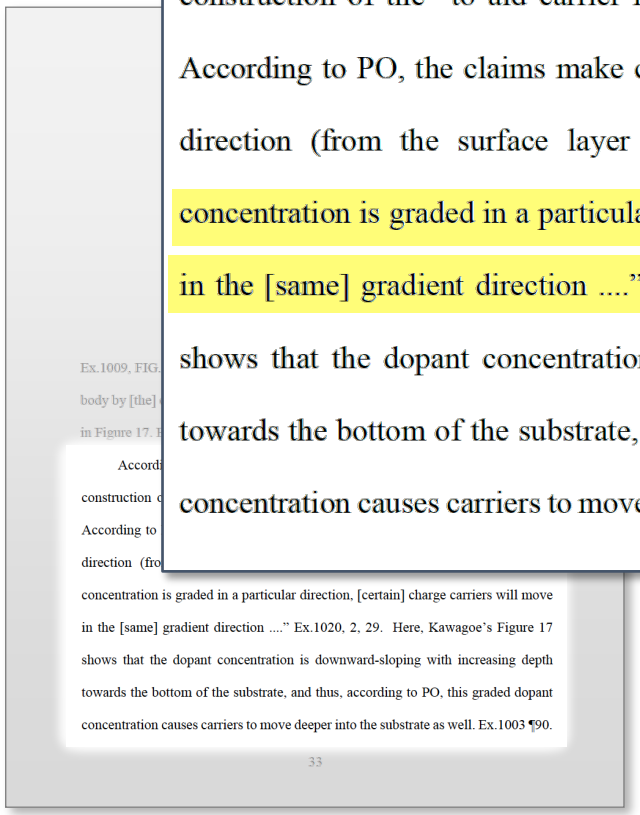
> [T]he impurity concentration of the p-well 6p is given such a gradient that it is ***gradually lowered in the depthwise direction*** from the surface of the epitaxial layer 2E, so that the influence to be caused by the carriers (or electrons) due to the α-ray is lowered. Specifically, the ***electrons produced by the α-ray are attracted to the substrate body 2S by that concentration gradient*** [] so that the soft errors can be reduced in case the MIS memory of the DRAM or the like is formed in the p-well *6p*.

Ex.1007, 16:2-11.[10]

-00001: Petition [1] at 31-32

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.



Accordingly, Kawagoe satisfies element[1.5] under PO's plain meaning construction of the "to aid carrier movement" term. Section VIII; Ex.1003, ¶90. According to PO, the claims make clear that "carriers [must move] in a particular direction (from the surface layer to the substrate)" and "[w]hen the dopant concentration is graded in a particular direction, [certain] charge carriers will move in the [same] gradient direction ...." Ex.1020, 2, 29. Here, Kawagoe's Figure 17 shows that the dopant concentration is downward-sloping with increasing depth towards the bottom of the substrate, and thus, according to PO, this graded dopant concentration causes carriers to move deeper into the substrate as well. Ex.1003 ¶90.

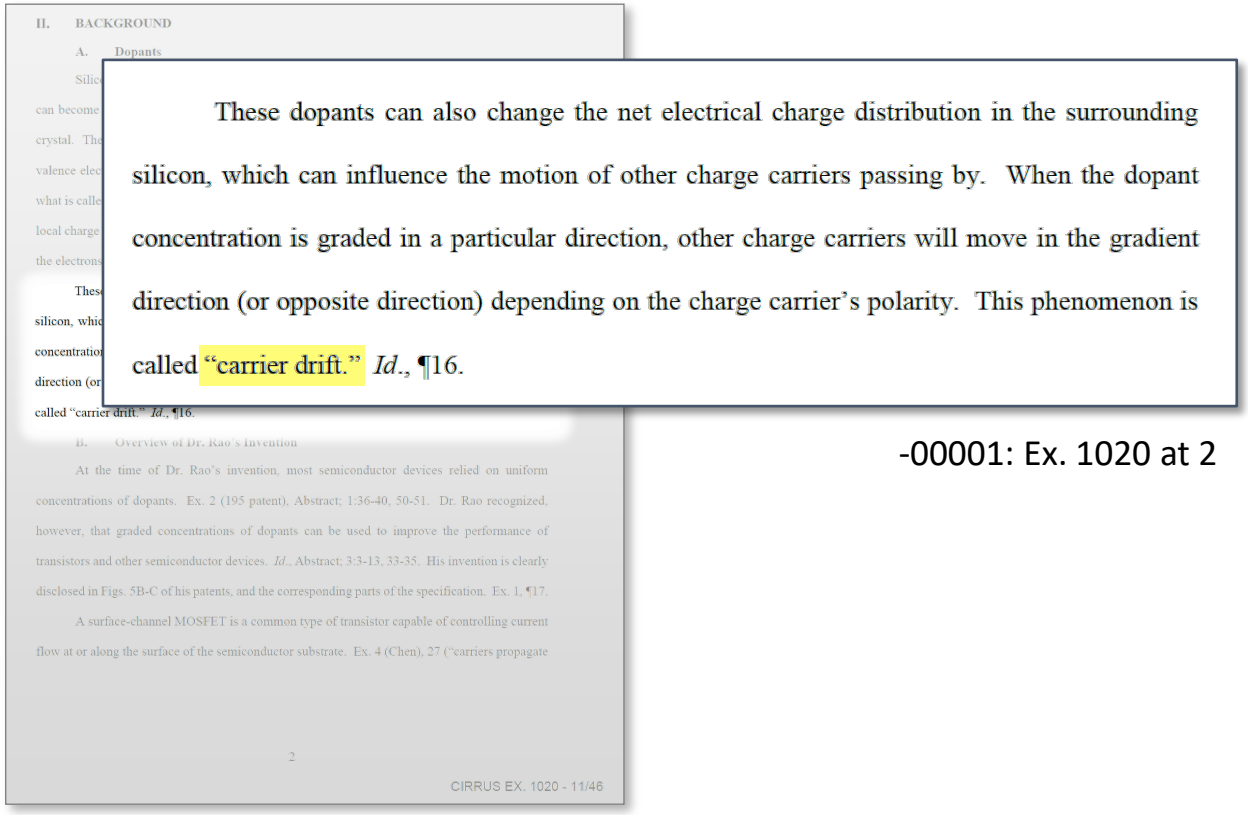
-00001: Petition [1] at 33
(citing claim construction brief)

Notably, Applicant represented to the Patent Office during prosecution of the parent '195 Patent that a downward-sloping graded dopant concentration was known to create an "inherent 'built-in' unidirectional electric field" that sweeps carriers down into the substrate. *See* Section X.A.1.g. Ex.1016, 289-290; Ex.1003, ¶91.

-00001: Petition [1] at 34
(citing prosecution history)

Petitioners' Prosecution-Related Arguments are Incorrect

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



II. BACKGROUND

A. Dopants

These dopants can also change the net electrical charge distribution in the surrounding silicon, which can influence the motion of other charge carriers passing by. When 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. This phenomenon is called "carrier drift." *Id.*, ¶16.

B. Overview of Dr. Rao's Invention

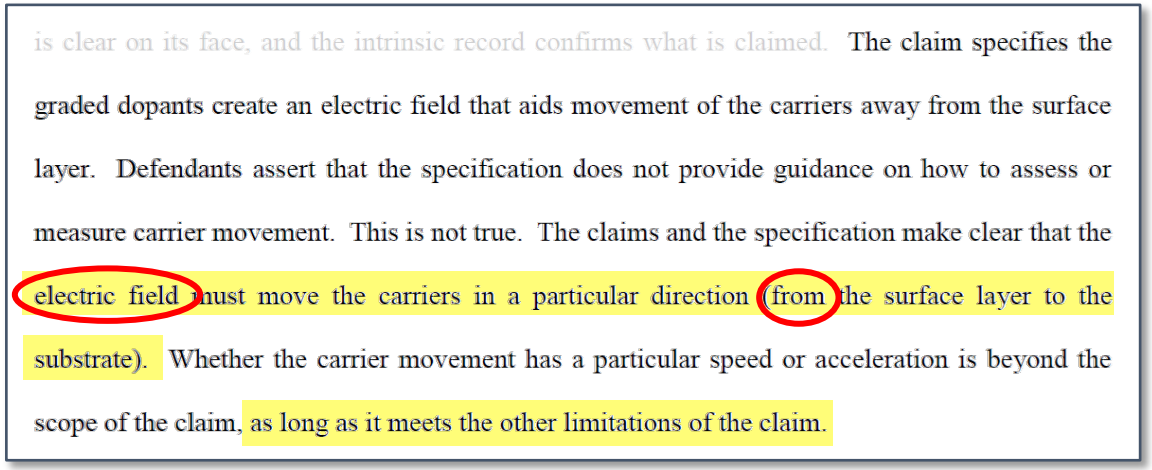
At the time of Dr. Rao's invention, most semiconductor devices relied on uniform concentrations of dopants. Ex. 2 (195 patent), Abstract; 1:36-40, 50-51. Dr. Rao recognized, however, that graded concentrations of dopants can be used to improve the performance of transistors and other semiconductor devices. *Id.*, Abstract; 3:3-13, 33-35. His invention is clearly disclosed in Figs. 5B-C of his patents, and the corresponding parts of the specification. Ex. 1, ¶17.

A surface-channel MOSFET is a common type of transistor capable of controlling current flow at or along the surface of the semiconductor substrate. Ex. 4 (Chen), 27 ("carriers propagate

2

CIRRUS EX. 1020 - 11/46

-00001: Ex. 1020 at 2



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.

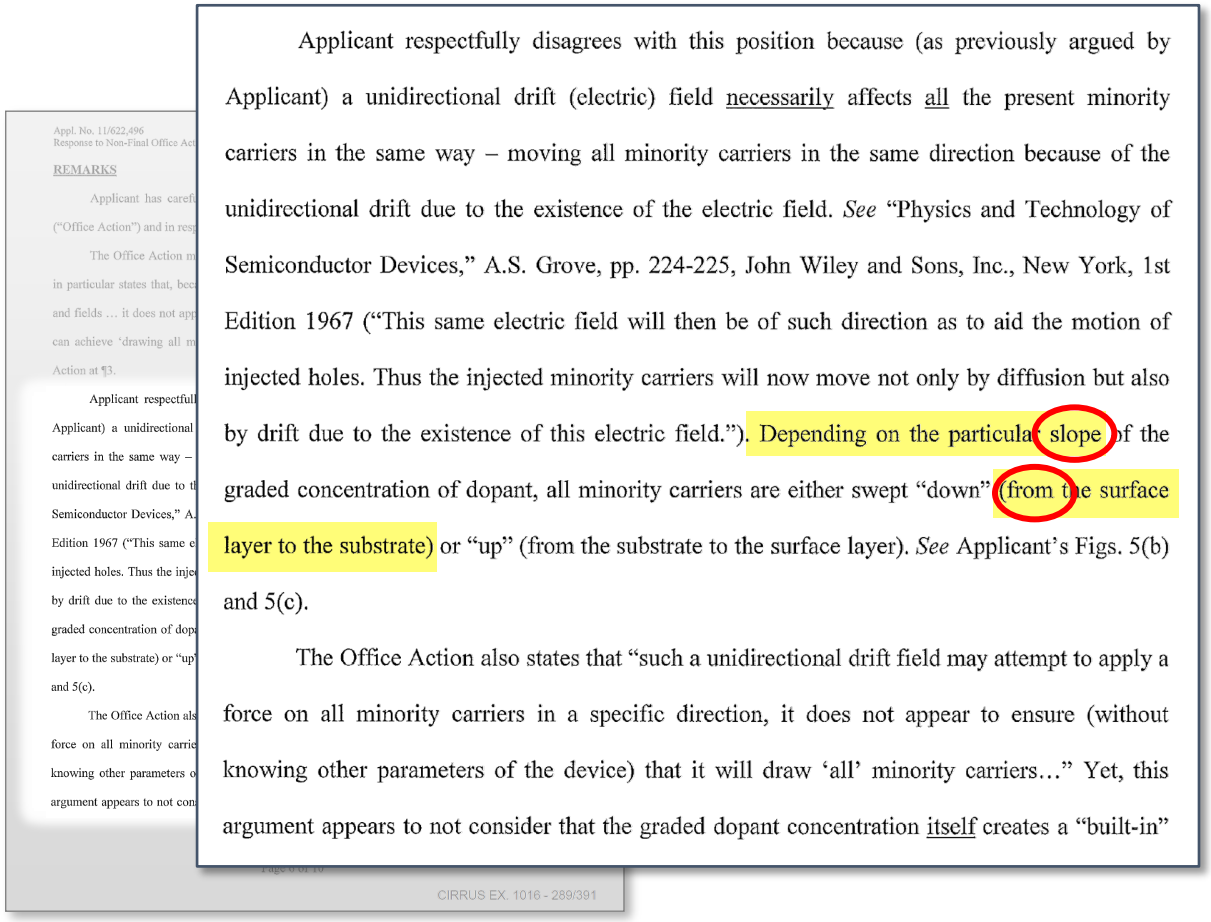
-00001: Ex. 1020 (Greenthread's Brief) at 29

-00001: PO Resp. [45] at 9-12; PO Sur-Reply [63] at 14-15

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Petitioners' Prosecution-Related Arguments are Incorrect

- Greenthread did not say: all "graded dopant concentrations" will move carriers from an "active region."
- 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"

CIRRUS EX. 1016 - 289/391

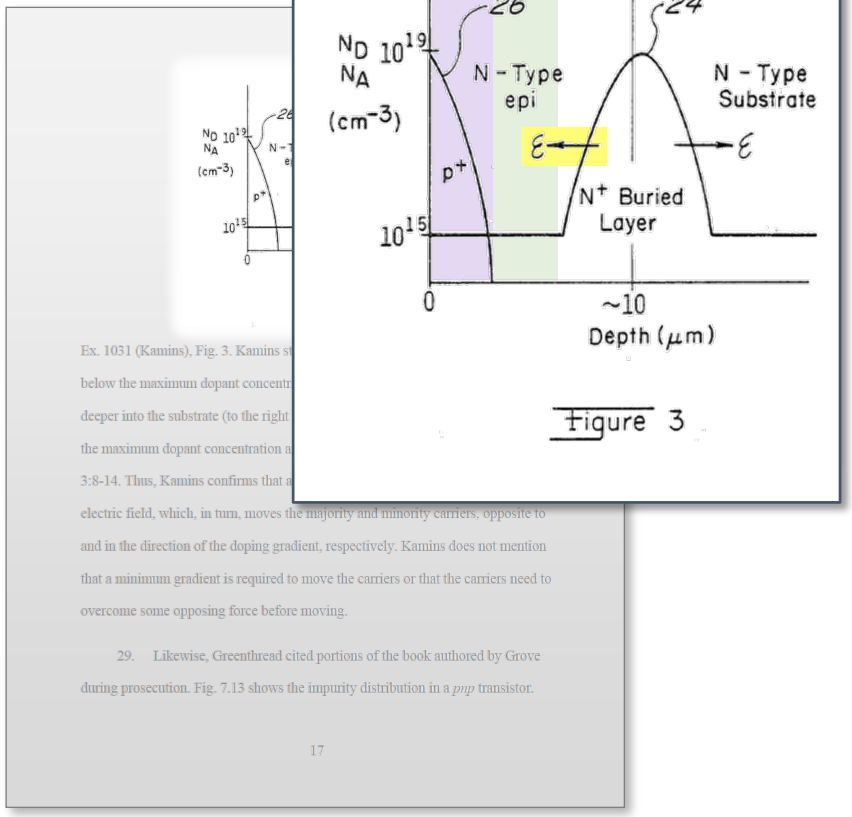
electrical field that forces the movement of carriers into a particular direction, whereby the "direction" of the electrical field and the resulting direction of the carrier movement depends solely on the slope of the graded concentration of dopant. With regard to the existence of a "built-in" electric 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.

-00001: Ex. 1016 ('195 Prosecution History) at 289-290

-00001: PO Resp. [45] at 9-12; PO Sur-Reply [63] at 14-15

Petitioners' Prosecution-Related Arguments are Incorrect

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



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.

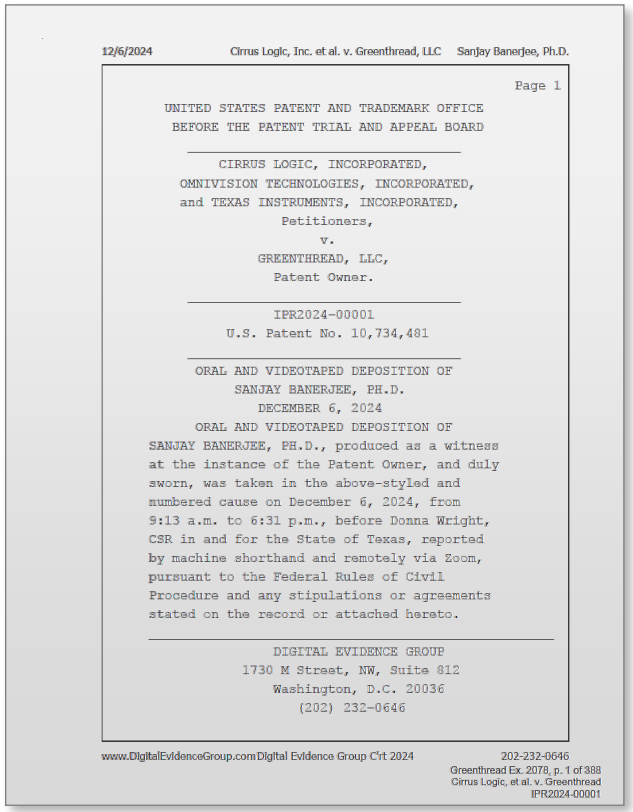
THE WITNESS: Yes, that electric field doesn't extend all the way to the surface. Therefore, there cannot be any drift velocity of the holes due to that electric field.

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 266:4-267:4

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," 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
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

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 272:14-274:2

-00001: PO Sur-Reply [63] at 7-8, 14-15

Petitioners' Prosecution-Related Arguments are Incorrect

- Dr. Banerjee also confirmed that other fields affect the movement of carriers in the active region.

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 222:4-224:7

Overview of Issues

- **The Challenged Claims require "carrier movement" from the "active region."**
- **Dr. Banerjee confirmed that the "electric field" must start in the "active region."**
- **Petitioners did not identify an electric field, much less an electric field that starts in the "active region."**
- **Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).**
- **Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."**
- **Petitioners have the burden to analyze all of the fields in the "active region."**
- **Dr. Banerjee testified that he did not analyze any of the fields in the "active region."**
  - **Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."**
  - **The graded dopant concentration is "uniform" in Wieczorek's "active region."**
- **Petitioners' prosecution-related arguments are incorrect.**
- **Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.**
- Kawagoe does not meet the "second doping type" limitation.
- Petitioners' expert declaration and testimony are untrustworthy.
  - Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.
  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

“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.

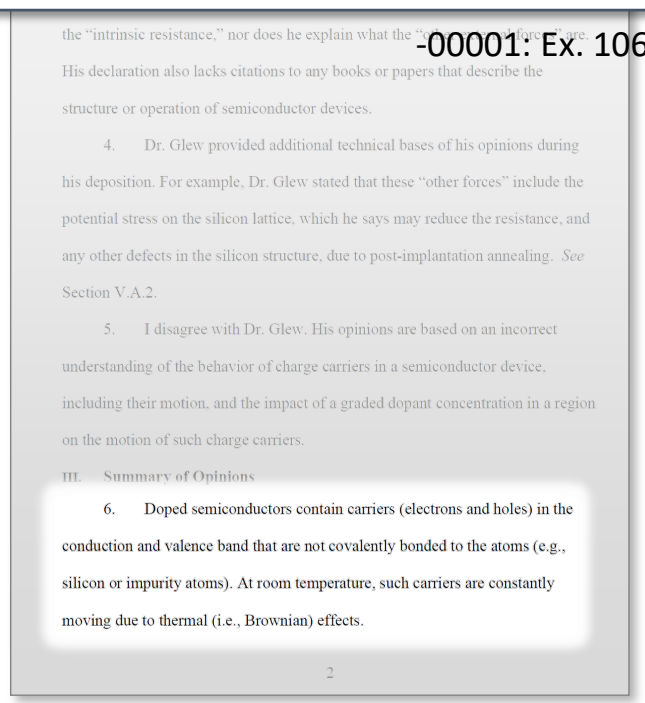
Satco Products, Inc. v. Seoul Semiconductor Co., Ltd., IPR2020-00146, Paper 44 at 20 (PTAB June 25, 2021)

“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.

-00001: Ex. 1060 at ¶ 6


the "intrinsic resistance," nor does he explain what the "other forces" 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.

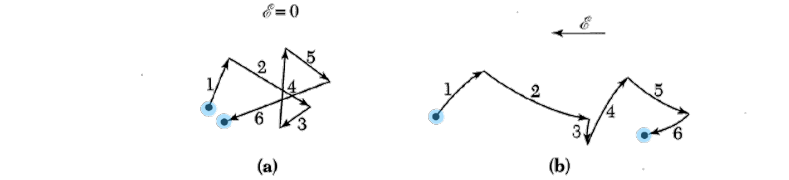


Fig. 1 Schematic path of an electron in a semiconductor. (*a*) Random thermal motion. (*b*) Combined motion due to random thermal motion and an applied electric field.

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.

-00001: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 19

“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.

-00001: Ex. 2078 at 196:3-11

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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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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 197:16-20

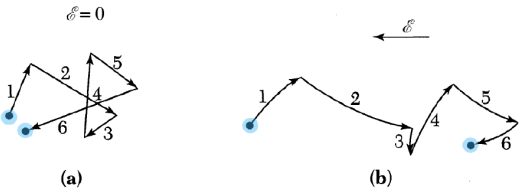


Fig. 1 Schematic path of an electron in a semiconductor. (*a*) Random thermal motion. (*b*) Combined motion due to random thermal motion and an applied electric field.

-00001: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 19

“Brownian Motion” is Not Relevant

- The claims require “carrier movement” from the “active region,” not “random thermal motion.”

US 10,734,481

1. A semiconductor device, comprising:
a substrate of a first doping type at a first doping level having first and second surfaces;
a first active region disposed adjacent the first surface of the substrate with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region;
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first surface to the second surface of the substrate; and
at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid carrier movement from the first surface to the second surface of the substrate.

-00001: Ex. 1001 (’481 pat.) at 4:50-5:3

US 10,510,842

1. A semiconductor device, comprising:
a substrate of a first doping type at a first doping level having first and second surfaces;
a first active region disposed adjacent the first surface of the substrate with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region; and
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first surface to the second surface of the substrate.

-00016: Ex. 1001 (’842 pat.) at 4:45-60

US 11,316,014

1. An electronic system, the system comprising:
at least one semiconductor device, the at least one semiconductor device including:
a substrate of a first doping type at a first doping level having a surface;
a first active region disposed adjacent the surface with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region;
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first and second active regions towards an area of the substrate where there are no active regions; and
at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid carrier movement from the surface towards the area of the substrate where there are no active regions, wherein at least some of the transistors form digital logic of the semiconductor device.

-00019: Ex. 1001 (’014 pat.) at 4:49-5:7

US 11,121,222

1. A VLSI semiconductor device, comprising:
a substrate of a first doping type at a first doping level having a surface;
a first active region disposed adjacent the surface with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region;
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first and second active regions towards an area of the substrate where there are no active regions; and
at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid carrier movement from the surface towards the area of the substrate where there are no active regions, wherein at least some of the transistors form digital logic of the VLSI semiconductor device.

-00020: Ex. 1001 (’222 pat.) at 4:38-62

Overview of Issues

- **The Challenged Claims require "carrier movement" from the "active region."**
- **Dr. Banerjee confirmed that the "electric field" must start in the "active region."**
- **Petitioners did not identify an electric field, much less an electric field that starts in the "active region."**
- **Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).**
- **Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."**
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  - **Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."**
  - **The graded dopant concentration is "uniform" in Wieczorek's "active region."**
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- **Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.**
- **Kawagoe does not meet the "second doping type" limitation.**
- Petitioners' expert declaration and testimony are untrustworthy.
  - Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.
  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

Kawagoe Does Not Meet "Second Doping Type" Limitation

- The Challenged Claims require the "active region" to have a "second doping type opposite in conductivity" to that of the substrate.

US 10,734,481

1. A semiconductor device, comprising:
a substrate of a first doping type at a first doping level having first and second surfaces;
a first active region disposed adjacent the first surface of the substrate with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region;
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first surface to the second surface of the substrate; and
at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid carrier movement from the first surface to the second surface of the substrate.

-00001: Ex. 1001 ('481 pat.) at 4:50-5:3

US 10,510,842

1. A semiconductor device, comprising:
a substrate of a first doping type at a first doping level having first and second surfaces;
a first active region disposed adjacent the first surface of the substrate with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region; and
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first surface to the second surface of the substrate.

-00016: Ex. 1001 ('842 pat.) at 4:45-60

US 11,316,014

1. An electronic system, the system comprising:
at least one semiconductor device, the at least one semiconductor device including:
a substrate of a first doping type at a first doping level having a surface;
a first active region disposed adjacent the surface with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region;
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first and second active regions towards an area of the substrate where there are no active regions; and
at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid carrier movement from the surface towards the area of the substrate where there are no active regions, wherein at least some of the transistors form digital logic of the semiconductor device.

-00019: Ex. 1001 ('014 pat.) at 4:49-5:7

US 11,121,222

1. A VLSI semiconductor device, comprising:
a substrate of a first doping type at a first doping level having a surface;
a first active region disposed adjacent the surface with a second doping type opposite in conductivity to the first doping type and within which transistors can be formed;
a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;
transistors formed in at least one of the first active region or second active region;
at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first and second active regions towards an area of the substrate where there are no active regions; and
at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid carrier movement from the surface towards the area of the substrate where there are no active regions, wherein at least some of the transistors form digital logic of the VLSI semiconductor device.

-00020: Ex. 1001 ('222 pat.) at 4:38-62

-00001: PO Resp. [45] at 23-24; PO Sur-Reply [63] at 16-17

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Kawagoe Does Not Meet "Second Doping Type" Limitation

- The Petition mapped "a first doping type" to p-type doping.
- The channel of transistor 4N is also doped *p-type*, since it is the top portion of a p-well.

IN THE UNITED STATES PATENT AND TRADEMAR

BEFORE THE PATENT TRIAL AND APPEAL B

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

v.

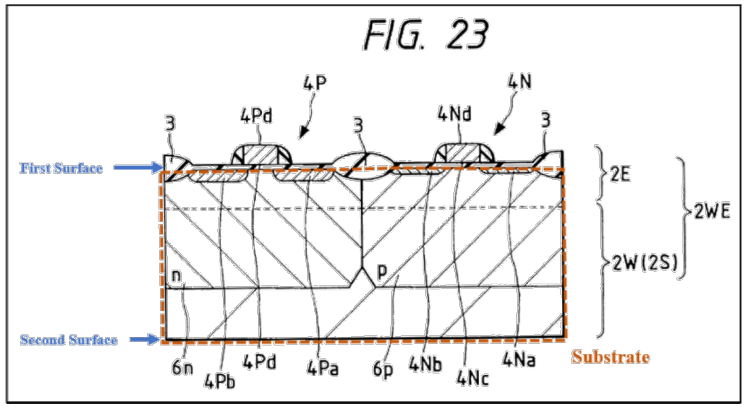
GREENTHREAD, LLC,
Patent Owner.

Case No. IPR2024-00001
Patent No. 10,734,481

PETITION FOR *INTER PARTES* REVIEW OF U.S. PA
10,734,481
UNDER 35 U.S.C. §§ 312 AND 37 C.F.R. § 42.1

b. Element[1.1]

Kawagoe discloses a substrate ("semiconductor substrate 2") of a first doping type (*p-type*) having a silicon "epitaxial layer 2E [] doped with a p-type impurity such as boron" formed over non-epitaxial "semiconductor substrate body 2S [also] doped with a p-type impurity such as boron...." Ex.1007, 14:61-15:12, 6:50-7:3. The substrate (orange) has top ("first surface") and bottom ("second surface") surfaces, as indicated below. Ex.1003, ¶65.



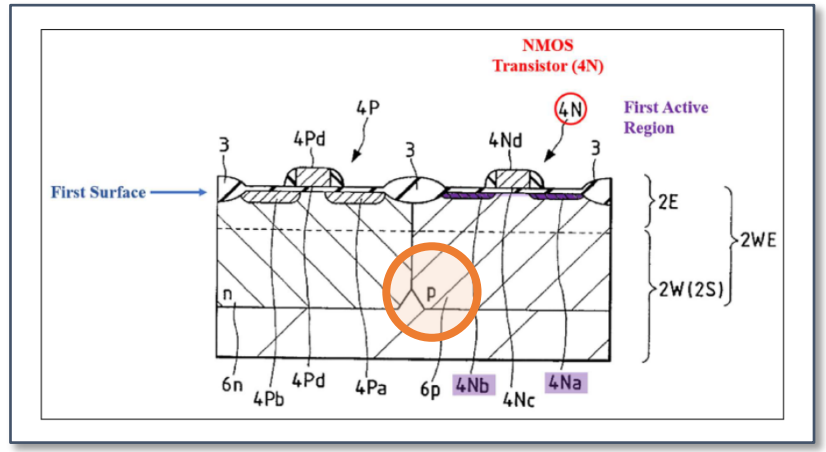
Ex.1007, FIG. 23.

-00001: Petition [1] at 17-18

c. Element[1.2]

Kawagoe discloses "semiconductor regions 4Na and 4Nb...for forming the source-drain regions of the nMOS [n-channel transistor] 4N." Ex.1007, 8:66-67; *id.*, 3:32-38, 8:45-52, 14:46-55, 15:26-40. Source-drain regions 4Na/4Nb (purple) form part of the claimed first active region, which also includes the channel region (light purple) between source-drain regions 4Na/4Nb and below insulating film 4Nc.

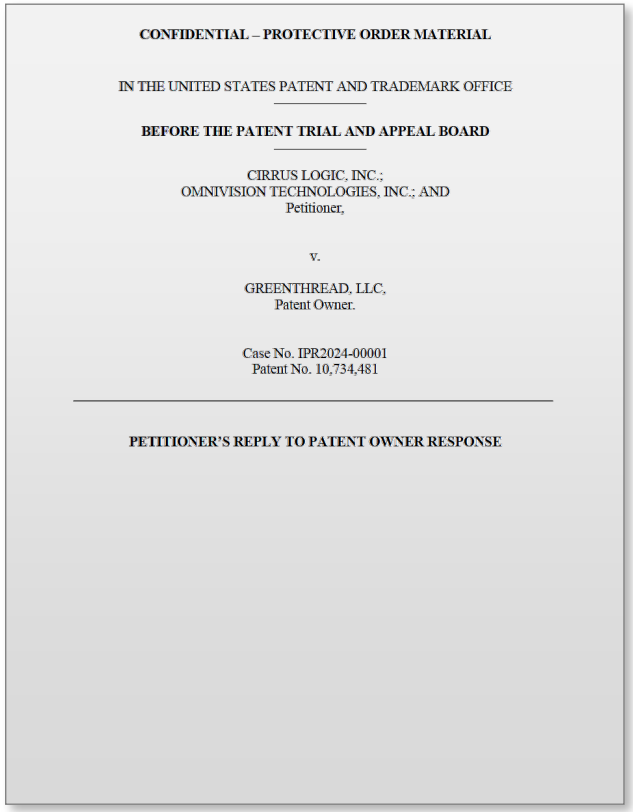
-00001: Petition [1] at 24



-00001: Petition [1] at 25

Kawagoe Does Not Meet "Second Doping Type" Limitation

- Petitioners later asserted (Reply) that the claim limitation is satisfied, because the source and drain have doping "opposite" the substrate.



CONFIDENTIAL – PROTECTIVE ORDER MATERIAL

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CIRRUS LOGIC, INC.;
OMNIVISION TECHNOLOGIES, INC.; AND
Petitioner,

v.

GREENTHREAD, LLC,
Patent Owner.

Case No. IPR2024-00001
Patent No. 10,734,481

PETITIONER'S REPLY TO PATENT OWNER RESPONSE

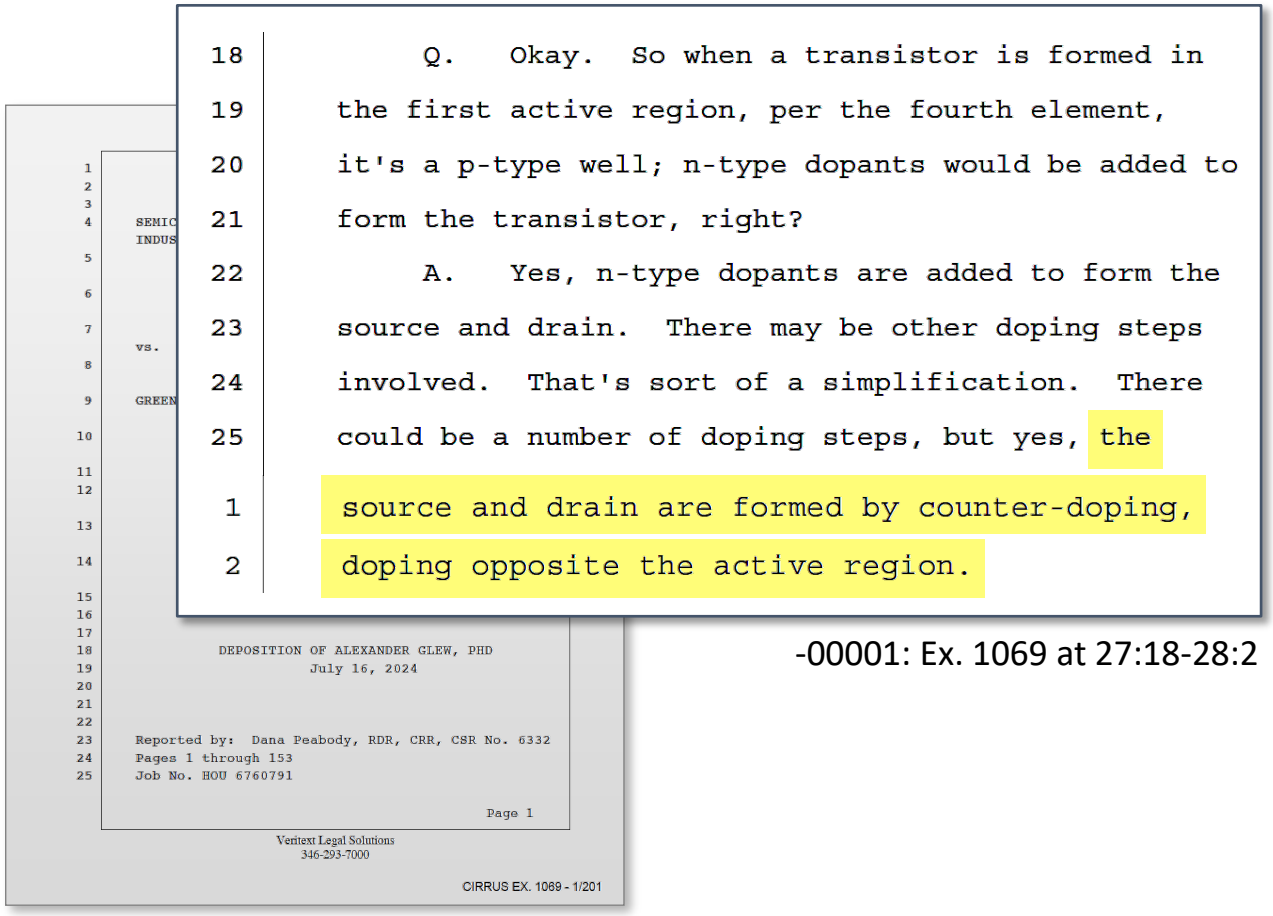
First, Greenthread's argument incorrectly presumes that the claims require the "second doping type" to be distributed *throughout the entirety* of the identified "first active region." That assumption defies the plain language of the claims, which simply call for "a first active region…*with* a second doping type." Ex.1001, cls. 1, 20. It is sufficient that *some portions* of the "first active region"—here, the source and drain of Kawagoe's NMOS (4N) formed in p-well 6p—include a "second doping type" (*e.g.*, n-type dopants). Greenthread concedes this. POR 23 (Kawagoe's "regions 4Na and 4Nb are doped n-type."). Similarly, Figures 5B and 5C—which Greenthread says "clearly disclose[]" the "claimed invention" (POR 4; Ex.2057, ¶34)—show NMOS devices having n-type source and drain regions and a p-type substrate. Ex.1001, Figs. 5B-5C; Ex.1060-Banerjee-Supp.-Decl., ¶¶99-100.

-00001: Pet. Reply [54] at 24

-00001: PO Sur-Reply [63] at 16

Kawagoe Does Not Meet "Second Doping Type" Limitation

- The claims refer to the source and drain as a "device" and the active region as a "region," with distinct doping.



DEPOSITION OF ALEXANDER GLEW, PHD
July 16, 2024

Reported by: Dana Peabody, RDR, CRR, CSR No. 6332
Pages 1 through 153
Job No. HOU 6760791

Page 1

Veritext Legal Solutions
346-293-7000

CIRRUS EX. 1069 - 1/201

18 Q. Okay. So when a transistor is formed in
19 the first active region, per the fourth element,
20 it's a p-type well; n-type dopants would be added to
21 form the transistor, right?
22 A. Yes, n-type dopants are added to form the
23 source and drain. There may be other doping steps
24 involved. That's sort of a simplification. There
25 could be a number of doping steps, but yes, the
1 source and drain are formed by counter-doping,
2 doping opposite the active region.

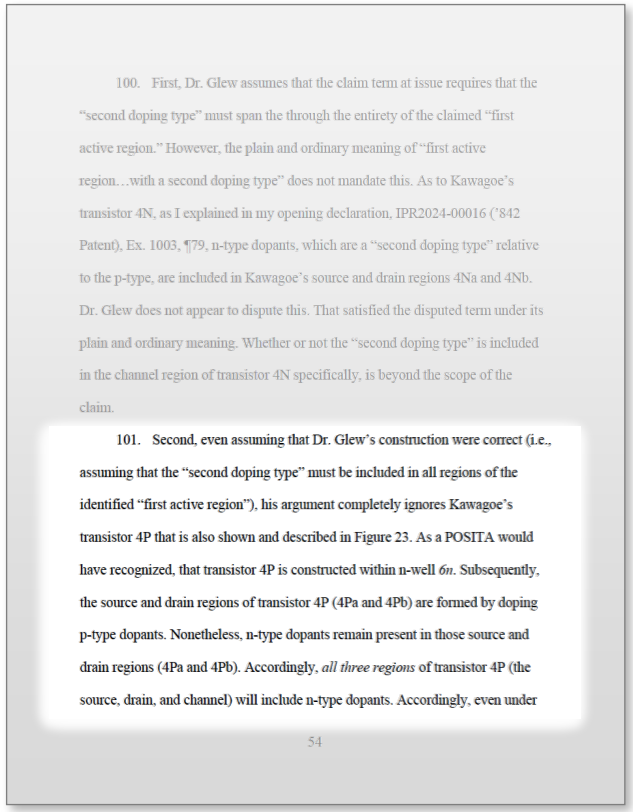
-00001: Ex. 1069 at 27:18-28:2

11 Q. Would you consider the source and drain
12 part of the active region?
13 MR. WHITEHURST: Object to form.
14 THE WITNESS: How should I put this?
15 The claim language describes transistors
16 formed in at least one of the first active region or
17 second active region. It describes the transistors
18 as a device, and the active region is a region. So
19 it's sort of like apples and oranges. They are
20 certainly -- on the top portion, they're made of the
21 active region. The active region is, for example,
22 silicon. And dopants, you know, boron or
23 phosphorous or something like that are added to the
24 silicon substrate.

-00001: Ex. 1069 (Glew Dep. Tr.) at 28:11-24

Kawagoe Does Not Meet "Second Doping Type" Limitation

- Dr. Banerjee's understanding renders the claim language requiring opposite doping types superfluous, because he concludes that *every* active region has both n- and p-type doping.



100. First, Dr. Glew assumes that the claim term at issue requires that the "second doping type" must span the through the entirety of the claimed "first active region." However, the plain and ordinary meaning of "first active region…with a second doping type" does not mandate this. As to Kawagoe's transistor 4N, as I explained in my opening declaration, IPR2024-00016 ('842 Patent), Ex. 1003, ¶79, n-type dopants, which are a "second doping type" relative to the p-type, are included in Kawagoe's source and drain regions 4Na and 4Nb. Dr. Glew does not appear to dispute this. That satisfied the disputed term under its plain and ordinary meaning. Whether or not the "second doping type" is included in the channel region of transistor 4N specifically, is beyond the scope of the claim.

101. Second, even assuming that Dr. Glew's construction were correct (i.e., assuming that the "second doping type" must be included in all regions of the identified "first active region"), his argument completely ignores Kawagoe's transistor 4P that is also shown and described in Figure 23. As a POSITA would have recognized, that transistor 4P is constructed within n-well *6n*. Subsequently, the source and drain regions of transistor 4P (4Pa and 4Pb) are formed by doping p-type dopants. Nonetheless, n-type dopants remain present in those source and drain regions (4Pa and 4Pb). Accordingly, *all three regions* of transistor 4P (the source, drain, and channel) will include n-type dopants. Accordingly, even under

54

101. Second, even assuming that Dr. Glew's construction were correct (i.e., assuming that the "second doping type" must be included in all regions of the identified "first active region"), his argument completely ignores Kawagoe's transistor 4P that is also shown and described in Figure 23. As a POSITA would have recognized, that transistor 4P is constructed within n-well *6n*. Subsequently, the source and drain regions of transistor 4P (4Pa and 4Pb) are formed by doping p-type dopants. Nonetheless, n-type dopants remain present in those source and drain regions (4Pa and 4Pb). Accordingly, *all three regions* of transistor 4P (the source, drain, and channel) will include n-type dopants. Accordingly, even under Dr. Glew's construction (which is incorrect), in my opinion Kawagoe's transistor 4P qualifies as the claimed "first active region…with a second doping type opposite in conductivity to the first doping type."

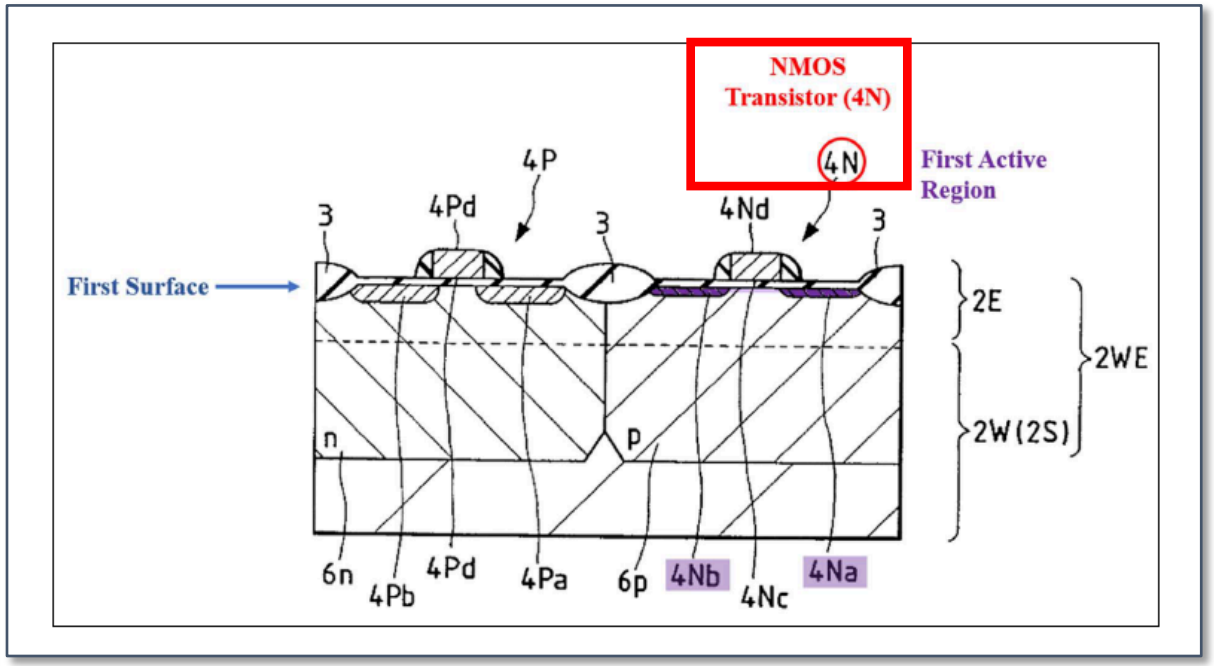
-00001: Ex. 1060 (Banerjee Supp. Decl.) at ¶ 101

Kawagoe Does Not Meet "Second Doping Type" Limitation

- Alternatively, Petitioners argue that a <u>different</u> transistor (4P) satisfied the claim limitations.
- Transistor 4P is not mapped in the Petition.

Second, even assuming the claim were read to require "second doping type" dopants to be distributed throughout the "first active region" (*i.e.*, not just in the source/drain, but also in the region where the channel is formed), that feature is still met by Kawagoe's PMOS (4P). As shown and described in Fig. 23, 4P is formed into an *n*-well, which contains *n*-type dopants *throughout* the well. Pet. 30-31; Ex.1007, 9:40-54, 17:50-54, 18:15-23, 21:55-61, Fig. 23. When the source and drain regions are subsequently formed, those *n*-type dopants remain present. Accordingly, even under Greenthread's unsupported construction, the source, drain, and channel region of Kawagoe's PMOS (4P) qualify as a "first active region" having a "second doping type" (*n*-type). Ex.1060-Banerjee-Supp.-Decl., ¶101.

-00001: Pet. Reply [54] at 24-25



-00001: Petition [1] at 25

Kawagoe Does Not Meet "Second Doping Type" Limitation

Even if a part of a prior art reference is discussed in the petition, it cannot be used to satisfy a claim element when the Petition does not use it for that purpose.

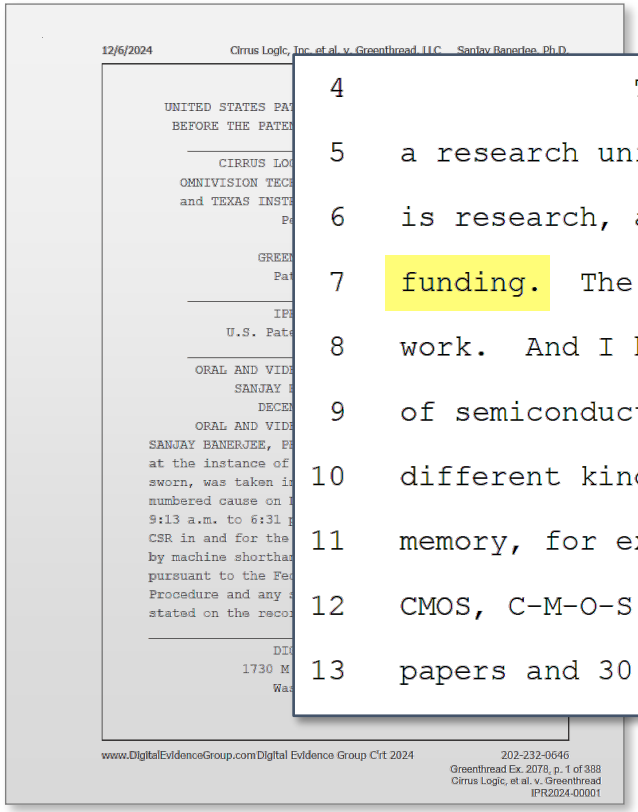
Oren Techs., LLC v. Proppant Express Invs. LLC, 2021 WL 3120819, at *4 (Fed. Cir. July 23, 2021)

Overview of Issues

- The Challenged Claims require "carrier movement" from the "active region."
- Dr. Banerjee confirmed that the "electric field" must start in the "active region."
- Petitioners did not identify an electric field, much less an electric field that starts in the "active region."
- Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
- Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."
- Petitioners have the burden to analyze all of the fields in the "active region."
- Dr. Banerjee testified that he did not analyze any of the fields in the "active region."
  - Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."
  - The graded dopant concentration is "uniform" in Wieczorek's "active region."
- Petitioners' prosecution-related arguments are incorrect.
- Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
- Kawagoe does not meet the "second doping type" limitation.
- **Petitioners' expert declaration and testimony are untrustworthy.**
  - **Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.**
  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

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.

-00001: Ex. 2078 at 29:4-13

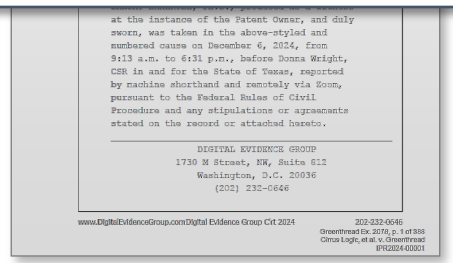
18 When did you -- when did it
19 become part of your job to secure research
20 funding?
21 A. From day one. I mean, if you
22 do not bring in research funding, you do not
1 get tenure at research universities. They
2 kick you out in six years. So that's
3 probably more important than being a good
4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

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 29:18-30:4

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.

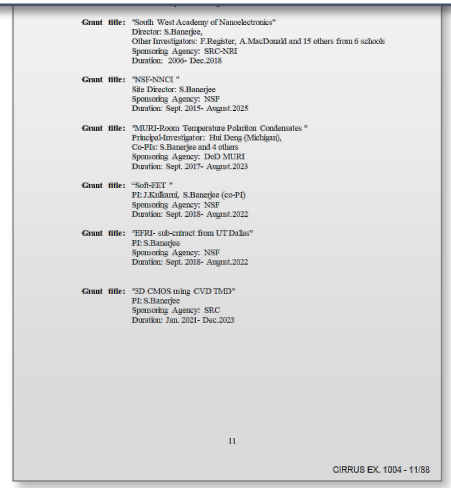

at the instance of the Patent Owner, and duly sworn, was taken in the above-styled and numbered cause on December 6, 2024, from 9:13 a.m. to 6:31 p.m., before Donna Wright, CSR in and for the State of Texas, reported by machine shorthand and remotely via Zoom, pursuant to the Federal Rules of Civil Procedure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

DIGITAL EVIDENCE GROUP
1730 M Street, NW, Suite 612
Washington, D.C. 20036
(202) 232-0646

www.DigitalEvidenceGroup.com Digital Evidence Group Crt 2024 202-232-0646

-00001: 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

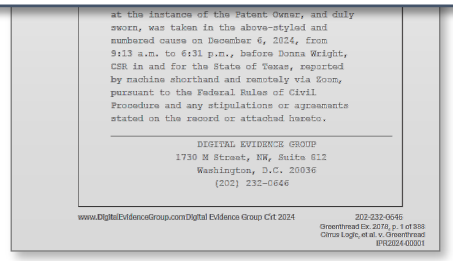
CIRRUS EX. 1004 - 11/88

-00001: Ex. 1004 (Banerjee CV) at pg. 11

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. 2079, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

-00001: 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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 49:15-50:1

-00001: PO Sur-Reply [63] at 12-13

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.

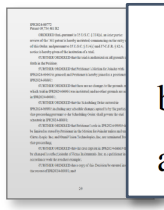
CIRRUS LOGIC, INCORPORATED,
OMNIVISION TECHNOLOGIES, INCORPORATED, and
TEXAS INSTRUMENTS INCORPORATED
Petitioner,

v.

GREENTHREAD, LLC,
Patent Owner.

IPR2024-00001*
Patent 10,734,481 B2

-00001: Paper 52, pg. 22



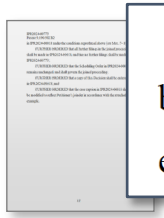
FURTHER ORDERED that the case caption in IPR2024-00001 shall be changed to reflect joinder of Texas Instruments, Inc. as a petitioner in accordance with the attached example;

-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

-00001: PO Sur-Reply [63] at 12-13

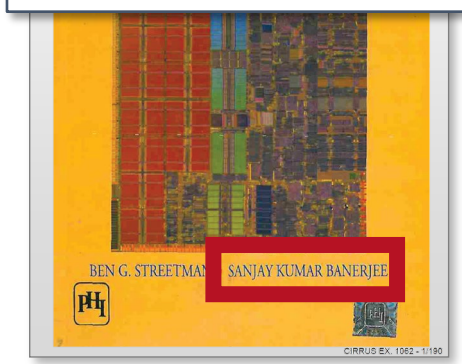
DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Dr. Banerjee's Relationship with Petitioner TI

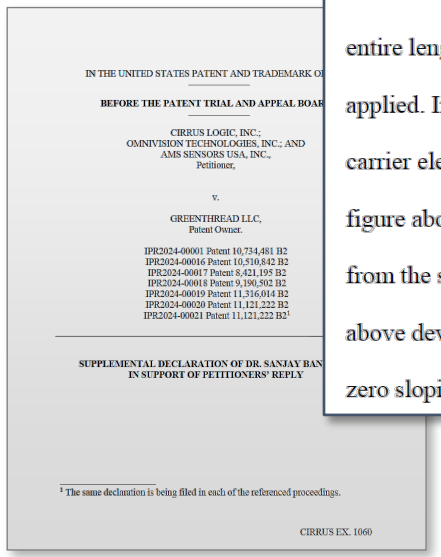
- Dr. Banerjee's current opinions are inconsistent with his earlier 2005 textbook.

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

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



-00001: 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

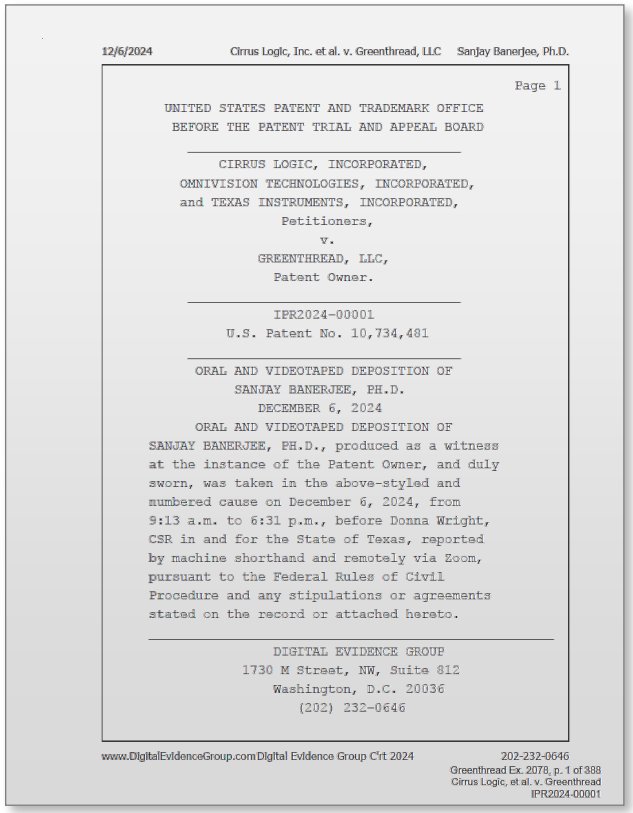
-00001: Ex. 1060 (Banerjee Supp. Decl.) at ¶25

Overview of Issues

- The Challenged Claims require "carrier movement" from the "active region."
- Dr. Banerjee confirmed that the "electric field" must start in the "active region."
- Petitioners did not identify an electric field, much less an electric field that starts in the "active region."
- Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
- Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."
- Petitioners have the burden to analyze all of the fields in the "active region."
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  - Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."
  - The graded dopant concentration is "uniform" in Wieczorek's "active region."
- Petitioners' prosecution-related arguments are incorrect.
- Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
- Kawagoe does not meet the "second doping type" limitation.
- **Petitioners' expert declaration and testimony are untrustworthy.**
  - **Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.**
  - **Petitioners' counsel conducted improper witness coaching prior to re-direct examination.**
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- Substantial evidence of objective indicia of non-obviousness supports patentability.

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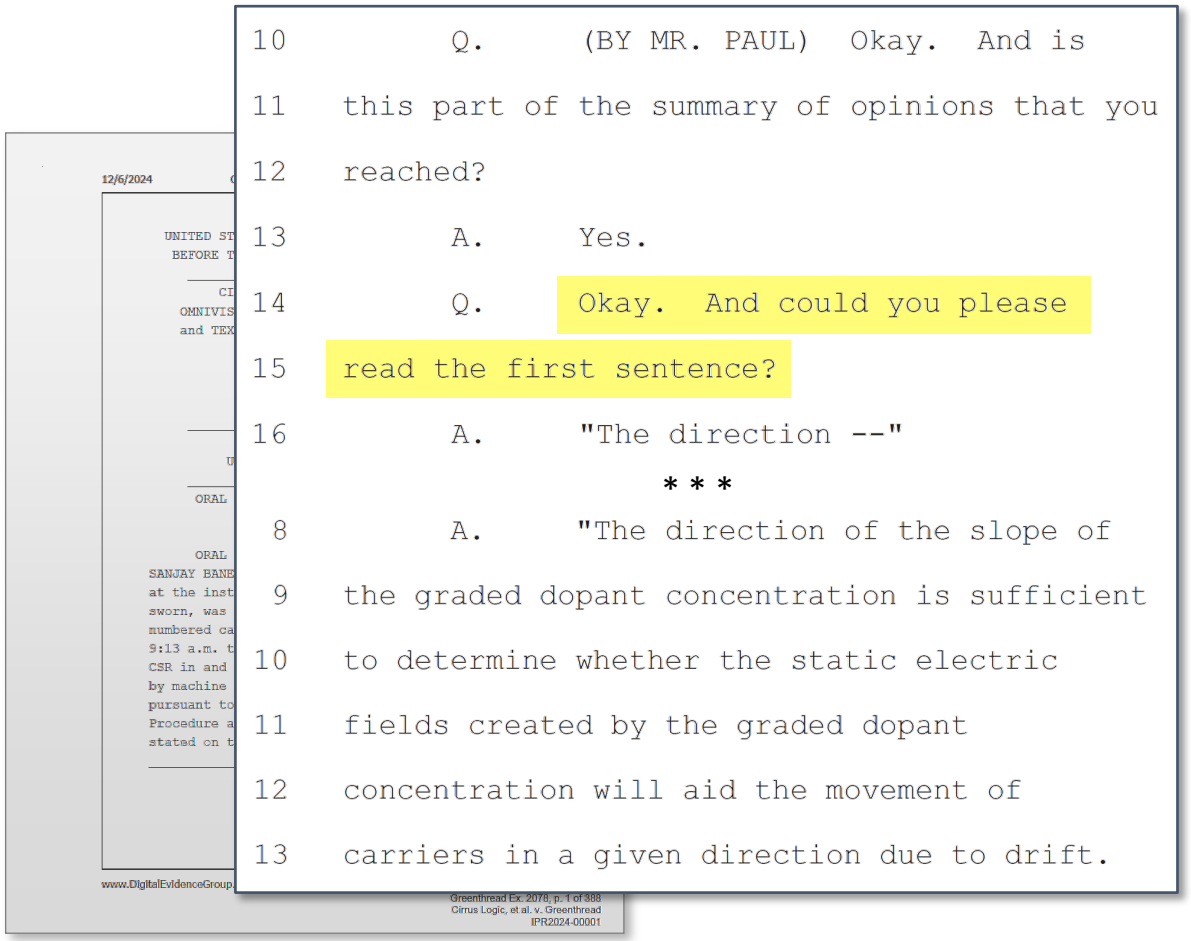
Greenthread Ex. 2078, p. 1 of 388
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 7:12-22

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 --"

* * *

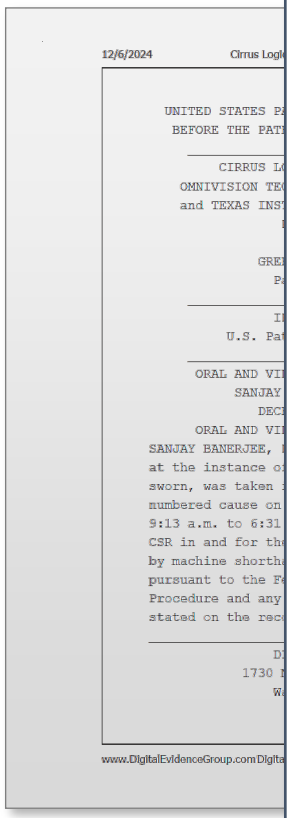
8 A. "The direction of the slope of
9 the graded dopant concentration is sufficient
10 to determine whether the static electric
11 fields created by the graded dopant
12 concentration will aid the movement of
13 carriers in a given direction due to drift.

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?

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 313:10-16; 314:8-315:4

Improper Witness Coaching

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



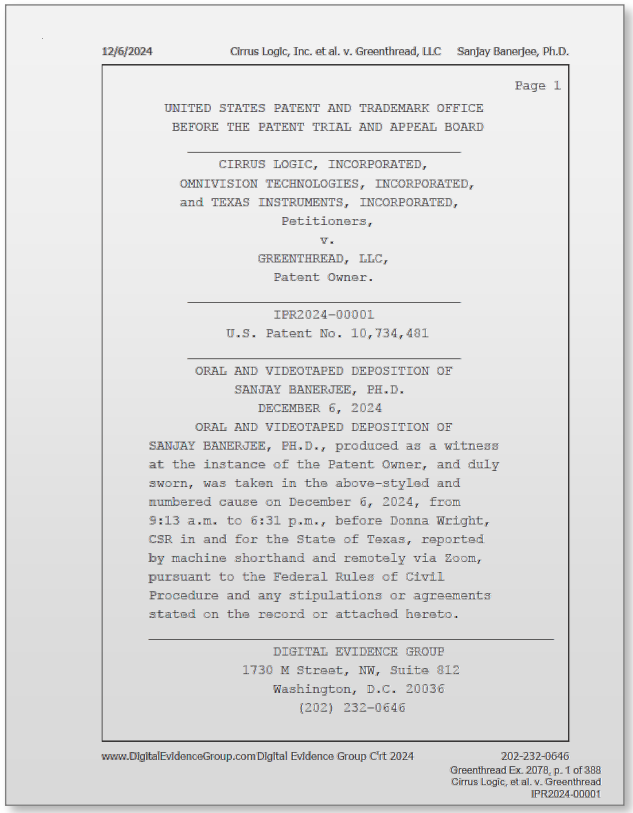
17 Q. I don't normally do this, but
18 this is rather extraordinary. You and your
19 attorneys took a 40-minute break. During
20 that 40-minute break, at any time did you
21 meet with any of the attorneys or other
22 persons sitting at the table with you now?
1 A. Yes.
2 Q. Which of the attorneys sitting
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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 337:17-338:20

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

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Petitioners,
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GREENTHREAD, LLC,
Patent Owner.

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

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.

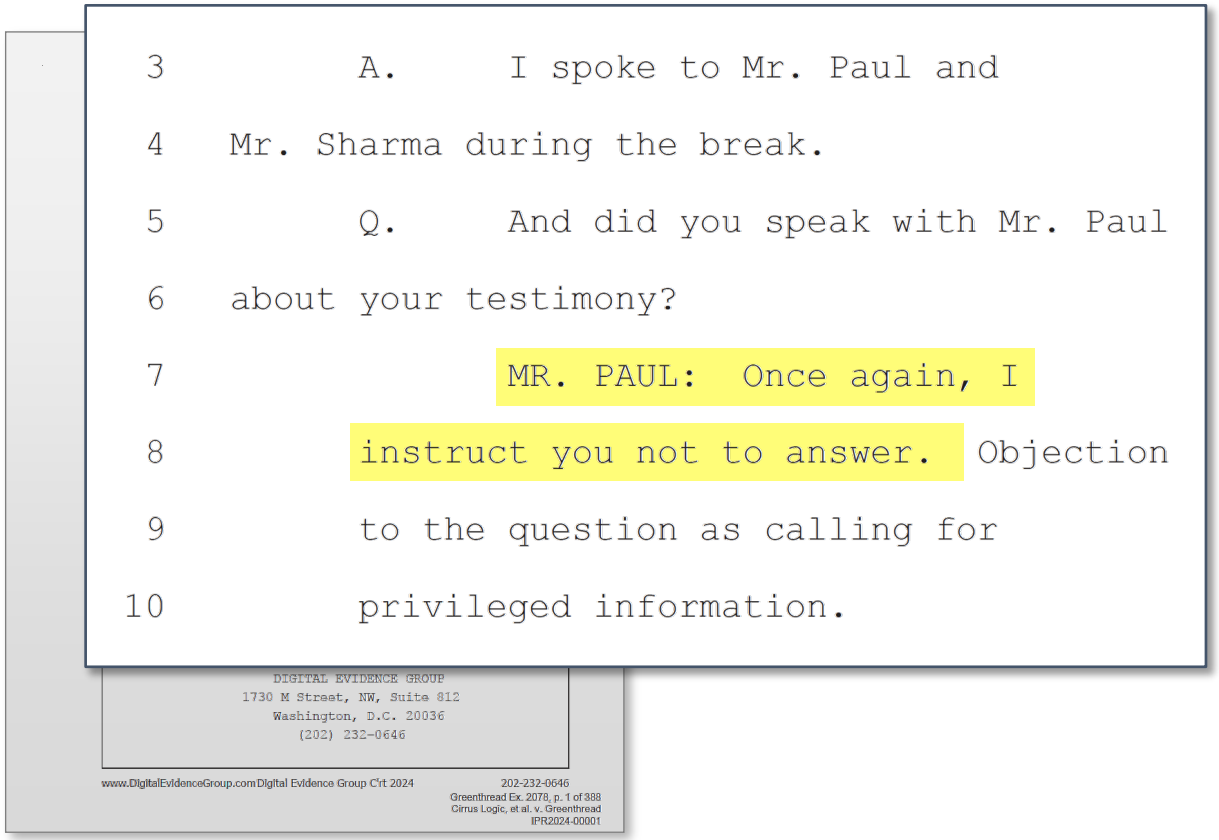
-00001: Ex. 2078 (Banerjee Dep. Tr.) at 339:9-20

-00001: PO Sur-Reply [63] at 14

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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

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.

-00001: Ex. 2078 (Banerjee Dep. Tr.) at 344:3-19

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***."

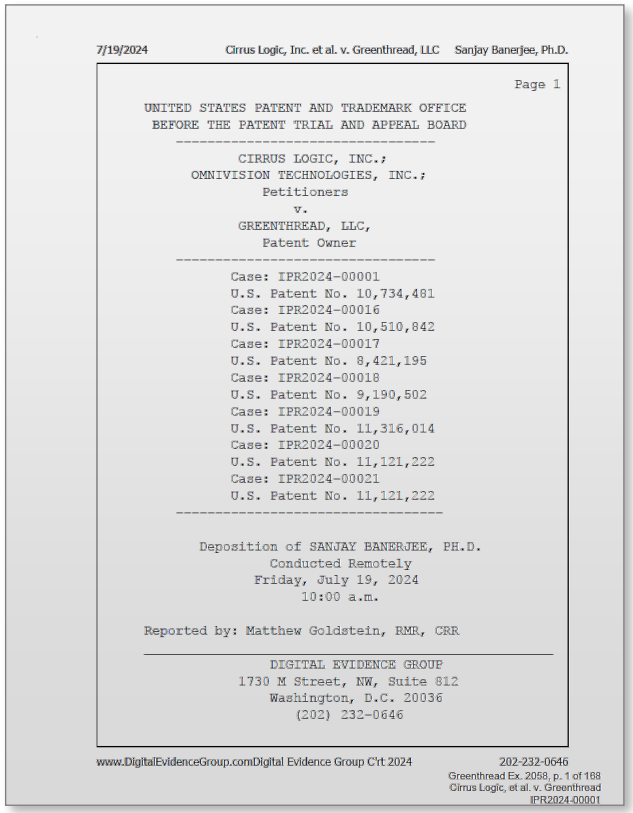
Flir Systems, Inc. v. Leak Surveys, Inc., IPR2014-00411, Paper 45 at 7 (PTAB Feb. 10, 2015)

Overview of Issues

- The Challenged Claims require "carrier movement" from the "active region."
- Dr. Banerjee confirmed that the "electric field" must start in the "active region."
- Petitioners did not identify an electric field, much less an electric field that starts in the "active region."
- Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
- Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."
- Petitioners have the burden to analyze all of the fields in the "active region."
- Dr. Banerjee testified that he did not analyze any of the fields in the "active region."
  - Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."
  - The graded dopant concentration is "uniform" in Wieczorek's "active region."
- Petitioners' prosecution-related arguments are incorrect.
- Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
- Kawagoe does not meet the "second doping type" limitation.
- **Petitioners' expert declaration and testimony are untrustworthy.**
  - **Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.**
  - **Petitioners' counsel conducted improper witness coaching prior to re-direct examination.**
  - **Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.**
- Substantial evidence of objective indicia of non-obviousness supports patentability.

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.
Conducted Remotely
Friday, July 19, 2024
10:00 a.m.

Reported by: Matthew Goldstein, RMR, CRR

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Greenthread Ex. 2058, p. 1 of 188
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

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

* * *

Q. And I would remind you, sir, that you are under oath.

A. I don't know how they could tell. As far as technical opinions regarding the validity of the claims, I do stand by those opinions. I think that's most important.

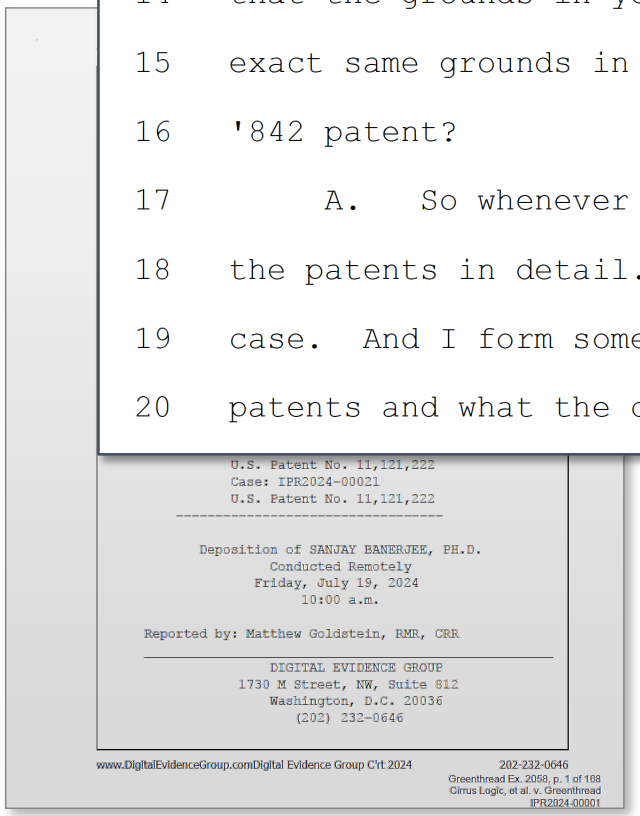
-00001: Ex. 2058 (Banerjee Dep. Tr.) at 125:11-126:1

-00001: PO Resp. [45] at 30; PO Sur-Reply [63] at 24

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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Greenthread Ex. 2058, p. 1 of 188
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

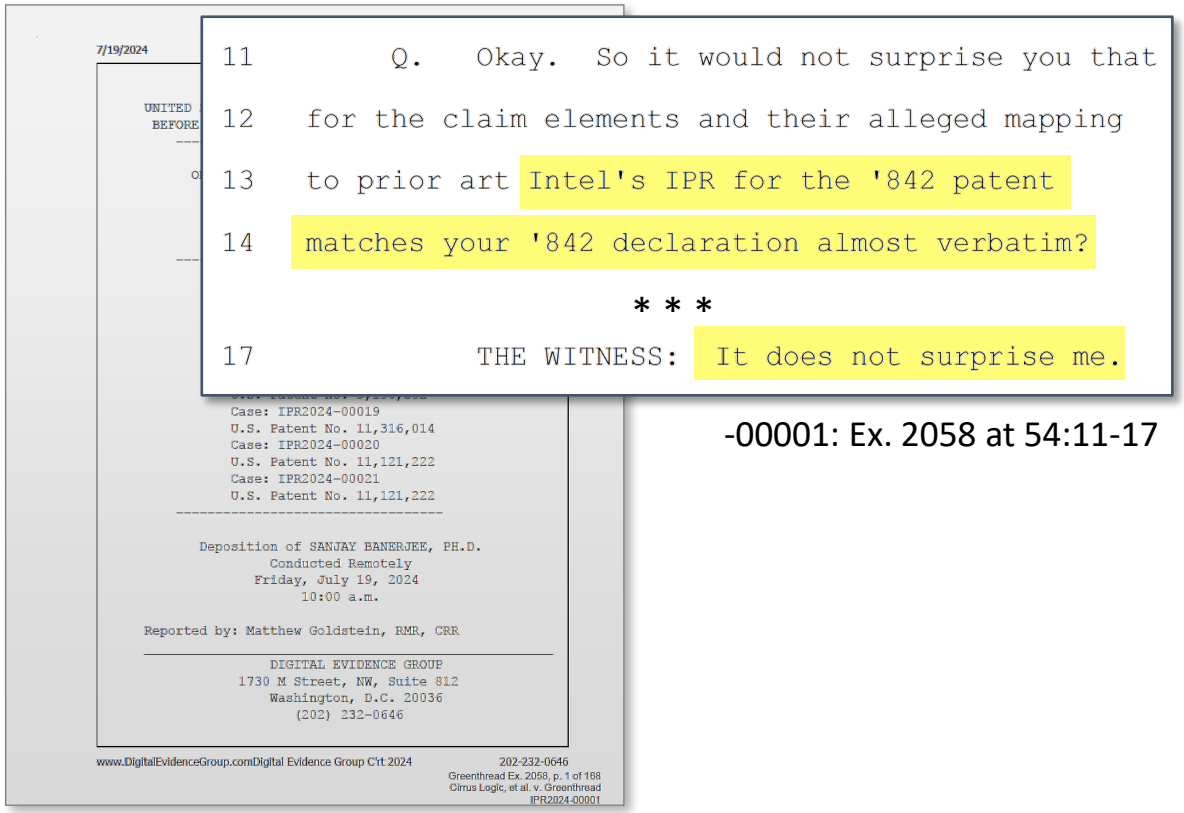
21 And in this case, the attorneys had
22 given me copies of the cited prior art. So I read
1 through those in detail, also. And I formed my
2 opinion about the validity or invalidity of the
3 various claims in the '842 patent. And that's
4 what's captured in my report.
5 I was given a copy of the Blalock
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.

-00001: Ex. 2058 (Banerjee Dep. Tr.) at 53:13-54:10

-00001: PO Resp. [45] at 31; PO Sur-Reply [63] at 24

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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Greenthread Ex. 2058, p. 1 of 188
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IPR2024-00001

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.

-00001: 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.

-00001: Ex. 2058 (Banerjee Dep. Tr.) at 57:13-58:5

-00001: PO Resp. [45] at 31; PO Sur-Reply [63] at 24

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Petitioners' Replicated Expert Declaration

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

f. Element [1.5]: "at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first surface to the second surface of the substrate; and"

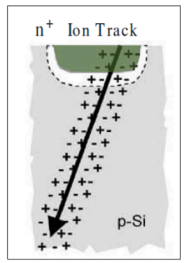
88. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. As illustrated in Figure 23 (below left), a channel region (light purple) formed at the top surface of the substrate connects the source-drain regions 4Na and 4Nb (purple) of transistor 4N. *See* Ex. 1008B, 298 ("A channel region in the Declaration of Dr. Blalock for *Inter Partes* Review of U.S. Patent No. 10,734,481 semiconductor under the gate electrode separates the source and drain"), 300-301 ("When positive bias is applied to an NMOS transistor gate … an *n*-type channel connects the source and drain regions"), FIG. 5-2; Ex. 1007, 8:60-67 ("The semiconductor regions 4Na and 4Nb are regions for forming the source-drain regions of the NMOS 4N."), 14:46-55, 15:26-30 ("The p-well 6p is formed with the nMOS 4N."), 15:37-40. Based on Patent Owner's representation in the District Court Case that the channel is "a thin layer below the surface" connecting the source and drain, Patent Owner does not appear to dispute this.

-00001: Ex. 2076 (Prior Blalock Decl.) at ¶¶ 88; 102-103

102. It is also my opinion that Kawagoe also satisfies this claim element under Petitioner's proposed constructions of these terms. *See* Section VIII. With regard to the "well region," it is mapped to Kawagoe's p-well 6p and this mapping, in my opinion, satisfies Petitioner's construction of the term. *Id.* Notably, p-well 6p

Declaration of Dr. Blalock for *Inter Partes* Review of U.S. Patent No. 10,734,481

is formed by implanting ions of "a p-type impurity such as boron." Ex. 1007, 17:43-49. With regard to the "aid carrier movement" term, Kawagoe satisfies Petitioner's alternative proposed construction, in my opinion, that the term means "to sweep the carriers from the first surface to the second surface of the substrate." *Id.* As discussed in Wang and as was well understood in the art, an α-ray generates a stream of millions of carriers (*e.g.*, electrons) that can cause single-event upset (SEU) soft errors. Ex. 1009, 431; Section X.A.1.f.

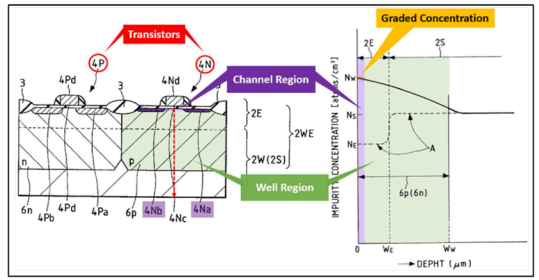


Ex. 1009, FIG. 2.

103. Kawagoe also explains that the graded dopant concentration illustrated in Figure 17 reduces soft errors by sweeping those carriers down to the second surface of the substrate. Ex. 1007, 16:2-11.

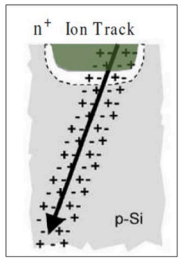
f. Element [1.5]: "at least a portion of at least one of the first and second active regions having at least one graded dopant concentration to aid carrier movement from the first surface to the second surface of the substrate; and"

85. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. As illustrated in my annotation of Figure 23 (below left), a channel region (light purple) formed at the top surface of the substrate connects the source-drain regions 4Na and 4Nb (purple) of transistor 4N. *See* Ex. 1008B, 298 ("A channel region in the semiconductor under the gate electrode separates the source and drain"), 300-301 ("When positive bias is applied to an NMOS transistor gate … an *n- type* channel connects the source and drain regions"), FIG. 5-2; Ex. 1007, 8:46-47 ("nMOS" is a shorthand for "n-***channel*** MOS.FET"), 8:60-67 ("The semiconductor regions 4Na and 4Nb are regions for forming the source-drain regions of the NMOS 4N."), 14:46-55, 15:26-30 ("The p-well 6p is formed with the nMOS 4N."), 15:37-40. Based on Patent Owner's representation in the District Court Case that the channel is "a thin layer below the surface" connecting the source and drain, Patent Owner does not appear to dispute this.



Ex. 1007, FIGS. 17, 23.

99. Further, as discussed in Wang and as was well understood in the art, an α-ray generates a stream of millions of carriers (*e.g.*, electrons) that can cause single-event upset (SEU) soft errors. Ex. 1009, 431; Section X.A.1.f.



Ex. 1009, FIG. 2.

100. Kawagoe also explains that the graded dopant concentration illustrated in Figure 17 reduces soft errors by sweeping those carriers down to the second surface of the substrate. Ex. 1007, 16:2-11.

-00001: Ex. 1003 (Banerjee Decl.) at ¶¶ 85; 102-103

Petitioners' Replicated Expert Declaration

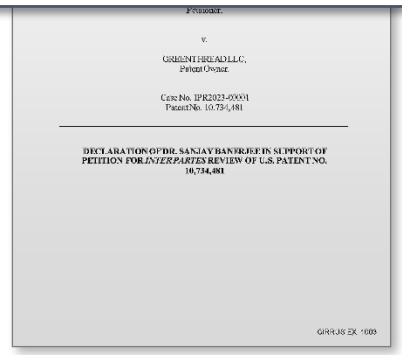
- Dr. Banerjee even copied minute details from the prior declaration.
- Dr. Banerjee allegedly conducted the exact same "internet search" as Dr. Blalock.

63. *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.



-00001: Ex. 2076 (Prior Blalock Decl.) at ¶ 63

60. *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. The Wolf textbook provides helpful context



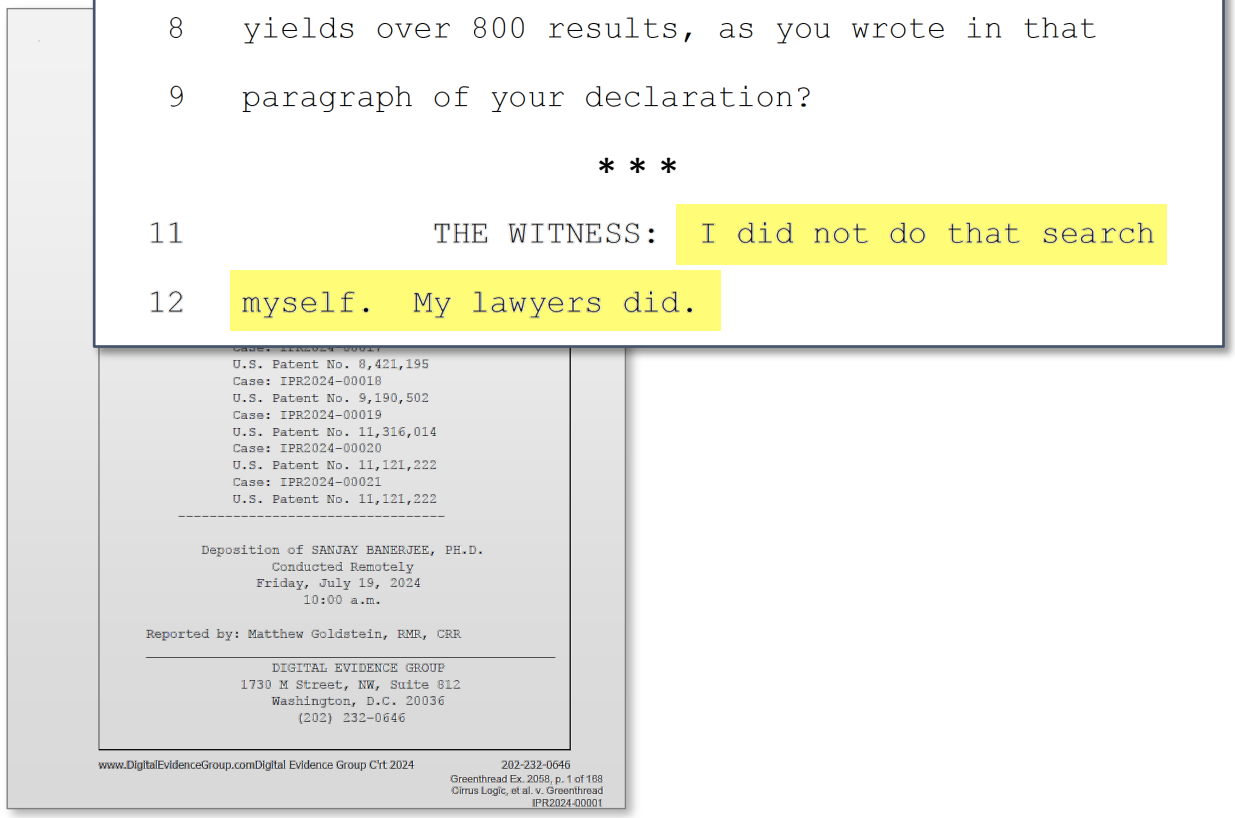
-00001: Ex. 1003 (Banerjee Decl.) at ¶ 60

-00001: PO Resp. [45] at 31-32

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Petitioners' Replicated Expert Declaration

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



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

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Greenthread Ex. 2058, p. 1 of 188
Cirrus Logic, et al. v. Greenthread
IPR2024-00001

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?

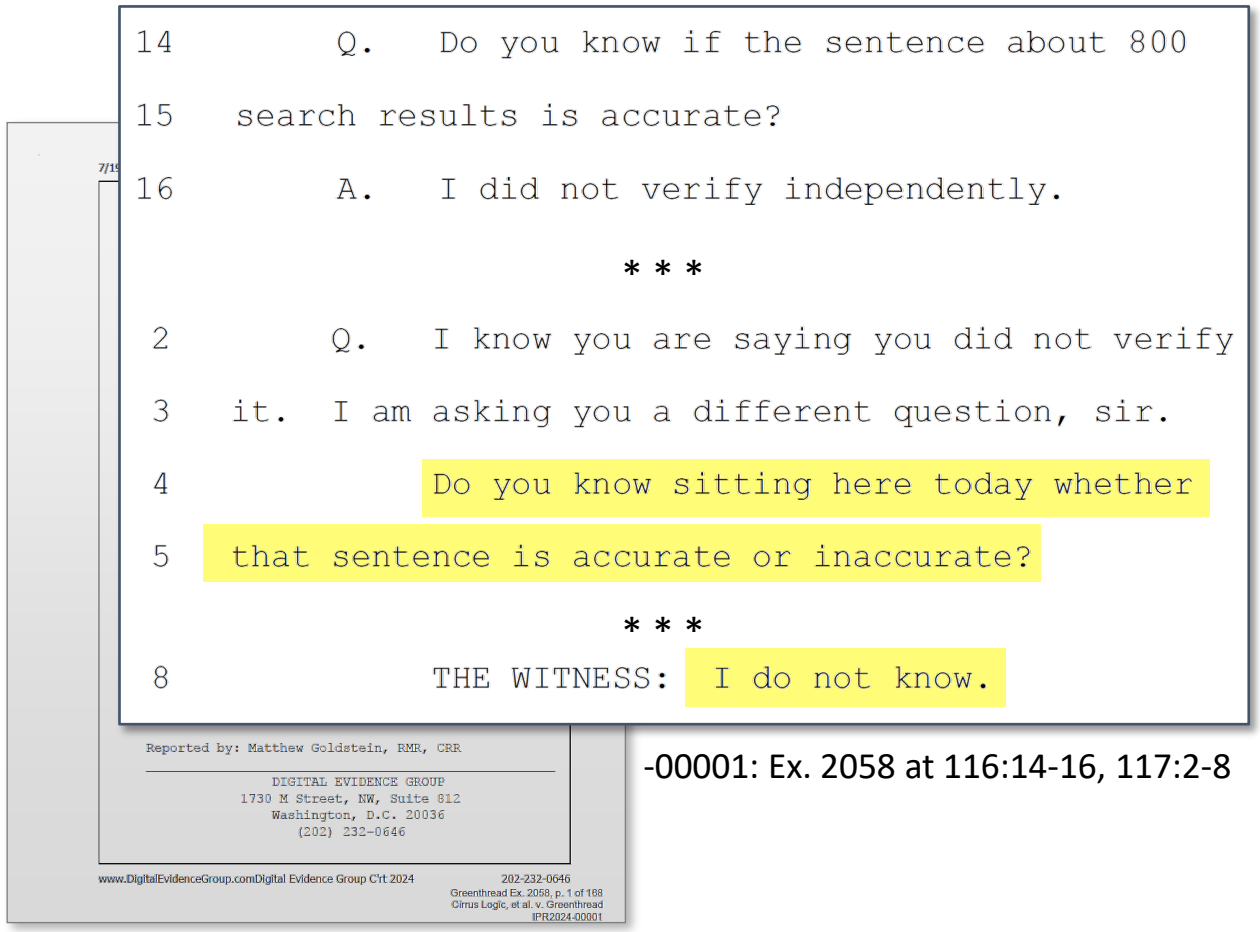
* * *

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.

-00001: Ex. 2058 (Banerjee Dep. Tr.) at 114:7-22

Petitioners' Replicated Expert Declaration

- Dr. Banerjee could not 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.

Reported by: Matthew Goldstein, RMR, CRR
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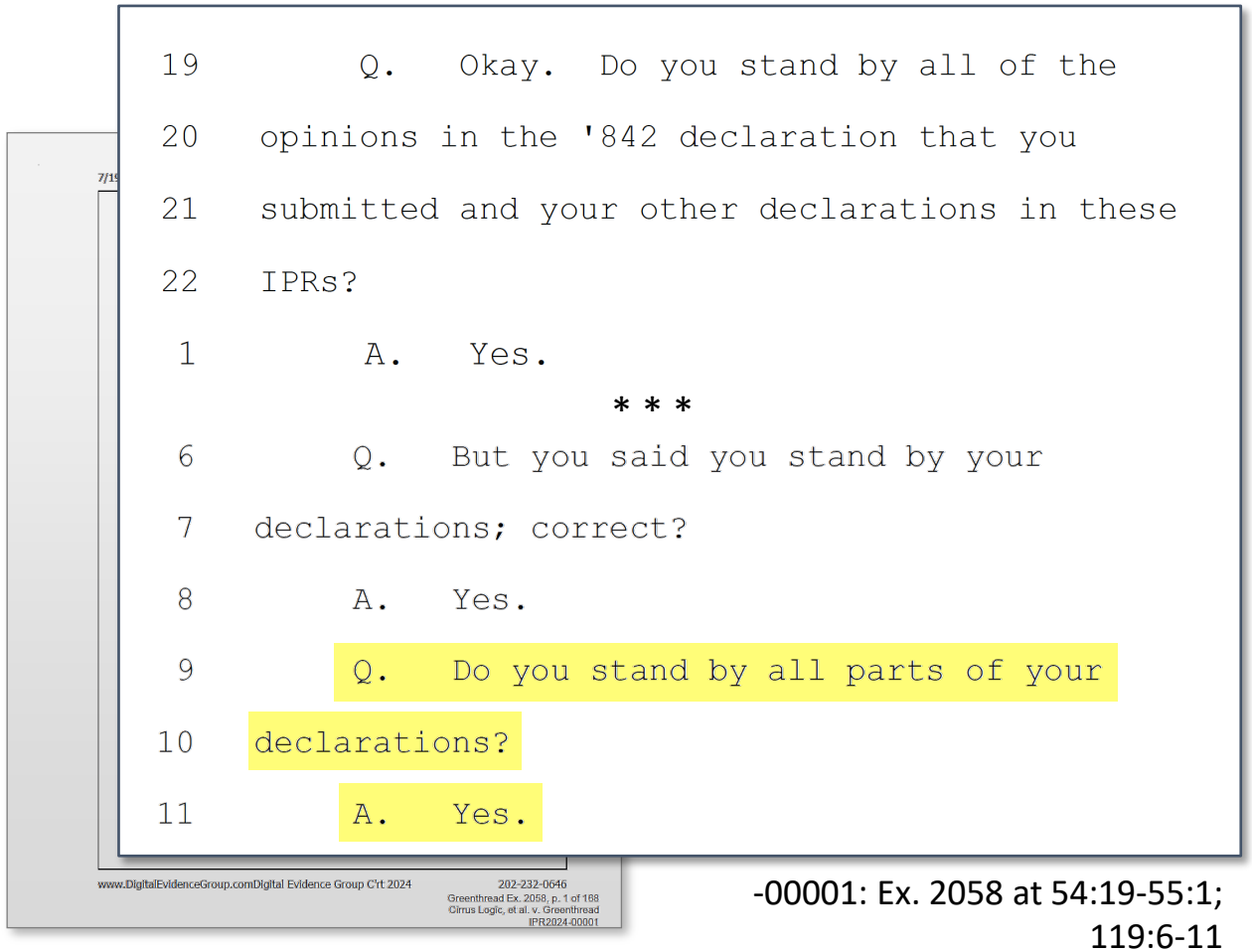
-00001: Ex. 2058 at 116:14-16, 117:2-8

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.

-00001: Ex. 2058 (Banerjee Dep. Tr.) at 122:20-123:5

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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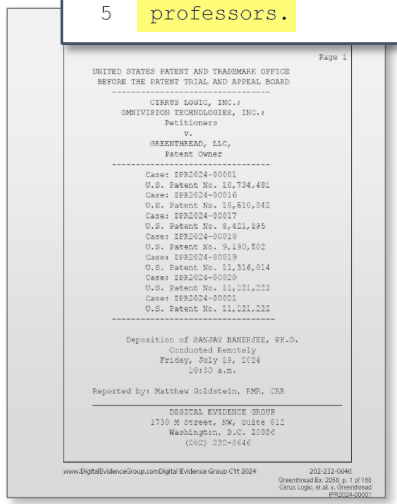
-00001: Ex. 2058 at 54:19-55:1; 119:6-11

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.

-00001: Ex. 2058 (Banerjee Dep. Tr.) at 122:20-123:5

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.

-00001: 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.

-00001: 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.

-00001: Ex. 2058 (Banerjee Dep. Tr.) 120:22-121:20

-00001: PO Resp. [45] at 32-33

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Overview of Issues

- The Challenged Claims require "carrier movement" from the "active region."
- Dr. Banerjee confirmed that the "electric field" must start in the "active region."
- Petitioners did not identify an electric field, much less an electric field that starts in the "active region."
- Dr. Banerjee confirmed that carriers in the "active region" are affected by numerous fields (*e.g.*, gate, gate oxide, temperature, and magnetic fields).
- Dr. Banerjee confirmed that "carrier movement" depends on the sum of all of the fields in the "active region."
- Petitioners have the burden to analyze all of the fields in the "active region."
- Dr. Banerjee testified that he did not analyze any of the fields in the "active region."
  - Dr. Banerjee did not analyze the gate, gate oxide, and other fields in Kawagoe's "active region."
  - The graded dopant concentration is "uniform" in Wieczorek's "active region."
- Petitioners' prosecution-related arguments are incorrect.
- Dr. Banerjee's belated "Brownian motion" argument is not relevant to the Challenged Claims.
- Kawagoe does not meet the "second doping type" limitation.
- Petitioners' expert declaration and testimony are untrustworthy.
  - Dr. Banerjee has an undisclosed financial relationship with one of the petitioners.
  - Petitioners' counsel conducted improper witness coaching prior to re-direct examination.
  - Dr. Banerjee copied verbatim the expert declaration from a separate petitioner's expert.
- **Substantial evidence of objective indicia of non-obviousness supports patentability.**

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."

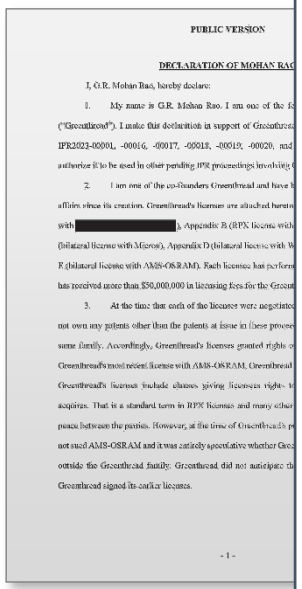
* * *

"[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)

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.


PUBLIC VERSION

DECLARATION OF MOHAN RAO

I, G.R. Mohan Rao, hereby declare:

1. My name is G.R. Mohan Rao. I am one of the

("Greenthread"). I make this declaration in support of Greenthread

IPR2023-00001, -00016, -00017, -00018, -00019, -00020, and

authorize it to be used in other pending IPR proceedings involving

2. I am one of the co-founders Greenthread and have

affairs since its creation. Greenthread's licenses are attached here

with [redacted]; Appendix B (RPX license with

(bilateral license with Micron), Appendix D (bilateral license with

F (bilateral license with AMS-OSRAM). Each licensee has perform

has received more than $50,000,000 in licensing fees for the Green

3. At the time that each of the licensees were negotiated

not own any patents other than the patents at issue in these proceed

same family. Accordingly, Greenthread's licenses granted rights

Greenthread's most recent license with AMS-OSRAM, Greenthread

Greenthread's licenses include clauses giving licensees rights

acquires. That is a standard term in RPX licenses and many other

peace between the parties. However, at the time of Greenthread's p

not sued AMS-OSRAM and it was entirely speculative whether Gre

outside the Greenthread family. Greenthread did not anticipate th

Greenthread signed its earlier licenses.

- 1 -

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.

-00001: Ex. 2072 (Dr. Rao Decl.) at 2

-00001: PO Resp. [45] at 27-28; PO Sur-Reply [63] at 23-24

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Objective Indicia of Non-Obviousness

- Intel, Sony, Micron, and Western Digital also licensed the patents.

EXHIBIT E

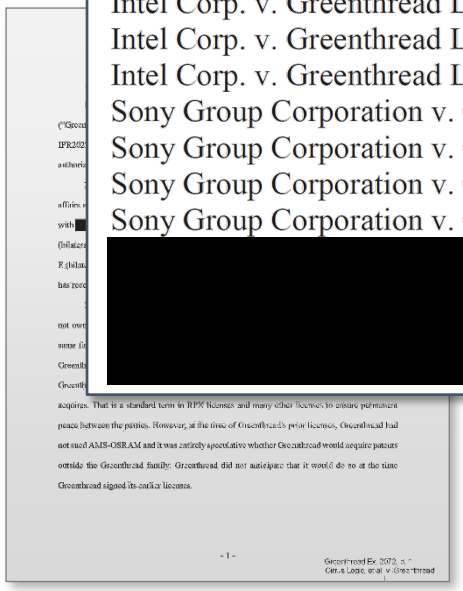
LICENSEE NULLITY PROCEEDINGS AND LICENSOR LITIGATIONS

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]



-00001: Ex. 2072 at 55

EXHIBIT D – LITIGATION

Greenthread, LLC v. Micron Technology, Inc. et al., 23-cv-00333 (D. Del.)

-00001: Ex. 2072 at 81

EXHIBIT D – LITIGATION

Greenthread, LLC v. Western Digital Corporation et al., 1:23-cv-00326-RGA (D. Del.)

-00001: 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.

-00001: Ex. 2072 (Dr. Rao Decl.) at 122

-00001: PO Resp. [45] at 29-30; PO Sur-Reply [63] at 24

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE