UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

INTEL CORPORATION,
Petitioner

v.

GREENTHREAD LLC,
Patent Owner

U.S. PATENT NO. 10,734,481

Case IPR2023-TBD

DECLARATION OF TRAVIS BLALOCK, PH.D.

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I, Dr. Travis Blalock, declare as follows:

1. My name is Travis Blalock.

2. I have been retained as an expert witness on behalf of Intel Corporation ("Intel" or "Petitioner") for the above-captioned Petition for *Inter Partes* Review ("Petition") of U.S. Patent No. 10,734,481 (the "'481 Patent") (Ex. 1001). I am being compensated for my time in connection with this Petition at my standard consulting rate of $450 per hour. My compensation is not affected by the outcome of this matter.

3. I have been asked to provide my opinions regarding whether claims 1-9, 13-18, 20-27, and 31-35 of the '481 Patent (the "Challenged Claims") are invalid as obvious to a person having ordinary skill in the art at the time of the alleged invention.

4. The '481 Patent issued on August 4, 2020 from Application No. 16/717,950, filed on December 17, 2019. The '481 Patent claims priority to Application No. 10/934,915, filed on September 3, 2004.

5. I am not currently, and have not at any time in the past been, an employee of Intel. I have no financial interest in Intel.

I. BACKGROUND AND QUALIFICATIONS

6. I am currently an Associate Professor at the University of Virginia. I served as an Associate Professor from 1998 until 2013 when I moved to a non-resident Associate Professor position so I could lead a Handheld Ultrasound R&D

team for Analogic, Inc. I earned my Bachelor of Science and Master of Science in Electrical Engineering from the University of Tennessee at Knoxville in 1985 and 1988 respectively. I earned my Ph.D. from Auburn University in 1991. The primary emphasis of my doctoral research was CMOS analog and digital integrated circuit design.

7. From 1991 through August 1998, I worked at Hewlett Packard Laboratories, first as a Member of the Technical Staff, and then as a Principal Scientist. My work at Hewlett Packard Laboratories involved design and implementation of digital and analog integrated circuits. I was the principal architect and designer of integrated circuits having a diverse range of applications, including CMOS analog signal processing integrated circuits for mass storage devices and optoelectronic image acquisition and processing integrated circuits. I also have experience with software and custom design tools that allow for improved analysis, modeling, and simulation of integrated circuit analysis and design.

8. While I was employed at Hewlett-Packard Laboratories (now Agilent Laboratories) I was the lead designer on several mixed-signal CMOS chips. One of these was a massively parallel analog signal processing prototype integrated circuit [1]. The chip measures position with an accuracy of better than 100 μm over 10 inches by cross-correlating past and present images acquired by the integrated photo-array. The photodetector design was based on an understanding of dopant profiles

and the resulting effects on detector sensitivity. This was incorporated into the detection circuit design to optimize response. The chip has a 2048 element 25,000 frame/second photoreceiver array coupled with an analog signal processing cross-correlation array. The array performs a set of 9 nearest-neighbor cross-correlations between the two images at a total computation throughput of 1.5 billion operations per second. Over 100 million second generation versions of this chip have been sold and the architecture forms the core of most optical mice.

9. I was also the technical lead in the design of a 1024 x 768 silicon backplane ferro-electric liquid-crystal microdisplay. The chip also includes 1024 compact, offset-corrected column amplifiers and high-speed analog signal distribution. Both of the above chip designs were the highest density mixed-signal integrated circuits ever produced within Hewlett-Packard (at that time) and were fully functional at first silicon. I was also directly involved in the testing and verification of these chips in the laboratory.

10. At the University of Virginia, I led research in design of low-power mixed-signal integrated circuits. This work covered a broad range of application areas including medical ultrasound, subthreshold RFID for mobile health applications, wearable sensors, custom RFID for bio-tracking of plaque propagation, infrared imaging, cryptographic hardening, and sensors for CMOS process reliability.

11. More recently, I have led the development of a CMOS 600 channel low power medical imaging front-end integrated circuit. The chip simultaneously amplifies, filters, and digitizes signals from 600 independent ultrasound transducer elements. The chip development was part of an independent medical ultrasound startup (PocketSonics, Inc.) I founded which was acquired by Analogic, Inc in 2013. This work led to the development and release of a handheld medical ultrasound product by Analogic, Inc. This device was powered by a lithium-ion battery and included circuits to manage high peak currents, pulse-width modulation for controlled power delivery, charge management, and battery protection circuits.

12. I am currently a collaborator with the Integrated Electromagnetics, Circuits, and Systems Lab at the University of Virginia. In this group we design a variety of high frequency RF integrated circuits and merged RF/Optical circuits. Of particular interest are low power wake-up receivers, clock recovery, and high efficiency power amps for battery powered RF circuits.

13. I have written widely in the field of electrical engineering, including several editions of a textbook that is used across the world to teach principles of microelectronic circuit design to undergraduate and graduate students. I have authored or co-authored over 50 journal and conference papers. My textbook includes discussions of the solid-state physics needed to understand the operation of semiconductor diodes, BJT transistors, and CMOS transistors. In the course of

integrated circuit design teaching and practice, particularly the low noise, high sensitivity circuits I have focused on, it has been essential to understand the device physics and how neighboring devices may interact to understand subtle effects that impact the success of both industrial and academic designs.

14. I have contributed to or consulted on the design, fabrication, and/or operation of integrated circuits, including microelectronic integrated circuits, for organizations such as Hewlett-Packard, NASA Langley Research Center, Agilent Technologies, Displaytech, PocketSonics, and Analogic.

15. I am a named inventor on at least 27 U.S. patents. Several of these concern analog circuitry or semiconductor design, including guard rings, charge storage devices, and photosensors.

16. My qualifications and publications are set forth more fully in my curriculum vitae, attached.

II. MATERIALS AND OTHER INFORMATION CONSIDERED

17. In forming the opinions expressed in this Declaration, I relied upon my education and experience in the relevant field of the art and have considered the viewpoint of a person having ordinary skill in the art (POSITA) at the time of the alleged invention.

18. I have considered the materials referenced herein, including the ’481 Patent (Ex. 1001), the file history of the ’481 Patent (Ex. 1002), the parent and

related applications, the file histories of the parent and related applications, including for the parent '195 Patent (Ex. 1016), the Petition, and other documents listed in the Exhibit List of the Petition, including:

Description	Date of Public Availability
U.S. Patent Application Publication No. 2003/0183856 to Wieczorek ("Wieczorek") (Ex. 1006)	Filed on October 29, 2002 (with priority to March 28, 2002).
U.S. Patent No. 6,043,114 to Kawagoe, et al. ("Kawagoe") (Ex. 1007)	Filed on September 22, 1997 (with priority to July 28, 1995) and issued on March 28, 2000.
Stanley Wolf and Richard N. Tauber, *Silicon Processing For The VLSI Era,* Vol 1, Lattice Press (2000) ("Wolf.1") (Ex. 1008A)	Published and publicly available no later than 2002.
Stanley Wolf and Richard N. Tauber, *Silicon Processing For The VLSI Era,* Vol. 2, Lattice Press (2000) ("Wolf.2") (Ex. 1008B)	Published and publicly available no later than 2002.
Stanley Wolf and Richard N. Tauber, *Silicon Processing For The VLSI Era,* Vol. 3, Lattice Press (2000) ("Wolf.3") (Ex. 1008C)	Published and publicly available no later than 2002.
Stanley Wolf and Richard N. Tauber, *Silicon Processing For The VLSI Era,* Vol. 4, Lattice Press (2000) ("Wolf.4") (Ex. 1008D)	Published and publicly available no later than 2002.
Wang and Agrawal, Single Event Upset: An Embedded Tutorial, 21st Intl Conf on VLSI Design, IEEE 2008 ("Wang") (Ex. 1009)	Published and publicly available in 2008.
U.S. Patent No. 4,481,522 ("Jastrzebski") (Ex. 1010)	Filed March 24, 1982 and issued on November 6, 1984.
U.S. Patent No. 6,163,877 ("Gupta") (Ex. 1014)	Filed November 5, 1996 and issued on December 19, 2000.
U.S. Patent No. 6,534,805 ("Jin") (Ex. 1015)	Filed April 9, 2001 and issued on March 18, 2003.

Description	Date of Public Availability
Sze, *Semiconductor Devices Physics and Technology*, 2d Ed., John Wiley & Sons (2002) (Ex. 1022)	Published and publicly available in 2002.
Maziasz and Hayes, *Layout Minimization of CMOS Cells*, Kluwer Academic Publishers (1992) ("Maziasz") (Ex. 1023)	Published and publicly available in 1992.
Rabaey *et al.*, *Digital Integrated Circuits, A Design Perspective,* Prentice Hall Electronics and VLSI Series (2003) ("Rabaey") (Ex. 1025)	Published and publicly available in 2003.
Gregory and Shafer, "Latch-Up In CMOS Integrated Circuits," IEEE Transactions on Nuclear Science, Volume 20, Issue 6 (1973) (Ex. 1026)	Published and publicly available in 1973.
U.S. Patent No. 4,160,985 to Kamins *et al.* ("Kamins") (Ex. 1031)	Filed November 25, 1977 and issued July 10, 1979.
McGraw-Hill Dictionary of Scientific and Technical Terms (2003) (Ex. 1032)	Published and publicly available in 2003.
U.S. Patent Application Publication No. 2003/0030488 to Hueting *et al.* ("Hueting") (Ex. 1035)	Filed July 25, 2002 (with priority to August 7, 2001).

19. The references listed above include prior art to the '481 Patent which is entitled to a priority date not earlier than September 3, 2004. None of the prior art references were before the Patent Office during prosecution.

III. UNDERSTANDING OF PATENT LAW

20. I am not an attorney. For purposes of this declaration, I have been informed about certain aspects of the law that are relevant to my opinions. My understanding of the law is as listed below.

A. Claim Construction

21. I understand that in an IPR petition filed after November 13, 2018, a claim must be construed under the *Phillips* standard. Under that standard, words of a claim are given their plain and ordinary meaning as understood by a POSITA at the time of invention, in light of the specification and prosecution history, unless those sources show an intent to depart from such meaning, as well as pertinent evidence extrinsic to the patent.

B. Obviousness

22. I have been informed and understand that a patent claim can be considered to have been obvious to a POSITA at the time the application was filed. This means that, even if all of the requirements of a claim are not found in a single prior art reference, the claim is not patentable if the differences between the subject matter in the prior art and the subject matter in the claim would have been obvious to a POSITA at the time the application was filed.

23. I have been informed and understand that a determination of whether a claim would have been obvious should be based upon several factors, including, among others:

- the level of ordinary skill in the art at the time the application was filed;
- the scope and content of the prior art; and
- what differences, if any, existed between the claimed invention and the prior art.

24. I have been informed and understand that the teachings of two or more references may be combined in the same way as disclosed in the claims, if such a combination would have been obvious to a POSITA. In determining whether a combination based on either a single reference or multiple references would have been obvious, it is appropriate to consider at least the following factors:

- whether the teachings of the prior art references disclose known concepts combined in familiar ways, which, when combined, would yield predictable results;
- whether a POSITA could implement a predictable variation, and would see the benefit of doing so;
- whether the claimed elements represent one of a limited number of known design choices, and would have a reasonable expectation of success by a POSITA;
- whether a POSITA would have recognized a reason to combine known elements in the manner described in the claim;
- whether there is some teaching or suggestion in the prior art to make the modification or combination of elements claimed in the patent; and
- whether the innovation applies a known technique that had been used to improve a similar device or method in a similar way.

25. I understand that a POSITA has ordinary creativity, and is not an automaton.

26. I understand that in considering obviousness, it is important not to determine obviousness using the benefit of hindsight derived from the patent being considered.

27. I understand that prior art to the ’481 Patent includes patents and printed publications in the relevant art that predate the Priority Date of the ’481 Patent.

28. I understand that certain factors—often called “secondary considerations”—may support or rebut an assertion of obviousness of a claim. I understand that such secondary considerations include, among other things, commercial success of the alleged invention, skepticism of those having ordinary skill in the art at the time of the alleged invention, unexpected results of the alleged invention, any long-felt but unsolved need in the art that was satisfied by the alleged invention, the failure of others to make the alleged invention, praise of the alleged invention by those having ordinary skill in the art, and copying of the alleged invention by others in the field. I further understand that there must be a nexus—a connection—between any such secondary considerations and the alleged invention. I also understand that contemporaneous and independent invention by others is a secondary consideration tending to show obviousness.

IV. SUMMARY OF OPINIONS

29. It is my opinion that claims 1-9, 13-14, 16-18, 20, 22-27, and 31-35 are disclosed or, at a minimum, rendered obvious by Kawagoe (Ground I).

30. It is my opinion that claims 1-2, 4-9, 13-18, 20-22, 24-27, and 31-35 obvious are rendered obvious by Wieczorek in combination with Wolf (Ground II).

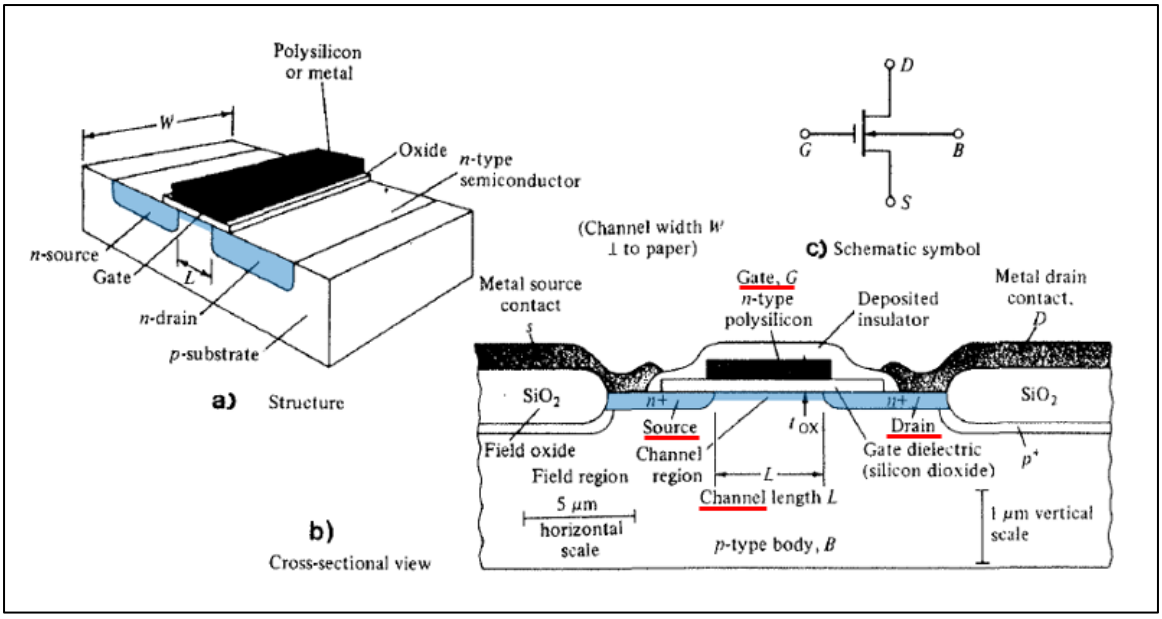
31. It is my opinion that claims 1-9, 13-14, 16-18, 20, 22-27, and 31-35 are rendered obvious by Kawagoe in view of Gupta (Ground III).

32. It is my opinion that claims 1-2, 4-9, 13-18, 20-22, 24-27, and 31-35 obvious are rendered obvious by Wieczorek in combination with Wolf and Gupta (Ground IV).

33. It is my opinion that for purposes of this proceeding, the claim terms need not be construed to resolve the prior art issues presented in this Petition.

V. OVERVIEW OF THE TECHNOLOGY

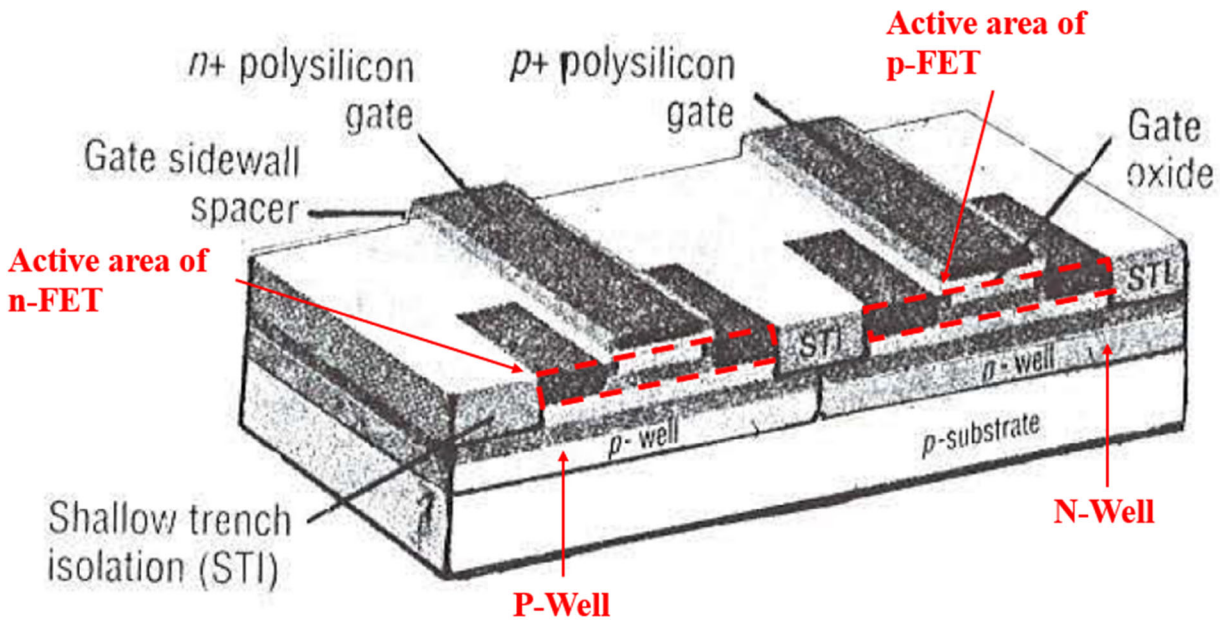
34. A Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) is a transistor that switches from an OFF state to an ON state when a voltage is applied to a gate terminal. Ex. 1008B, 402. In the ON, or active state, current flows from a source to a drain through a channel region (the length of such channel region is labelled "L" below). The channel region is under the gate and gate oxide, and between the source and drain.



Ex. 1008B, FIG. 5-1; *id*., 298-301, FIGS. 5-2, 6-4. The combination of the source, drain, and channel regions form the active region of a transistor. Ex. 1008B, 299-300 ("The top surface of the [substrate] body consists of active or transistor regions as well as passive or (field) regions. The ***active regions*** are those in which transistor action occurs; i.e., the ***channel*** and the heavily doped ***source*** and ***drain*** regions."), FIG. 5-2, 382, FIG. 6-8(c), 387, FIG. 6-10; Ex. 1008C, 525, FIG. 8-1(e).

35. MOSFETs are characterized by the material used in the source and drain. A MOSFET with source/drain regions made from "p-type" material in such areas (as shown in the figure above, labelled "p^+") is known as a PMOS or p-FET, while a MOSFET with source/drain regions made from "n-type" material ("n+") in such areas is known as a NMOS or n-FET. In the mid-1980s, Complementary MOS (CMOS) devices became popular, which have both PMOS (p-FET) and NMOS (n-

FET) transistors on the same device. In such devices, the active areas (and associated transistors) are generally formed in regions called "wells," which have opposite dopant type to the dopants of the source/drain, as illustrated below.

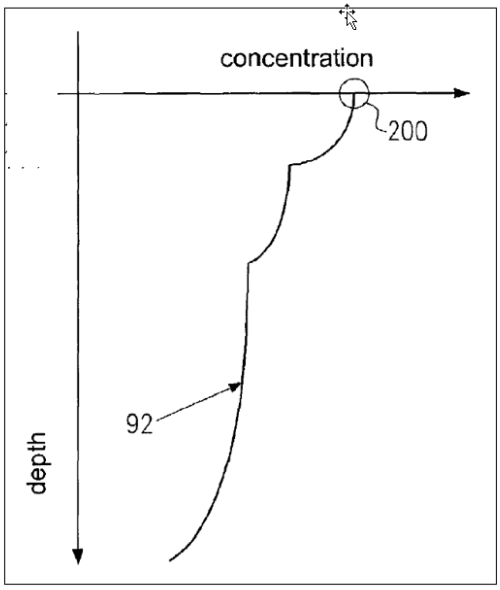


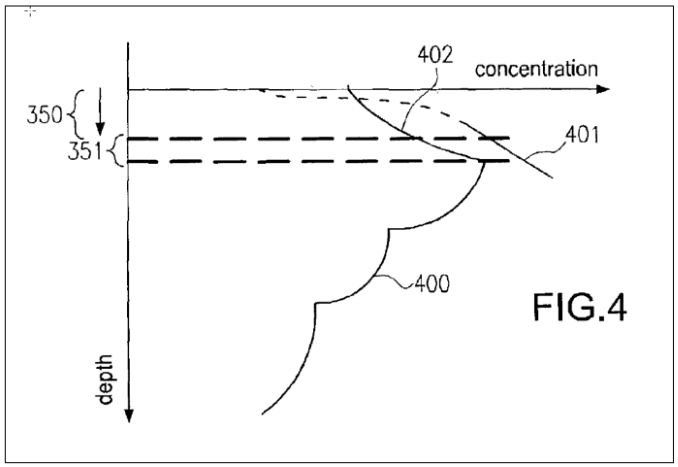
Ex. 1008A, FIG. 16-28 (annotations in red).[1]

36. Impurities known as "dopants" are added to the active areas and wells to add charge carriers and tailor the electrical properties of these regions such as their conductivity. Charge carriers can be electrons or holes. Ex. 1008C, 86. When a region is doped with p-type dopants, the holes are majority carriers and the electrons are minority carriers. Ex. 1008C, 86. When a region is doped with n-type dopants, the electrons are majority carriers and the holes are minority carriers. Ex. 1008C, 86.

[1] All emphases and annotations added unless otherwise noted.

37. A "dopant profile" refers to the "map" of concentration of dopants over a doped region and, in certain simplified scenarios, can be expressed as as a function of depth. For example, a dopant concentration that does not change with depth is a uniform concentration. A non-uniform dopant concentration that varies for example with depth, e.g., increases or decreases with depth, is a non-uniform dopant concentration called "graded." A graded dopant concentration that peaks at some depth of the doped region(s) instead of at the top or bottom of the doped region(s) is called "retrograde." All such doping profiles were known in the art, as shown in the Wieczorek figures below.





See Ex. 1006, FIG. 2B (left) and FIG. 4 (right).

VI. THE '481 PATENT

38. The '481 Patent issued on August 4, 2020 from Application No. 16/717,950, filed on December 17, 2019. The '481 Patent claims priority to Application No. 10/934,915, filed on September 3, 2004. Ex. 1001, cover.

A. Claims

39. The '481 Patent has 36 claims, including two independent claims numbered 1 and 20. Ex. 1001, 4:49-6:60. Claims 1-9, 13-18, 20-27, and 31-35 are the Challenged Claims.

40. Exemplary Claim 1 is reproduced below:

> **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

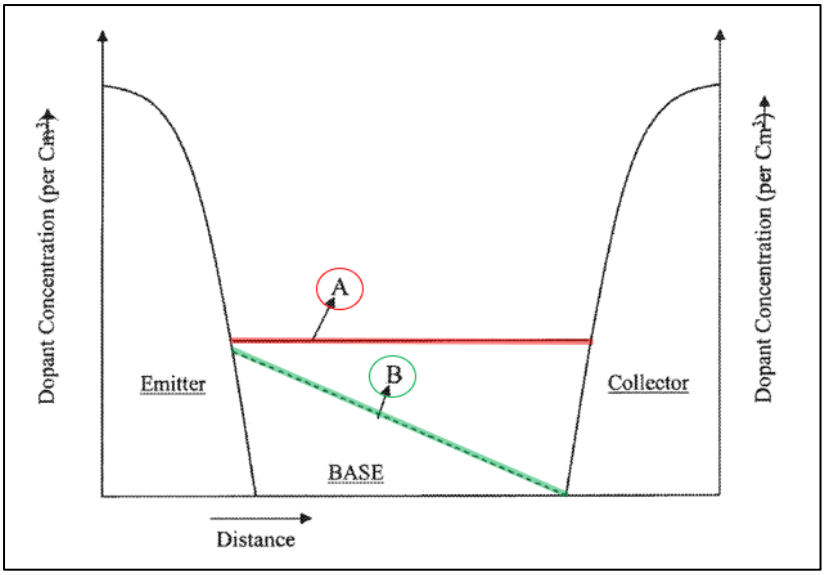
> region to aid carrier movement from the first surface to the second surface of the substrate.

Ex. 1001, 4:50-5:3.

B. Summary of the Specification

41. The ’481 Patent is directed to “grading the dopant concentration” in certain regions of a semiconductor device. Ex. 1001, Abstract. In particular, the Challenged Claims claim that an active region and a well region of a semiconductor device have graded dopant concentrations to aid carrier movement. *Id*., Cl. 1 (“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 …” and “at least one well region … containing at least one graded dopant region to aid carrier movement …”). I understand that those claims are asserted against CMOS products in the District Court Case. In my opinion, the references relied on in the Petition (*i.e.*, Kawagoe, Wieczorek, Wolf, and Gupta) are also directed to CMOS devices and technology.

42. According to the ’481 Patent, the figure below “illustrates the relative doping profiles of emitter, base and collector for the two most popular bipolar junction transistors: namely, uniform base (‘A’) [(red)] and graded base (‘B’) [(green)].” Ex. 1001, 2:39-42.



Id., FIG. 1 ("Prior Art").[2] The '481 Patent states that such "uniform base" and "graded base" bipolar junction transistors existed in the prior art. *Id*.

43. The '481 Patent explains that "[r]etrograde wells have been attempted, with little success, to help improve soft error immunity in SRAMs and visual quality in imaging circuits." Ex. 1001, 2:18-20. The '481 Patent further states that "[r]etrograde and halo wells have also been attempted to improve refresh time in DRAMs (dynamic random-access memories), as well as, reducing dark current (background noise) and enhance RGB (Red, Green, Blue) color resolution in digital camera ICs." *Id*., 2:24-28. The '481 Patent also explains that "these techniques" in the prior art "either divert the minority carriers away from the active regions of

[2] All colors and colored annotations to figures added.

critical charge storage nodes at the surface, or, increase minority carrier density locally as the particular application requires." *Id*., 2:28-32.

44. In my opinion, the only description of graded dopant concentrations and purported carrier movement in CMOS devices (the only types of devices accused of infringement in the District Court Case) in the '481 Patent is in two paragraphs of the specification and associated Figures 5A-5C. Ex. 1001, 3:48-4:30, FIGS. 5A-5C. In my opinion, the specification does not provide any guidance, such as dopant concentration ranges or doping gradients, on the grading of dopant concentration that would accomplish "sweep[ing] [] carriers from the active circuitry at the surface into the substrate" or "aid[ing]" carrier movement in CMOS devices as recited in the Challenged Claims. It is my further opinion that the specification does not provide any guidance as to the degree or nature of the "aiding" referenced in the Challenged Claims. Instead, the specification contrasts "graded channel[s]" with "uniformly doped channel (as practiced in the prior art)." *Id*. at 4:15-18. Thus, in my opinion, the specification uses "graded" dopant to describe a dopant concentration that is not uniform.

45. In my opinion, the specification also does not describe grading in an active region of a CMOS device to move carriers to the "second surface of the substrate" as claimed in the Challenged Claims. Ex. 1001, Cl. 1. Instead, the

specification discusses only grading the channel region of an active region "to accelerate majority carriers towards the drain." *Id*., 4:9-11

C. Summary of the Prosecution History

46. I understand that the Challenged Claims issued without any office action rejection, and none of the prior art relied on in this Petition was cited or considered by the Examiner. I understand that in the Notice of Allowance, the Examiner stated that the claimed "aiding of carrier movement [] 'from the first surface to the second surface of the substrate' [was] known in the art." Ex. 1002, 81-83. According to the Examiner, the claims issued over the "closest reference" (U.S. Patent Application Publication No. 2007/0045682 ("Hong")) because Hong does not disclose "active" regions within which transistors can be formed. *Id*. I note that Hong is not prior art and was also the only reference discussed in prosecution of the immediate parent application that issued as U.S. Patent No. 10,510,842 ("the '842 Patent"). I also note that none of the claims at issue during prosecution of the earlier parent applications to both the '842 and '481 Patents are of the same or similar scope as the Challenged Claims. For example, the claims of the parent U.S. Patent No. 9,647,070 ("the '070 Patent") are directed to bipolar devices and claim aiding carrier movement "from an ***emitter*** in the active region to a ***collector*** in the substrate," and not "from the first surface to the second surface of the substrate" as claimed in the Challenged Claims. Ex. 1034, Cl. 1. Other claims that claim graded dopant in an

active region were withdrawn prior to substantive examination. Ex. 1016, 73 (withdrawing claims 1-2); Ex. 1028, 9 (same); Ex. 1029, 7 (canceling claims 1-2); Ex. 1030, 18 (same).

VII. LEVEL OF ORDINARY SKILL IN THE ART

47. I understand that there are multiple factors relevant to determining the level of ordinary skill in the pertinent art, including the educational level of active workers in the field at the time of the alleged invention, the sophistication of the technology, the type of problems encountered in the art, and the prior art solutions to those problems.

48. In determining the characteristics of a hypothetical person of ordinary skill in the art of the ’481 Patent at the time of the alleged invention, I considered several things, including the type of problems encountered in this field, and the rapidity with which innovations were made. I also considered the sophistication of the technology involved, and the educational background and experience of those actively working in the field, and the level of education that would be necessary to understand the ’481 Patent. Finally, I placed myself back in the relevant periods of time, and considered the state of the art and the level of skill of the engineers working in this field in those times.

49. It is my opinion that a POSITA at the time of the ’481 Patent would have had a Bachelors degree in electrical engineering, material science, applied

physics, or a related field, and four years of experience in semiconductor design and manufacturing or equivalent work experience. Additional education might compensate for a deficiency in experience, and vice-versa.

50. I also note that my opinions provided in this Declaration would not change in view of any minor modifications to this level of skill.

VIII. CLAIM CONSTRUCTION

51. It is my opinion that for purposes of this proceeding, the claim terms need not be construed to resolve the prior art issues presented in this Petition.

52. Nothing in this section should be construed as expressing any opinion as to whether the claims constitute patentable subject matter under 35 U.S.C. § 101, or whether they satisfy the definiteness, enablement, best mode, or written description requirements under § 112.

53. I understand that the parties have proposed claim constructions in the District Court Case as set forth in the table below. Exs. 1017-1021.

Claim Term	Patent Owner's Proposed Construction	Petitioner's Proposed Construction
"substrate"	Plain Meaning ("an underlying layer")	"the initial material within which or on which the semiconductor device is fabricated"
"active region"	Plain Meaning ("a doped silicon region at the surface of a semiconductor device	"region that forms the current path of a device" or "the source, drain and

	(*e.g.*, the source and drain and silicon between them) where a transistor can be formed")	channel region of a device"
"to aid carrier movement from … [to/towards] …"	Plain Meaning	Indefinite Alternative Construction: "to sweep the carriers from … [to/towards] …"
"well region"	Plain Meaning ("a doped region that surrounds the active region of a semiconductor device")	"A well, whether formed by single or multiple implants. Portions of a well are not well regions."
"active region … within which transistors can be formed"	Plain Meaning ("a doped silicon region at the surface of a semiconductor device where a transistor can be formed")	Indefinite

54. I support Petitioner's proposed constructions. However, I do not believe any terms need be construed to resolve the issues presented in this Petition because, in my opinion, as the Challenged Claims are unpatentable under either party's proposed constructions (except for the term "active region … within which transistors can be formed," which I address under Patent Owner's proposed construction). I reserve the right to respond to any purported claim constructions that Patent Owner raises.

IX. OVERVIEW OF THE PRIOR ART

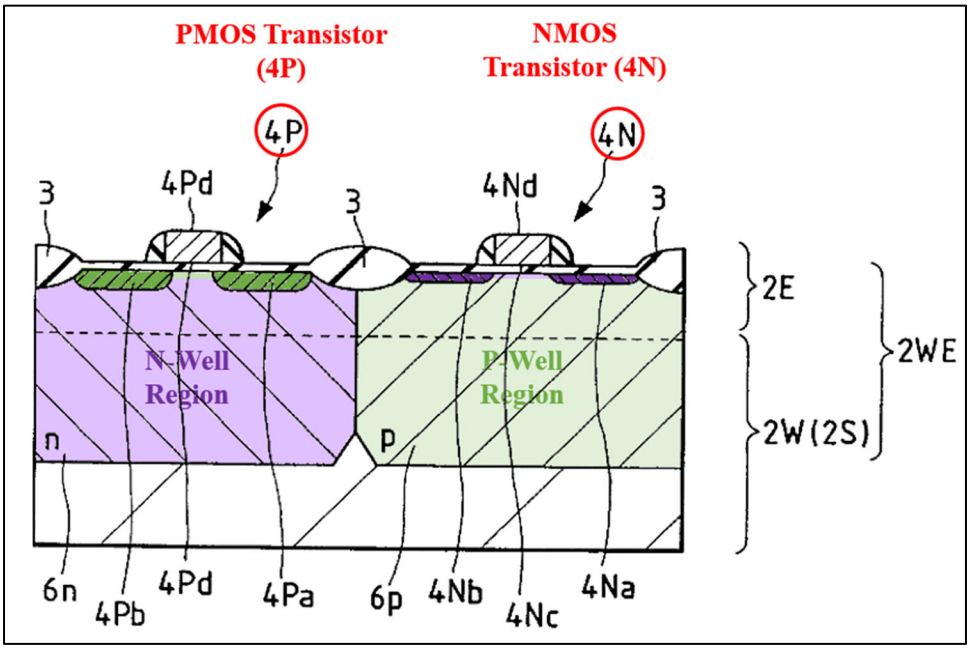
A. Kawagoe

55. Kawagoe discloses "a semiconductor integrated circuit device manufacturing method characterized in that said first semiconductor region is a well to be used for forming a complementary MOS.FET (Metal-Oxide-Semiconductor. Field Effect-Transistor) [(CMOS)] circuit (i.e., for forming a complementary MIS (Metal-Insulator-Semiconductor). FET circuit)." Ex. 1007, 3:32-38.

56. Kawagoe explains that, in its Embodiment 1, the "epitaxial layer 2E is doped … in a concentration equal to the [concentration] of the substrate body 2S." Ex. 1007, 6:65-7:3; *see also id*., 8:40-52. In its Embodiment 4, "the impurity concentration of the semiconductor substrate body 2S is made higher than that of the epitaxial layer 2E … to improve the resistance to the latchup." *Id*., 15:13-17; *see also id*., 15:26-40.

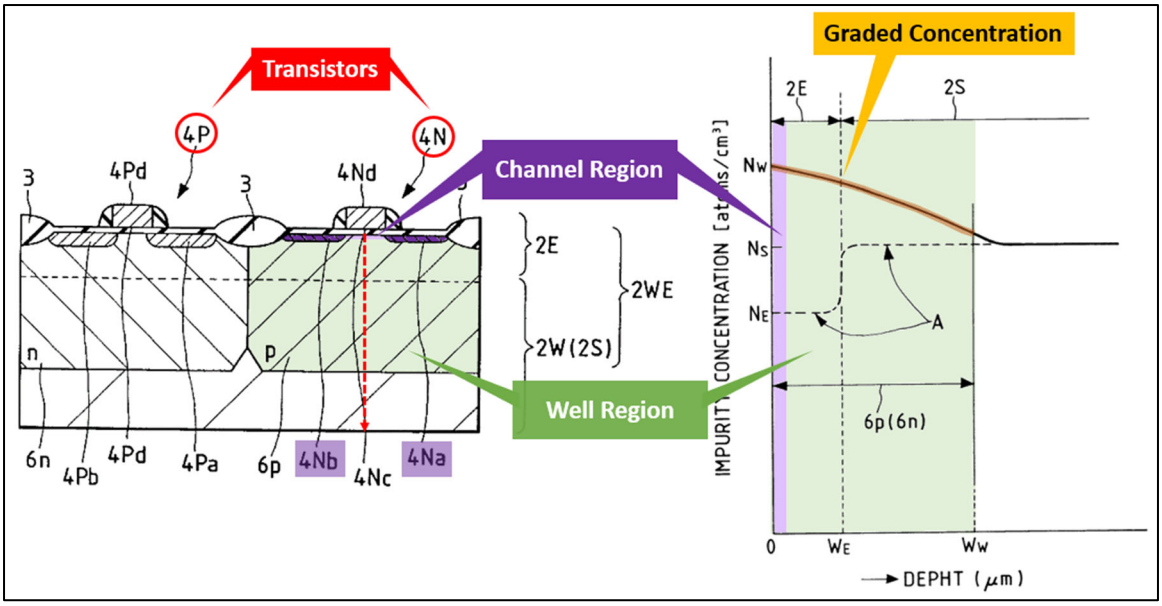
57. I am of the opinion that the figure below from Kawagoe illustrates a conventional twin-well CMOS structure. A conventional twin-well CMOS structure includes "two separate wells [] formed for *n*- and *p*-channel transistors." Ex. 1008B, 387; *see also, e.g.*, Ex. 1008A, 227, FIG. 7-3 (showing a "[c]ross-section of a twin-well CMOS structure built in a p^- epitaxial layer and a p^+ substrate"); Ex. 1008B, 382, FIG. 6-8(c) (illustrating a "CMOS circuit[] [] designed using … twin-well technology"). The figure below from Kawagoe shows source-drain regions (purple)

of an NMOS transistor formed in a p-well (light green) and the source-drain regions (green) of a PMOS transistor formed in an n-well (light purple). Ex. 1007, 8:46-9:6, 9:32-54, 14:46-55, 15:26-40, 18:18-23.



Ex. 1007, FIG. 23.

58. Kawagoe further teaches that "the p-well 6p and n-well 6n have their impurity concentrations gradually lowered in the depthwise direction from the principal surface (having an impurity concentration N_W) of the epitaxial layer 2E." Ex. 1007, 15:62-16:2; *see also id.*, 14:46-55, 16:2-40. In other words, Kawagoe teaches that the well regions have a graded dopant concentration that decreases with depth, as illustrated in the doping profile in Figure 17 below in the context of a p-well (light green).



Id., FIGS. 17 and 23.

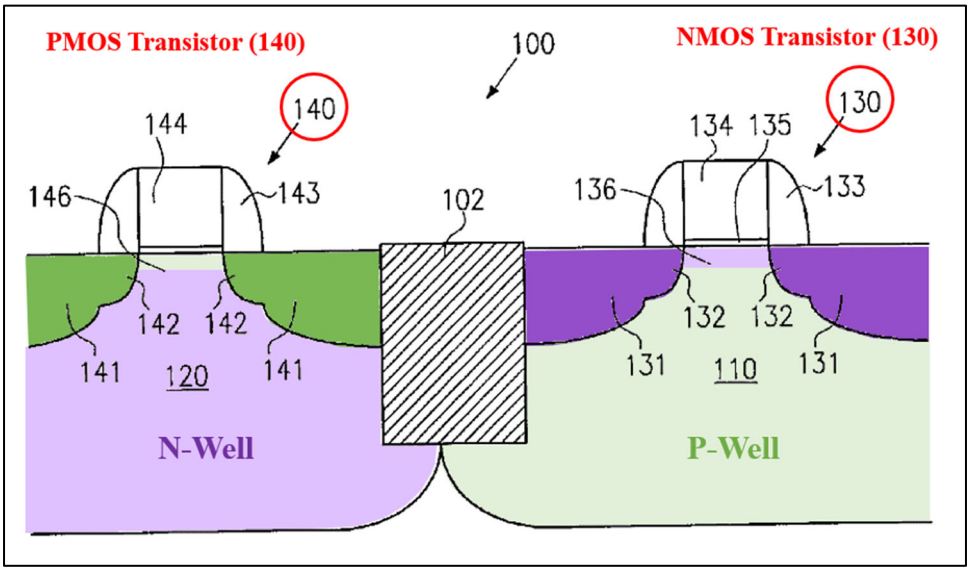
59. Kawagoe explains that "the impurity concentration of the p-well 6p is given such a gradient that it is ***gradually lowered*** in the depthwise direction from the surface of the epitaxial layer 2E, so that the influence to be caused by the carriers (or electrons) due to the α-ray is lowered." Ex. 1007, 16:2-7.[3] Kawagoe further explains that "the electrons produced by the α-ray are attracted to the substrate body 2S by that concentration gradient and prevented from entering the p-well 6p 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." *Id*., 16:7-11.

[3] All emphases added unless otherwise noted.

B. Wieczorek

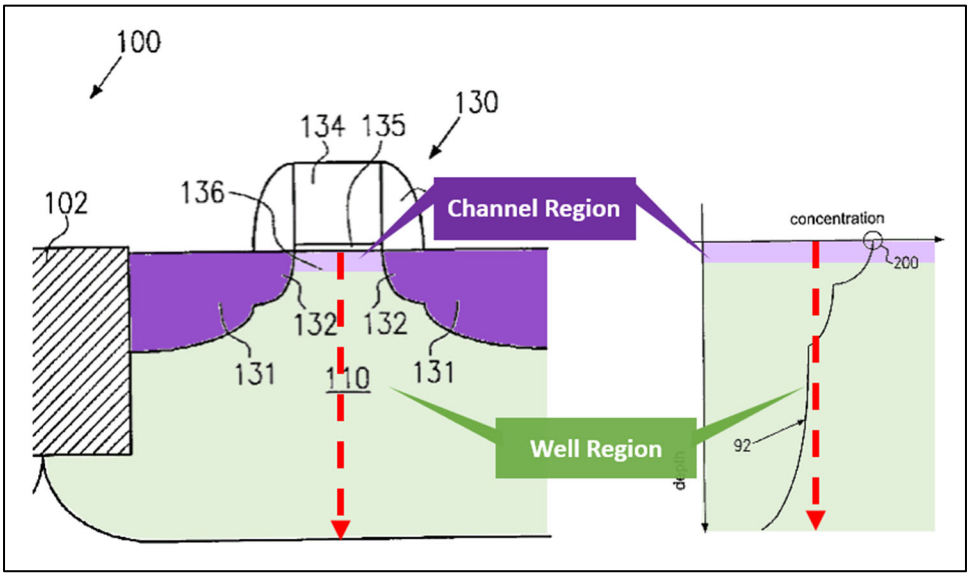
60. For purposes of this Petition, I rely on Wieczorek's description of conventional prior art CMOS devices, such as the twin-well CMOS device illustrated in Figure 1b below. Ex. 1006, [0007], [0012], [0020]-[0021]; *see also* Section IX.A (discussing conventional twin-well CMOS devices).

61. The semiconductor device 100 illustrated in the figure below from Wieczorek is "a complementary MOS transistor pair." Ex. 1006, [0007]. The figure below illustrates the source-drain and channel regions (purple/light purple) of an NMOS transistor formed in a p-well (light green) and the source-drain and channel regions (green/light green) of a PMOS transistor formed in an n-well (light purple). *Id*., [0007], [0012].



Ex. 1006, FIG. 1b.

62. Wieczorek explains that graded dopant concentrations in prior art CMOS devices peak at the surface of the substrate and decrease with depth, as shown below. Ex. 1006, [0004], [0007]-[0013]



Id., FIGS. 1b and 2b.

C. Wolf

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.

D. Gupta

64. Gupta "relates to the field of complimentary metal oxide semiconductor (CMOS) circuits, and more particularly to [] layouts for CMOS circuits." Ex. 1014. 1:7-10. Gupta reflects the common knowledge of a POSITA when it explains that "[c]onservation of semiconductor area is a primary goal in semiconductor chip development" and a common technique to conserve area is "by placing transistors so as to share diffusion area [(active region)]." *Id*., 1:32-54, 2:17-21.

X. SPECIFIC GROUNDS FOR PETITION

A. Ground I:

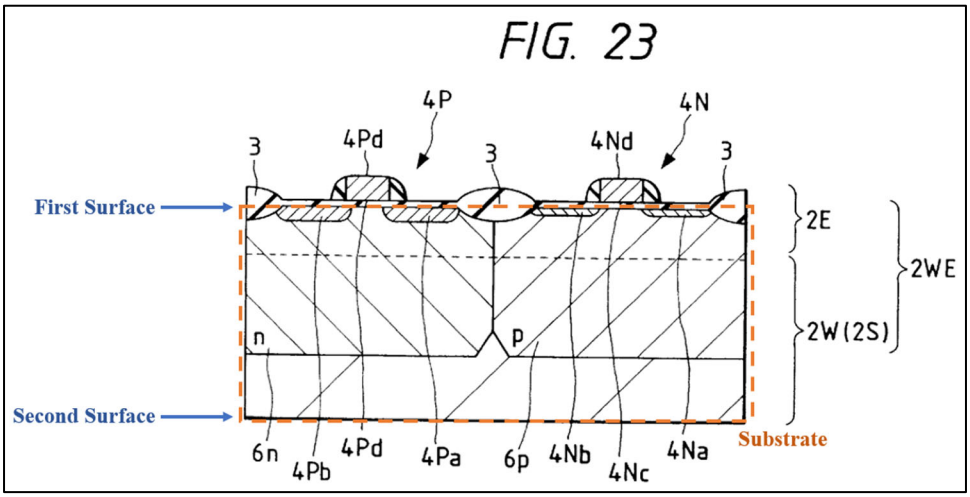
65. In my opinion, Kawagoe renders claims 1-9, 13-14, 16-18, 20, 22-27, and 31-35 obvious.

1. Independent Claim 1

a. Preamble: "A semiconductor device, comprising"

66. To the extent the preamble is limiting, in my opinion, Kawagoe discloses it. Kawagoe discloses a "semiconductor integrated circuit device" and process for making the same. *See* Ex. 1007, Title, 1:13-23, 14:46-67, FIGS. 16-17, 23. For Ground I, I primarily focus on the twin-well CMOS device in Figure 23

(Embodiment 4) of Kawagoe, fabricated on a uniformly-doped epitaxial substrate, as taught in Embodiment 1 of Kawagoe.[4] *See* Section X.A.1.b.



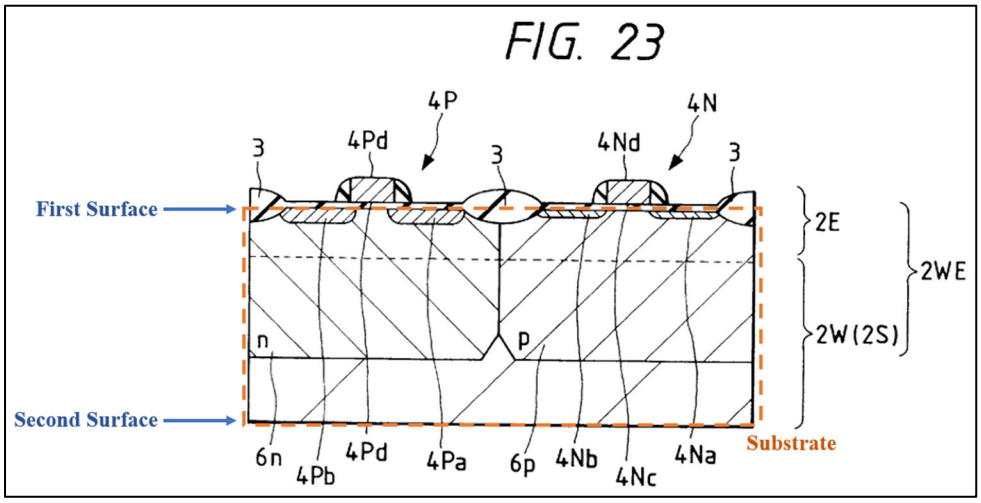
Ex. 1007, FIG. 23.

b. Element [1.1]: "a substrate of a first doping type at a first doping level having first and second surfaces;"

67. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. Kawagoe discloses a substrate ("semiconductor substrate 2") of a first doping type (p-type) having a silicon "epitaxial layer 2E [that] is 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-

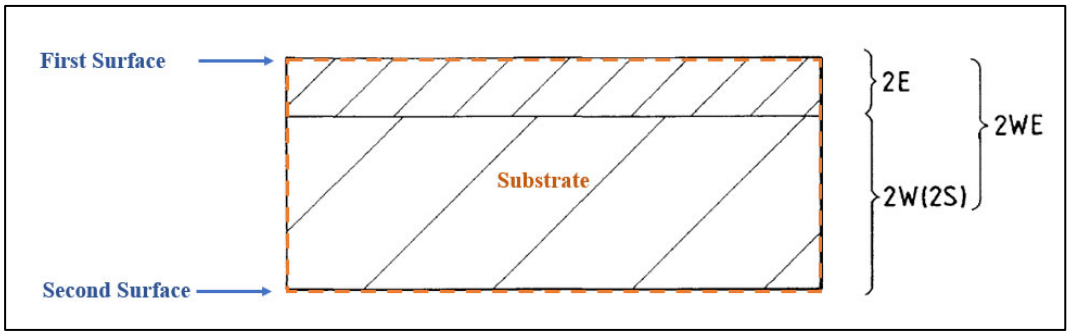
[4] Figures 16, 17 and 23 are all directed to the same Embodiment 4 of Kawagoe. *See* Ex. 1007, 14:46-60. Figure 23 shows the same twin-well CMOS structures depicted in Figure 16 without the metal layers that are, in my opinion, not relevant to the claims. *Id.,* 17:10-18:38.

15:12, 6:50-7:3. The substrate (orange) has a top surface ("first surface") and a bottom surface ("second surface"), as shown below.



Ex. 1007, FIG. 23.

68. In my opinion, Kawagoe satisfies element [1.1] under Patent Owner's position that the term "substrate" should be given its plain meaning and under Petitioner's proposed construction that a substrate is the initial material within which or on which Kawagoe's "semiconductor integrated circuit device 1" is later fabricated. *See* Section VIII; Ex. 1007, 6:51-56, 14:61-67, 17:10-18:38.



Ex. 1007, FIG. 20. Specifically, 2WE epitaxial wafers are produced by manufacturers and supplied as the starting point material for subsequent processing

by integrated circuit (IC) foundries. Alternatively, foundries may deposit their own epitaxial layer, but in either case, the result is the starting point for the circuit fabrication process.

69. As I explain in more detail below, Ground I relies on a uniformly-doped epitaxial substrate in which the silicon epitaxial layer 2E of the substrate is doped at the same level as the silicon substrate body 2S, so that the entire substrate in Figure 20 is "at a first doping level" as recited in the claims. Ex. 1007, 6:60-7:3.

70. **"at a first doping level"** - Kawagoe teaches an epitaxial substrate (2S+2E), illustrated in Figure 20, in which the non-epitaxial silicon substrate body (2S) is either doped at the same level or at a higher level compared to the epitaxial silicon layer (2E). For example, Embodiment 1 describes a uniformly-doped epitaxial substrate in which the "epitaxial layer 2E is doped … in a concentration ***equal*** to the [concentration] of the semiconductor substrate body 2S, e.g., 1.3×10^{15} atoms/cm^3." Ex. 1007, 6:60-7:3; *see also id.*, Abstract (describing "an epitaxial layer which contains an impurity of the ***same*** conduction type [and at] … the ***same concentration***" as the bulk substrate), 2:57-3:9 (same). I note that this uniformly-doped epitaxial substrate is Kawagoe's "benchmark" substrate that is repeatedly discussed in other embodiments, including in Embodiment 4. *Id.*, 12:64-65, 13:12-15, 13:66-67, 14:18-20, 15:7-25.

71. Embodiment 4 introduces an optional latchup-resistant substrate in which "the impurity concentration of the semiconductor substrate body 2S is made ***higher*** than that of the epitaxial layer 2E … ***to improve*** the resistance to latchup." Ex. 1007, 15:13-17.

72. In my opinion, a POSITA would have understood that Kawagoe teaches forming the twin-well CMOS device illustrated in Figure 23 (Embodiment 4) on either a uniformly-doped epitaxial substrate described in Embodiment 1 or the optional latchup-resistant substrate described in Embodiment 4. My opinion is supported by the fact that Kawagoe emphasizes the benefits of Embodiment 1's uniformly-doped epitaxial substrate and explains that the substrate used in Embodiment 4 is formed "***as in the foregoing embodiment 1*** so that … the cost of the semiconductor substrate 2 is lowered to about one half." Ex. 1007, 15:7-25.

73. In any event, in my opinion, a POSITA would have been motivated to use a uniformly-doped epitaxial substrate to form the twin-well CMOS device of Figure 23 because this substrate provides "excellent film quality" that "drastically reduce[s] the defect densities of the gate insulating films" and thus "improve[s] the performance, reliability and production yield" of the device. Ex. 1007, 12:8-40; *see also id*., 15:7-25. This substrate is also easier to manufacture, which helps "lower the cost" of the substrate and the chip. *Id*., 12:8-40.

74. In my opinion, a POSITA would understand that the use of a uniformly-doped epitaxial substrate as the starting material in lieu of Embodiment 4's latchup-resistant substrate to form the twin-well CMOS devices of Figure 23 is a simple substitution of one known element with another known, closely related element, both of which are described in Kawagoe, and would have been obvious to try because it involves nothing more than choosing one of two ways of doping an epitaxial substrate that are both described in Kawagoe.

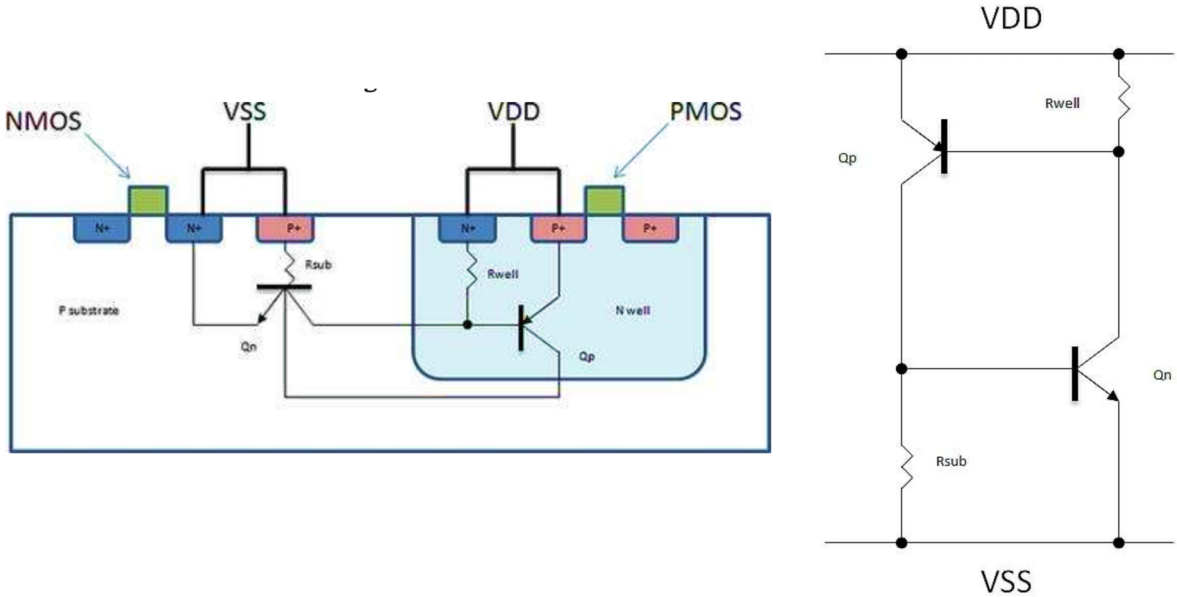
75. In my opinion, twin-well CMOS devices (illustrated in Figure 23) fabricated on a uniformly-doped epitaxial substrate would have worked for their intended purpose. As discussed in Wolf, twin-well CMOS devices were commonly formed over a "***uniformly***, lightly doped *p*- or *n*- type substrate" that provides no improved latchup resistance. Ex. 1008C, 523, *id*., 530 ("With the twin-tub [(twin-well)] approach, … two separate wells are formed for *n*- and *p*-channel transistors on a lightly doped substrate …"); Ex. 1008B, 387-389; Ex. 1007, 2:57-65 (discussing a uniform "lightly doped" epitaxial substrate).

76. In my opinion, there would be a reasonable expectation of success because Kawagoe describes in detail the use of both the uniformly-doped epitaxial substrate and the latchup-resistant substrate in forming CMOS devices, and repeatedly emphasizes their similarity. Ex. 1007, 8:40-52, 12:8-40, 14:58-60, 15:7-12 (substrate), 15:18-25 (epitaxial layer), 15:26-40 (transistors), 19:48-63

(describing latchup resistance as just another "effect" over Embodiment 1). A uniformly-doped ***epitaxial*** substrate is also better, in my opinion, than the bulk (non-epitaxial) substrate commonly used to fabricate twin-well CMOS devices. *Id.*, 1:33-40 ("The epitaxial wafer is advantageous [compared to bulk wafer/substrate] in that … the gate insulating film to be formed over the epitaxial layer can have excellent breakdown characteristics to drastically reduce the defect density of the gate insulating film."); *id.*, 12:8-40; Ex. 1008B, 387-88 (discussing twin-well CMOS devices fabricated over bulk substrate).

77. Kawagoe characterizes the improved latchup tolerance provided by Embodiment 4's optional latchup-tolerant substrate as just another "effect[] [that] can be achieved in addition to those of the foregoing embodiment 1." Ex. 1007, 19:49-63. In my opinion, and consistent with Kawagoe's teachings, a POSITA would have understood that having a uniformly-doped epitaxial substrate is a perfectly suitable choice of substrate because, among other benefits, it "drastically reduce[s] the defect densities of the gate insulating films" of CMOS transistors. Ex. 1007, 12:8-40. Moreover, in my opinion, a POSITA would have understood that improved latchup resistance is not needed for CMOS chips that are not susceptible to latchup or for which latchup (a "short-circuit" failure condition in poorly designed circuits) is not a concern. Ex. 1008B, 406 ("four conditions must exist in a CMOS circuit in order for latchup to occur."); Ex. 1026, 1 ("several conditions must be met"

to cause latchup). For example, in my opinion, a POSITA would have understood that latchup is dependent upon parasitic bipolar devices associated with the NMOS and PMOS structures of typical CMOS. The latchup phenomenon was first described in 1973 in a paper by Gregory and Shafer (Ex. 1026) and has been analyzed in more detail in numerous publications and books since that time. The simplified figure below is commonly used to illustrate the basic issue. The circuit on the right is a redrawing of the circuit super imposed on the device structure shown on the the left.



If there is enough current (and associated voltage drop) through Rsub and/or Rwell, and the current gain through the parasitic bipolar transistors is greater than 1, the cross coupled parasitic bipolar devices create a self-sustaining current that will flow through the circuit between VDD and VSS. That condition is known as latchup. This condition is avoided if the current gain of the parasitic bipolar devices is reduced, typically by increasing spacing as was well-known in the art and described in Wolf.

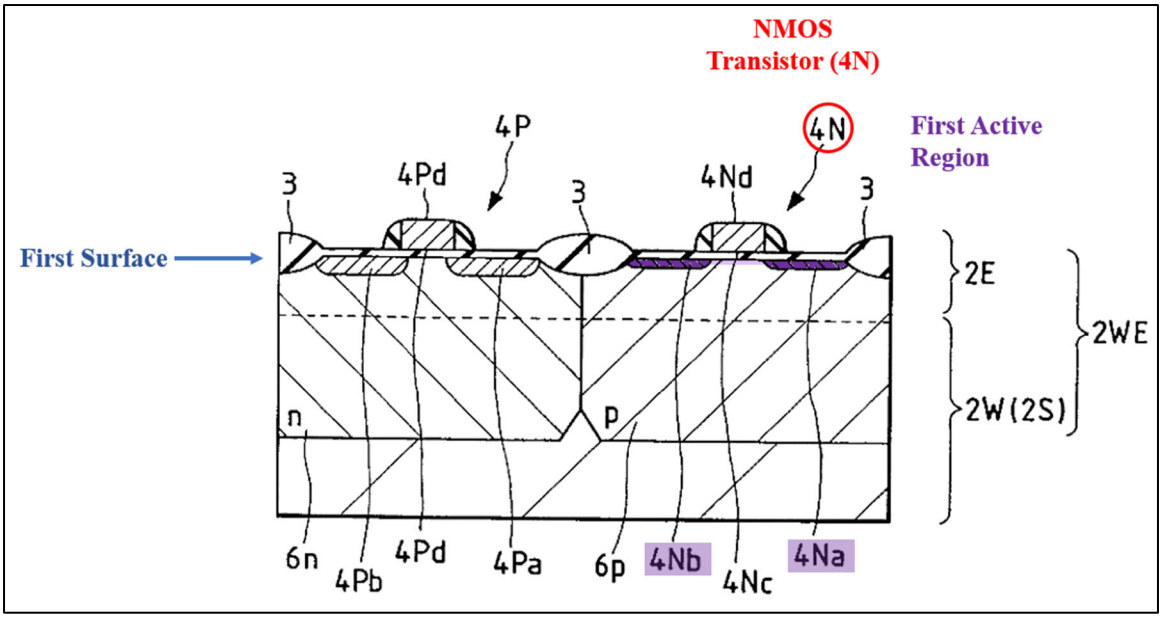
Ex. 1008B, 381 ("Latchup tolerance can [] be improved by spacing *n*- and *p*-channel transistors farther apart"). The Rsub and Rwell resistors can be reduced by increasing dopant densities or using retrograde wells. Currents which lead to latchup can also be removed from the structure via additional well and substrate contacts and/or the addition of guard rings. Ex. 1008B, 419 ("Increasing the number of well contacts to V_{DD} reduces latchup susceptibility" and thus "can serve as an alternative approach to improving latchup immunity.") If these steps are taken, as was well-known in the art and described in Wolf, a chip can be fabricated on an epitaxial substrate that is uniformly doped, whereby the bulk substrate 2S and epitaxial layer 2E are doped at the same level, as described in Kawagoe's Embodiment 1, without being susceptible to latchup.

78. My opinion is also grounded in the well-known fact that twin-well CMOS devices were commonly fabricated on uniformly-doped bulk substrates that provide no improved latchup resistance. Ex. 1008B, 387-388 ("With the [twin-well] approach, … [t]he substrate may be [] a lightly doped wafer …"). And as I described above, even if latchup were to remain a concern, a POSITA would have understood, in my opinion, that improved latchup resistance can be achieved by other means unrelated to the choice of substrate, such as through careful circuit layout. Ex. 1008B, 381 ("Latchup tolerance can [] be improved by spacing *n*- and *p*-channel transistors farther apart"), 419 ("Increasing the number of well contacts to V_{DD}

reduces latchup susceptibility" and thus "can serve as an alternative approach to improving latchup immunity.").

c. Element [1.2]: "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;"

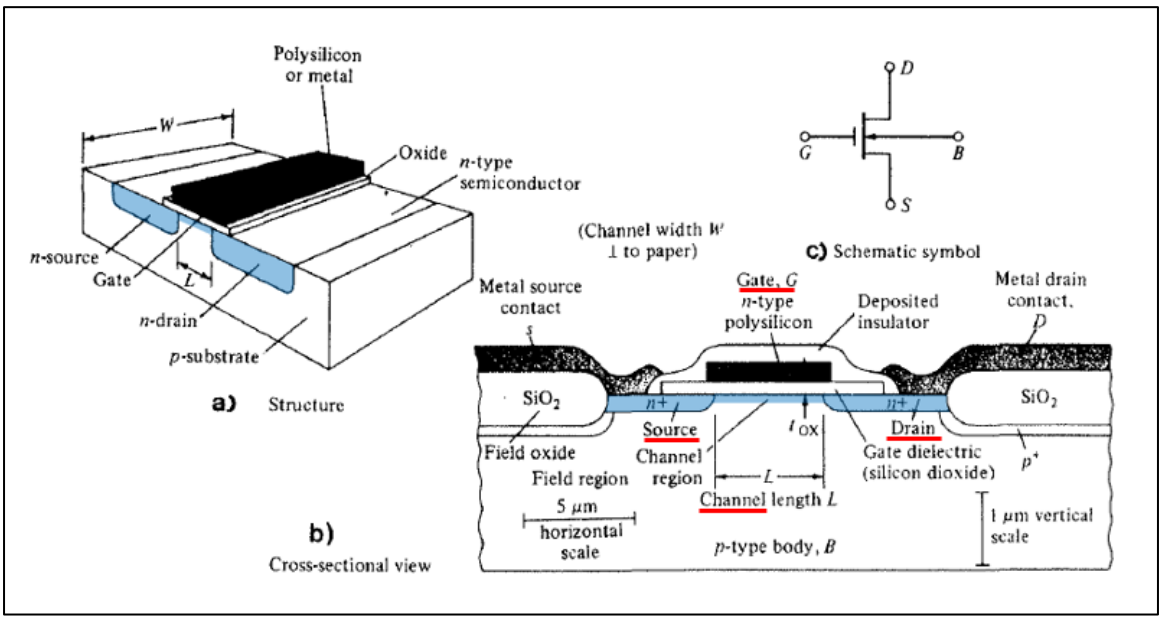
79. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. Kawagoe discloses "semiconductor regions 4Na and 4Nb … for forming the ***source-drain regions*** of the nMOS [n-channel transistor] 4N." Ex. 1007, 8:66-67; *see also, id*., 3:35-37, 8:46-52, 14:46-55, 15:26-40. The source-drain regions 4Na and 4Nb (purple) form part of the claimed first active region, which also includes the channel region (light purple) in between the source-drain regions 4Na and 4Nb and below the gate insulating film 4Nc. Ex. 1007, 8:46-65, 14:46-55, 15:26-40; Ex. 1008B, 299-300 ("The top surface of the [substrate] body consists of active or transistor regions as well as passive or (field) regions. The active regions are those in which transistor action occurs; i.e., the ***channel*** and the heavily doped ***source*** and ***drain*** regions."), FIG. 5-2, 382, FIG. 6-8(c), 387, FIG. 6-10; Ex. 1008C, 525, FIG. 8-1(e). As shown in Figure 23 below, nMOS transistor 4N is formed in the first active region, which is adjacent the first surface of the substrate.



Ex. 1007, FIG. 23. "The semiconductor regions 4Na and 4Nb are doped with an ***n-type impurity***" and thus, in my opinion, have a second doping type (n-type) opposite in conductivity to the first doping type (p-type) of the substrate. *Id.*, 8:67-9:3, 14:46-55, 15:26-40.

80. While Figure 23 above illustrates an exemplary nMOS (n-channel) transistor 4N formed in the first active region, in my opinion, a POSITA would have understood that Kawagoe teaches forming multiple nMOS transistors in the first active region to minimize chip area, as good layout practice dictates and as described in many references such as Gupta and Maziasz. Ex. 1014, 1:52-54, 2:17-21. In any event, I understand that according to Patent Owner's representations in the District Court Case, an "active region … within which transistors can be formed" means "an active region … where ***a transistor*** can be formed." Ex. 1020, 31.

81. In my opinion, Kawagoe satisfies element [1.2] under Patent Owner's position that the term "active region" means "a doped silicon region at the surface of a semiconductor device (*e.g.*, the source and drain and silicon between them) where a transistor can be formed." Ex. 1020, 20; *see also* Section VIII. This is consistent with my understanding, and Wolf's teaching, that an active region of a MOS transistor is "[its] channel and [its] heavily doped source and drain regions," highlighted in blue in the figure below. Ex. 1008B, 299.



Ex. 1008B, 299, FIG. 5-1; *see also id.*, 298-301, FIGS. 5-2, 6-4.

82. It is also my opinion that Kawagoe satisfies this claim element under Petitioner's proposed construction that an active region is the "region that forms the current path of a device" or "the source, drain and channel region of a device" because current flows through the channel region that connects the source and drain regions of a transistor when the transistor is active (when an appropriate voltage is

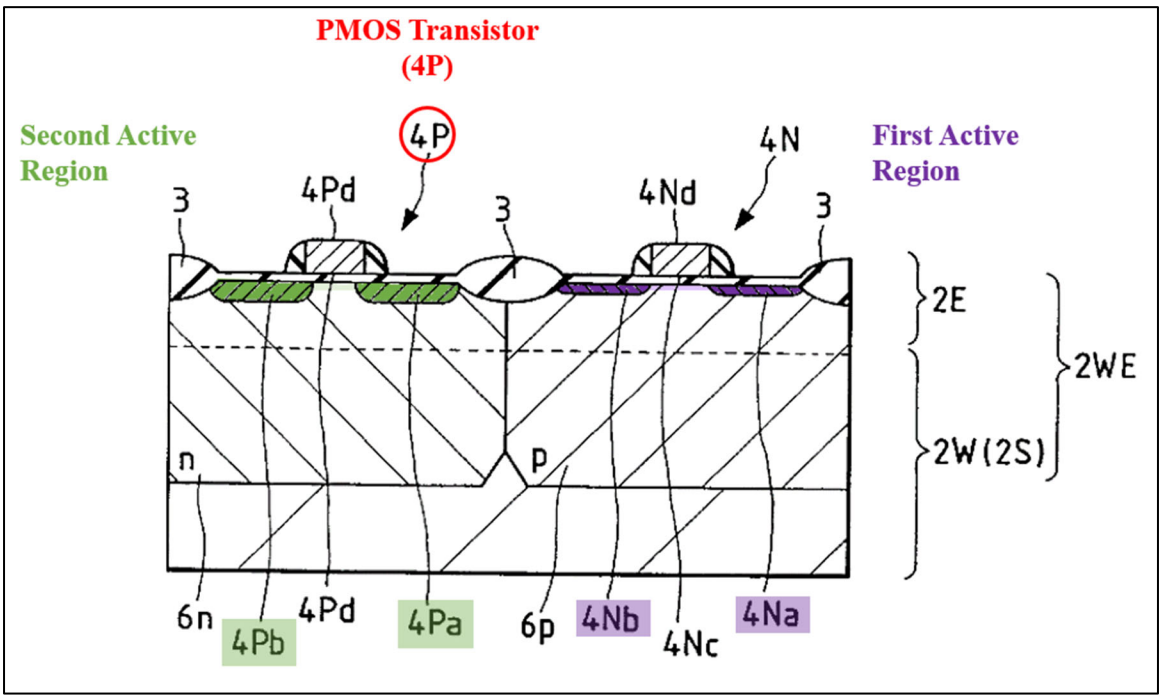
applied to its gate). *See* Section VIII; Ex. 1008B, 299-301, FIGS. 5-1, 5-2. This is because current flows through the source and drain regions as well as the channel region that connects the source and drain regions of a transistor when the transistor is active (when an appropriate voltage is applied to its gate). Ex. 1008B, 299-301; Ex. 1008D, 197, FIG. 5-13. It is also common usage in the art to refer to the active region as the region defined by the thin oxide mask, which also includes the channel and the source-drain regions. In my opinion, Patent Owner agrees with this, as, in the District Court Case, Patent Owner represented that "when a positive voltage is applied to the gate … a conductive ***channel*** [is formed] between the ***source*** and the ***drain***, and ***current*** can begin to flow through the transistor." Ex. 1020, 3-4.

d. Element [1.3]: "a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;"

83. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. Kawagoe discloses "semiconductor regions 4Pa and 4Pb … for forming the source-drain regions of the pMOS [p-channel transistor] 4P." Ex. 1007, 3:35-37, 8:46-52, 9:41-48, 15:26-40. The source-drain regions 4Pa/4Pb (green) are part of the claimed second active region, which also includes the channel region (light green) in between them and below the gate 4Pd. Ex. 1007, 8:46-57, 9:41-46, 14:46-55, 15:26-40; Ex. 1008B, 299-301, FIGS. 5-1, 5-2, 6-4; Section X.A.1.c. As shown in Figure 23 below, pMOS transistor 4P is formed in the second active region

(green/light green), which is separate from and disposed adjacent to the first active region (purple/light purple). Ex. 1007, 14:46-55.

84. In my opinion, a POSITA would understand that adjacent active regions are separated by an isolation region (such as insulating film 3). Ex. 1008A, 818-20, FIG. 16-11(f). In fact, claim 6, which depends from claim 1, claims that "the first active region and second active region are each separated by at least one isolation region." Ex. 1001, Cl. 6.



Ex. 1007, FIG. 23.

85. While Figure 23 illustrates an exemplary pMOS (p-channel) transistor 4P formed in the second active region, in my opinion, a POSITA would have understood that Kawagoe teaches forming multiple pMOS transistors in the second active region. Section X.A.1.c. In any event, I understand that according to Patent

Owner's representations in the District Court Case, an "active region … within which transistors can be formed" means "an active region … where ***a transistor*** can be formed." Ex. 1020, 31.

86. In my opinion, Kawagoe satisfies element [1.3] under Patent Owner's position that the term "active region" means "a doped silicon region at the surface of a semiconductor device (*e.g.*, the source and drain and silicon between them) where a transistor can be formed." Section X.A.1.c. In my opinion, Kawagoe also satisfies this claim element in my opinion under Petitioner's proposed construction that an active region is the "region that forms the current path of a device" or "the source, drain and channel region of a device." *Id*.

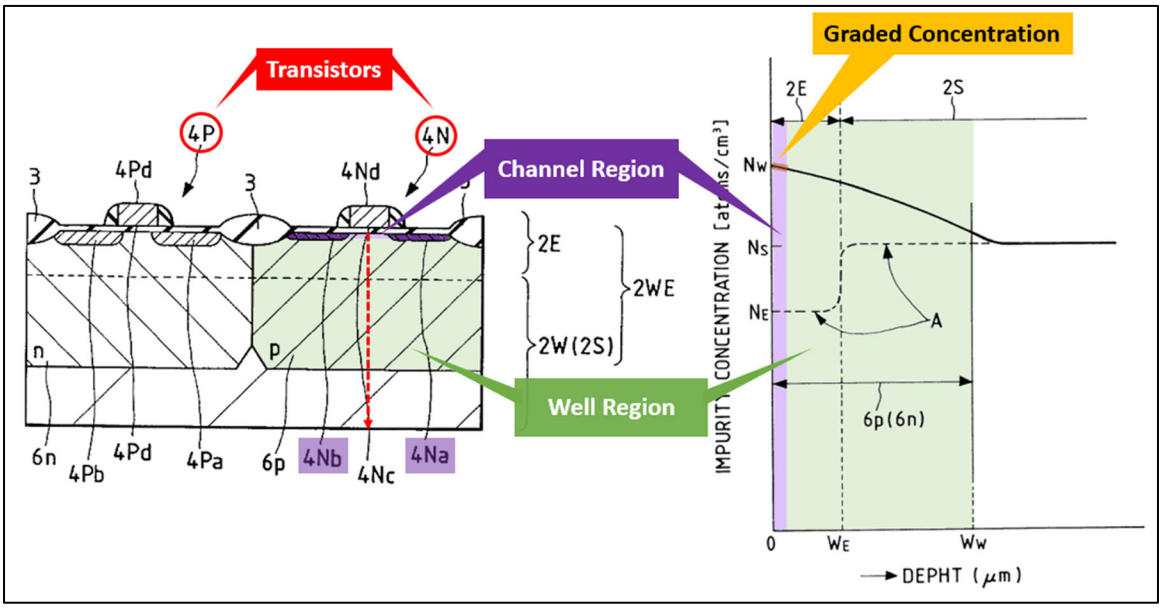
e. Element [1.4]: "transistors formed in at least one of the first active region or second active region;"

87. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. *See* Sections X.A.1.c-d.

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

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.

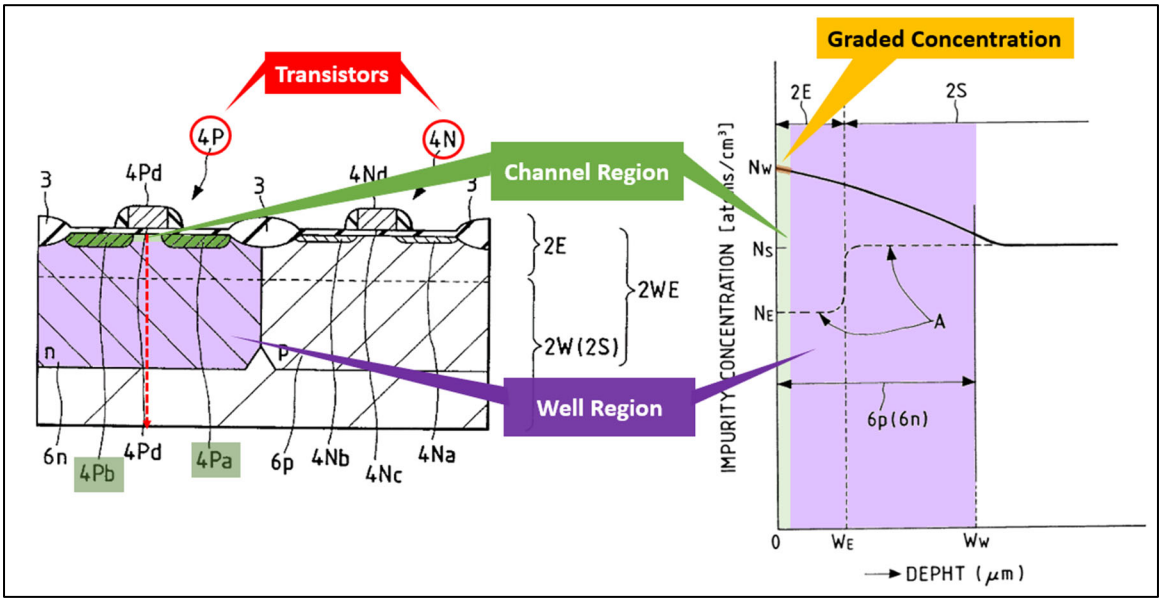


Ex. 1007, FIGS. 17, 23.

89. Kawagoe's Figure 17 (above right) illustrates the doping concentration measured for example along the red dotted line in Figure 23 (above left), which starts from the top surface of the substrate (at depth 0) and includes the doping profile in the channel region (light purple). Ex. 1007, 5:41-45 ("Figure 17 is an impurity

distribution diagram in the semiconductor integrated circuit device of FIG. 16 and has an abscissa indicating the depth from the surface of an epitaxial layer 2E and an ordinate indicating an impurity concentration"). 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." Ex. 1007, 15:62-16:40. 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 the epitaxial layer 2E.

90. In my opinion, the same applies to the channel region of pMOS transistor 4P (a portion of the second active region), as illustrated below. Ex. 1007, 15:62-16:2 ("p-well 6p and n-well 6n have their impurity concentrations gradually lowered in the depthwise direction from the principal surface [] of the epitaxial layer 2E."), 9:41-48, 14:46-55, 15:32, 15:37-40; Ex. 1008B, 298-301, FIGS. 5-2, 6-4.



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

91. 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 6*p*.

Ex. 1007, 16:2-11.[5]

92. During a so-called single event upset (SEU), an α-ray generates millions of carriers, some of which are produced in or near the active region at the top surface of the substrate, as illustrated in the figure below. Ex. 1009, 431 ("A[n]

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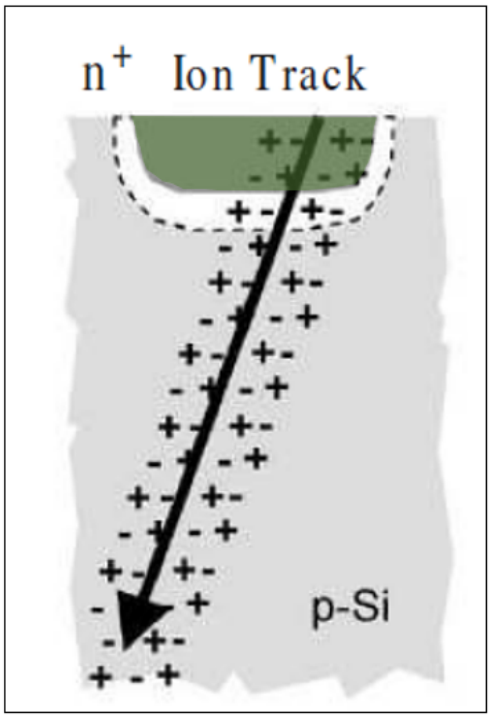
[5] Kawagoe also states that "electrons produced by the α-ray [are] … prevented from entering the p-well 6p …" Ex. 1007, 16:7-9. This refers to electrons created by an α-ray in the substrate body below the wells, which is by far the largest volumetric region of any chip. *See* Ex. 1009, FIG. 2.

[α-]particle can induce SEU when it strikes at the channel region of an off nMOS transistor or the drain region [(green)] of an off pMOS transistor.")



Id., FIG. 2. Kawagoe teaches that those carriers are "attracted to the substrate body by [the] concentration gradient" of the graded dopant concentration illustrated in Figure 17. Ex. 1007, 16:2-11.

93. In light of the above, it is my opinion that Kawagoe satisfies element [1.5] under Patent Owner's position that the term "to aid carrier movement from the first surface to the second surface of the substrate" should be accorded plain meaning. *See* Section VIII. I understand that, according to Patent Owner's representations in the District Court Case, the claims recite that "carriers [must move] in a particular direction (from the surface layer to the substrate)." Ex. 1020,

29. Also, according to Patent Owner's statements in the District Court case, "when the dopant concentration is graded in a particular direction, [certain] charge carriers will move in the [same] gradient direction …". *Id*., 2. 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 Patent Owner's representations in the District Court Case and Patent Owner's representation to the Patent Office, discussed below in Section X.A.1.g, this graded dopant concentration causes carriers to move deeper into the substrate.

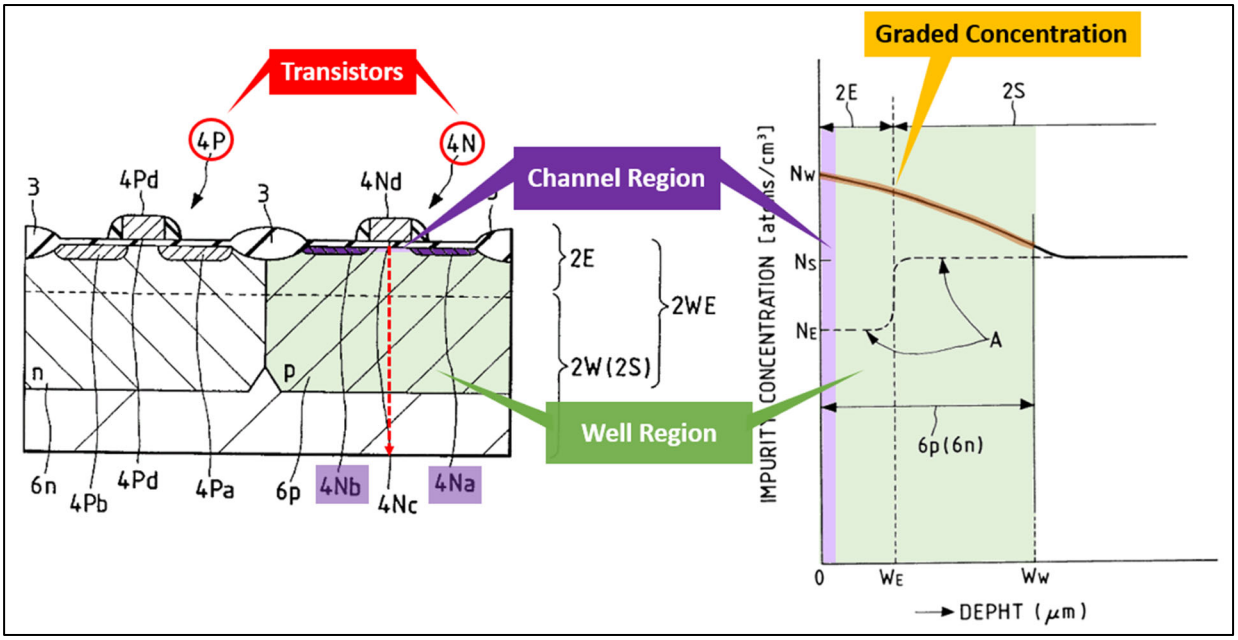
94. It is also my opinion that Kawagoe satisfies this claim element under Petitioner's alternative proposed construction that the term means "to sweep the carriers from the first surface to the second surface of the substrate." *See* Section VIII. Kawagoe's Figure 17 illustrates a downward-sloping graded dopant concentration and Applicant represented to Patent Office during prosecution of the parent '195 Patent that a downward-sloping graded dopant concentration was known in the prior art to create an "inherent 'built-in' unidirectional electric field" that sweeps carriers down into the substrate, as detailed below in Section X.A.1.g. Ex. 1016, 289-290.

g. Element [1.6]: "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."

95. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. As shown in Figure 23 (below left), Kawagoe discloses "a p-well 6p" (light green) adjacent to the first active region (purple/light purple). Ex. 1007, 8:66-67, 14:46-55, 15:26-40.

96. In addition, as discussed above and as shown in the dopant concentration profile (brown) of Figure 17 (below right), the dopant concentration in the p-well 6p—measured along the exemplary red dotted line in Figure 23 is gradually decreasing with depth. Section X.A.1.f; Ex. 1007, 14:46-55, 15:62-16:40 ("the p-well 6p and n-well 6n have their impurity concentrations ***gradually lowered*** in the depthwise direction from the principal surface (having an impurity concentration N_W) of the epitaxial layer 2E."), 16:11-15 ("The impurity concentration N_W in the principal surface of the epitaxial layer 2E of the p-well 6p and the n-well 6n is at about $6x10^{16}$ atoms/cm^3"). Thus, in my opinion, Kawagoe discloses a well region containing at least one graded dopant region (*e.g.,* the region highlighted in light green in both Figures 23 and 17) having a downward-sloping graded dopant concentration.



Ex. 1007, FIGS. 17 and 23.

97. Kawagoe further explains that this downward-sloping graded dopant concentration aids carrier movement 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.

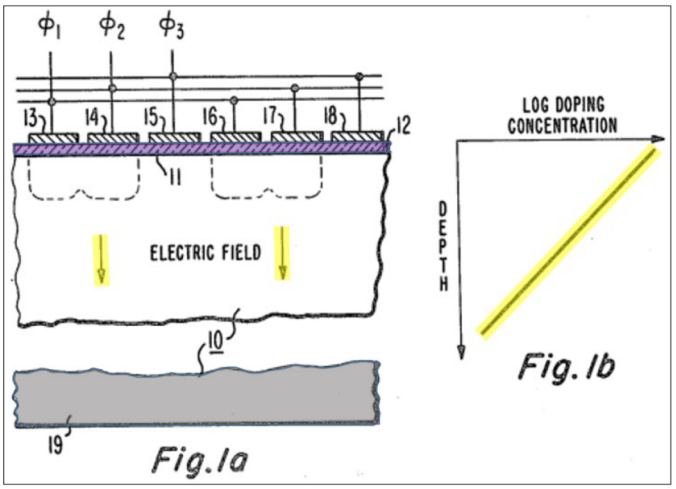
98. In my opinion, Kawagoe's teaching is consistent with Applicant's representation to the Patent Office during prosecution of the parent '195 Patent that

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

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

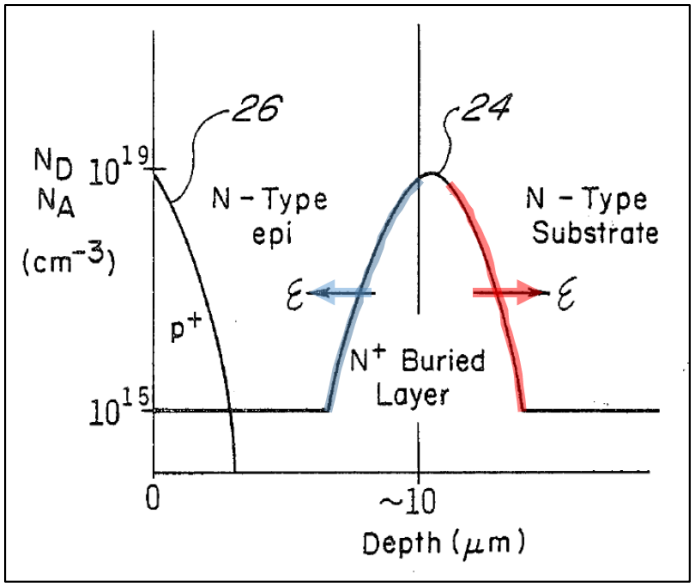
Ex. 1016, 289-290 (underlining in original). Applicant also represented that "a unidirectional drift (electric) field necessarily affects ***all*** the present minority carriers in the same way…. Depending on the particular slope of the graded concentration of dopant, ***all*** minority carriers are either ***swept*** 'down' … or 'up.'" *Id*., 289.

99. Applicant cited Jastrzebski in support. *See* Ex. 1016, 290. In Jastrzebski, the doping concentration is "decreasing with depth" from the top surface 11 (purple) of the substrate 10, as shown in Figure 1b below. Ex. 1010, 5:14-22. According to Jastrzebski, this downward-sloping graded dopant concentration creates an electric drift field that "force[s] most of the charge carriers … ***deep into the substrate*** [.]" *Id.*, 2:27-32, 5:14-22.



Id., FIGS. 1a-1b.

100. Applicant made the same representation to the Patent Office regarding Kamins. Ex. 1016, 237-238. According to Applicant, Kamins' Figure 3 shows "two electric fields with opposing directions" (highlighted in blue and red) that correspond to increasing and decreasing graded dopant concentrations, respectively. *Id.*, 237 (citing Ex. 1031, 3:6-13). Applicant explained that the electric field associated with the downward-sloping graded concentration at a depth beyond ~10μm (red) causes "carriers created [in that region to be] ***accelerated into the substrate*** …" *Id.* (citing Ex. 1031, 3:6-13, FIGS. 2-3).

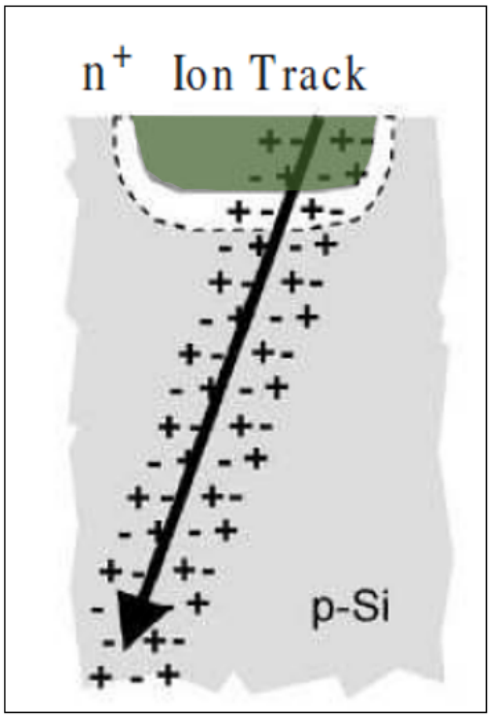


Ex. 1031, FIG. 3.

101. In my opinion, and in light of the above, Kawagoe satisfies element [1.6] under Patent Owner's construction that the term "well region" means "a doped region that surrounds the active region of a semiconductor device." Ex. 1020, 30; *see also* Section VIII. As shown in Figure 23 above, the p-well region (light green) is a doped region that surrounds the first active region (purple/light purple). Kawagoe also satisfies element [1.6], in my opinion, under Patent Owner's construction that "to aid carrier movement from the first surface to the second surface of the substrate" should be accorded plain meaning. Section VIII.

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

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.

2. Dependent Claim 2: "The semiconductor device of claim 1, wherein the substrate is a p-type substrate."

104. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 2. *See* Section X.A.1.b.

3. Dependent Claim 3: "The semiconductor device of claim 1, wherein the substrate has epitaxial silicon on top of a nonepitaxial substrate."

105. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 3. *See* Section X.A.1.b.

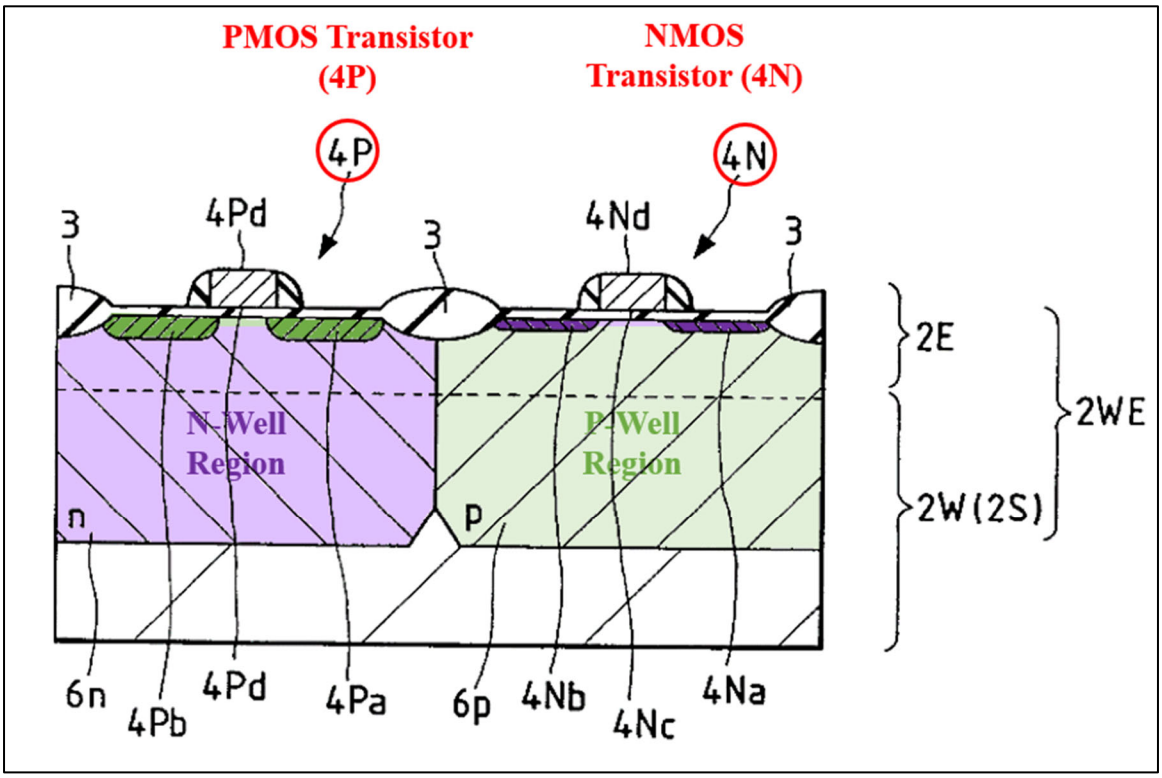
4. Dependent Claim 4: "The semiconductor device of claim 1, wherein the first active region and second active region contain one of either p-channel and n-channel devices."

106. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 4. *See* Sections X.A.1.c-e.

5. Dependent Claim 5: "The semiconductor device of claim 1, wherein the first active region and second active region contain either p-channel or n-channel devices in n-wells or p-wells respectively, and each well has at least one graded dopant."

107. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 5. Kawagoe's Figure 23 illustrates a conventional twin-well architecture, whereby the first active region contains nMOS (n-channel) transistor 4N) formed in "p-well 6p" and the second active region contains pMOS (p-channel) transistor 4P formed in "n-well 6n." Ex. 1007, 8:46-52, 14:46-55, 15:26-43; Sections X.A.1.c-d; Ex. 1008B, 387-88.

108. In my opinion, this mapping satisfies this claim under Patent Owner's interpretation that an active region in the claims can contain only "***a transistor***." Ex. 1020, 31. A POSITA would have also understood that Kawagoe teaches forming multiple transistors in an active region to save chip area, as good layout practice dictates. Ex. 1014, 1:52-54, 2:17-21.



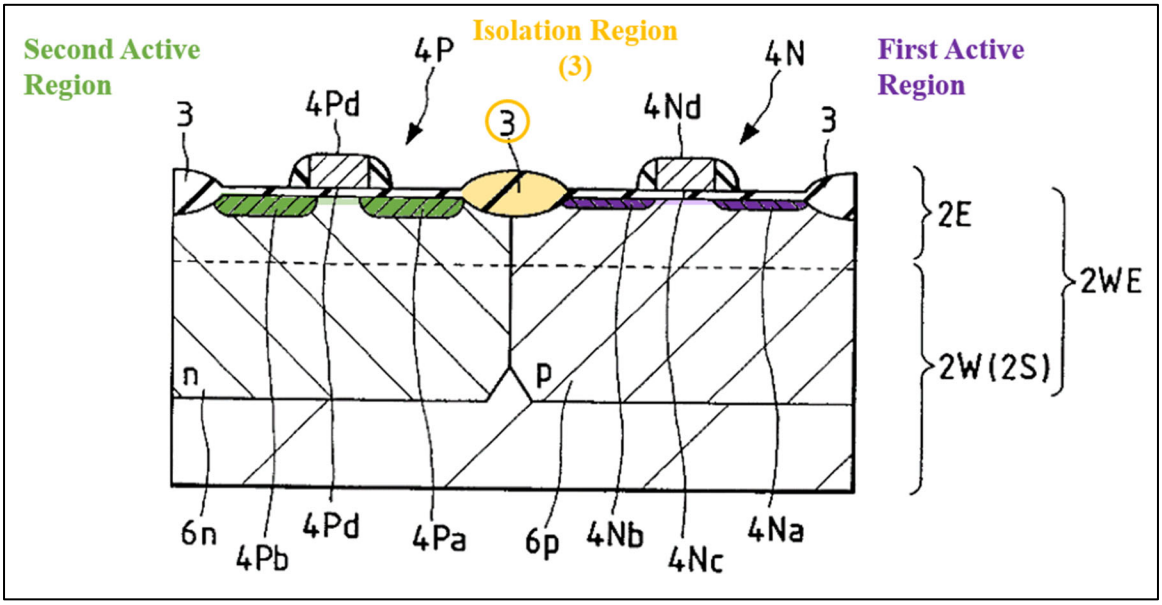
Ex. 1007, FIG. 23.

109. Further, in my opinion, Kawagoe's n-wells and p-wells have graded dopants. Ex. 1007, 14:46-55, 15:62-16:2 ("as shown in FIGS. 16 and 17, … the p-well 6p and n-well 6n have their impurity concentrations ***gradually lowered*** in the depthwise direction from the principal surface (having an impurity concentration

N_W) of the epitaxial layer 2E."); *see also* Section X.A.1.g (discussing the graded dopants in p-well 6p).

6. Dependent Claim 6: "The semiconductor device of claim 1, wherein the first active region and second active region are each separated by at least one isolation region."

110. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 6. As shown below, the first active region (purple/light purple) and second active region (green/light green) are separated by a "field insulating film 3" (claimed "isolation region") (yellow). Ex. 1007, 8:40-52, 15:37-40, 17:62-18:8; Ex. 1008A, 818-820, FIG. 16-11(f).



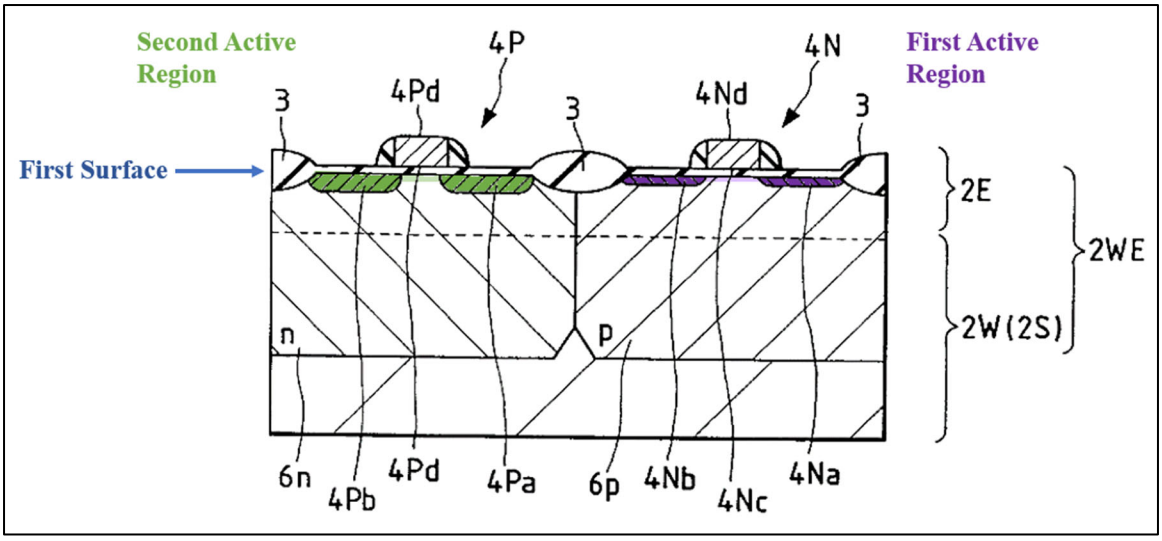
Ex. 1007, FIG. 23.

7. Dependent Claim 7: "The semiconductor device of claim 1, wherein the graded dopant is fabricated with an ion implantation process."

111. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 7. In my opinion, Kawagoe discloses that the graded dopants in n-well 6n and p-well 6p are "formed by the ion implantation method." Ex. 1007, 4:11-12, 15:26-36, 17:10-12, 17:31-39 (n-well 6n formed by implanting "ions of an n-type impurity such as phosphor"), 17:43-49 (p-well 6p formed by implanting ions of "a p-type impurity such as boron"); Sections X.A.1.f-g.

8. Dependent Claim 8: "The semiconductor device of claim 1, wherein the first and second active regions are formed adjacent the first surface of the substrate."

112. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 8. In my opinion, and as shown below, Kawagoe discloses that the first (purple/light purple) and second (green/light green) active regions are formed adjacent the first surface of the substrate (blue). Ex. 1007, 8:66-9:6, 9:47-54, 15:37-40, 17:10-12, 17:31-18:35; Ex. 1008B, 299 ("The top surface of the [substrate] body consists of active or transistor regions…."), 298, 300-301, FIG. 5-2; Sections X.A.1.c-d.



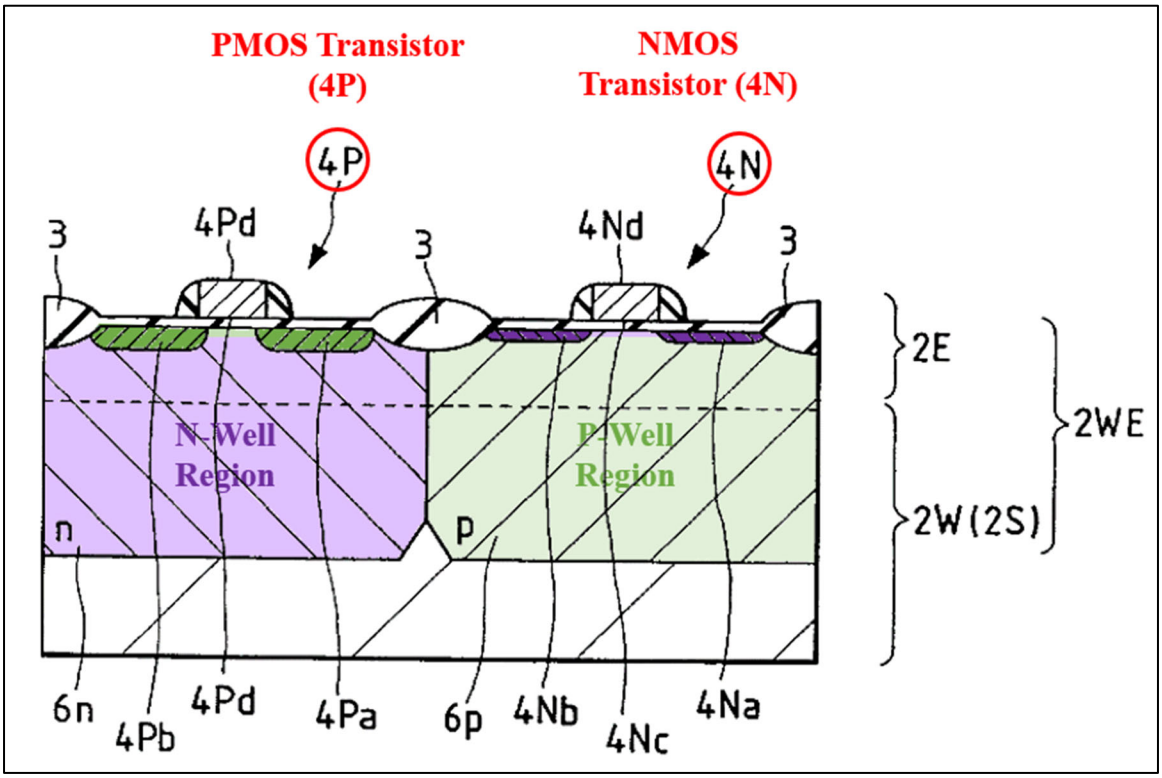
Ex. 1007, FIG. 23.

9. Dependent Claim 9: "The semiconductor device of claim 1, wherein dopants of the graded dopant concentration in the first active region or the second active region are either p-type or n-type."

113. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 9. In my opinion, as discussed above and shown in Figure 23 below, the channel region (light purple) of the first active region (between the source-drain regions 4Na and 4Nb and below the insulating film 4Nc) formed at the top of p-well 6p is of the same doping type (p-type) as p-well 6p. Ex. 1007, 15:26-36 ("The p-well 6p is doped with a p-type impurity such as boron."); *id.*, 17:10-12, 17:43-49.

114. Likewise, in my opinion, the channel region (light green) of the second active region (between the source-drain regions 4Pa and 4Pb and below the insulating film 4Pc) formed at the top of n-well 6n is of the same doping type (n-

type) as n-well 6n. Ex. 1007, 15:26-36 ("an n-well 6n is doped with an n-type impurity such as phosphor."), 17:10-12, 17:33-39.



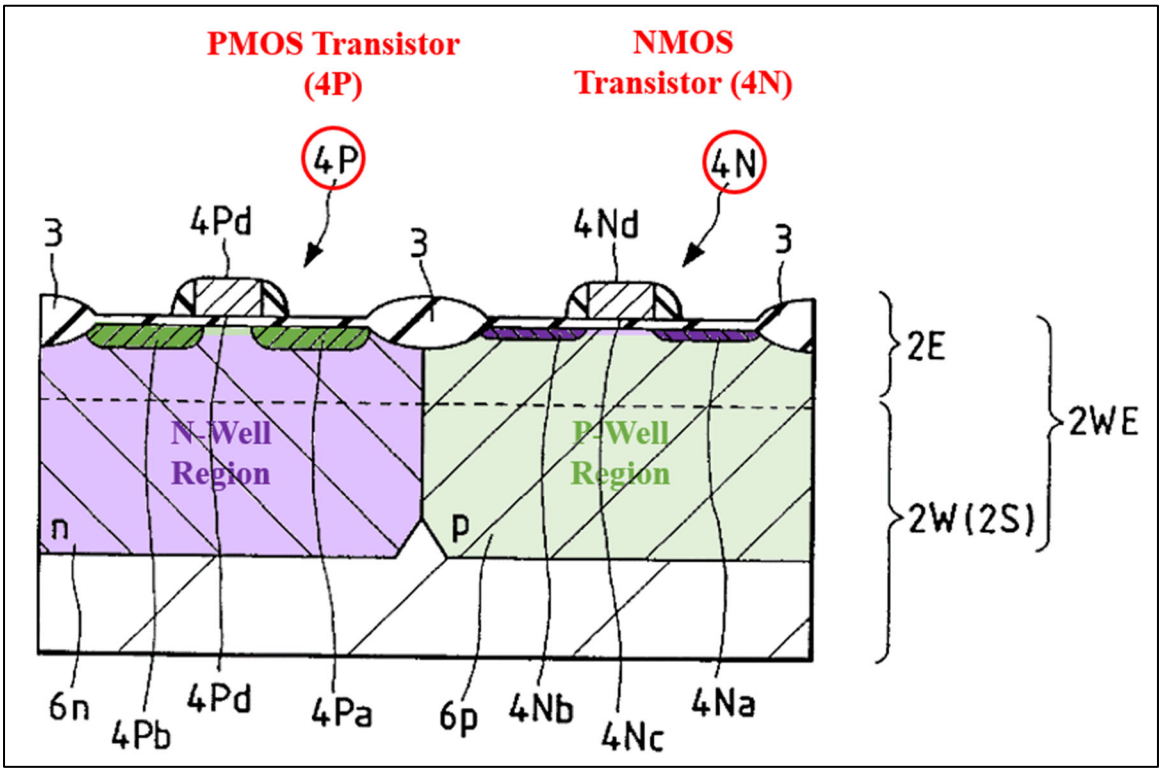
Ex. 1007, FIG. 23.

115. In my opinion, those channel regions all have graded dopant concentrations, as discussed above. Section X.A.1.f.

10. Dependent Claim 13: "The semiconductor device of claim 1, wherein the transistors which can be formed in the first and second active regions are CMOS transistors requiring at least a source, a drain, a gate and a channel."

116. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 13. In my opinion, as explained above and shown below, Kawagoe teaches an nMOS transistor 4N formed in the first active region

and a pMOS transistor 4P formed in the second active region, which are CMOS transistors. Ex. 1007, 8:45-52, 14:46-55, 15:37-40; Sections X.A.1.c-d, X.A.1.f.



Ex. 1007, FIG. 23.

117. Each of the CMOS transistors includes a source, drain, gate, and channel. For example, the nMOS transistor 4N includes "source-drain regions" 4Na and 4Nb spaced apart by an "n-channel" region, and a gate electrode 4Nd. Ex. 1007, 8:60-67, 8:42-48, 8:55-57, 14:46-55, 15:37-40, FIG. 23. Similarly, the pMOS transistor 4P includes "source-drain regions" 4Pa and 4Pb spaced apart by a "p-channel" region, and a gate electrode 4Pd. Ex. 1007, 8:42-67, 9:41-48, 14:46-55, 15:37-40, FIG. 23; Sections X.A.1.c-d, X.A.1.f

11. Dependent Claim 14: "The semiconductor device of claim 1, wherein the device is a dynamic random access memory (DRAM)."

118. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 14. In my opinion, Kawagoe explains that "embodiment 4" (Figures 16-17, 20-24), relied upon for claim 1, can be advantageously used to fabricate a DRAM device with reduced soft errors, reduced defect density, and "excellent gate breakdown performance." Ex. 1007, 16:2-11 (explaining that the graded dopant concentration in p-well 6p that is illustrated in Figure 17 moves "electrons produced by the α-ray" to the substrate body 2S so that "soft errors can be reduced in case … DRAM or the like is formed in the p-well 6p"), 19:15-23 ("the structure of the present embodiment 4 is applied to a 4M DRAM (i.e., 4 Megabit Dynamic RAM"), 19:43-48, 20:1-33 (DRAM formed in accordance with embodiment 5, which uses the same downward sloping graded dopant concentration described for embodiment 4).

12. Dependent Claim 16: "The semiconductor device of claim 1, wherein the device is a flash memory."

119. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 16. In my opinion, Kawagoe teaches a semiconductor flash memory device. Ex. 1007, 22:14-18 ("The semiconductor integrated circuit device 1 of the present embodiment 7, as shown in FIG. 28, is exemplified by a flash memory."). The flash memory device includes a CMOS

"peripheral circuit region [] formed with the nMOS 4N and the pMOS 4P…." *Id.*, 22:51-23:2. This peripheral circuit is fabricated according to twin-well CMOS technology, whereby NMOS transistors (*e.g.*, 4N) are formed in "p-well 6p3," and PMOS transistors (*e.g.*, 4P) are formed in "n-well 6n2." *Id.*, 22:51-65, FIG. 28.

120. Kawagoe explains that the teachings of Embodiment 4 (relied upon in the claim mapping for claim 1) are applicable to Embodiment 7 and therefore, in my opinion, to flash memory. In particular, Embodiment 7 applies the teachings of Embodiment 4 relating to the use of an epitaxial substrate to form a twin-well architecture with a pMOS transistor 4P formed in an n-well and nMOS transistor 4N formed in a p-well, where both wells have a downward-sloping graded dopant concentration. Ex. 1007, 22:22-29 ("In the present embodiment 7, too, the semiconductor substrate 2 is formed thereover with a p-well 6*p*3 and an n-well 6*n*2. The p-well 6*p*3 and n-well 6*n*2 are formed, ***as in the foregoing embodiments 4 and 6***, to extend from the surface of the epitaxial layer 2E to the upper portion of the semiconductor substrate body 2S. Moreover, their impurity concentrations are made gradually lower depthwise of the semiconductor region 2, ***as in the foregoing embodiment 4***."), FIG. 28.

13. Dependent Claim 17: "The semiconductor device of claim 1, wherein the device is a logic device."

121. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 17. In my opinion, Kawagoe teaches that its

disclosed "techniques of the foregoing embodiments 1 to 7 can … be applied to the semiconductor integrated circuit device which has a ***logic circuit*** such as the so-called 'microcomputer.'" Ex. 1007, 24:28-31.

14. Dependent Claim 18: "The semiconductor device of claim 17, wherein the device is central processing unit."

122. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 18. In my opinion, Kawagoe teaches that its disclosures can be applied to a "microcomputer." Section X.A.13. In my opinion, a POSITA would have understood that a microcomputer includes a central processing unit (CPU). Ex. 1032, 1334.

15. Independent Claim 20

a. Preamble: "A semiconductor device, comprising:"

123. To the extent the preamble is limiting, in my opinion, Kawagoe discloses it. *See* Section X.A.1.a.

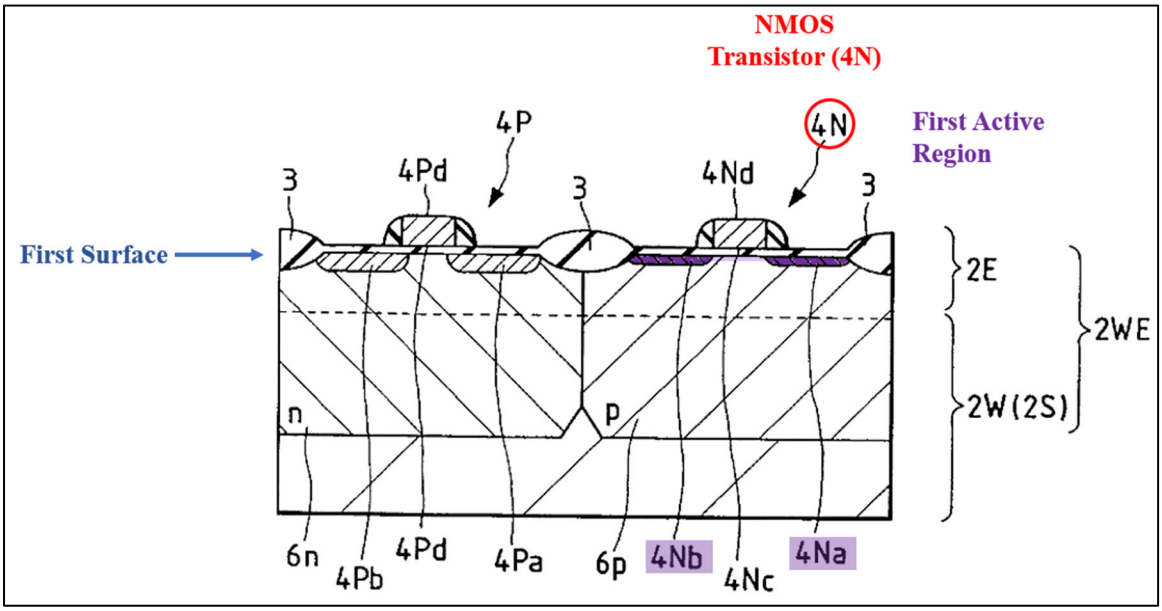
b. Element [20.1]: "a substrate of a first doping type at a first doping level having first and second surfaces;"

124. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. *See* Section X.A.1.b.

c. Element [20.2]: "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 in the surface thereof;"

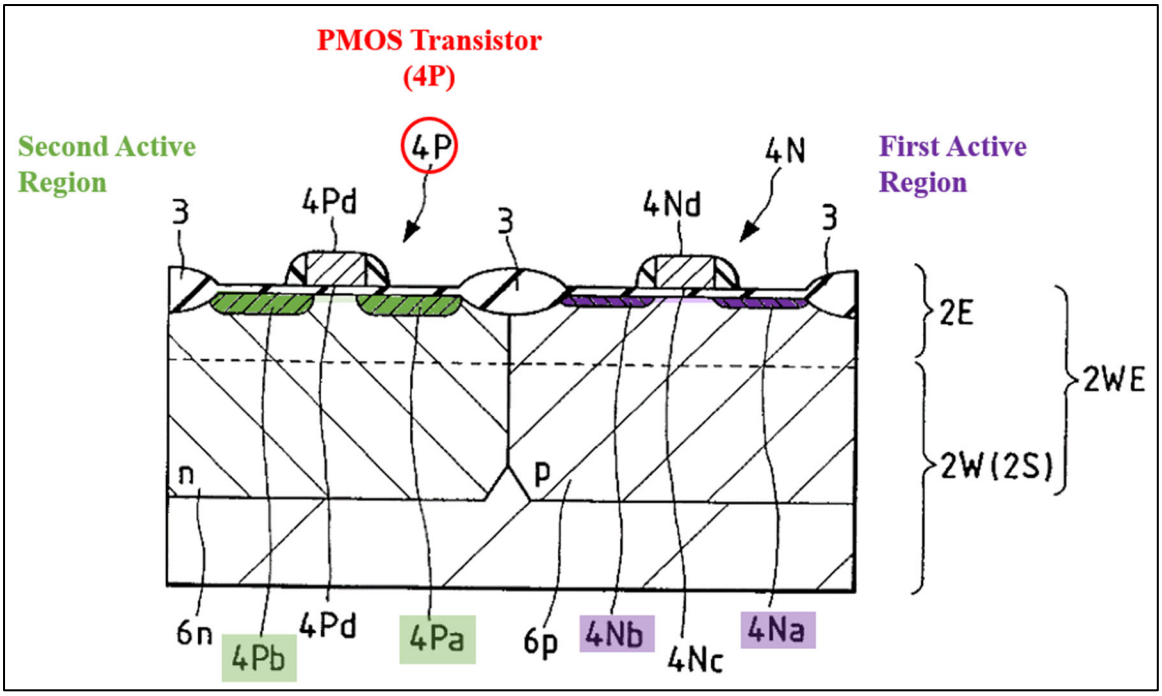
125. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. *See* Section X.A.1.c. Kawagoe discloses nMOS transistor 4N formed in the surface of the first active region, as shown below.



Ex. 1007, FIG. 23.

d. Element [20.3]: "a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed in the surface thereof;"

126. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. *See* Section X.A.1.d. Kawagoe discloses pMOS transistor 4P formed in the surface of the second active region, as shown below.



Ex. 1007, FIG. 23.

e. Element [20.4]: "transistors formed in at least one of the first active region or second active region;"

127. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. *See* Section X.A.1.e.

f. Element [20.5]: "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 surface to the substrate; and"

128. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. *See* Section X.A.1.f.

g. Element [20.6]: "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."

129. In my opinion, Kawagoe discloses or, at a minimum, renders obvious this element. *See* Section X.A.1.g.

16. Dependent Claim 22: "The semiconductor device of claim 20, wherein the substrate is a p-type substrate."

130. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 22. *See* Section X.A.2.

17. Dependent Claim 23: "The semiconductor device of claim 20, wherein the substrate has epitaxial silicon on top of a nonepitaxial substrate."

131. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 23. *See* Section X.A.3.

18. Dependent Claim 24: "The semiconductor device of claim 20, wherein the first active region and second active region contain at least one of either p-channel and n-channel devices."

132. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 24. *See* Section X.A.4.

19. Dependent Claim 25: "The semiconductor device of claim 20, wherein the first active region and second active region contain either p-channel or n-channel devices in n-wells or p-wells, respectively, and each well has at least one graded dopant."

133. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 25. *See* Section X.A.5.

20. Dependent Claim 26: "The semiconductor device of claim 20, wherein the first active region and second active region are each separated by at least one isolation region."

134. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 26. *See* Section X.A.6.

21. Dependent Claim 27: "The semiconductor device of claim 20, wherein dopants of the graded dopant concentration in the first active region or the second active region are either p-type or n-type."

135. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 27. *See* Section X.A.9.

22. Dependent Claim 31: "The semiconductor device of claim 20, wherein the graded dopant is fabricated with an ion implantation process."

136. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 31. *See* Section X.A.7.

23. Dependent Claim 32: "The semiconductor device of claim 20, wherein the substrate is a complementary metal oxide semiconductor (CMOS) device."

137. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 32. In my opinion, Kawagoe teaches that "nMOS 4N and pMOS 4P constitute a CMOS" device formed in and including a substrate. Ex. 1007, 8:46-52, 15:26-40, 8:60-9:6, 9:41-54, 14:46-55; *see also* Section X.A.15.b.

24. Dependent Claim 33: "The semiconductor device of claim 20, wherein the device is a flash memory."

138. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 33. *See* Section X.A.12.

25. Dependent Claim 34: "The semiconductor device of claim 20, wherein the device is a logic device."

139. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 34. *See* Section X.A.13.

26. Dependent Claim 35: "The semiconductor device of claim 34, wherein the device is central processing unit."

140. In my opinion, Kawagoe discloses or, at a minimum, renders obvious the additional limitation of claim 35. *See* Section X.A.14.

B. Ground II:

141. In my opinion, Wieczorek in combination with Wolf renders claims 1-2, 4-9, 13-18, 20-22, 24-27, and 31-35 obvious.

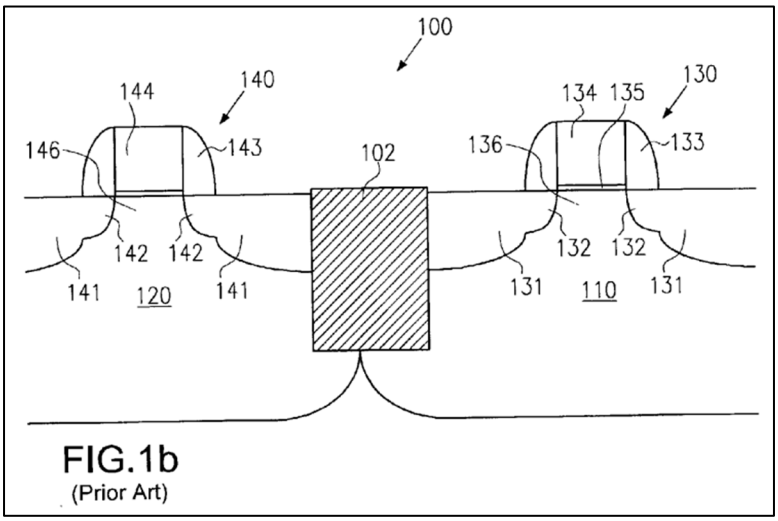
142. In my opinion, a POSITA would have been motivated to combine Wieczorek with Wolf. I rely herein on Wieczorek's description of a conventional prior-art CMOS device. *See, e.g.*, Ex. 1006, [0020]-[0021], [0004] ("Field effect transistors, such as MOS transistors, represent one of the most frequently used circuit elements in modem [*sic*] integrated circuits."), [0007]-[0008] (describing "[a] typical process flow for forming the semiconductor device 100" which is "a complementary MOS transistor pair"), [0012], FIG. 1b.

143. As discussed earlier, Wolf is a well-known textbook that teaches known fundamental features and concepts related to semiconductor manufacturing, with particular emphasis on CMOS devices. *See generally* Ex. 1008A; *id.*, Chapter 16 ("CMOS Process Integration"). In my opinion, a POSITA would have therefore understood and expected that the teachings of Wolf would apply to Wieczorek's conventional CMOS device. *Id.* A POSITA would have looked to Wolf for additional details related to conventional CMOS devices, as further detailed below.

1. Independent Claim 1

a. Preamble: "A semiconductor device, comprising"

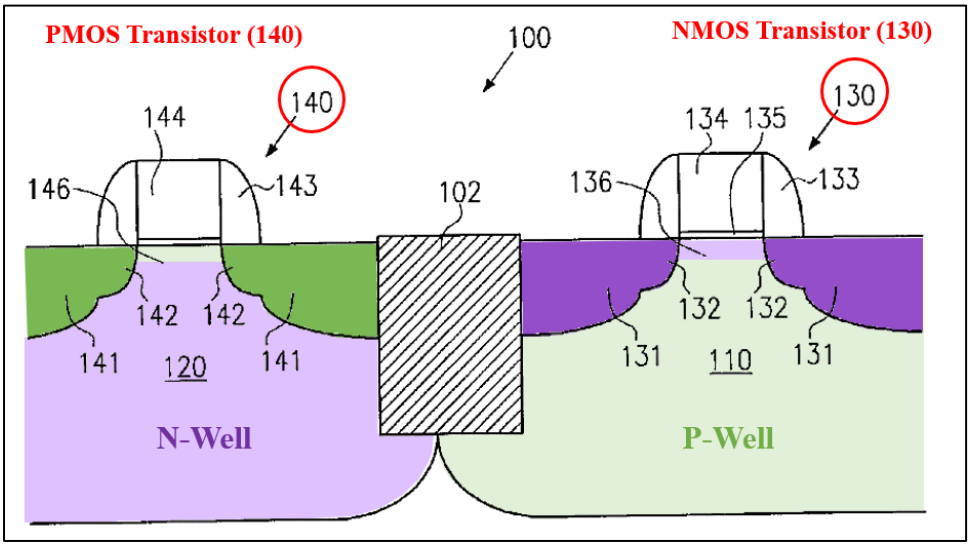
144. To the extent the preamble is limiting, in my opinion, Wieczorek discloses it. Wieczorek teaches a "semiconductor device 100" illustrated in the figure below. Ex. 1006, [0012].



Id., FIG. 1b.

b. Element [1.1]: "a substrate of a first doping type at a first doping level having first and second surfaces;"

145. In my opinion, Wieczorek, alone or in combination with Wolf (hereinafter "Wieczorek-Wolf"), renders this element obvious. Wieczorek's Figure 1b illustrates a conventional twin-well CMOS device, in which N-channel transistor 130 (nMOS) with source/drain regions 131-132 (purple) and channel region 136 (light purple) is formed in P-well 110 (light green) and P-channel transistor 140 (pMOS) with source/drain regions 141-142 (green) and channel region 146 (light green) is formed in N-well 120 (light purple). Ex. 1006, [0007], [0012], [0020]-[0021]; Ex. 1008C, 525, FIG. 8-1(e); *see also* Section IX.A (discussing conventional twin-well CMOS devices).

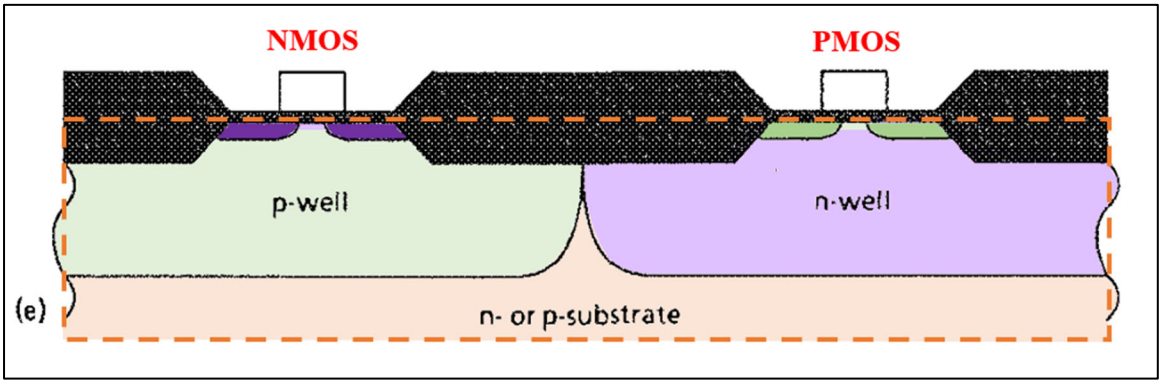


Ex. 1006, FIG. 1b (labelled as "Prior Art").

146. In my opinion, a POSITA would have understood that a twin well (or twin-tub) CMOS approach "is independent of starting material type" for the

substrate. Ex. 1008C, 524; Ex. 1006, [0004] (discussing the use of "an appropriate substrate" for forming MOS transistors without further specificity).

147. In my opinion, because Wieczorek does not specify what constitutes an appropriate substrate, a POSITA would have been motivated to consult the teachings of Wolf, which confirms that a "uniform, lightly doped *p*- or *n*-type substrate" is a suitable substrate commonly used in twin-well CMOS devices. Ex. 1008C, 523, 530 ("With the twin-tub [(twin-well)] approach, two separate wells are formed for *n*- and *p*-channel transistors on a lightly doped substrate … of *n* or *p* material."); Ex. 1008B, 387-389.



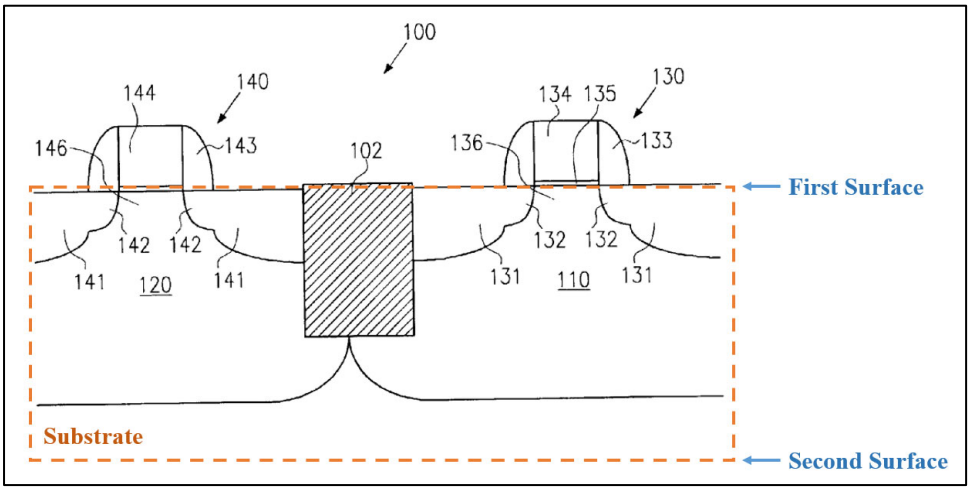
Ex. 1008C, 525, FIG. 8-1(e) ("twin-well CMOS on *n* or *p*-substrate").

148. In my opinion, and consistent with Wieczorek's teaching, a POSITA would have found it obvious to use a uniformly doped n- or p-type substrate ("a substrate of a first doping type at a first doping level") as a suitable substrate for the CMOS device in Wieczorek's Figure 1b. Doing so would amount to combining known prior art elements (*i.e.*, the use of a uniform, lightly doped n- or p-type

substrate with Wieczorek's process for forming a conventional CMOS device) according to known methods (*i.e.*, the known use of an "appropriate substrate" for the conventional process of forming the CMOS device in Wieczorek [0007]-[0013]) to obtain predictable results (*i.e.*, the conventional CMOS device in Wieczorek's Figure 1b). Doing so would have also been obvious to try because it involves nothing more than choosing one of a finite number of known appropriate substrates that are described by Wolf as suitable for use in forming a twin-well CMOS device like Wieczorek's. There would have been reasonable expectation of success because Wolf shows that a POSITA would have known how to use a uniformly doped n- or p-type substrate to form a twin-well CMOS device similarly as described in Wieczorek.

149. For purposes of claim mapping, and without loss of generality, I have considered Wieczorek-Wolf's substrate is taken as a p-type nonepitaxial substrate, a widely used choice in my experience and which has the advantage of lower cost compared to an epitaxial substrate. Ex. 1008A, 816 ("Typically, in twin-well CMOS the starting material is also ***either*** a lightly *p*-doped wafer (***p-bulk wafer***, Fig. 16-7a), or a heavily *p*-doped wafer on which a thin, lightly *p*-doped epi layer is grown" and noting the cost disadvantage of epitaxial wafers), FIG. 16-7. Consistent with the teachings of Wolf, Wieczorek's substrate (orange dotted line) in Figure 1b below,

has a top surface ("first surface") and a bottom surface ("second surface"). Ex. 1008B, 382, FIG. 6-8(c), 387, FIG. 6-10; Ex. 1008C, 525, FIG. 8-1(e).



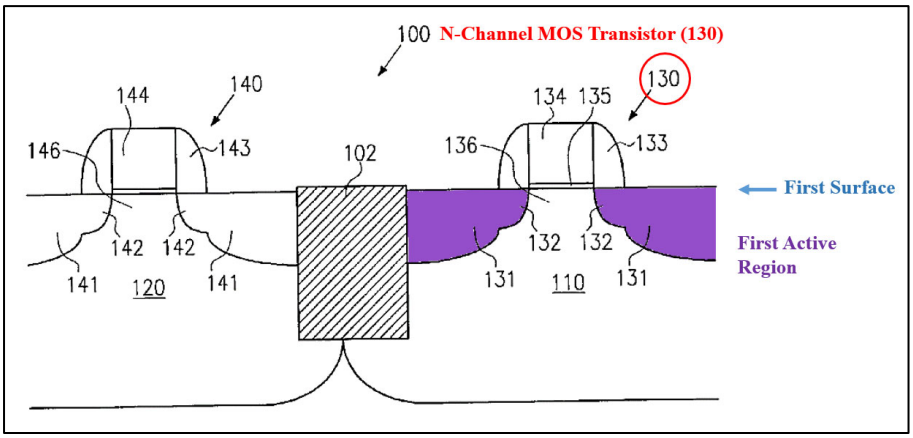
Ex. 1006, FIG. 1b.

150. In my opinion, Wieczorek-Wolf satisfies element [1.1] under Patent Owner's position that the term "substrate" should be given its plain meaning and under Petitioner's proposed construction because Wieczorek-Wolf's substrate is the initial material within which or on which Wieczorek's "semiconductor device 100" is fabricated. *See* Section VIII; Ex. 1006, [0004], [0012].

c. Element [1.2]: "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;"

151. In my opinion, Wieczorek-Wolf renders obvious this element. Wieczorek discloses "an N-channel transistor 130" that includes "heavily N-doped ***source and drain regions*** 131, including lightly doped extensions 132," and "***channel region*** 136." Ex. 1006, [0012]-[0013]; *id.*, [0004] ("[A] field effect

transistor comprises two highly doped semiconductor regions … referred to as ***drain and source regions***, and which are embedded in a lightly and inversely doped semiconductor region, the so-called N-well or P-well … The drain and source regions are spaced apart with a ***channel region*** interposed, wherein a conductive channel forms between the drain and source regions in the channel region" when the transistor is active). As illustrated in the figure below, the source-drain regions 131-132 (purple) form part of the claimed first active region, which also includes channel region 136 (light purple) in between them. *Id*., [0012]; Ex. 1008B, 299 ("The top surface of the [substrate] body consists of active or transistor regions as well as passive or (field) regions. The ***active regions*** are those in which transistor action occurs; i.e., the ***channel*** and the heavily doped ***source and drain*** regions."), 300, FIG. 5-2, 382, FIG. 6-8(c), 387, FIG. 6-10; Ex. 1008C, 525, FIG. 8-1(e). As shown below in Figure 1b, nMOS transistor 130 is formed in the first active region, which is adjacent the first surface of the substrate.

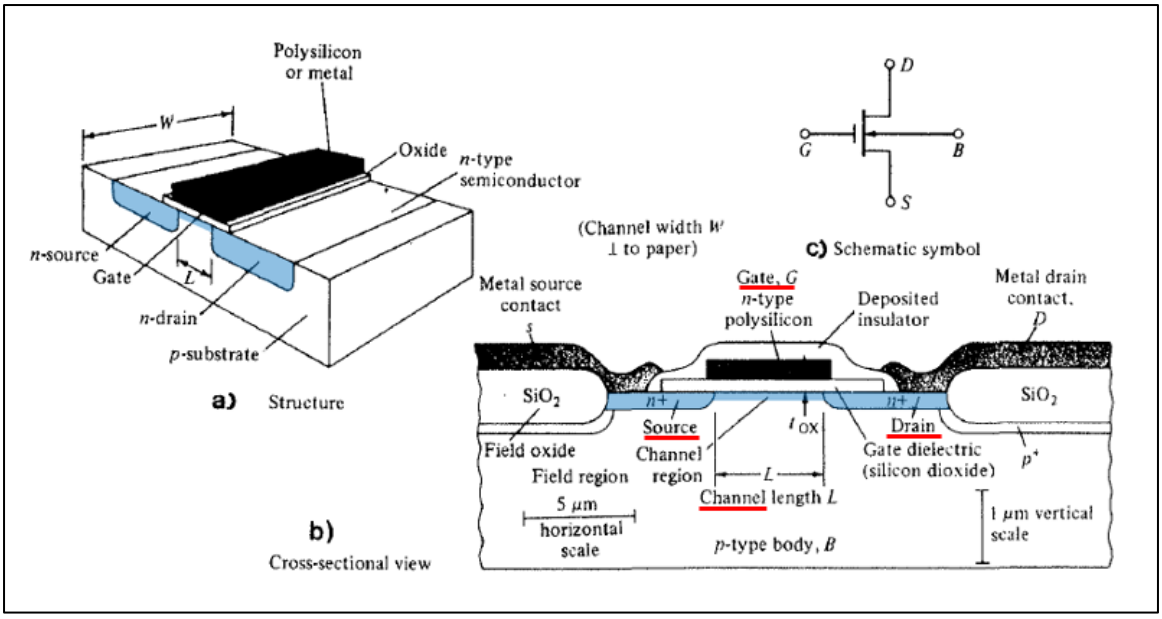


Ex. 1006, FIG. 1b, [0007].

152. In my opinion, because the source-drain regions of the first active region are N-doped, Wieczorek-Wolf's first active region has a second doping type (N-type) opposite in conductivity to the first doping type (P-type) of the substrate. Ex. 1006, [0012].

153. While Figure 1b illustrates a single exemplary nMOS transistor 130 formed in the first active region, in my opinion, a POSITA would have understood that Wieczorek contemplates forming multiple nMOS transistors in the first active region to minimize chip area, as good layout practice dictates. Ex. 1006, [0004]; Ex. 1014, 1:52-54, 2:17-21; *see* Section X.A.1.c. I was taught this technique in school in the 1980s and had used it myself in numerous designs by 2000. In any event, I understand that according to Patent Owner's representations in the District Court Case, an "active region … within which transistors can be formed" means "an active region … where ***a transistor*** can be formed." Ex. 1020, 31.

154. In my opinion, Wieczorek satisfies element [1.2] under Patent Owner's construction that the term "active region" means "a doped silicon region at the surface of a semiconductor device (*e.g.*, the source and drain and silicon between them) where a transistor can be formed." Ex. 2020, 20; *see also* Section VIII. In my opinion, the active region of a CMOS transistor is "[its] channel and [its] heavily doped source and drain regions" as illustrated in blue in the figure below. Ex. 1008B, 299.



Ex. 1008B, FIG. 5-1; *id*., 298-301, FIGS. 5-2, 6-4.

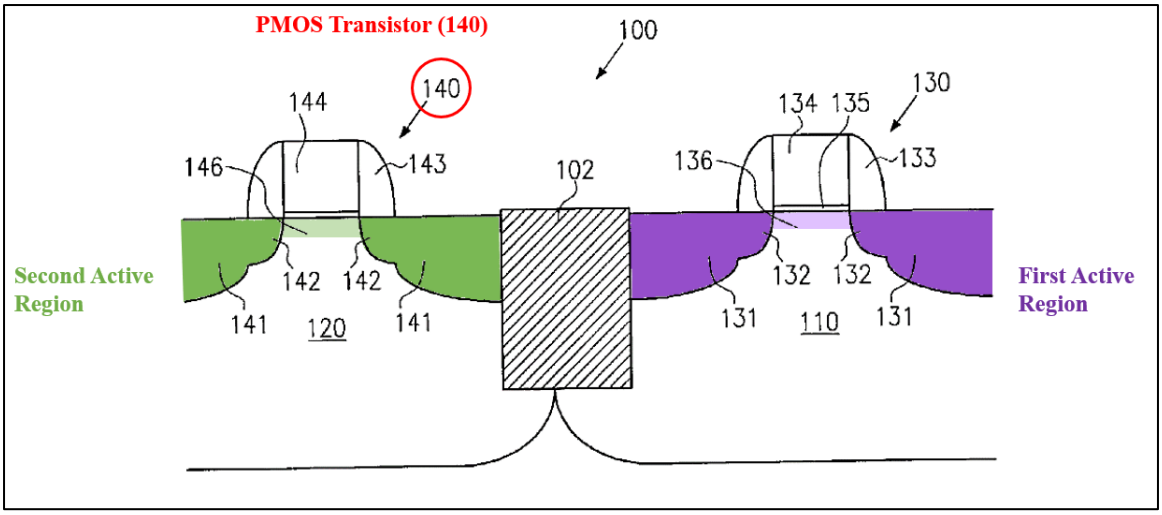
155. It is also my opinion that Wieczorek also satisfies this claim element under Petitioner's proposed construction that an active region is the "region that forms the current path of a device" or "the source, drain and channel region of a device" because current flows through the channel region that connects the source and drain regions of a transistor when the transistor is active (when an appropriate voltage is applied to its gate).Section VIII; Ex. 1008B, 299-301; Ex. 1008D, 197, FIG. 5-13. In my opinion, and based on Patent Owner's representations in the District Court Case, Patent Owner does not dispute this. *See* Ex. 1020, 3-4 ("when a positive voltage is applied to the gate … a ***conductive channel*** [is formed] between the ***source*** and the ***drain***, and ***current*** can begin to flow through the transistor").

d. Element [1.3]: "a second active region separate from the first active region disposed adjacent to the first

active region and within which transistors can be formed;"

156. Wieczorek discloses or, at a minimum, renders obvious this element. Wieczorek discloses "a P-channel transistor 140" that includes "heavily P-doped source and drain regions 141, including lightly doped extensions 142," and "channel region 146." Ex. 1006, [0004], [0007], [0012]-[0013]. The source and drain regions 141-142 (green) are part of the claimed second active region, which also includes channel region 146 (light green) in between them and below the gate insulation layer 135. Ex. 1006, [0012]; Ex. 1008B, 298-301, FIGS. 5-1, 5-2, 6-4; Secyion X.B.1.c.

157. As shown in Figure 1b, pMOS transistor 140 is formed in the second active region (green/light green), which is separate from and disposed adjacent to the first active region (purple/light purple). Ex. 1006, [0012]. Adjacent active regions are separated by an isolation region (such as shallow trench isolation 102). Ex. 1006, [0007]; Ex. 1008A, 818-20, FIG. 16-11(f); Ex. 1001, Cl. 6; Section X.A.1.d.



Ex. 1006, FIG. 1b, [0007].

158. While the figure shows an exemplary pMOS transistor 140 formed in the second active region, a POSITA would have understood that Wieczorek contemplates forming multiple pMOS transistors in the second active region to minimize chip area, as good layout practice dictates. Ex. 1006, [0004]; Section X.B.1.c. In any event, I understand that according to Patent Owner's representations in the District Court Case, an "active region … within which transistors can be formed" means "an active region … where ***a transistor*** can be formed." Ex. 1020, 31.

159. In my opinion, Wieczorek satisfies element [1.3] under Patent Owner's position that the term "active region" means "a doped silicon region at the surface of a semiconductor device (*e.g.*, the source and drain and silicon between them) where a transistor can be formed." Section X.B.1.c. Wieczorek also satisfies this claim element under Petitioner's proposed construction that an active region is the

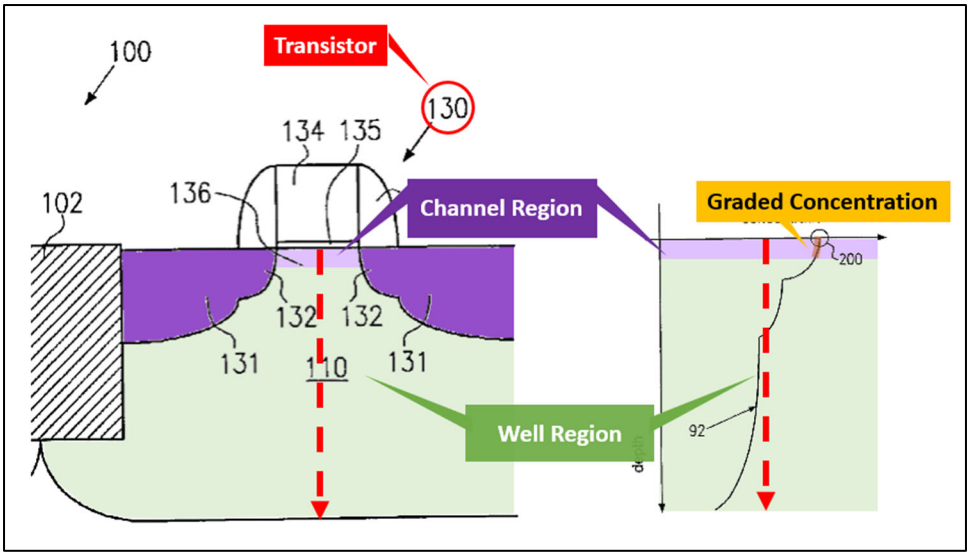
"region that forms the current path of a device" or "the source, drain and channel region of a device." *Id*.

e. Element [1.4]: "transistors formed in at least one of the first active region or second active region;"

160. It is my opinion that Wieczorek discloses or, at a minimum, renders obvious this element. *See* Sections X.B.1.c-d.

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"

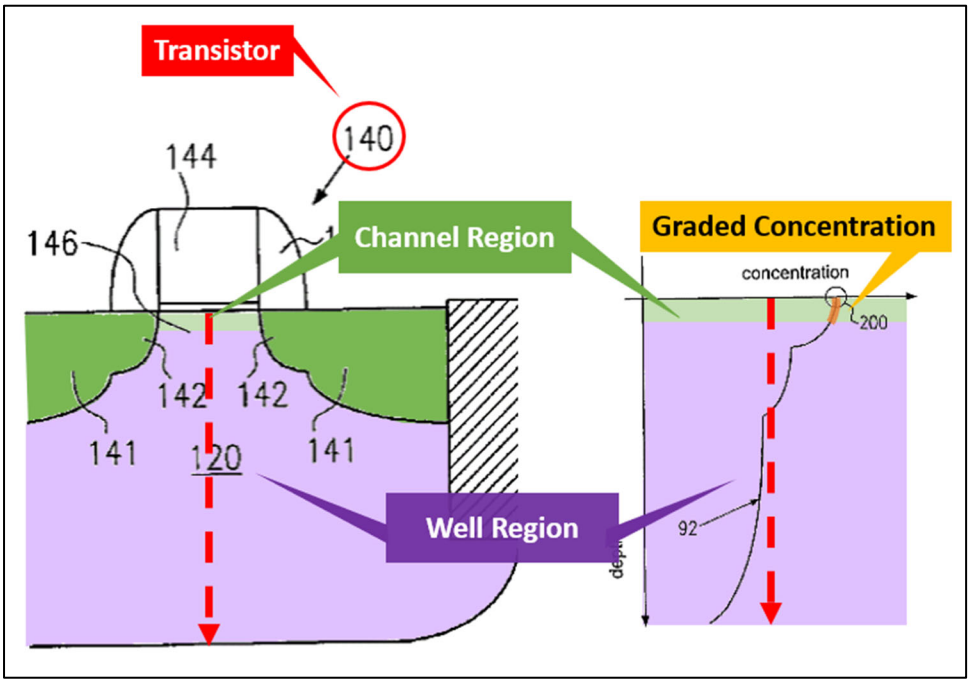
161. It is my opinion that Wieczorek-Wolf renders obvious this element. As illustrated in Figure 1b (below left), the channel region 136 (light purple) of nMOS transistor 130, formed at the top surface of the substrate, is a portion of the first active region. Ex. 1006, [0012]-[0013], [0004] ("The drain and source regions are spaced apart with a ***channel region*** interposed"); Ex. 1008B, 298-301 ("The top surface of the [substrate] body consists of active or transistor regions as well as passive or (field) regions. The ***active regions*** are those in which transistor action occurs; i.e., the ***channel*** and the heavily doped ***source and drain*** regions."), FIG. 5-2.



Ex. 1006, FIGS. 1b, 2b. The doping concentration in the channel region is highlighted in brown in the doping profile of Figure 2b (above right), which is measured for example along the red dotted line in Figure 1b that traverses the channel region. *Id*., [0011] ("FIG. 2b shows … a typical dopant profile with respect to the depth of the respective well structure."), [0013] ("after the plurality of heat treatments, the actual dopant concentration will be represented by the graph shown in FIG. 2b."), [0009], FIG. 2a.

162. In my opinion, and as Figure 2b shows, the dopant concentration is highest at the surface of the substrate and decreases with depth. Therefore, the channel region 136 has a graded dopant concentration. And as shown in the figures below, Wieczorek teaches that the channel region 146 (light green) of pMOS transistor 140, which is a portion of the second active region, also has a graded

dopant concentration for the same reasons. Ex. 1006, [0004], [0009], [0011]-[0013], FIGS. 2a-2b; Ex. 1008B, 298-301, FIG. 5-2.

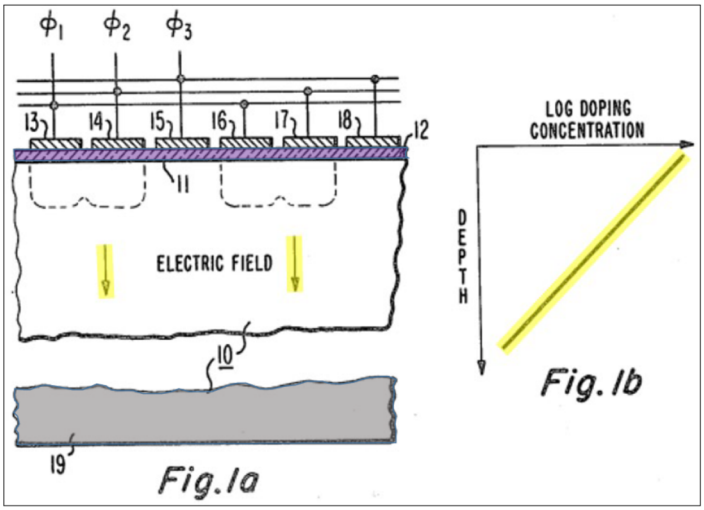


Ex. 1006, FIGS. 1b, 2b. Thus, in my opinion, Wieczorek discloses "at least a portion of" the first and second active regions (the channel regions) having a downward-sloping graded dopant concentration. Ex. 1006, [0009]. [0011], [0013].

163. Further, Wieczorek's downward-sloping graded dopant concentration aids carrier movement from the first surface to the second surface of the substrate to the same extent to which Applicant relied on the prior art and admitted to the Patent Office that such carrier movement would occur under the same scenario. As detailed in Section X.A.1.g, during prosecution of the parent '195 Patent, Applicant represented to the Patent Office that a downward-sloping graded dopant

concentration was known in the prior art to move carriers deep into the substrate. Applicant cited Jastrzebski and Kamins in support. Section X.A.1.g.

164. According to Jastrzebski, a downward-sloping graded dopant concentration creates an electric drift field that "force[s] most of the charge carriers … ***deep into the substrate***[.]". Ex. 1010, 2:27-32, 5:14-22.



Id., FIGS. 1a-1b.

165. In light of the above, it is my opinion that Wieczorek satisfies element [1.5] under Patent Owner's position that the term "to aid carrier movement from the first surface to the second surface of the substrate" should be accorded plain meaning. *See* Section VIII. According to Patent Owner's representations in the District Court Case, the claims make clear that "carriers [must move] in a particular direction (from the surface layer to the substrate)." Ex. 1020, 29. Also, according to Patent Owner's statements in the District Court Case, "when the dopant concentration is graded in a particular direction, [certain] charge carriers will move

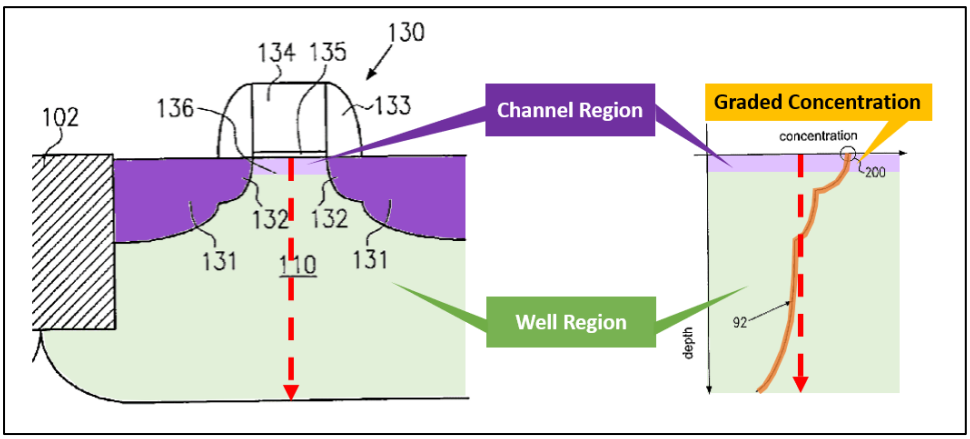
in the [same] gradient direction …". *Id*., 2. Here, in my opinion, Wieczorek's Figure 2b shows that the dopant concentration is downward-sloping with increasing depth towards the bottom of the substrate, and thus, according to Patent Owner, this graded dopant concentration causes carriers to move deeper into the substrate as well.

166. It is also my opinion that Wieczorek also satisfies this claim element under Petitioner's alternative proposed construction that the term means "to sweep the carriers from the first surface to the second surface of the substrate." *See* Section VIII. Wieczorek Figure 2b illustrates a downward-sloping graded dopant concentration in the channel regions and Applicant represented to Patent Office during prosecution of the parent '195 Patent that a downward-sloping graded dopant concentration was known in the prior art to create an "inherent 'built-in' unidirectional electric field" that sweeps carriers into the substrate, as further detailed above in Section X.A.1.g. Ex. 1016, 289-290.

g. Element [1.6]: "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."

167. In my opinion, Wieczorek-Wolf renders obvious this element. As shown in Figure 1b (below left), Wieczorek discloses a "P-well structure 110" (light green) adjacent to the first active region (purple/light purple). Ex. 1006, [0012]-[0013]. As discussed above and shown in the dopant concentration profile (brown)

of Figure 2b (below right), the dopant concentration in P-well 110—measured along the exemplary red dotted line in Figure 1b—is gradually decreasing with depth. Section X.B.1.f; Ex. 1006, [0009], [0011] ("FIG. 2b shows … a typical dopant profile with respect to the depth of the respective well structure [110 and 120]"), [0013]. Thus, Wieczorek discloses a well region containing at least one graded dopant region (*e.g.,* the region highlighted in light green in both Figures 1b and 2b) having a downward-sloping graded dopant concentration.



Ex. 1006, FIGS. 1b, 2b.

168. Under Applicant's representation to the Patent Office, discussed above in Section X.B.1.f, such a downward-sloping graded dopant concentration was known in the prior art to create a "built-in" electric field that moves carriers deep into the substrate and thus aids carrier movement from the first surface to the second surface of the substrate. *See* Section X.B.1.f.

169. In light of the above, in my opinion, Wieczorek satisfies element [1.6] under Patent Owner's construction that the term "well region" means "a doped

region that surrounds the active region of a semiconductor device." Ex. 1020, 30; *see also* Section VIII. As shown in Figure 1b above, the p-well region 110 (light green) is a doped region that surrounds the first active region (purple/light purple). *Id.* In my opinion, Wieczorek also satisfies this element under Patent Owner's construction that "to aid carrier movement from the first surface to the second surface of the substrate" should be accorded plain meaning. *See* Section VIII.

170. It is also my opinion that Wieczorek also satisfies this claim element under Petitioner's proposed constructions of these terms. *See* Section VIII. With regard to the "well region," the claimed well region is mapped to Wieczorek's P-well 110 (adjacent to the first active region) and this mapping satisfies Petitioner's construction of the term because P-well 110 and N-well 120 are formed using "ion implantation processes." Ex. 1006, [0008], [0007]-[0011], FIGS. 1a, 2a-2b. With regard to the "aid carrier movement" term, Wieczorek satisfies Petitioner's alternative proposed construction that the term means "to sweep the carriers from the first surface to the second surface of the substrate." *Id.* Wieczorek Figure 2b illustrates a graded dopant region with a downward-sloping graded dopant concentration and Applicant represented to Patent Office during prosecution of the parent '195 Patent that a downward-sloping graded dopant concentration was known in the prior art to create an "inherent 'built-in' unidirectional electric field" that

sweeps carriers into the substrate, as further detailed in Section X.A.1.g. Ex. 1016, 4/17/2012 Resp. at 6-7.

2. Dependent Claim 2: "The semiconductor device of claim 1, wherein the substrate is a p-type substrate."

171. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 2. *See* Section X.B.1.b.

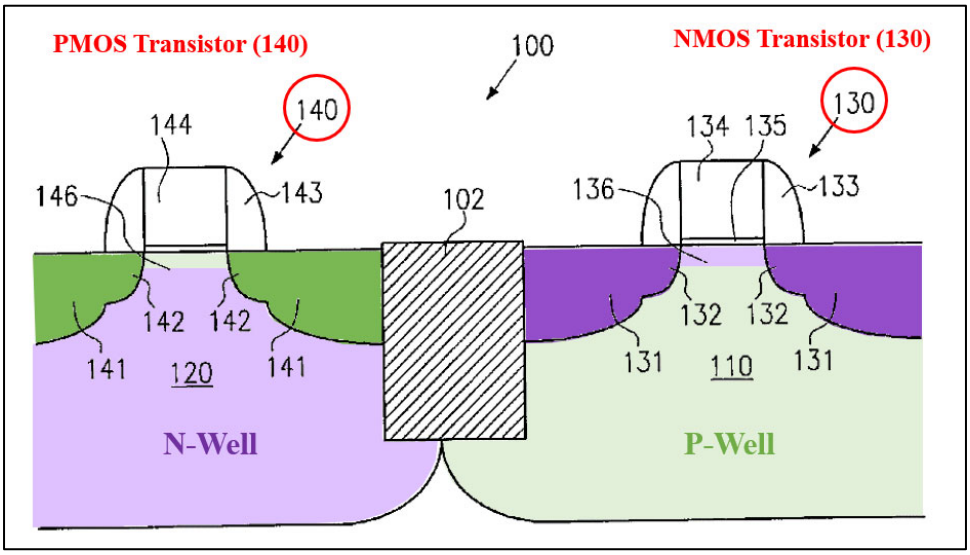
3. Dependent Claim 4: "The semiconductor device of claim 1, wherein the first active region and second active region contain one of either p-channel and n-channel devices."

172. In my opinion, Wieczorek discloses or renders obvious the additional limitation of claim 4. *See* Section X.B.1.c-e.

4. Dependent Claim 5: "The semiconductor device of claim 1, wherein the first active region and second active region contain either p-channel or n-channel devices in n-wells or p-wells, respectively, and each well has at least one graded dopant."

173. In my opinion, Wieczorek discloses or renders obvious the additional limitation of claim 5. Wieczorek's Figure 1b illustrates a conventional twin-well architecture, whereby the first active region contains an "N-channel transistor 130" in "P-well structure 110" and the second active region contains a "P-channel transistor 140" in "N-well structure 120." Ex. 1006, [0012]-[0013], [0004]; Sections X.B.1.c-d. In my opinion, this mapping satisfies this claim element under Patent Owner's interpretation that an active region in the claims can contain only "***a transistor***." Ex. 1020, 31. A POSITA would have also understood that Wieczorek

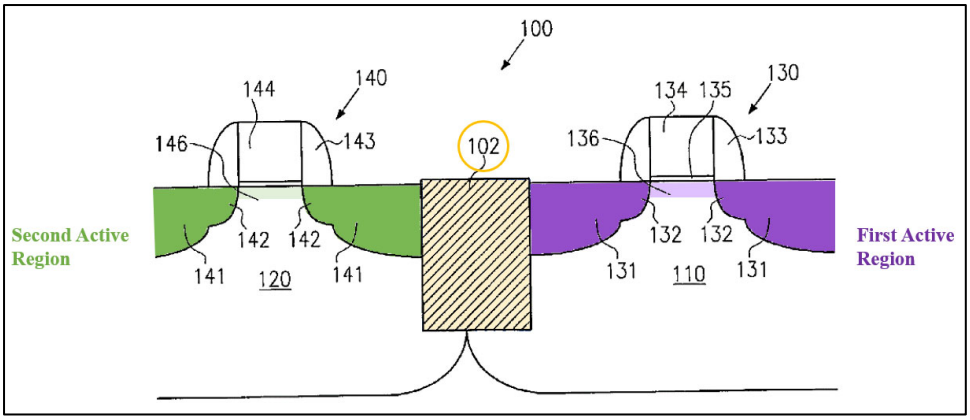
teaches forming multiple transistors in an active region to save chip area, as good layout practice dictates. Ex. 1014, 1:52-54, 2:17-21.



Ex. 1006, FIG. 1b. Further, in my opinion, Wieczorek's wells have a graded concentration of dopants. Ex. 1006, [0009]-[0011] ("FIG. 2b shows … a typical dopant profile with respect to the depth of the respective well structure [110/120]."), [0013], FIGS. 2a-2b; Section X.B.1.g (discussing graded dopants in P-well 110).

5. Dependent Claim 6: "The semiconductor device of claim 1, wherein the first active region and second active region are each separated by at least one isolation region."

174. In my opinion, Wieczorek discloses or renders obvious the additional limitation of claim 6. As shown below, the first active region (purple/light purple) and second active region (green/light green) are separated by the "shallow trench isolation 102" (yellow). Ex. 1006, [0007]; Ex. 1008A, 818-820, FIG. 16-11(f).



Ex. 1006, FIG. 1b.

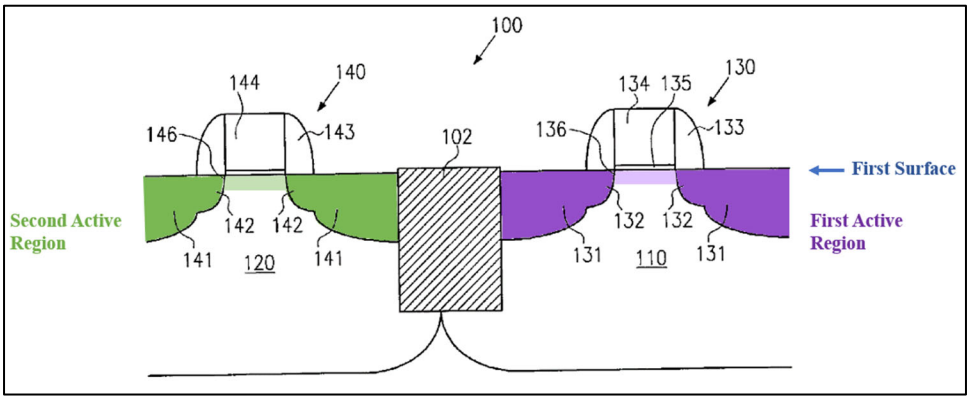
6. Dependent Claim 7: "The semiconductor device of claim 1, wherein the graded dopant is fabricated with an ion implantation process."

175. In my opinion, Wieczorek discloses or renders obvious the additional limitation of claim 7. Wieczorek teaches, in my opinion, that the graded dopants in "the P-well structure 110 and the N-well structure 120 are defined by sequentially performed ion implantation processes." Ex. 1006, [0008], [0007]-[0011], FIGS. 1a, 2a-2b; Sections X.B.1.f-g.

7. Dependent Claim 8: "The semiconductor device of claim 1, wherein the first and second active regions are formed adjacent the first surface of the substrate."

176. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 8. As shown below, Wieczorek discloses that the first active region (purple/light purple) and second active region (green/light green) are formed adjacent the first surface of the substrate (blue). Ex. 1006, [0007]-[0010], [0012]-

[0013]; Ex. 1008B, 299 ("The top surface of the [substrate] body consists of active or transistor regions…."), 298-301, FIG. 5-2; Sections X.B.1.c-d.



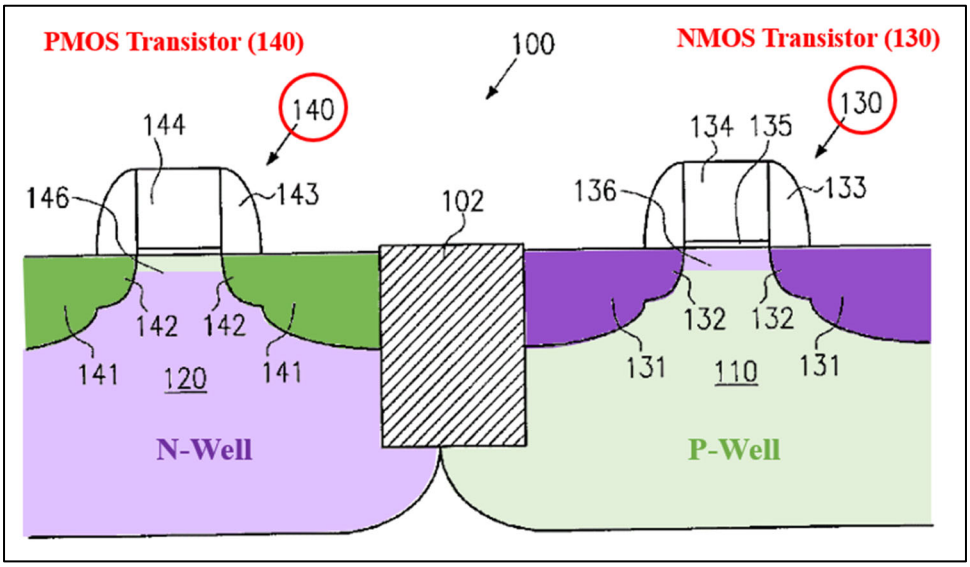
Ex. 1006, FIG. 1b.

8. Dependent Claim 9: "The semiconductor device of claim 1, wherein dopants of the graded dopant concentration in the first active region or the second active region are either p-type or n-type."

177. In my opinion, Wieczorek discloses or renders obvious the additional limitation of claim 9. As discussed above and illustrated in Figure 1b below, the channel region 136 (light purple) of the first active region is formed at the top of P-well 110 is, in my opinion, of the same doping type (p-type) as P-well 110. Ex. 1006, [0008] ("for defining the P-well structure 110, typically boron ions are employed"). Boron ions are p-type dopants. *See, e.g.*, Ex. 1007, 15:28-29.

178. Likewise, the channel region 146 (light green) of the second active region is formed at the top of N-well 120 and is of the same doping type (n-type) as N-well 120. Ex. 1006, [0008] ("[f]or defining the N-well structure 120, typically

phosphorous or arsenic ions are used"). Phosphorous and arsenic ions are n-type dopants. *See, e.g.*, Ex. 1007, 9:33-35.

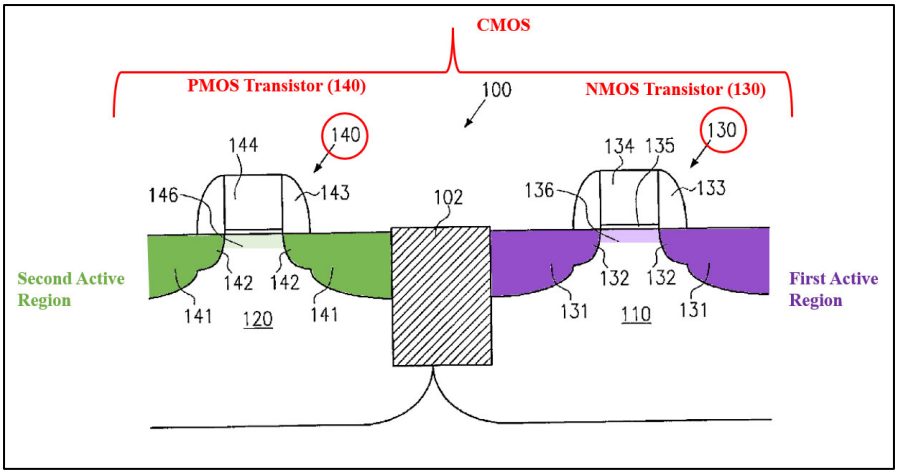


Ex. 1006, FIG. 1b.

179. In my opinion, those channel regions have a graded dopant concentration, as discussed above. Section X.B.1.f

9. Dependent Claim 13: "The semiconductor device of claim 1, wherein the transistors which can be formed in the first and second active regions are CMOS transistors requiring at least a source, a drain, a gate and a channel."

180. In my opinion, Wieczorek discloses or renders obvious the additional limitation of claim 13. Wieczorek discloses "a complementary MOS [(CMOS)] transistor pair" comprising "an N-channel transistor 130" in the first active region (purple/light purple) and "a P-channel transistor 140" in the second active region (green/light green). Ex. 1006, [0007], [0012]-[0013].



Ex. 1006, FIG. 1b.

181. Each of the CMOS transistors include a source, drain, gate, and channel. For example, N-channel transistor 130 includes "heavily N-doped source and drain regions 131" (purple), "gate electrode 134," and "channel region 136" (light purple). Ex. 1006, [0012]-[0013]. Similarly, P-channel transistor 140 includes "heavily P-doped source and drain regions 141" (green), "gate electrode 144," and "channel region 146" (light green). Ex. 1006, [0012]-[0013]; Sections X.A.1.c-d, X.A.1.f.

10. Dependent Claim 14: "The semiconductor device of claim 1, wherein the device is a dynamic random access memory (DRAM)."

182. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 14. In my opinion, Wieczorek's teaching relied on in this declaration is directed to conventional CMOS technology. Section X.B.1.b; Ex. 1006, [0007], [0020]-[0021]. It would have been obvious, in my opinion, to fabricate

DRAM using Wieczorek's conventional CMOS technology to take advantage of the "lower power dissipation [] and smaller soft error rates" of CMOS technology and to realize "the advantages of cost per bit, device density, and flexibility of use (i.e., both read and write operations are possible)" which "have made DRAMs the most widely used form of semiconductor memory to date." Ex. 1008B, 587, 597. Wieczorek also suggests doing so in teaching the frequent application of its technology to "modern integrated circuits." Ex. 1006, [0004], [0026]. Indeed, DRAMs were known to be designed using CMOS technology. Ex. 1008B, 596-597.

183. Additionally, in my opinion, using Wieczorek's technology to form a DRAM would have merely amounted to combining known, conventional prior art elements (*i.e.*, Wieczorek's CMOS process and known CMOS DRAM designs) according to known methods (*i.e.*, Wieczorek's CMOS process) and, at most, involves a simple substitution of one known element (*i.e.*, CMOS technology contemplated by Wolf for DRAM) with another (*i.e.*, Wieczorek's conventional CMOS technology). In my opinion, there would have been a reasonable expectation of success with predictable results because Wieczorek's conventional CMOS process was known and would have been used for its intended purpose in manufacturing a known DRAM designed for implementation using CMOS technology.

11. Dependent Claim 15: "The semiconductor device of claim 1, wherein the device is a complementary metal oxide semiconductor (CMOS) with a nonepitaxial substrate."

184. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 15. *See* Section X.B.1.b.

12. Dependent Claim 16: "The semiconductor device of claim 1, wherein the device is a flash memory."

185. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 16. In my opinion, Wieczorek's teaching relied on in this declaration is directed to conventional CMOS technology. Section X.B.1.b; Ex. 1006, [0007], [0020]-[0021]. Further, in my opinion, it would have been obvious to fabricate flash memory using Wieczorek's conventional CMOS technology to achieve the benefits of "lower power dissipation" of CMOS technology and the "high density [], small-die size, lower cost, and hot-electron writability of EPROMs, together with the easy erasability, on-board reprogrammability, and electron-tunneling erasure features of EEPROMs." Ex. 1008B, 634; Ex. 1008A, 808-810. Wieczorek also suggests doing so in teaching the frequent application of its technology to "modern integrated circuits." Ex. 1006, [0004], [0026]. Indeed, flash memory devices commonly used CMOS technology. Ex. 1008B, 633-635 (describing known "CMOS flash-EEPROM" devices); Ex. 1007, 22:16-17 (flash EEPROM is flash memory), 22:10-23:2, FIG. 28 (peripheral flash memory circuit with CMOS transistors); Section X.A.12.

186. Additionally, in my opinion, using Wieczorek's technology to form flash memory would have merely amounted to combining known, conventional prior art elements (*i.e.*, Wieczorek's CMOS process and known CMOS flash memory designs) according to known methods (*i.e.*, Wieczorek's CMOS process) and, at most, involves a simple substitution of one known element (*i.e.*, CMOS technology for prior art flash memory) with another (*i.e.*, Wieczorek's conventional CMOS technology). There would have been, in my opinion, a reasonable expectation of success with predictable results because Wieczorek's conventional CMOS process was known and would have been used for its intended purpose in manufacturing a known flash memory designed for implementation using CMOS technology.

13. Dependent Claim 17: "The semiconductor device of claim 1, wherein the device is a logic device."

187. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 17. Section X.B.1.a; Ex. 1006, Title, [0007]. Wieczorek's teaching relied on in this declaration is directed to conventional CMOS technology. Section X.B.1.b; Ex. 1006, [0007], [0020]-[0021]. In my opinion, it would have been obvious to fabricate known logic devices, including inverters and microprocessors (CPUs), using Wieczorek's conventional CMOS technology to achieve the benefits of "lower power-dissipation" of CMOS technology in such devices. Ex. 1008B, 368-370; Ex. 1032, 1334. Wieczorek suggests doing so in teaching the frequent application of its technology to "modern integrated circuits." Ex. 1006, [0004],

[0026]. Indeed, twin-well CMOS technology was, by the early 2000s, "the dominant CMOS technology in IC production." Ex. 1008D, 181.

188. Rabaey, confirms this. Ex. 1025, 180 ("The [CMOS] inverter is truly the nucleus of all digital [logic] designs" and, together with other "[logic] gates such as NAND, NOR, or XOR … form the building blocks for modules such as multipliers and processors."); *id.*, 37 ("Modern [CMOS] processes are increasingly using a dual-well [(twin-well)] approach that uses both n- and p-wells …"), 383-384, FIG. 8-6 (showing Intel Pentium processor "designed in a 0.18μm CMOS technology"). Inverters and processors are logic devices.

189. Sze also confirms this, describing a system-on-a-chip that includes CMOS "***logic IC (e.g., CPU)***" fabricated using twin-well CMOS technology. Ex. 1022, 525-26, FIGS. 37-38.

190. Additionally, in my opinion, using Wieczorek's technology to form logic devices such as CPUs would have merely amounted to combining known, conventional prior art elements (*i.e.*, conventional twin-well CMOS process described in Wieczorek and known digital device designs, including CPUs) according to known methods (*i.e.*, Wieczorek's conventional twin-well CMOS process) and, at most, involves a simple substitution of one known element (*i.e.*, CMOS technology for prior art logic devices, including CPUs) with another (*i.e.*, Wieczorek's conventional CMOS technology). There would have been a reasonable

expectation of success with predictable results because Wieczorek's conventional twin-well CMOS process was known and would have been used for its intended purpose in manufacturing known logic devices, including CPUs, designed for implementation using CMOS technology.

14. Dependent Claim 18: "The semiconductor device of claim 17, wherein the device is central processing unit."

191. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 18. *See* Section X.B.13. In my opinion, a POSITA would have understood that a microprocessor includes a central processing unit (CPU). Ex. 1032, 1334.

15. Independent Claim 20

a. Preamble: "A semiconductor device, comprising:"

192. To the extent the preamble is limiting, in my opinion, Wieczorek discloses it. *See* Section X.B.1.a.

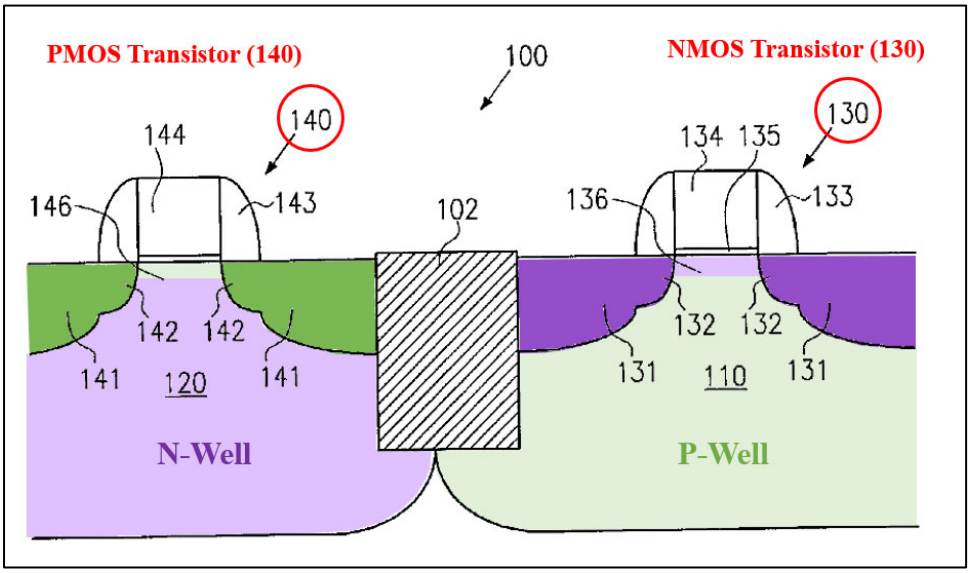
b. Element [20.1]: "a substrate of a first doping type at a first doping level having first and second surfaces;"

193. In my opinion, Wieczore-Wolf renders this element obvious. *See* Section X.B.1.b.

c. Element [20.2]: "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 in the surface thereof;"

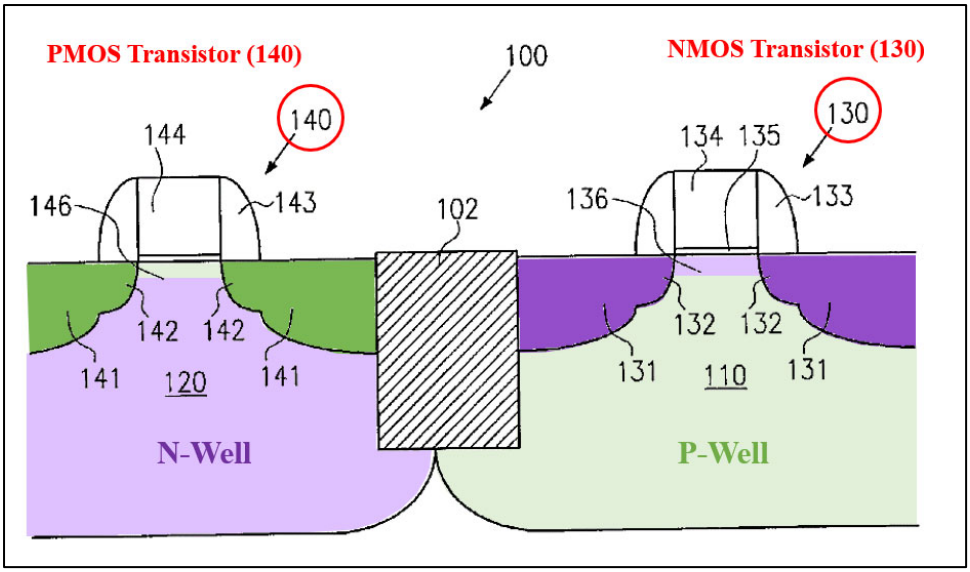
194. In my opinion, Wieczorek-Wolf renders obvious this element. *See* Section X.B.1.c. As shown below, Wieczorek discloses an N-channel transistor 130 formed in the surface of the first active region.



Ex. 1006, FIG. 1b.

d. Element [20.3]: "a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed in the surface thereof;"

195. In my opinion, Wieczorek discloses or renders obvious this element. *See* Section X.B.1.d. As shown below, Wieczorek discloses a P-channel transistor 140 formed in the surface of the second active region.



Ex. 1006, FIG. 1b.

e. Element [20.4]: "transistors formed in at least one of the first active region or second active region;"

196. In my opinion, Wieczorek discloses or, at a minimum, renders obvious this element. *See* Section X.B.1.e.

f. Element [20.5]: "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 surface to the substrate; and"

197. In my opinion, Wieczorek-Wolf renders obvious this element. *See* Section X.B.1.f.

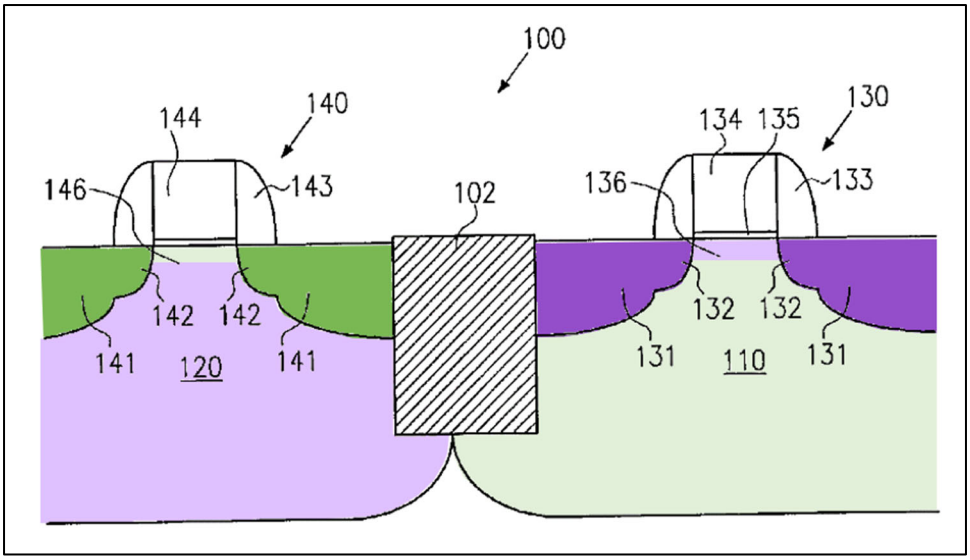
g. Element [20.6]: "at least one well region adjacent to the first or second active region containing at least one graded dopant region, the graded dopant region to aid

carrier movement from the first surface to the second surface of the substrate."

198. In my opinion, Wieczorek-Wolf renders obvious this element. *See* Section X.B.1.g.

16. Dependent Claim 21: "The semiconductor device of claim 20, "wherein the substrate is an n-type substrate."

199. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 21. As I explained in Section X.B.1.b, n-type and p-type substrates are both suitable for Wieczorek's CMOS device, and a p-type substrate is chosen for claim mapping of claims 1 and 20. Section X.B.1.b. With an n-type substrate, claim element [20.2] requiring "a first active region … with a second doping type opposite in conductivity to the first doping type" of the substrate is met by mapping the first active region to the source/drain/channel regions 141/142/146 (green/light green) of pMOS transistor 140, and claim element [20.3] is met by mapping the second active region to the source/drain/channel regions 131/132/136 (purple/light purple) of nMOS transistor 130. *Id.*



Ex. 1006, FIG. 1b.

17. Dependent Claim 22: "The semiconductor device of claim 20, wherein the substrate is a p-type substrate."

200. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 22. *See* Section X.B.2.

18. Dependent Claim 24: "The semiconductor device of claim 20, wherein the first active region and second active region contain at least one of either p-channel and n-channel devices."

201. In my opinion, Wieczorek discloses or, at a minimum, renders obvious the additional limitation of claim 24. *See* Section X.B.3.

19. Dependent Claim 25: "The semiconductor device of claim 20, wherein the first active region and second active region contain either p-channel or n-channel devices in n-wells or -wells, respectively, and each well has at least one graded dopant."

202. In my opinion, Wieczorek discloses or, at a minimum, renders obvious the additional limitation of claim 25. *See* Section X.B.4.

20. Dependent Claim 26: "The semiconductor device of claim 20, wherein the first active region and second active region are each separated by at least one isolation region."

203. In my opinion, Wieczorek discloses or, at a minimum, renders obvious the additional limitation of claim 26. *See* Section X.B.5.

21. Dependent Claim 27: "The semiconductor device of claim 20, wherein dopants of the graded dopant concentration in the first active region or the second active region are either p-type or n-type."

204. In my opinion, Wieczorek discloses or, at a minimum, renders obvious the additional limitation of claim 27. *See* Section X.B.8.

22. Dependent Claim 31: "The semiconductor device of claim 20, wherein the graded dopant is fabricated with an ion implantation process."

205. In my opinion, Wieczorek discloses or, at a minimum, renders obvious the additional limitation of claim 31. *See* Section X.B.6.

23. Dependent Claim 32: "The semiconductor device of claim 20, wherein the substrate is a complementary metal oxide semiconductor (CMOS) device."

206. In my opinion, Wieczorek discloses or, at a minimum, renders obvious the additional limitation of claim 32. *See* Section X.B.15.b. Wieczorek teaches a "complementary MOS [(CMOS)] transistor pair" formed in and including a substrate. Ex. 1006, [0007], [0012]-[0013].

24. Dependent Claim 33: "The semiconductor device of claim 20, wherein the device is a flash memory."

207. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 33. *See* Section X.B.12.

25. Dependent Claim 34: "The semiconductor device of claim 20, wherein the device is a logic device."

208. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 34. *See* Section X.B.13.

26. Dependent Claim 35: "The semiconductor device of claim 34, wherein the device is central processing unit."

209. In my opinion, Wieczorek-Wolf renders obvious the additional limitation of claim 35. *See* Section X.B.14.

C. GROUNDS III/IV

210. Several claim elements of the Challenged Claims recite "transistors" or "devices." *See* Claim Elements [1.2]-[1.4], [20.2]-[20.4] and Dependent Claims 4, 5, 13, 24, 25. As I discussed above under Grounds I and II, I understand that the Patent Owner interprets these claim elements as requiring one or more transistors, and not a plurality of transistors. *See* Sections X.A.1.c-d, X.B.1.c-d. Notably, I understand that according to Patent Owner, an "active region … within which ***transistors*** can be formed" means "an active region … where ***a transistor*** can be formed." Ex. 1020, 31.

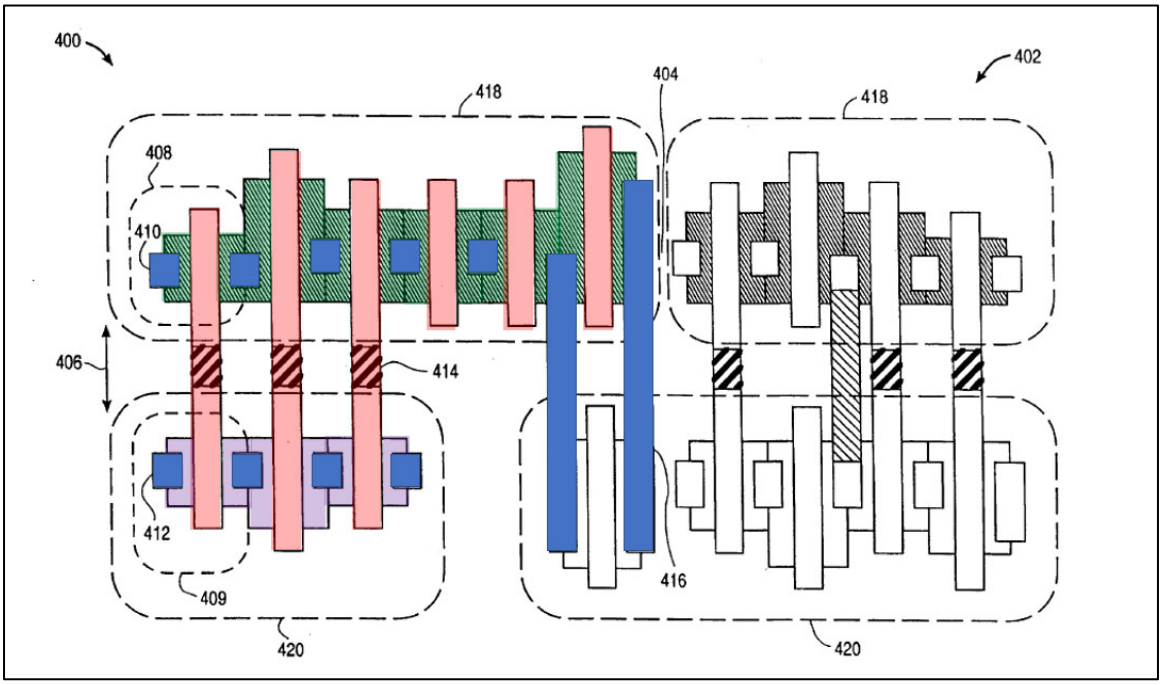
211. The present Grounds III and IV mirror grounds I and II, respectively, except that I have combined Gupta with the ground references (Kawagoe of Ground

I, Wieczorek-Wolf of Ground II) to render obvious those claim elements under an interpretation of "transistors" or "devices" to require a plurality of such devices.

212. Gupta is directed to "automatically producing layouts for CMOS circuits," recognizing that "semiconductor chips [have] become ever larger, incorporating ever more devices." Ex. 1014, 1:7-10, 1:28-31. Wolf confirms that, at the time, various chips (e.g., DRAM, microprocessors, and flash memory) were fabricated with tens of millions to more than a billion devices. Ex. 1008A, xxxiii, FIG. 1; Ex. 1008B, 634. In my opinion, Gupta reflects the knowledge of a POSITA by explaining that a "primary goal" of semiconductor chip development has therefore been to minimize the chip area required to form any circuit so that more transistors can be packed in the same chip, regardless of the technology and chip fabrication process. Ex. 1014, 1:28-35 ("As semiconductor chips become ever larger, incorporating ever more devices, it becomes increasingly important to minimize semiconductor area used by a given number of devices. Conservation of semiconductor area is a ***primary goal*** in semiconductor chip development…."). Gupta further reflects the knowledge of a POSITA by explaining that good circuit layout practice dictates forming as many transistors in the same active region through diffusion abutment as possible, to minimize area-wasting diffusion gaps. *Id*., 1:52-54 ("One technique conserves area by placing transistors so as to ***share diffusion area***."), 2:17-21 ("Transistors which are abutted in a layout form transistor

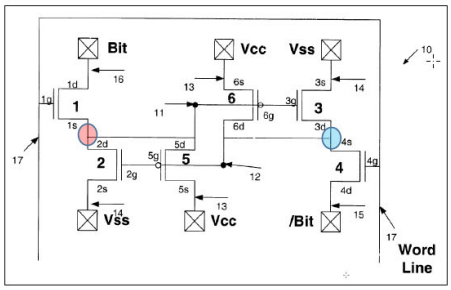
chains. It is desirable to produce a layout with a ***maximum number of transistors chained*** so as to minimize diffusion gaps."); Ex. 1023, 5 ("An important layout task is to place and orient the transistors on the chip to ***minimize the layout area*** of the circuit" by avoiding "area-wasting diffusion gap[s]"). Gupta describes several techniques to perform this, such as transistor folding and chaining, to achieve an optimal layout. Ex. 1014, 1:49-2:24, 3:64-4:1, FIGS. 2-3.

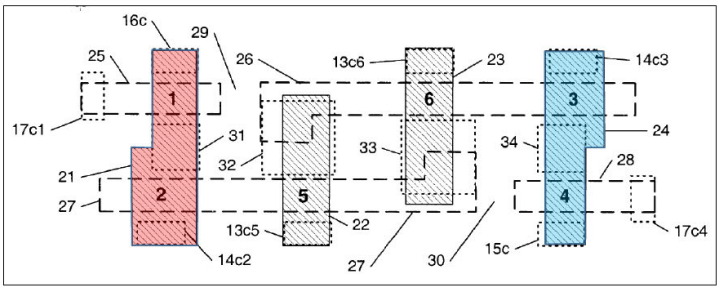
213. Gupta's Figure 4 (below)—where transistor gates and metal contacts that overlay the active regions are colored in red and blue respectively—illustrates ***six*** chained PMOS transistors formed in a p-channel active region (green) and ***three*** chained NMOS transistors formed in an n-channel active region (purple). Ex. 1014, 4:23-43.



Ex. 1014, FIG. 4.

214. In my opinion, Jin further confirms that transistors arranged as in Gupta are formed in a common active region. Below left is the circuit schematic of a conventional 6T SRAM cell, and the cell layout (below right) shows two transistors (1 and 2) formed in active region 21 (red), and two other transistors (3 and 4) formed in active region 24 (blue). Ex. 1015, 6:17-29; Ex. 1025, 48 ("*Diffusion regions* (n^+ and p^+), which define the areas where transistors can be formed[,] are often called the *active areas*.") (italics in original).





Ex. 1015, FIGS. 1 and 2.

215. In my opinion, a POSITA would have been motivated to fabricate a CMOS chip according to the combined teachings of Kawagoe and Gupta (and likewise, of Wieczorek-Wolf and Gupta) to achieve high packing density (as taught by Gupta) at submicron dimensions (for which a twin-well CMOS process of the type taught in Kawagoe and Wieczorek-Wolf was known to be the technology of choice (Ex. 1008B, 373, 388)).

216. In my opinion, the combinations gain the additional benefit of improved immunity to soft errors through appropriate well doping. Ex. 1007, 15:62-16:11.

Combining the teachings of Gupta with those of Kawagoe or Wieczorek-Wolf merely amounds to (1) use of a known technique (*i.e.*, Kawagoe's or Wieczorek's CMOS fabrication process) to improve similar devices (*i.e.*, CMOS chips designed with Gupta's layout) in the same way (*i.e.*, to achieve submicron dimensions and improve immunity to soft errors); (2) use of a known technique (*i.e.*, Gupta's optimal layout generation) to improve similar devices (*i.e.*, submicron CMOS chips fabricated according to Kawagoe or Wieczorek-Wolf's CMOS fabrication process) in the same way (*i.e.*, to minimize chip area and increase packing density); and (3) combining prior art elements (*i.e.*, Kawagoe or Wieczorek's CMOS fabrication process and Gupta's CMOS layout generation) according to known methods (*i.e.*, as taught by Kawagoe or Wieczorek and Gupta). There is reasonable expectation of success with predictable results because Kawagoe's and Wieczorek's CMOS fabrication process would be used for their intended purpose of fabricating CMOS circuits according to known CMOS layouts generated by Gupta, which would also be used for its intended purpose. Further, it is my opinion that Gupta's optimal circuit layout is process-agnostic, and applies to the layout of ***any*** CMOS semiconductor chip, including the layout of CMOS chips fabricated according to the teachings of Kawagoe and/or Wieczorek-Wolf.

217. In my opinion, a POSITA would have understood that, in such a combination, the active regions in Gupta's figures are formed in wells (*i.e.,* n-

channel active regions are formed in p-wells, and p-channel active regions are formed in n-wells), whereby the wells have downward-sloping graded dopant concentrations as shown in Kawagoe's Figure 17 and Wieczorek's Figure 2b. *Id.* I am also of the opinion that the n-channel active region (purple) in Gupta's Figure 4 is an example of the claimed first active region, and that the p-channel active region (green) is an example of the claimed second active region. The two active regions are adjacent and separated by an isolation region (field oxide), as required under elements [1.3], [20.3] and claims 6 and 26. Ex. 1014, 1:16-19, 4:39; Ex. 1008A, 818-820; Sections X.A.1.d, X.A.6, X.B.1.d, X.B.5.

218. Conversely, in my opinion, a POSITA would have understood that each of the active regions of Kawagoe's and Wieczorek's CMOS devices typically contains many transistors, as taught by Gupta and illustrated in Gupta's Figure 4. This is the case whether the device is a DRAM, flash memory, logic device or CPU (as claimed in claims 14, 16-18, 33-35). Each such device is a "very large scale integrated circuit" for which "it becomes increasingly important to minimize semiconductor area used[,]" and this requires forming as many transistors as possible in any active region. Ex. 1014, 1:13-14, 1:28-34, 2:17-21.

219. In light of the above, in my opinion, Kawagoe in view of Gupta renders claims 1-9, 13-14, 16-18, 20, 22-27, and 31-35 obvious (Ground III). Likewise, in

my opinion, Wieczorek-Wolf in view of Gupta renders claims 1-2, 4-9, 13-18, 20-22, 24-27, and 31-35 obvious (Ground IV).

XI. CONCLUSION

220. For the aforementioned reasons, in my opinion, to a person of ordinary skill in the art, the Challenged Claims of the '481 Patent are rendered obvious by the prior art.

221. I understand that the Patent Owner has not asserted secondary considerations of non-obviousness. I reserve the right to respond to any such assertions.

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

Date: November 27, 2022

Respectfully submitted,

Travis Blalock, Ph.D.

LISTING OF CHALLENGED CLAIMS

Element	Claim Language
[1.pre]	"A semiconductor device, comprising"
[1.1]	"a substrate of a first doping type at a first doping level having first and second surfaces;"
[1.2]	"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;"
[1.3]	"a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed;"
[1.4]	"transistors formed in at least one of the first active region or second active region;"
[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"
[1.6]	"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."
2	The semiconductor device of claim 1, wherein the substrate is a p-type substrate.
3	The semiconductor device of claim 1, wherein the substrate has epitaxial silicon on top of a nonepitaxial substrate.
4	The semiconductor device of claim 1, wherein the first active region and second active region contain one of either p-channel and n-channel devices.
5	The semiconductor device of claim 1, wherein the first active region and second active region contain either p-channel or n-channel devices in n-wells or p-wells, respectively, and each well has at least one graded dopant.
6	The semiconductor device of claim 1, wherein the first active region and second active region are each separated by at least one isolation region.
7	The semiconductor device of claim 1, wherein the graded dopant is fabricated with an ion implantation process.

8	The semiconductor device of claim 1, wherein the first and second active regions are formed adjacent the first surface of the substrate.
9	The semiconductor device of claim 1, wherein dopants of the graded dopant concentration in the first active region or the second active region are either p-type or n-type.
13	The semiconductor device of claim 1, wherein the transistors which can be formed in the first and second active regions are CMOS transistors requiring at least a source, a drain, a gate and a channel.
14	The semiconductor device of claim 1, wherein the device is a dynamic random access memory (DRAM).
15	The semiconductor device of claim 1, wherein the device is a complementary metal oxide semiconductor (CMOS) with a nonepitaxial substrate.
16	The semiconductor device of claim 1, wherein the device is a flash memory.
17	The semiconductor device of claim 1, wherein the device is a logic device.
18	The semiconductor device of claim 17, wherein the device is central processing unit.
[20.pre]	A semiconductor device, comprising:
[20.1]	a substrate of a first doping type at a first doping level having first and second surfaces;
[20.2]	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 in the surface thereof;
[20.3]	a second active region separate from the first active region disposed adjacent to the first active region and within which transistors can be formed in the surface thereof;
[20.4]	transistors formed in at least one of the first active region or second active region;
[20.5]	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 surface to the substrate; and
[20.6]	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.
21	The semiconductor device of claim 20, wherein the substrate is an n-type substrate.
22	The semiconductor device of claim 20, wherein the substrate is a p-type substrate.
23	The semiconductor device of claim 20, wherein the substrate has epitaxial silicon on top of a nonepitaxial substrate.
24	The semiconductor device of claim 20, wherein the first active region and second active region contain at least one of either p-channel and n-channel devices.
25	The semiconductor device of claim 20, wherein the first active region and second active region contain either p-channel or n-channel devices in n-wells or p-wells, respectively, and each well has at least one graded dopant.
26	The semiconductor device of claim 20, wherein the first active region and second active region are each separated by at least one isolation region.
27	The semiconductor device of claim 20, wherein dopants of the graded dopant concentration in the first active region or the second active region are either p-type or n-type.
31	The semiconductor device of claim 20, wherein the graded dopant is fabricated with an ion implantation process.
32	The semiconductor device of claim 20, wherein the substrate is a complementary metal oxide semiconductor (CMOS) device.
33	The semiconductor device of claim 20, wherein the device is a flash memory.
34	The semiconductor device of claim 20, wherein the device is a logic device.
35	The semiconductor device of claim 34, wherein the device is central processing unit.