

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG ELECTRONICS CO., LTD.,
Petitioner,

v.

PROMOS TECHNOLOGIES, INC.,
Patent Owner.

Case IPR2017-01418
Patent 6,559,044 B1

Before JAMESON LEE, KEVIN F. TURNER, and
JOHN A. HUDALLA, *Administrative Patent Judges*.

LEE, *Administrative Patent Judge*.

FINAL WRITTEN DECISION
35 U.S.C. § 318(a)

I. INTRODUCTION

A. Background and Summary

Petitioner¹ filed a Petition (Paper 1, “Pet.”) to institute *inter partes* review of claims 1–23 of U.S. Patent No. 6,559,044 B1 (Ex. 1001, “the ’044 patent”). We instituted review of claims 1–23 on all grounds asserted in the Petition. Paper 7 (“Decision on Institution”). Patent Owner² filed a Patent Owner Response.³ Paper 13 (“PO Resp.”). Petitioner filed a Reply.⁴ Paper 19. An oral hearing was held on August 16, 2018. A copy of the transcript for the oral hearing has been entered as Paper 32.

Petitioner has shown, by a preponderance of the evidence, that each of claims 1–4, 6, 8–14, 16–18, and 20–22 is unpatentable. Petitioner has not, however, shown that any of claims 5, 7, 15, 19, and 23 is unpatentable.

B. Related Matters

Both Petitioner and Patent Owner have identified the following action as involving the ’044 patent: *ProMOS Technologies, Inc. v. Samsung*

¹ Samsung Electronics Co., Ltd.

² ProMOS Technologies, Inc.

³ Patent Owner has not submitted objective evidence of nonobviousness, i.e., secondary considerations, for consideration. Patent Owner submitted the declaration of Mr. Dhaval Brahmbhatt in support of the Patent Owner Response. Ex. 2004.

⁴ Patent Owner filed a paper styled as a “Motion to Exclude” (Paper 24), but the substance of the paper is actually a motion to strike. By way of explanation, a motion to exclude must be based on admissibility issues under the Federal Rules of Evidence, but Patent Owner’s motion is not of that type. We informed the parties that Patent Owner’s motion will be treated as a Motion to Strike. Paper 28. Petitioner filed an Opposition. Paper 29. The Motion to Strike is addressed in Section II.L. below.

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Electronics Co., Ltd., No. 1:16-cv-00335-SLR (D. Del.). Pet. 1; Paper 4. In that action, Patent Owner also asserted other patents against Petitioner.

Pet. 1. Petitioner has filed *inter partes* review petitions against those other patents in IPR2017-01412, IPR2017-01413, IPR2017-01414, IPR2017-01415, IPR2017-01416, IPR2017-01417, and IPR2017-01419. Paper 4.

Petitioner also identifies these *inter partes* review proceedings, initiated by petitions filed by Petitioner, as involving additional patents asserted by Patent Owner against Petitioner in *ProMOS Technologies, Inc. v. Samsung Electronics Co., Ltd.*, No. 1:15-cv-00898-SLR-SRF (D. Del.): IPR2017-00032, IPR2017-00033, IPR2017-00035, IPR2017-00036, IPR2017-00037, IPR2017-00038, IPR2017-00039, and IPR2017-00040. Pet. 1–2.

C. The '044 Patent

The '044 patent pertains generally to a method for manufacturing a semiconductor device and particularly to a method for forming contacts in such a device. Ex. 1001, 1:7–9. The '044 patent describes that in a conventional process, (1) a plurality of active devices, such as transistors and memory cells, are formed over a semiconductor substrate, (2) one or more metal layers are formed over the active devices, and (3) contacts, through vias, serve to electrically connect certain active regions of the active devices to one of the metal layers. *Id.* at 1:19–25. With that background, the '044 patent states that it is desirable to reduce the number of required processing steps associated with forming an integrated circuit. *Id.* at 1:32–34. The '044 patent disclosure, however, does not articulate how the disclosed invention, relative to the prior art methods of manufacturing a

semiconductor device, reduces the number of required processing steps associated with forming an integrated circuit.

The '044 patent summarizes its invention as follows:

In accordance with the invention, there is provided a method for manufacturing a semiconductor device that includes providing at least two active devices over a substrate, each of the active devices includes a gate electrode provided over a gate oxide, a silicide formed over the gate electrode, a cap formed over the silicide, and a pair of spaced-apart diffused regions formed in the substrate. The method also includes depositing a first layer of dielectric material over the substrate and active devices, providing a first photoresist over the first layer of dielectric material, defining and patterning the first photoresist, etching the first layer of dielectric material unmasked by the first photoresist to form a first opening, wherein the first opening exposes a first silicide of a first active device, removing the first photoresist, depositing a second layer of dielectric material over the first layer of dielectric material and in the first opening, providing a mask over the second layer of dielectric material, providing a second photoresist over the mask, defining and patterning the second photoresist, and forming a second opening and a third opening, wherein the second opening is aligned with the first opening and exposes the first silicide of the first active device, and the third opening exposes one of the pair of the spaced-apart diffused regions of a second active device.

Also in accordance with the present invention, there is provided a method for forming contacts in a semiconductor device including a plurality of active devices over [] a substrate that includes depositing a first layer of dielectric material over the substrate and plurality of active devices, forming a first opening in the first layer of dielectric material, depositing a second layer of dielectric material over the first layer of dielectric material and in the first opening, providing a mask over the second layer of dielectric material, wherein the mask material is distinguishable over silicon oxides, and forming a second opening and a third opening in the second layer of dielectric material, wherein the second opening is aligned with the first opening and exposes a first silicide of a first active device, and

the third opening exposes one of diffused regions of a second active device.

Id. at 1:40–2:12.

Figure 1D of the '044 patent is reproduced below:

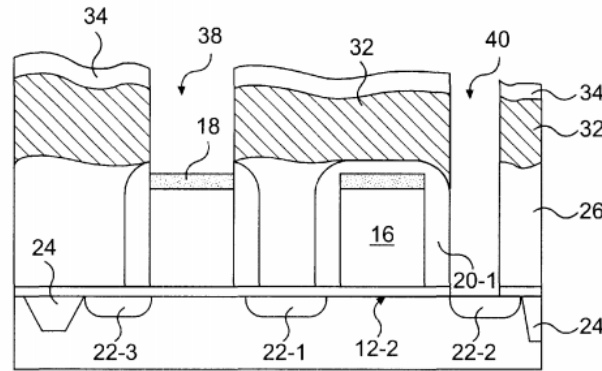


FIG. 1D

Figure 1D illustrates a cross-sectional view of the semiconductor structure at a point in the fabrication process after the formation of the second and third openings. *Id.* at 2:41–43, 3:66–4:6. The '044 patent states the following regarding Figure 1D:

Referring to FIG. 1D, with hardmask 34 in place, an etching step is performed to form vertical openings 38 and 40. Vertical opening 38, aligned with vertical opening 30 shown in FIG. 1C, exposes silicide 18, and will later become a contact for gate electrode 16. Vertical opening 40 extends through to substrate 10, exposing diffused region 22-2, and will later become a contact for one of the source and drain regions of active device 12-2. In one embodiment, the etching step is a self-aligned contact step that forms vertical openings for gate and source/drain contacts of an active device at the same time. In addition, etchants for the etching step may be one of C₅F₈ or C₄F₈. Conventional semiconductor processes follow to fill vertical openings 38 and 40 with conductive materials to complete formation of contacts.

Id. at 3:66–4:12.

Of the challenged claims, claims 1 and 16 are the only independent claims. Claims 1 and 16 are reproduced below:

1. A method for manufacturing a semiconductor device, comprising:

providing at least two active devices over a substrate, each of the active devices includes a gate electrode provided over a gate oxide, a silicide formed over the gate electrode, a cap formed over the silicide, and a pair of spaced-apart diffused regions formed in the substrate;

depositing a first layer of dielectric material over the substrate and active devices;

providing a first photoresist over the first layer of dielectric material;

defining and patterning the first photoresist;

etching the first layer of dielectric material unmasked by the first photoresist to form a first opening, wherein the first opening exposes a first silicide of a first active device;

removing the first photoresist;

depositing a second layer of dielectric material over the first layer of dielectric material and in the first opening;

providing a mask over the second layer of dielectric material;

providing a second photoresist over the mask;

defining and patterning the second photoresist; and

forming a second opening and a third opening, wherein the second opening is aligned with the first opening and exposes the first silicide of the first active device, and the third opening exposes one of the pairs of the spaced-apart diffused regions of a second active device.

Ex. 1001, 4:20–49.

16. A method for forming contacts in a semiconductor device including a plurality of active devices formed over a substrate, comprising:

depositing a first layer of dielectric material over the substrate and plurality of active devices;

forming a first opening in the first layer of dielectric material;
depositing a second layer of dielectric material over the first
layer of dielectric material and in the first opening;
providing a mask over the second layer of dielectric material,
wherein the mask material is distinguishable over silicon
oxides; and
forming a second opening and a third opening in the second
layer of dielectric material, wherein the second opening is
aligned with the first opening and exposes a first silicide of
a first active device, and the third opening exposes one of
diffused regions of a second active device.

Id. at 5:24–6:7.

D. Evidence Relied Upon by Petitioner

Petitioner relies on the following references⁵:

Reference		Date	Exhibit
Ho	U.S. Pat. No. 6,620,733 B2	Sept. 16, 2003, filed Feb. 12, 2001	Ex. 1007
Fujimoto	U.S. Pat. No. 6,399,470 B1	June 4, 2002, filed Feb. 13, 2001	Ex. 1005
Yaung	U.S. Pat. No. 6,165,880	Dec. 26, 2000	Ex. 1006
Sonego	U.S. Pat. No. 6,156,637	Dec. 5, 2000	Ex. 1013
Ohkawa	U.S. Pat. No. 6,091,154	July 18, 2000	Ex. 1025
Paterson	U.S. Pat. No. 5,108,941	April 28, 1992	Ex. 1008

Petitioner also relies on the Declarations of Gary Rubloff, Ph.D.
(Exs. 1002, 1029).

E. The Asserted Grounds

Petitioner asserts the following grounds of unpatentability (Pet. 3–4):

⁵ The '044 patent was filed on September 10, 2002 and does not claim priority to any earlier application. Ex. 1001, [22].

Claim(s) Challenged	Basis	References
1–4, 6–8, and 12–14	§ 103(a)	Fujimoto, Yaung, and Ho
5	§ 103(a)	Fujimoto, Yaung, Ho, and Paterson
9–11	§ 103(a)	Fujimoto, Yaung, Ho, and Sonogo
16, 19, and 22	§ 103(a)	Fujimoto and Ho
17, 18, and 20	§ 103(a)	Fujimoto, Ho, and Yaung
21	§ 103(a)	Fujimoto, Ho, and Sonogo
15	§ 103(a)	Fujimoto, Yaung, Ho, and Ohkawa
23	§ 103(a)	Fujimoto, Ho, and Ohkawa

II. ANALYSIS

A. The Law on Obviousness

The question of obviousness is resolved on the basis of underlying factual determinations including (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the prior art; (3) the level of ordinary skill in the art; and (4) objective evidence of nonobviousness. *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966). Prior art references must be “considered together with the knowledge of one of ordinary skill in the pertinent art.” *In re Paulsen*, 30 F.3d 1475, 1480 (Fed. Cir. 1994) (citation omitted). Also, “it is proper to take into account not only specific teachings of the reference but also the inferences which one skilled in the art would reasonably be expected to draw therefrom.” *In re Preda*, 401 F.2d 825, 826 (CCPA 1968). One seeking to establish obviousness based on more than one reference also must articulate sufficient reasoning with rational underpinning to combine teachings. *See KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 418 (2007).

B. Level of Ordinary Skill in the Art

Petitioner proposes that a person of ordinary skill in the art at the time of the alleged invention of the '044 patent “would have had a master’s degree or higher in a field relating to semiconductor manufacturing processes, such as material science, physics, electrical engineering, or other related subjects, and three to four years of experience in the design and fabrication of semiconductor devices. (Ex. 1002, ¶¶ 19-20.)” Pet. 5. Petitioner also states that “[m]ore education can supplement practical experience and vice versa.” *Id.* Patent Owner’s declarant, Mr. Brahmhatt, testifies that one of ordinary skill in the art at the time of the invention “is a person with a Bachelor’s of Science degree in material science, physics, electrical engineering, or chemical engineering and three to four years of practical experience in the development, design, processing, and manufacturing/testing of semiconductor chips and technology.” Ex. 2004 ¶ 33.

We find Petitioner’s proposal vague insofar as it includes the qualifier “or higher” to describe the level of education. The qualifier results in a range that is too broad to provide a meaningful indication of what knowledge and skills would have been possessed by one with ordinary skill in the art. Also, by definition, the level of ordinary skill is less than that of an expert. A “master’s degree or higher” is an advanced degree. Without Petitioner explaining why the level of “ordinary skill” is reflected by an advanced degree, we are not persuaded by Petitioner’s articulation of the level of ordinary skill.

For the foregoing reasons, we credit the testimony of Mr. Brahmhatt and find the level of ordinary skill is reflected by a bachelor of science degree in material science, physics, electrical engineering, or chemical

engineering, and three to four years of practical experience in the development, design, processing, and manufacturing/testing of semiconductor chips and technology.

C. Claim Construction

In an *inter partes* review, claim terms in an unexpired patent are interpreted according to their broadest reasonable construction in light of the specification of the patent in which they appear. 37 C.F.R. § 42.100(b) (2016); *Cuozzo Speed Techs., LLC v. Lee*, 136 S. Ct. 2131, 2142–46 (2016). Consistent with that standard, claim terms are generally given their ordinary and customary meaning, as would have been understood by one of ordinary skill in the art in the context of the entire disclosure. *See In re Translogic Tech., Inc.*, 504 F.3d 1249, 1257 (Fed. Cir. 2007). There are, however, two exceptions to that rule: “1) when a patentee sets out a definition and acts as his own lexicographer,” and “2) when the patentee disavows the full scope of a claim term either in the specification or during prosecution.” *Thornerv. Sony Comp. Entm’t Am. LLC*, 669 F.3d 1362, 1365 (Fed. Cir. 2012).

Only terms that are in controversy need to be construed, and only to the extent necessary to resolve the controversy. *See Wellman, Inc. v. Eastman Chem. Co.*, 642 F.3d 1355, 1361 (Fed. Cir. 2011); *Vivid Techs., Inc. v. Am. Sci. & Eng’g, Inc.*, 200 F.3d 795, 803 (Fed. Cir. 1999).

Petitioner has not proposed an express construction for any claim term. In the Decision on Institution, we determined that there was no need to construe expressly any term, but also stated that the claim term “mask” is generic and not limited to a hardmask, noting that the specification of the ’044 patent identifies three different types of masks, a hardmask, a photoresist mask, and a reticle mask. Paper 7, 10, 24. In the Patent Owner Response, Patent Owner argues that “mask” must be construed as only

covering a hardmask, because all claims require a photoresist over the mask and no person of ordinary skill would form a photoresist on top of a photoresist, and because in the field of semiconductor processing, there are only two types of masks, a hardmask or a photoresist. PO Resp. 24–25. We need not resolve the issue of whether the claimed “mask” is limited to a hardmask, because the grounds of unpatentability as presented by Petitioner all rely on a hardmask to meet the claimed “mask.” Thus, it remains the case that no term requires an express construction.

D. Alleged Unpatentability of Claims 1–4, 6–8,
and 12–14 as Obvious over Fujimoto, Yaung, and Ho

1. Fujimoto

Fujimoto relates to a method for manufacturing a semiconductor device, and more particularly to a method for forming contact holes for conductive strips passing through an insulating film, such as an interlayer insulating film. Ex. 1005, 1:9–13. Fujimoto explains that in conventional semiconductor devices, it is often required to provide two contact holes: (1) a contact hole that opens to the surface of the semiconductor substrate, and (2) another contact hole that opens to a conductor, such as a gate electrode under a protective film. *Id.* at 1:49–54. In that regard, Fujimoto further explains:

In the former [(1)], the contact hole can be formed by a single etching process in a specified position of the insulating film. In the latter [(2)], however, after the insulating film has been etched, the exposed protective film needs to be etched. Because the protective film has a different etching-resistant characteristic from that of the insulating film, their etching conditions differ to a large extent in the forming process of the two contact holes.

For this reason, in the conventional manufacturing method, it is necessary to separately carry out an etching process

using a mask for the contact hole that opens to the surface of the semiconductor substrate, and an etching process using a mask for the contact hole that opens to the conductive line under the protective film.

Id. at 1:55–2:1. According to the method of Fujimoto, “the protective film above the conductor, where the second contact hole is to be formed, is removed in advance, when the etched-away opening is formed to expose the top portion of the corresponding conductor from the surface of the insulating film, and the etched-away opening is refilled.” *Id.* at 2:41–45. Fujimoto summarizes as follows:

Therefore, according to the above-mentioned method of the present invention, a final etching process to form the first and second contact holes after refilling of the etched-away opening can be carried out substantially under the same condition, and therefore both contact holes can be formed collectively by an etching process using a single etching mask having arranged therein two opening patterns for the first and second contact holes.

Id. at 2:58–65.

2. Yaung

Yaung is directed to a method for making contacts in semiconductor transistors. Ex. 1006, 1:8–27, 2:31–37, 4:16–20. Yaung discloses a field effect transistor that includes gate oxide 12 formed under polysilicon layer 14. *Id.* at 4:47–54.

3. Ho

Ho is directed to a method for etching features in an integrated circuit wafer that incorporates at least one dielectric layer. Ex. 1007, Abstr. The wafer comprises a dielectric layer placed over a substrate. *Id.* at 7:17–18. A hardmask layer is placed over the dielectric layer, and a bottom antireflective coating (BARC) is placed over the hardmask layer. *Id.* at

7:20–22. A photoresist mask is placed over the hardmask layer. *Id.* at 7:22–23.

4. Claim 1

a.

Claim 1 recites: “A method for manufacturing a semiconductor device.” Ex. 1001, 4:20–21. As is noted by Petitioner (Pet. 8), Fujimoto discloses such a method. Ex. 1005, 1:9–13; 2:10–3:9 (cited at Pet. 8). Petitioner’s assertion also is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶¶ 53–55. We find that Fujimoto discloses a method for manufacturing a semiconductor device.

b.

Claim 1 further recites: “providing at least two active devices over a substrate, each of the active devices includes a gate electrode provided over a gate oxide, a silicide formed over the gate electrode, a cap formed over the silicide, and a pair of spaced-apart diffused regions formed in the substrate.” Ex. 1001, 4:22–26. Petitioner asserts that Fujimoto either alone or in combination with Yaung disclose this limitation. Pet. 8. For reasons discussed below, we find that Fujimoto alone and alternatively, Fujimoto in combination with Yaung, teach this limitation.

Fujimoto’s Figure 1(a), cited by Petitioner at page 10 of the Petition, is reproduced below:

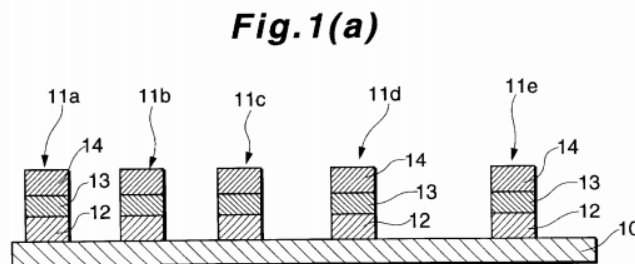


Figure 1(a) illustrates an intermediate structure in the execution of a semiconductor device manufacturing method according to Fujimoto. Ex. 1005, 3:13–15. With regard to Figure 1(a), Fujimoto states that a plurality of gate electrodes 11 for MOS (metal-oxide-semiconductor) transistors are formed in parallel and mutually spaced apart in an active region of a silicon semiconductor substrate 10. *Id.* at 3:37–40. Petitioner asserts that Fujimoto’s stacked layer structure “includes a polysilicon layer 12, tungsten silicide layer 13, and protective film 14 (made of silicon nitride) in that order.” Pet. 10–11 (citing Ex. 1005, 3:41–54, Fig. 1(a); Ex. 1002 ¶ 60). The assertion is supported by the cited evidence including the testimony of Dr. Rubloff. Ex. 1002 ¶ 60.

Petitioner identifies Fujimoto’s polysilicon layer 12 as the recited “gate electrode provided over a gate oxide.” Pet. 10. Petitioner explains that although Fujimoto itself identifies the entire stack structure, including polysilicon layer 12, tungsten silicide layer 13, and protective film 14, collectively, as forming “gate electrode 11,” one with ordinary skill in the art would have readily understood that polysilicon layer 12, on its own, is a gate electrode in the context of the ’044 patent. Pet. 10. That assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 59. Dr. Rubloff points out that the stacked structure of the ’044 patent, including gate electrode 16, silicide 18 over the gate electrode, and cap 20-2 over silicide 18, and the stacked structure of Fujimoto, including polysilicon layer 12, tungsten silicide layer 13 over polysilicon layer 12, and protective film 14 over the tungsten silicide layer 13, are the same. *Id.* ¶ 60.

With regard to identifying Fujimoto’s polysilicon layer 12 as the gate electrode provided over a gate oxide, Petitioner explains: “Although the figures of *Fujimoto* do not explicitly disclose that its polysilicon layer 12

(‘gate electrode’) is provided over a gate oxide, a [person of ordinary skill in the art] would have understood based on *Fujimoto*’s disclosure that it necessarily discloses a gate oxide film underneath the polysilicon layer 12.”

Pet. 11. The assertion is supported by the testimony of Dr. Rubloff, who explains:

Fujimoto discloses “removing unwanted portions of the stacked structure **and the gate oxide film** by selective etching with the protective film [14] used as the etching mask” after forming the gate electrodes 11 having the stacked structure (i.e., polysilicon layer 12, tungsten silicide layer 13, and protective film 14). (Ex. 1005 at 3:46–54 (emphasis added).) A person having ordinary skill in the art would have understood that “a gate oxide film” is an oxide layer underneath a “gate” that separates the gate electrode from the substrate, which was a typical configuration in semiconductor devices known to such a person prior to the alleged invention.

Ex. 1002 ¶ 61 (citing Pet. 11). Dr. Rubloff further explains:

Given that *Fujimoto* discloses that its figure 1 embodiment is directed to “MOS [metal **oxide** semiconductor] transistors” (Ex. 1005 at 3:37–40 (emphasis added)), a person having ordinary skill in the art would have known that the “gate oxide film” disclosed in *Fujimoto* would necessarily be included underneath the polysilicon layer 12 (“gate electrode”). This is because the structure of a MOS transistor (e.g., a MOS field effect transistor (MOSFET)) resembles a capacitor, and a dielectric film (e.g., gate oxide film) would necessarily be provided under the polysilicon layer for the MOSFET to perform its intended function. (Ex. 1002 at 112–113.)

Id. We credit the above-quoted testimony of Dr. Rubloff, and find it to be persuasive. Accordingly, for all of the reasons as discussed above, we find that *Fujimoto*’s polysilicon layer 12 is “a gate electrode provided over a gate oxide,” as recited in claim 1.

In the alternative, Petitioner asserts that in light of the combined teachings of *Fujimoto* and *Yaung*, it would have been obvious to one with

ordinary skill in the art “to form a gate oxide film underneath the polysilicon layer 12.” Pet. 12. The assertion is persuasive, as explained below.

Yaung is directed to a method for making contacts in semiconductor transistors. Ex. 1006, 1:8–27, 2:31–37, 4:16–20 (cited at Pet. 12). Yaung discloses a field effect transistor that includes gate oxide 12 formed under polysilicon layer 14. *Id.* at 4:47–54 (cited at Pet. 12). Thus, Petitioner correctly asserts that Yaung discloses forming a polysilicon layer over gate oxide for a field effect transistor. Pet. 12. Petitioner further asserts that in light of Fujimoto’s own disclosure regarding a “gate oxide film” in its MOSFET, and Yaung’s disclosure of forming gate oxide underneath a polysilicon layer, it would have been obvious to one with ordinary skill in the art to modify Fujimoto’s manufacturing process to form a MOSFET device such that its polysilicon layer is formed over a gate oxide film. Pet. 13. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 63. Specifically, Dr. Rubloff testifies:

A person having ordinary skill in the art would have been motivated to modify *Fujimoto*’s process in this way to ensure proper operation of the manufactured device. For example, as I discussed above, a person having ordinary skill in the art would have understood that a MOSFET functions like a capacitor, and a dielectric film (e.g., gate oxide film) would be needed under the polysilicon layer for the MOSFET to perform its intended function. (Ex. 1020 at 112–113.) Therefore, in my opinion, a skilled person would have recognized that the combined *Fujimoto*-*Yaung* method would have involved the combination of known elements (e.g., a gate oxide similar to the one disclosed by *Yaung* underneath the polysilicon layer 12 of *Fujimoto*) using a known technique (e.g., “gate oxide is typically formed by thermal oxidation” before forming the polysilicon layer (Ex. 1006 at 4:47–54)) that would have yielded the expected result of fabricating an operational MOSFET device. Given the disclosures of *Fujimoto* and *Yaung*, and the knowledge of one

skilled in the art, a person having ordinary skill in the art would have found using such techniques, as I discussed above, a predictable implementation at the time of the alleged invention of the '044 patent. Additionally, a person having ordinary skill in the art would have known and had the capability to implement the above modifications in such a way to ensure the process of manufacturing the semiconductor device disclosed by *Fujimoto* would be workable, as well as the resulting device being formed.

Ex. 1002 ¶ 63. We credit the above-quoted testimony of Dr. Rubloff because it is consistent with and supported by the cited evidence of record.

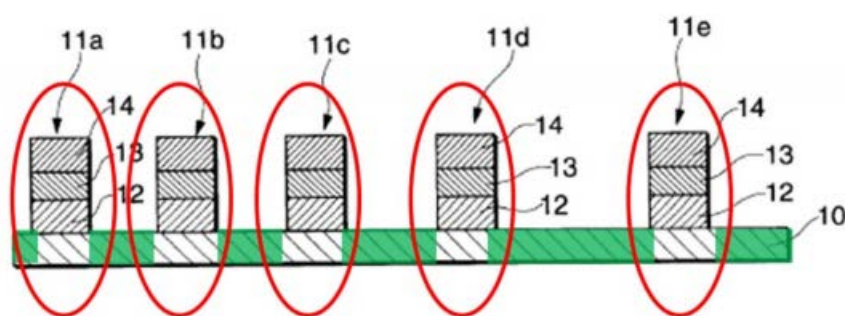
Petitioner identifies *Fujimoto*'s tungsten silicide layer 13 as satisfying the recited "silicide formed over the gate electrode" of claim 1. Pet. 14. According to Petitioner, silicide is formed in *Fujimoto* after formation of the polysilicon layer, so one with ordinary skill in the art would have understood that the tungsten silicide layer 13 is formed over polysilicon layer 12. Pet. 14–15. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 64. The relative positions of the layers also are illustrated in Figure 1(a) of *Fujimoto* reproduced above (cited at Pet. 15–16). For these reasons, we find that *Fujimoto* discloses the claimed silicide of claim 1.

Petitioner identifies *Fujimoto*'s protective film 14 as satisfying the recited "cap formed over the silicide" of claim 1. Pet. 15. Petitioner cites to column 3, lines 46–51, of *Fujimoto*, which describes that stack structures 11 are provided by depositing polysilicon and silicide, in that order, and then forming protective film 14 of silicon nitride on the stack structures. *Id.* That reading of *Fujimoto* is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 65. For these reasons, we find that *Fujimoto* discloses the claimed cap over the silicide.

With regard to claim 1's recited "pair of spaced-apart diffused regions formed in the substrate," Petitioner asserts: "Although *Fujimoto*'s figures do

not include a depiction of the source and drain regions, *Fujimoto* discloses this feature by noting that source and drain regions are formed spaced apart in the substrate 10.” Pet. 16 (citing Ex. 1005, 3:55–59). *Fujimoto* states: “Though not illustrated, by using the gate electrodes 11 each having a protective film 14 at the top portion as a mask, impurity atoms to form the source and drain regions are injected into the substrate 10 on either side of the gate electrodes 11 by ion implantation, for example.” Ex. 1005, 3:55–59. Petitioner’s assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 66 (cited at Pet. 16–17). Dr. Rubloff presents an annotated version of *Fujimoto*’s Figure 1(a), reproduced below:

Fig. 1(a)



Id. The annotated version of *Fujimoto*’s Figure 1(a) shows active devices in red circles and marks in green the general location of the source and drain regions in the substrate, within an intermediate structure in the execution of a semiconductor device manufacturing method according to *Fujimoto*. *Id.*

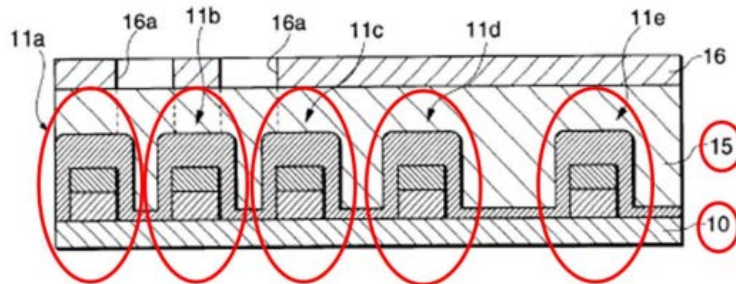
Dr. Rubloff testifies that *Fujimoto*’s source and drain regions are spaced-apart because they are formed on either side of gate electrodes 11 in the substrate. *Id.* Dr. Rubloff further testifies that a person having ordinary skill in the art would have known that the source and drain regions in *Fujimoto* are diffused regions. *Id.* ¶ 67. For these reasons, we find that

Fujimoto discloses the claimed “pair of spaced-apart diffused regions formed in the substrate.”

c.

Claim 1 further recites: “depositing a first layer of dielectric material over the substrate and active devices.” Ex. 1001, 4:27–28. Petitioner identifies Fujimoto’s interlayer insulating film 15 as the recited first dielectric layer of claim 1, as shown in Petitioner’s annotated version of Fujimoto’s Figure 1(c), reproduced below (Pet. 18–19):

Fig. 1(c)



The annotated version of Fujimoto’s Figure 1(c) shows a cross-sectional view of an intermediate structure undergoing the fabrication process of Fujimoto, and shows the deposition of interlayer insulating film 15. Ex. 1005, 3:13–15, 4:8–11. As noted by Petitioner (Pet. 19), Fujimoto describes that interlayer insulation film is made of silicon oxide film. Ex. 1005, 4:8–12. Dr. Rubloff testifies that a person of ordinary skill in the art would have known that silicon oxide is a dielectric material. Ex. 1002 ¶ 70. We find that Fujimoto discloses “depositing a first layer of dielectric material over the substrate and active devices.”

Claim 1 further recites: “providing a first photoresist over the first layer of dielectric material.” Ex. 1001, 4:30–31. Figure 1(d) of Fujimoto is reproduced below:

Fig. 1(d)

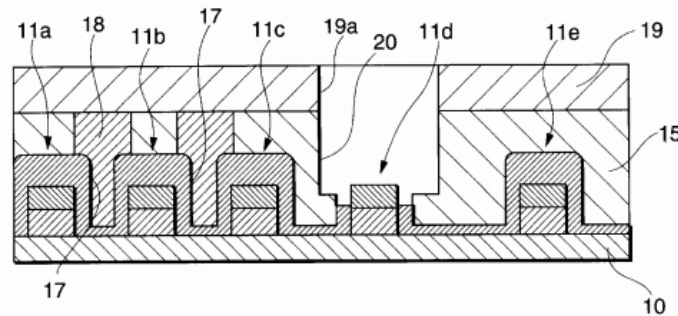


Figure 1(d) shows a cross-sectional view of an intermediate structure undergoing the fabrication process of Fujimoto, and shows the formation of etching mask 19 on insulating film 15. Ex. 1005, 3:13–15, 4:57–64.

Petitioner asserts that although Fujimoto does not explicitly disclose that etching mask 19 is a photoresist, it would have been obvious to one with ordinary skill in the art to provide a photoresist over the first layer of interlayer insulating film 15 in Fujimoto’s process based on the disclosure of Yaung. Pet. 20. Petitioner explains:

Yaung discloses a structure similar to the one disclosed in *Fujimoto* where a first interpolysilicon oxide (IPO1) layer 22[] is deposited over a conformal third insulating layer 20 made of silicon nitride (analogous to *Fujimoto*’s protective film 14 made of silicon nitride). (Ex. 1006, 5:22–37, FIG. 1; Ex. 1002, ¶ 73.) *Yaung* further discloses that a photoresist layer 24 is formed over the first IPO1 layer 22. (*Id.*) *Yaung* discloses that this **“photoresist layer 24 is patterned using conventional photolithographic techniques to form an etch mask having openings** for etching contact openings to the gate electrode 14.” (*Id.*, 5:32–37 (emphasis added).)

Pet. 20–21. Petitioner summarizes *Yaung*’s disclosure as follows: “*Yaung* discloses that the etch mask with openings (like *Fujimoto*’s etch mask 19 having an opening 19a) is formed by patterning the photoresist layer 4 using conventional photolithographic techniques. (Ex. 1002 ¶ 73).” Pet. 21. That

reading of Yaung is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 73.

Petitioner further explains that one with ordinary skill in the art would have looked to Yaung to refine the process of Fujimoto, given Yaung's disclosure of processes relating to semiconductor fabrication and contact hole formation, and also given that Fujimoto does not disclose any details regarding how its etching mask 19 is implemented. Pet. 22. Petitioner asserts that one with ordinary skill in the art would have been motivated to combine Fujimoto's teachings with Yaung's teachings such that Yaung's photoresist layer 24 would be used to implement Fujimoto's etching mask 19, because "it was well-known to construct an etching mask by patterning a photoresist layer using conventional photolithographic techniques, as disclosed by *Yaung*." Pet. 22–23. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 75. Dr. Rubloff further testifies:

[D]rawing from *Yaung* to implement *Fujimoto*'s etching mask 19 as a photoresist layer would have [been] only the mere substitution of one known element (photoresist layer similar to the photoresist layer 24 in *Yaung*) for another (etching mask 19 in *Fujimoto*) yielding the predictable result of forming contact holes at desired locations in the device using the patterned photoresist layer 24. Indeed, a person of ordinary skill in the art would have known that the use of a photoresist as a mask is one of the "simpler technique[s]" for making openings and it is cheaper to use a photoresist compared to a hardmask. (Ex. 1026 at 6:43–46; *see also* Ex. 1027 at 1:14–23 (discussing the tradeoff between using a hardmask and a photoresist, and explaining that using a photoresist is cheaper).)

Id. ¶ 76. We are persuaded by this testimony and find that the combined teachings of Fujimoto and Yaung disclose "providing a first photoresist over the first layer of dielectric material." We also find that Petitioner has

articulated adequate reasoning with a rational underpinning to combine the teachings of Fujimoto and Yaung in that manner.

d.

Claim 1 further recites: “defining and patterning the first photoresist.” Ex. 1001, 4:32. Petitioner asserts that by disclosing that opening 19a is formed in mask 19, Fujimoto discloses that the photoresist layer (corresponding to mask 19) in the combined Fujimoto-Yaung method would be “patterned.” Pet. 26. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 79. Petitioner asserts that by forming opening 19a at a specified location (i.e., above a desired gate electrode), Fujimoto discloses that the photoresist layer in the combined Fujimoto-Yaung method would be “defined.” Pet. 26. That assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 79. For these reasons, we find that the combined teachings of Fujimoto and Yaung disclose “defining and patterning the first photoresist.”

e.

Claim 1 further recites: “etching the first layer of dielectric material unmasked by the first photoresist to form a first opening, wherein the first opening exposes a first silicide of a first active device.” Ex. 1001, 4:33–36. Petitioner asserts that the combined Fujimoto-Yaung method discloses etching interlayer insulating film 15 (first layer of dielectric material) unmasked by the etching mask (photoresist layer) to form an opening 20. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 81.

Petitioner also asserts that the combined Fujimoto-Yaung process discloses that opening 20 would expose tungsten silicide layer 13. Pet. 28. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 81. Dr. Rubloff further notes that opening 20 exposes tungsten silicide layer 13

because Fujimoto describes that protective film 14 is removed from the etched-away opening. *Id.* ¶¶ 83–84. Fujimoto describes that protective film 14 covers polysilicon layer 12 and tungsten silicide layer 13 in gate electrodes for MOS transistors. Ex. 1005, 3:37–46. We find that the combined teachings of Fujimoto and Yaung disclose “etching the first layer of dielectric material unmasked by the first photoresist to form a first opening, wherein the first opening exposes a first silicide of a first active device.”

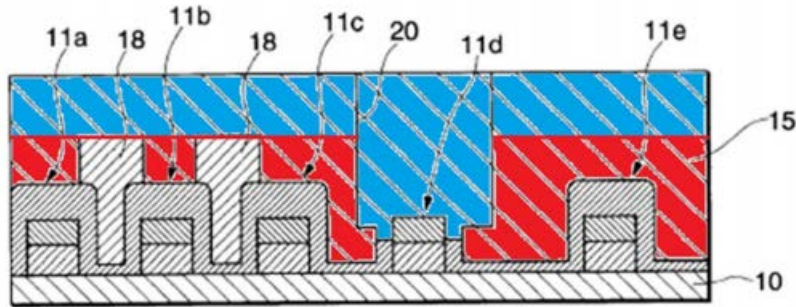
f.

Claim 1 further recites: “removing the first photoresist.” Ex. 1001, 4:17. Fujimoto describes that after the etched-away opening is formed, etching mask 19 is removed. Ex. 1005, 5:58–59 (cited at Pet. 29). Dr. Rubloff testifies that one with ordinary skill in the art “would have understood that in the combined *Fujimoto-Yaung* method, the etching mask 19 (which is implemented by a photoresist layer similar to Yaung’s photoresist layer 24) is removed.” Ex. 1002 ¶ 85. For these reasons, we find that the combined teachings of Fujimoto and Yaung disclose “removing the first photoresist.”

g.

Claim 1 further recites: “depositing a second layer of dielectric material over the first layer of dielectric material and in the first opening.” Ex. 1001, 4:38–39. An annotated version of Figure 2(a) is reproduced below (with blue and red colored annotations added by Petitioner):

Fig.2(a)



Pet. 31. Figure 2(a) shows a cross-sectional view of an intermediate structure undergoing the fabrication process of Fujimoto, and shows the deposition of another layer of silicon oxide, which is the same material as that of insulating film 15, after etching mask 19 is removed. Ex. 1005, 3:15–17, 5:58–61. Petitioner identifies the layer of silicon oxide, shown in blue in the annotated figure and deposited over insulation film 15 and opening 20, as the second layer of dielectric material in claim 1. Pet. 31. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶¶ 87–88 (cited at Pet. 31). For these reasons, we find that the combined teachings of Fujimoto and Yaung disclose “depositing a second layer of dielectric material over the first layer of dielectric material and in the first opening.”

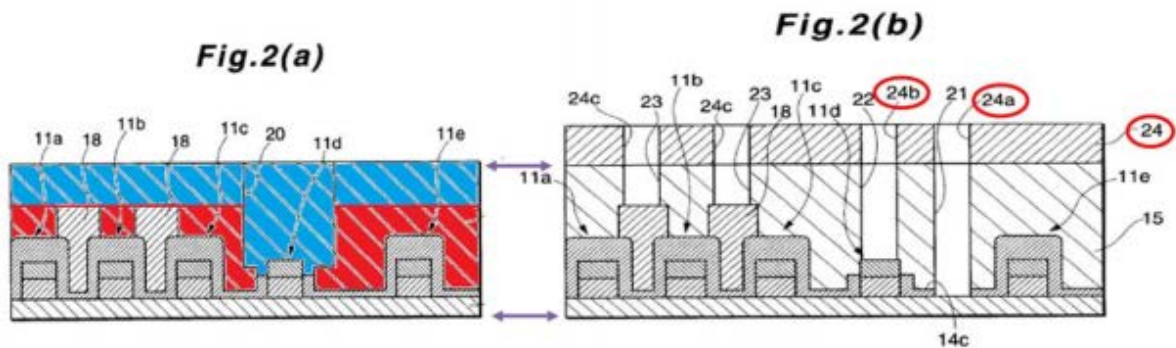
h.

Claim 1 further recites: “providing a mask over the second layer of dielectric material.” Ex. 1001, 4:41–42. For this limitation, Petitioner cites Fujimoto (*see* Pet. 33), which states:

After [depositing a second layer of silicon oxide as shown in Figure 2(a)], as shown in FIG. 2(b), on the insulating film 15, an etching mask 24 is formed, which has openings 24a and 24b formed respectively to form the first contact hole 21 to open the active region of the substrate 10 and the second contact hole 22 to open to the gate electrode 11.

Ex. 1005, 5:65–6:4. On that basis, Petitioner asserts that Fujimoto provides etching mask 24 over the second layer of dielectric material, i.e., the silicon oxide over the first insulating film 15. Pet. 34. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 92.

On page 35 of the Petition, Petitioner provides a side-by-side comparison of Fujimoto’s Figures 2(a) and 2(b), both annotated by Petitioner, to illustrate deposition of etching mask 24. The annotated Figures 2(a) and 2(b) are reproduced below:



Annotated Figures 2(a) and 2(b) of Fujimoto show a cross-sectional view of intermediate structures undergoing the fabrication process of Fujimoto at two different but consecutive points in the process. Ex. 1005, 3:15–17, 5:65–6:4.

Petitioner further proposes to implement Fujimoto’s etching mask 24 by a specific mask structure similar to that disclosed in Ho. Pet. 35–36. Petitioner explains “*Fujimoto* generally describes an etching mask 24 without specifying its construction or configuration and therefore a [person of ordinary skill in the art] would have been motivated to look to another reference that provides additional detail regarding the makeup of an etching mask.” *Id.* at 36. Petitioner identifies Ho as such a reference. *Id.* at 35–36. Figure 4A of Ho is reproduced below:

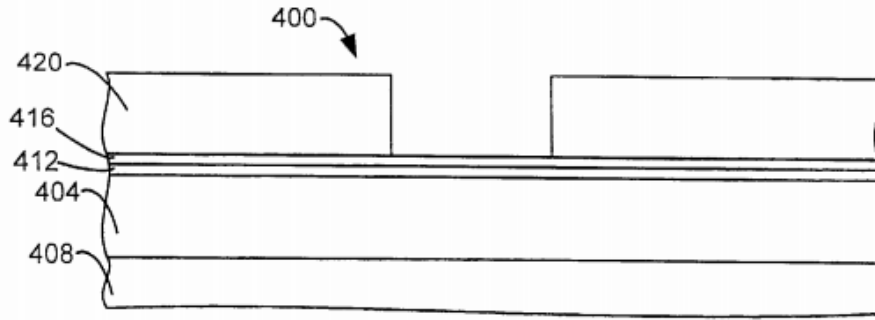


FIG. 4A

Figure 4A is a schematic cross-section of a wafer that is etched by a process disclosed in *Ho*. Ex. 1007, 4:39–40.

Petitioner explains the etching mask structure shown in Figure 4A of *Ho*, as follows:

Ho is directed to etching processes of semiconductor wafers, similar to *Fujimoto*. (*Id.*; see also *id.*, ¶¶ 42-43.) (Ex. 1007, 1:25-30, 4:1-11.) *Ho* discloses a semiconductor structure similar to *Fujimoto*'s in which a dielectric layer 404 is placed over a substrate 408. (*Id.*, 7:16–24.) A hardmask layer 412 (“mask”) is placed over the dielectric layer 404. (*Id.*) A bottom antireflective coating (BARC) 416 is placed over the hardmask layer 412. (*Id.*) A photoresist mask 420 (“second photoresist”) is placed over the hardmask layer 412. (*Id.*) Therefore, *Ho* discloses an etching mask structure that is a combination of a hardmask layer 412, antireflective coating 416, and a photoresist mask 420. (*Id.*)

Pet. 35.

With respect to a motivation to combine the teachings of *Ho* with those of *Fujimoto*, Petitioner further explains:

It would have been obvious to a POSITA to further modify the *Fujimoto-Yaung* process based on *Ho*'s teachings to implement *Fujimoto*'s etching mask 24 using an etching mask structure similar to *Ho* that includes a photoresist mask over a BARC layer and a hardmask layer in order to improve the etching of the underlying second layer of insulating film 15

(“second layer of dielectric material”) in *Fujimoto*. (Ex. 1002, ¶¶ 94–97.)

In this regard, *Ho* discloses the details of layers making up an etching mask structure such as the combination of hardmask layer 412, BARC 416, and photoresist mask 420. (*Id.*) Moreover, *Fujimoto* discloses that two openings 21 and 22 are etched using the mask 24, and that the etching involves penetrating to different structures (gate electrode and source/drain/substrate levels) at different distances from the mask 24. (*Id.*) This would have motivated a person of ordinary skill in the art to consider using a hardmask (i.e., an inorganic material such as silicon nitride) for mask 24. (*Id.*) An additional advantage of *Ho*’s etching mask structure compared to an etching mask made solely of photoresist would have been that the etching mask structure allows for “maintain[ing] critical dimensions” in the etching procedure(s) even if the photoresist is etched away during the etching. (*Id.*; Ex. 1007, 9:35–50.) Moreover, by including the BARC layer in the etching mask structure under the photoresist mask, undesirable standing wave patterns would have been reduced. (Ex. 1002, ¶ 97, citing Ex. 1017 (Campbell, *The Science and Engineering of Microelectronic Fabrication*, “*Campbell*”), 176-78.)

Pet. 36–37. The above-noted explanations are supported by the cited testimony of Dr. Rubloff. See Ex. 1002 ¶¶ 94–97.

Petitioner asserts that based on *Ho*’s disclosure regarding its etching mask structure, one with ordinary skill in the art would have been motivated to implement *Fujimoto*’s etching mask 24 using a combination of a photoresist mask over a BARC layer and hardmask layer. Pet. 37. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶¶ 98–99. Petitioner further asserts that making that combination would have constituted the mere substitution of one known element for another and would have predictably resulted in an etching mask structure that allows for the etching of the underlying dielectric layer to different depths to contact

both the gate electrode and the silicon substrate. That further assertion also is supported by the testimony of Dr. Rubloff. *Id.*

Notwithstanding the contrary arguments of Patent Owner, which we discuss below, we determine that Petitioner has shown adequate motivation for one with ordinary skill to implement Fujimoto’s etch mask 24 by an etch mask structure as disclosed by Ho, i.e., an etch mask structure including a photoresist layer, a BARC layer, and a hardmask layer, with the photoresist at the top, the BARC layer in the middle, and the hardmask at the bottom.

According to Patent Owner, “Ho specifically instructs the person of ordinary skill in the art not to use fluorine based etchants because that type of etchant will cause unwanted lateral etching of the hardmask.” PO Resp. 29 (citing Ex. 1007, 3:52–56, 10:6–7.).⁶ The cited portions of Ho are reproduced below:

A problem *may exist* with the use of fluorine. First, the use of fluorine *may have a negative impact* on critical dimension, CD, control during the etching. This is because fluorine *may cause lateral etching* of both the hardmask material and the organic low-K material.

Ex. 1007, 3:52–56 (emphases added).

Since Fluorine is not used in the invention, critical dimensions control may be improved and bowing *may be* reduced.

Id. at 10:6–7 (emphasis added).

Petitioner asserts that Patent Owner misreads and exaggerates these statements from Ho as “an absolute admonition against using a hardmask

⁶ Patent Owner’s expert, Mr. Dhaval Brahmhatt, testifies that “lateral etching will erode the hardmask, reduce the precision of the etch, and negatively affect the critical dimension of the resulting structure.” Ex. 2004 ¶ 60 (cited at PO Resp. 30).

with a fluorine-based etch.” Reply 7. We agree with Petitioner. We find that the above-quoted text from Ho does not constitute a prohibition on using fluorine based etchants on a hardmask. As Petitioner explains:

Ho simply states that “[a] problem *may exist*” as the “fluorine *may have a negative impact* on critical dimension, CD, control during etching” “because fluorine *may cause lateral etching*” of the hardmask material. (Ex. 1007, 3:52–55 (emphasis added).) A [person of ordinary skill in the art] would not have understood such statements to be an absolute and unequivocal admonition against using a hardmask with a fluorine-based etchant. (Ex. 1029, ¶¶ 3–6.)

Instead, when read in the context of *Ho*’s overall disclosure, a [person of ordinary skill in the art] would have understood these statements in *Ho* to mean that if you use a fluorine-based etchant with a hardmask, you may have to sacrifice some lithographic resolution in order to achieve other benefits (e.g., elimination of “grass” that results from micromasking)—a tradeoff that was well-known and well-understood by a [person of ordinary skill in the art]. (*Id.*, ¶ 5; *see also* Ex. 2005, 146:7–19, 147:4–16, 148:4–150:4.) Indeed, *Ho* states that at high ion densities (i.e., when a higher etching rate is desired), “fluorine may be required to form volatile by products with sputtered materials” (Ex. 1007, 9:51–10:5.) *Ho* would not have made this statement if a hardmask could not be used with a fluorine-based etchant. (Ex. 1029, ¶ 6; *see also* Ex. 2005 at 146:7–19, 147:4–16, 148:4–150:4.)

Reply 8. These explanations are supported by the cited testimony of Dr. Rubloff. For instance, Dr. Rubloff testifies:

The use of the term “may” in *Ho*’s statements is telling as it would have suggested to a person of ordinary skill in the art that it is not necessarily the case that any meaningful lateral etching will occur. I add the qualification “meaningful” because in any etching system, there will be some etching of the mask regardless of the etching gas or the type of mask. . . . *Ho*’s statements therefore suggest that it is not certain that fluorine will meaningfully etch a hardmask.

Ex. 1029 ¶ 4. Dr. Rubloff further testifies:

Ho explains the well-known phenomenon of micromasking in which an etchant will sputter away a portion of the hardmask such that small particles of the hardmask material are deposited on the surface being etched, thereby masking the material underneath which is yet to be etched. (Ex. 1007 at 3:25–50.) These small particles have the visual appearance of “grass.” (*Id.*) To mitigate “grass,” fluorine was added to the etching gases with the understanding that the addition of fluorine “may” result in a bit of lateral etching of the hardmask and some lithographic resolution may have to be sacrificed. (*Id.*) This tradeoff was well-known and well-understood by a person of ordinary skill in the art.

Ex. 1029 ¶ 5. Dr. Rubloff still further testifies:

Ho states that at high ion densities (i.e., when a higher etching rate is desired), “fluorine may be required to form volatile by products with sputtered materials . . .” Ex. 1007 at 9:51–10:5.) *Ho* would not have made this statement if a hardmask could not be used with a fluorine-based etchant.

Ex. 1029 ¶ 6.

We recognize that the testimony of Patent Owner’s expert, Mr. Dhaval Brahmbhatt, is to the contrary. Mr. Brahmbhatt testifies that “*Ho specifically warns against* the use of the same type of fluorine based etchant when performing the contact etch step because that type of etchant *will cause* unwanted lateral etching of the hardmask.” Ex. 2004 ¶ 60. But Mr. Brahmbhatt cites to the same permissive “may exist” and “may have a negative impact” language in *Ho*, without explaining how the permissive “may” disclosure is transformed into a “will cause unwanted lateral etching” understanding. *Id.* Moreover, on cross-examination, Mr. Brahmbhatt stated: “So there might be situations where you will not see any noticeable etching at all in the hardmask, even with the fluorine.” Ex. 1028, 89:22–24.

Overall, we credit the testimony of Dr. Rubloff over the testimony of Mr. Brahmhatt. We find that one with ordinary skill in the art would not have interpreted Ho as prohibiting the use of fluorine-based etchant to etch a hardmask. Rather, we find that Ho discloses to one with ordinary skill in the art that if fluorine-based etchant is used, it “may” result in a bit of lateral etching of the hardmask and some lithographic resolution might be sacrificed as a tradeoff. *See* Ex. 1029 ¶ 5.

In addition, Patent Owner argues that “Ho’s hardmask cannot be used in Fujimoto’s process because Fujimoto’s contact etch is performed using precisely the type of fluorine-based etchant that Ho says should not be used with its mask.” PO Resp. 31. Patent Owner notes that Fujimoto discloses using fluorocarbon (CF) etching gas. *Id.* (citing Ex. 1005, 6:8–10). Patent Owner asserts that fluorocarbon etchants “are exactly the type of fluorine-based etchants that can etch Ho’s hardmask material,” and that using such an etchant “would result in unwanted lateral etching and make it difficult to maintain the critical dimension.” *Id.* (citing Ex. 2004 ¶ 63).

According to Patent Owner, Fujimoto “only” teaches the use of CF or fluorine-based etchants for etching the contact hole. *Id.* at 34. Patent Owner asserts that “[t]he mere assumption that other suitable etchants would have been available is insufficient to support a Board finding of obviousness.” *Id.* at 35. Patent Owner further asserts that the “only suitable etchants” for performing dry etching of silicon oxide at the time of the ’044 patent were fluorine-based. *Id.* at 35 (citing Ex. 2004 ¶ 67; Ex. 2006 at 9.5.1). Patent Owner explains:

When fluorine-based etchants react with silicon oxide, the byproduct is SiF₄, a highly volatile gas that can be easily exhausted from the etching chamber. Ex. 2004 at ¶ 68. Other etchants like chlorine or bromine-based etchants form

byproducts (SiCl_4 and SiBr_4) that are less volatile and more difficult to ensure complete removal. *Id.* at ¶ 68. *See also* Ex. 2007 (Dry Etching Technology for Semiconductors) at Table 2.3 (showing boiling point of SiF_4 as -95°C , SiCl_4 as 57.6°C , and SiBr_4 as 153.4°C). If the byproduct isn't removed completely, the contamination could lead to metal corrosion or cross contamination of other processes. Ex. 2004 at ¶ 68. This is why a person of ordinary skill in the art would understand that the only type of etchant suitable for dry etching of silicon oxide are the fluorine-based CF etchants disclosed in Fujimoto. *Id.*

PO Resp. 37–38.

For the above-noted reasons, Patent Owner asserts that using an etching process including fluorine-based etchant with Ho's hardmask would result in loss of critical dimension control, and therefore one with ordinary skill in the art seeking to improve on critical dimension control, as asserted by Petitioner, "would not look to using Ho's hardmask." *Id.* at 32.

Additionally, Patent Owner notes that while Fujimoto must etch both oxide and nitride materials to complete formation of a substrate contact hole, Ho identifies silicon oxide and silicon nitride for use as hardmask material. *Id.* at 32–33. Patent Owner states that "[a] mask that gets etched during the etching process is not a mask at all," and therefore "[n]o one of ordinary skill would make such a combination [Ho's hardmask and Fujimoto's etching process]." *Id.* at 33.

We do not agree with Patent Owner arguments. First, we agree with Petitioner that "*Ho's* disclosure of a hardmask cannot be ignored for purposes of combination with *Fujimoto* simply because *Ho* identified an alleged shortcoming of a hardmask." Reply 9. This line of argument comports with the guidance of our reviewing court that "[a] reference must be considered for everything it *teaches* by way of technology and is not limited to the particular *invention* it is describing and attempting to protect."

EWP Corp. v. Reliance Universal Inc., 755 F.2d 898, 907 (Fed. Cir. 1985); *see also In re Applied Materials, Inc.*, 692 F.3d 1289, 1298 (Fed. Cir. 2012) (“A reference must be considered for everything that it teaches, not simply the described invention or a preferred embodiment.”). Second, Mr. Brahmhatt acknowledged at his deposition that it was possible to use a hardmask with a fluorine-based etchant. Ex. 1028, 89:22–24, 85:14–86:8. Third, the ’044 patent itself describes using a hardmask together with fluorine-based etchants. Ex. 1001, 3:66–4:10.

Fourth, the evidence of record also indicates that non-fluorine-based etchants were known to persons with ordinary skill in the art. In that regard, we credit the following testimony of Dr. Rubloff because it is consistent with and supported by the cited evidence of record:

Other non-fluorine based etchants were well known and suitable for etching silicon dioxide. For example, chapter 2 of the Jaeger book, which I submitted with my opening declaration, has a section on dry etching. (See Ex. 1021 at 24, section 2.2.2.) In that section, *Jaeger* states that for “plasma etching . . . [t]he plasma contains fluorine **or chlorine** ions which etch silicon dioxide” confirming what a person of ordinary skill in the art knew—that dry etching of silicon dioxide can be performed using a chlorine-based etching gas. (*Id.*, emphasis added.)

Ex. 1029 ¶ 8. In contrast, we do not credit the testimony of Mr. Brahmhatt that “[a] person of ordinary skill in the art would understand that [] Fujimoto must use a fluorine-based etchant to perform its contact etch step,” and that “[t]he only suitable etchants for performing dry etching of silicon dioxide at the time of the ’044 patent were fluorine-based.” Ex. 2004 ¶¶ 67–68. The reasoning Mr. Brahmhatt provided in support of his opinion is that fluorine-based etchants were “most commonly used” and “generally accepted and preferred.” *Id.* ¶ 68. That reasoning fails to support

sufficiently his opinion that fluorine-based etchants must be used or that such etchants are the only suitable choice for dry etching of silicon oxide. *Id.* ¶ 68.

In addition, Mr. Brahmbhatt’s discussion about non-fluorine-based etchants forming byproducts that are less volatile and thus “more difficult to ensure complete removal” also fails to support his opinion that fluorine-based etchants must be used for dry etching of silicon oxide. For instance, Mr. Brahmbhatt’s testimony does not consider certain techniques that one with ordinary skill in the art would have known for mitigating the drawbacks of non-fluorine-based etchants. According to Dr. Rubloff, one with ordinary skill in the art would have been capable of ensuring that any such “less volatile” byproducts are removed to a sufficient extent so as not to cause corrosion problems. Ex. 1029 ¶ 9. In light of this evidence, we decline to find, as Patent Owner urges (PO Resp. 35), that the only suitable etchants for performing dry etching of silicon oxide at the time of the ’044 patent were fluorine-based.

Patent Owner also argues that if Ho’s hardmask structure were used with the Fujimoto process, it would be severely etched by Fujimoto’s fluorine-based etchants and, consequently, the mask would lose its ability to function as an etch mask. PO Resp. 20. Patent Owner asserts that “[a] mask that gets etched during the etching process is not a mask at all.” *Id.* at 33. However, as discussed above, one with ordinary skill in the art would have known that non-fluorine-based etchants were a known alternative at the time of the ’044 patent. Also as noted above, the ’044 patent itself discloses use of a hardmask in combination with a fluorine-based etchant. Ex. 1001, 3:66–4:10.

Similarly, Patent Owner argues that Ho's hardmask would be severely eroded if not entirely consumed during Fujimoto's etching process, because Fujimoto's process etches oxide and nitride and those are the materials forming Ho's hardmask. PO Resp. 32–33. We do not agree with this argument because it incorrectly assumes that Ho's hardmask materials are limited to silicon oxide or silicon nitride. Indeed, Ho discloses other hardmask materials: "Hard mask may be formed of SiO₂, Si₃N₄, or other hard mask materials, specifically inorganic hard mask materials." Ex. 1007, 3:16–18. In that regard, Dr. Rubloff testifies:

[A] person of ordinary skill in the art would have known that a hardmask could be made out of material other than silicon oxide or silicon nitride. . . . For instance, a person of ordinary skill would have known of a polysilicon hardmask. (Ex. 1030 (Nulty) at 4:34–35, 11:6–8.) It was within the capability of a person of ordinary skill to select the appropriate hardmask material depending on the materials being etched and the etch chemistry being used.

Ex. 1029 ¶ 10. We credit the above-quoted testimony of Dr. Rubloff because it is consistent with and supported by the cited evidence of record, and we find it persuasive. And we agree with Petitioner's statement that in an obviousness analysis, a person of ordinary skill in the art is not an automaton, but is a person of ordinary creativity. *See KSR*, 550 U.S. at 421; *In re Sovish*, 769 F.2d 738, 743 (Fed. Cir. 1985). Thus, one with ordinary skill in the art would have known to choose a hardmask material that is appropriate for the etchant being used.

Finally, Patent Owner contends that Petitioner's stated motivation for one with ordinary skill in the art to apply Ho's hardmask in Fujimoto's process, i.e., to improve critical dimension control for the contact etch, is flawed because using Ho's hardmask in Fujimoto's process "would result in

unwanted lateral etching and make it difficult to maintain the critical dimension.” PO Resp. 31–32. The argument is misplaced. Potential imperfections, especially those which may be addressed by ordinary skill as discussed above, do not undermine the overall motivation to obtain benefits by adopting a hardmask structure like that disclosed in Ho.

Petitioner explains “*Fujimoto* generally describes an etching mask 24 without specifying its construction or configuration and therefore a POSITA would have been motivated to look to another reference that provides additional detail regarding the makeup of an etching mask.” Pet. 36 (citing Ex. 1002 ¶¶ 94–97). Given the lack of disclosure in *Fujimoto* about the structure of etching mask 24, the detailed disclosure in Ho of its mask structure provides an improvement for performing the contact etch in *Fujimoto* in all aspects including that of providing critical dimension control. The motivation as articulated by Petitioner is not complex.

In any event, Dr. Rubloff specifically explains a particular benefit provided by the mask structure disclosed by Ho,

In this regard, *Ho* discloses the details of layers making up an etching mask structure such as the combination of hardmask layer 412, BARC 416, and photoresist mask 420. A person of ordinary skill in the art would have known that a photoresist would have been provided over a hardmask to define the openings in the hardmask after which the photoresist can be removed. (Ex. 1007 at 9:35–50.) Then, an underlying dielectric layer would have been etched using the openings defined in the remaining hardmask layer. (*Id.*) The benefit of providing the hardmask layer under the photoresist in an etching mask structure such as in *Ho* would have been that the etching mask structure allows for “maintain[ing] critical dimensions” in the etching procedure(s) even if the photoresist is etched away during the etching. (*Id.*) That is, an additional advantage of *Ho*’s etching mask structure compared to an etching mask made solely of photoresist would have been that the etching mask structure

allows for “maintain[ing] critical dimensions” in the etching procedure(s). (*Id.*)

Ex. 1002 ¶ 96 (cited at Pet. 36). We credit this testimony of Dr. Rubloff because it is consistent with and supported by the cited evidence of record. It supports Petitioner’s stated motivation for adopting a mask structure like that disclosed in Ho within Fujimoto’s process.

For the foregoing reasons, we find that the combined teachings of Fujimoto, Yaung, and Ho disclose the step of “providing a mask over the second layer of dielectric material.”

i.

Claim 1 further recites: “providing a second photoresist over the mask.” Ex. 1001, 4:43. As discussed above in connection with the claimed step of “providing a mask over the second layer of dielectric material” (*see supra* § II.D.4.h), one of ordinary skill in the art would have known to use a mask structure like that disclosed in Ho within Fujimoto’s etching process. Because Ho’s mask structure includes a photoresist layer over a hardmask,⁷ as discussed above, we find that the combined teachings of Fujimoto, Yaung, and Ho disclose the step of “providing a second photoresist over the mask.”

Claim 1 further recites: “defining and patterning the second photoresist.” Ex. 1001, 4:44. Petitioner explains that openings 24a and 24b would have been formed in the etching mask of the combined Fujimoto-Yaung-Ho method because Fujimoto discloses forming

⁷ “In this example, a hardmask layer 412 is placed over the dielectric layer 404. A bottom antireflective coating (BARC) 416 is placed over the hardmask layer 412. A photoresist mask 420 is placed over the hardmask layer 412.” Ex. 1007, 7:16–24 (cited at Pet. 35).

openings 24a and 24b in the etching mask 24, which is replaced by the mask structure of Ho in Petitioner’s proposed combination. Pet. 38–39. The assertion is logical and supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 102. Dr. Rubloff testifies: “A person of ordinary skill in the art would have understood and Ho confirms, in order to form such openings 24a and 24b in the etching mask structure, the photoresist (‘second photoresist’) of the etching mask structure would necessarily have to be defined and patterned.” *Id.* Dr. Rubloff further testifies:

Therefore, because the photoresist mask 420 [in *Ho*] has a hole formed therein, a person of ordinary skill in the art would have understood that *Ho*’s photoresist mask 420 is “pattern[ed].” And because the hole in the photoresist mask 420 is defined at a desired etching location to subsequently etch the underlying BARC layer and hardmask layer, a person of ordinary skill in the art would have understood that the photoresist mask 420 is “defin[ed].” (*Id.*; Ex. 1007 at 9:40–43 (explaining that the “hard mask layer is used to provide patterning to maintain critical dimensions after the photoresist layer has been etched away.”).) (*See also* my analysis and citations above for claim element 1(e) explaining the defining and patterning of first photoresist.)

Ex. 1002 ¶ 104 (cited at Pet. 40). Dr. Rubloff further still testifies:

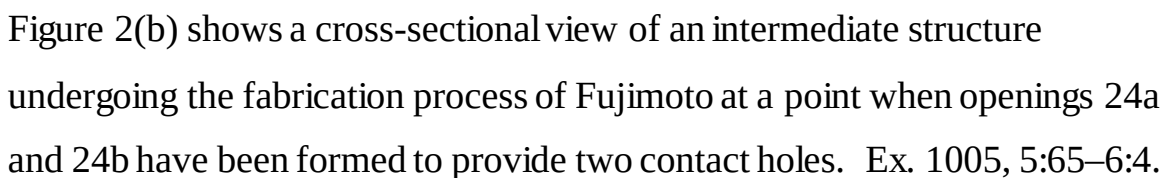
Similarly, to form openings 24a and 24b in the etching mask structure of the combined *Fujimoto-Yaung-Ho* method, the photoresist mask in the etching mask structure would necessarily have to be defined and patterned to meet *Fujimoto*’s etching objectives (*e.g.*, to ensure that the contact holes 21 and 22 are formed in the second layer of interlayer insulating film 15 in a subsequent etching step). (*See infra*, Section IX.A.1(k).)

Ex. 1002 ¶ 105 (cited at Pet. 40).

As outlined above, Petitioner asserts that the *Fujimoto-Yaung-Ho* combination teaches “defining and patterning the second photoresist.”

Pet. 38. Patent Owner does not present arguments specifically directed to the step of defining and patterning the second photoresist. Based on the

Fig.2(b)



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hole 21 exposes one of the pair of spaced-apart diffused source/drain regions (shown in green at the bottom of annotated Figure 2(b)) of an adjacent active device. *Id.* The assertions are supported by the testimony Dr. Rubloff.

Ex. 1002 ¶¶ 109–110. In particular, Dr. Rubloff testifies that both opening 20 and contact hole 22 lead to gate electrode 11d and thus the two must be aligned. *Id.* ¶ 109. Fujimoto also describes that contact hole 21 is “open to the active region of the substrate 10” and that contact hole 22 is “open to the gate electrode, with the protective film 14 eliminated.”

Ex. 1005, 5:67–6:3 (cited at Pet. 41).

Relying on the arguments and evidence discussed above, Petitioner asserts that the combined teachings of Fujimoto, Yaung, and Ho teach the limitation “forming a second opening and a third opening, wherein the second opening is aligned with the first opening and exposes the first silicide of the first active device, and the third opening exposes one of the pair of the spaced-apart diffused regions of a second active device.” Pet. 41. Patent Owner does not present arguments specifically directed to this limitation. Based on the analysis provided by Petitioner, we find that the combined teachings of Fujimoto, Yaung, and Ho disclose “forming a second opening and a third opening, wherein the second opening is aligned with the first opening and exposes the first silicide of the first active device, and the third opening exposes one of the pair of the spaced-apart diffused regions of a second active device.”

For the foregoing reasons, Petitioner has established, by a preponderance of the evidence, that claim 1 would have been obvious over Fujimoto, Yaung, and Ho.

5. Claims 2–4, 6, 8, and 12–14

For reasons discussed below, we find that Petitioner has established, by a preponderance of the evidence, that each of claims 2–4, 6, 8, and 12–14 would have been obvious over Fujimoto, Yaung, and Ho.

Claim 2 depends from claim 1 and further recites: “wherein the two active devices share one of the pair of the spaced-apart diffused regions.” Ex. 1001, 4:50–52. Petitioner adequately accounts for the added limitation of claim 2 by citing portions of Fujimoto and the testimony of Dr. Rubloff. Pet. 43. Fujimoto describes that active devices 11d and 11e share the pair of spaced-apart source/drain diffused regions. Ex. 1005, 3:37–40, 55–59 (cited at Pet. 43). Figure 1(a) of Fujimoto (cited at Pet. 43) also shows the same. For claim 2, Patent Owner advances no argument separate from those it has presented for independent claim 1, which we have discussed and rejected above. We find that the combined teachings of Fujimoto, Yaung, and Ho additionally disclose the feature “wherein the two active devices share one of the pair of the spaced-apart diffused regions.”

Claim 3 depends from claim 1 and further recites: “wherein the first layer of dielectric material may be comprised of boro-phospho silicate glass, tetraethylorthosilicate, or high-density plasma.” Ex. 1001, 4:53–56. Petitioner asserts that the added limitation of claim 3 should not be given any weight, because it is phrased as an optional limitation by using the phrase “may be comprised.” Pet. 45. Patent Owner does not provide a response to that argument. We agree with Petitioner. Based on the use of the permissive phrase “may be comprised,” claim 3 does not “require” the first layer of dielectric material to include boro-phospho silicate glass or some other particular material. *In re Johnston*, 435 F.3d 1381, 1384 (Fed. Cir. 2006) (“As a matter of linguistic precision, optional elements do not

narrow the claim because they can always be omitted.”). Patent Owner advances no argument separate from those it has presented for independent claim 1, which we have discussed and rejected above.

Claim 4 depends from claim 1 and further recites: “planarizing the first layer of dielectric material through chemical-mechanical polishing.” Ex. 1001, 4:57–59. Petitioner asserts that Fujimoto in combination with Yaung and Ho “discloses or suggests” this added limitation. Pet. 48. In that regard, Petitioner asserts:

Fujimoto does not expressly disclose a technique for planarizing the first layer of interlayer insulating film 15, including doing so by chemical mechanical polishing (CMP). (Ex. 1002, ¶ 119–20.) It would have been obvious to implement such techniques in the combined *Fujimoto-Yaung-Ho* process based on the disclosure of *Yaung* and the knowledge of a POSITA at the time of the alleged invention.

Pet. 48.

Petitioner further asserts that Yaung discloses a layer 22, which may be made of silicon oxide, is comparable to Fujimoto’s first layer of interlayer insulating film 15, and is planarized using chemical/mechanical polishing as is commonly practiced in the industry. Pet. 48–49 (citing Ex. 1006, 3:7–12, 5:23–26). The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 120. Dr. Rubloff also provides reasoning with a rational underpinning why one with ordinary skill in the art would have been motivated to planarize the interlayer insulating film 15 in Fujimoto using chemical/mechanical polishing similar to the planarizing performed in Yaung. Ex. 1002 ¶¶ 121–22. For instance, Dr. Rubloff testifies:

Given *Fujimoto* discloses flattening the interlayer insulating film 15 but does not disclose the technique for carrying out such flattening, a person having ordinary skill in the art would have been motivated to look at techniques for performing the

flattening (i.e., planarizing) of a dielectric layer and would have realized that a common industry practice was to use CMP [chemical/mechanical polishing] to planarize a dielectric layer's surface, like that disclosed by *Yaung*.

Ex. 1002 ¶ 121.

For claim 4, Patent Owner advances no argument separate from those it has presented for independent claim 1, which we have discussed and rejected above. Accordingly, we find that the combined teachings of Fujimoto, *Yaung*, and Ho disclose the added limitation “planarizing the first layer of dielectric material through chemical-mechanical polishing.”

Claim 6 depends from claim 1 and further recites: “wherein the etching step for forming a first opening comprises dry etch.” Ex. 1001, 4:62–63. Petitioner asserts that Fujimoto in combination with *Yaung* and Ho “discloses or suggests” this added limitation. Pet. 50. Petitioner asserts:

Fujimoto discloses that the etching step for forming the opening 20 (“first opening”) comprises using the mixed gas of CHF_3 and CO (“dry etch”) as an etching medium. (Ex. 1005, 5:1–6.) A POSITA would have understood that using the mixed gas of CHF_3 and CO as an etching medium for employing a plasma-based gaseous etch process would constitute a dry etch. (Ex. 1002, ¶ 126, citing Ex. 1018.)

Pet. 50–51. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 126.

For claim 6, Patent Owner advances no argument separate from those it has presented for independent claim 1, which we have discussed and rejected above. Accordingly, we find that the combined teachings of Fujimoto, *Yaung*, and Ho disclose the added limitation “wherein the etching step for forming a first opening comprises dry etch.”

Claim 8 depends from claim 1 and further recites: “wherein the second layer of dielectric material may be comprised of boro-phospho

silicate glass, tetraethylorthosilicate, or high-density plasma.” Ex. 1001, 5:1–4. Petitioner asserts that the added limitation of claim 8 should not be given any weight, because it is phrased as an optional limitation by using the phrase “may be comprised.” Pet. 54–55. Patent Owner does not provide a response to that argument. We agree with Petitioner. Based on the use of the permissive phrase “may be comprised,” claim 8 does not “require” the second layer of dielectric material to include boro-phospho silicate glass, tetraethylorthosilicate, or high-density plasma. *See Johnston*, 435 F.3d at 1384. Patent Owner advances no argument separate from those it has presented for independent claim 1, which we have discussed and rejected above.

Claim 12 depends from claim 1 and further recites “providing a layer of anti-reflection coating over the second layer of dielectric material.” Ex. 1001, 5:14–16. Petitioner asserts that Fujimoto in combination with Yaung and Ho “discloses or suggests” this added limitation. Pet. 55.

As discussed above in the context of claim 1, the combined teachings of Fujimoto, Yaung, and Ho disclose providing an etching mask structure over the second layer of interlayer insulating film 15, which mask structure includes a photoresist over a BARC layer which is over a hardmask. Petitioner asserts that the BARC layer in that mask structure is an anti-reflective coating. Pet. 55. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 131. Dr. Rubloff testifies that the BARC layer “is a bottom antireflective coating provided over the second layer of interlayer insulating film 15 in the combined *Fujimoto-Yaung-Ho* method. *Id.* Dr. Rubloff explains: “The BARC layer is provided over the second layer of interlayer insulating film 15 because it is part of the etching mask structure provided over the second layer.” *Id.*

For claim 12, Patent Owner advances no argument separate from those it has presented for independent claim 1, which we have discussed and rejected above. Accordingly, we find that the combined teachings of Fujimoto, Yaung, and Ho disclose the added limitation “providing a layer of anti-reflection coating over the second layer of dielectric material.”

Claim 13 depends from claim 1 and further recites: “wherein the mask material is distinguishable over silicon oxides.” Ex. 1001, 5:17–18. Petitioner asserts that Fujimoto in combination with Yaung and Ho “discloses or suggests” this added limitation. Pet. 56. Based on our review of the Petition, we understand Petitioner to be making two separate arguments: (1) that the method according to the combined teachings of Fujimoto, Yaung, and Ho discloses the added limitation (Pet. 56–57), and (2) the added limitation also would have been obvious over the combined teachings of Fujimoto, Yaung, and Ho (Pet. 57–58).

First, Petitioner notes that in the combined method of Fujimoto, Yaung, and Ho discussed in the context of claim 1, an etching mask structure is provided over the second layer of interlayer insulating film 15, which mask structure includes a photoresist over a BARC layer disposed on a hardmask. Pet. 56. Petitioner asserts that one with ordinary skill in the art would have realized that etching mask 24 of Fujimoto, as replaced by the mask structure of Ho, *must be* distinguishable over silicon oxides because otherwise the process of etching the second layer of interlayer insulating film 15 in Fujimoto would also etch away the mask and render it useless. *Id.* (citing Ex. 1002 ¶ 133). Dr. Rubloff testifies:

[I]n the combined *Fujimoto-Yaung-Ho* method where the mask 24 is configured as an etching mask structure including a photoresist mask over a hardmask layer based on *Yaung’s* teachings, a person having ordinary skill in the art would have

known that the hardmask layer would *necessarily* have been distinguishable over silicon oxides to ensure it serves its purpose of allowing etching of the silicon oxide making up the second layer of interlayer insulating film 15.

Ex. 1002 ¶ 133 (emphasis added). Although we were sufficiently persuaded by this reasoning in the Decision on Institution (Paper 7, 38), we recognize now that Ho discloses silicon dioxide as a material for forming its hardmask, which is not “distinguishable over silicon oxides.” See Ex. 1007, 3:16–18 (“Hard mask may be formed of SiO₂, Si₃N₄, or other hard mask materials, specifically inorganic hard mask materials.”). Therefore, we reject Petitioner’s contention that any hardmask as taught by Ho necessarily is or must be distinguishable over silicon oxides.

In the alternative, Petitioner asserts that it would have been obvious to one with ordinary skill in the art, in the method according to the combined teachings of Fujimoto, Yaung, and Ho discussed above in the context of claim 1, and based on Ho’s teaching of using various hardmask materials including Si₃N₄, to implement the hardmask layer with material that is distinguishable over silicon oxides such as Si₃N₄ disclosed in Ho. Pet. 57–58. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 134. Dr. Rubloff testifies that Si₃N₄, as disclosed in Ho, “is distinguishable from silicon oxides.” *Id.* Dr. Rubloff further testifies:

As disclosed in *Ho*, the use of a mask material distinguishable over silicon oxides was well known, and a person having ordinary skill in the art would have been motivated to choose such a mask material, particularly because the ’044 patent does not disclose any criticality associated with such a feature. Using such a material as recited in claim 13 as a mask material would have been nothing more than the application of a known technique (forming a hardmask layer using silicon nitride) to a known device (the hardmask layer in the combined *Fujimoto-Yaung-Ho* method) ready for improvement to yield predictable

results, i.e., to obtain a hardmask layer allowing for the objective of the subsequent etching step to be met. Additionally, a person having ordinary skill in the art would have known and had the capability to implement the above modifications in such a way to ensure the process of manufacturing the semiconductor device disclosed by *Fujimoto* would be workable, as well as the resulting device being formed.

Ex. 1002 ¶ 135. We also agree with Petitioner (Pet. 56) that using a mask distinguishable from silicon oxides serves *Fujimoto*'s purpose of allowing etching of the silicon oxide making up the second layer of interlayer insulating film 15.

For claim 13 Patent Owner advances no argument separate from those it has presented for independent claim 1, which we have discussed and rejected above. Accordingly, we find the combined teachings of *Fujimoto*, *Yaung*, and *Ho* disclose the added limitation "wherein the mask material is distinguishable over silicon oxides," not because mask material distinguishable from oxides must be used but because the combined teachings render obvious the use of material distinguishable from oxides.

Claim 14 depends from claim 13 and further recites: "wherein the mask may be comprised of silicon nitride or polysilicon." Ex. 1001, 4:19–20. Petitioner asserts that the added limitation of claim 13 should not be given any weight, because it is phrased as an optional limitation by using the phrase "may be comprised." Pet. 58. Patent Owner does not provide a response to that argument. We agree with Petitioner. Based on the use of the permissive phrase "may be comprised," claim 14 does not "require" the mask to be comprised of silicon nitride or polysilicon. *See Johnston*, 435 F.3d at 1384. Patent Owner advances no argument separate from those it has presented for independent claim 1, which we have discussed and rejected above.

For the foregoing reasons, we determine that Petitioner has established, by a preponderance of the evidence, that each of claims 2–4, 6, 8, and 12–14 would have been obvious over the combined teachings of Fujimoto, Yaung, and Ho.

6. Claim 7

Claim 7 depends from claim 1 and further recites: “wherein the etching step for forming a first opening comprises an etching selectivity between silicon nitrides and silicon oxides of approximately 10 to 40.” Ex. 1001, 4:64–67. Petitioner asserts that Fujimoto in combination with Yaung and Ho “discloses or suggests” this added limitation. Pet. 51.

Petitioner explains that in the method of the combined teachings of Fujimoto, Yaung, and Ho, as discussed in the context of claim 1, the first layer of interlayer insulating film 15 is etched to form opening 20, and that the etching step involves removing a portion of interlayer insulating film 15 made of silicon oxide and a portion of the protective film 14 made of silicon nitride. Pet. 51. Petitioner asserts that one with ordinary skill in the art would have known that etching selectivity is generally a ratio of an etching rate of a film that is preferentially etched to an etching rate of another film. Pet. 52. The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 127. Fujimoto discloses that in the etching step at issue, silicon nitride is etched at a rate that is 1.3 to 2.0 times faster than the rate at which the silicon oxide is etched. Ex. 1005, 5:5–13, 5:54–57 (cited at Pet. 52). Fujimoto also describes that the particular etch rate is selected so that the etched-away opening 20 does not become like a beer barrel with the circumferential wall swelling outward at its middle portion or taper off downwardly. *Id.* at 5:28–37 (cited at Pet. 52).

Based on the disclosure of Fujimoto, Dr. Rubloff testifies that “a person having ordinary skill in the art would have understood that *Fujimoto* recognizes the etching selectivity between the nitride and oxide layers as a variable that is recognized for influencing the vertical profile of the opening 20.” Ex. 1002 ¶ 128 (cited at Pet. 52). Dr. Rubloff further testifies that “discovering an optimum value of a variable to achieve a recognized result in a known process would have been well within the skill of the art.” *Id.* Based on this testimony, Petitioner characterizes the etching selectivity between the nitride and oxide layers as a result-effective variable. Pet. 52. Notably, Dr. Rubloff additionally testifies:

[C]onsistent with *Fujimoto*’s disclosure of etching the nitride at a faster rate than the oxide, the prior art in this field envisioned setting the etching selectivity of such an etch in the claimed range. (Ex. 1012 (*Jeng*), 4:59–5:1 (disclosing an etch that etches nitride 5 to 20 times faster than the rate at [which] oxide is etched), FIG. 4–6.)¹⁴

¹⁴ I am referring to *Jeng* to show what a person of ordinary skill in the art would have known at the time of the alleged invention.

Ex. 1002 ¶ 129 (cited at Pet. 53).

In the Decision on Institution, we were sufficiently persuaded by Petitioner’s arguments relating to optimization of a result-effective variable. Paper 7, 36. However, subsequent to institution of trial, upon further review of the evidence presented by Petitioner, we find that Petitioner has not established that an etching selectivity of 10 to 40 favoring nitrides over oxides constitutes “optimization” as alleged by Petitioner, particularly optimization in the context of *Fujimoto*. Dr. Rubloff nowhere explains why or how the claimed selectivity range of 10–40 constitutes “optimization.” For instance, it is unexplained why *Fujimoto*’s disclosed selectivity range of

1.3 to 2.0 is not already optimized, and why a selectivity range of 10–40 is an optimized range in the context of Fujimoto, which discloses a different and nonoverlapping range of 1.3 to 2.0.

We recognize that discovery of optimum values for result-effective variables is normally considered to be within the skill of one with ordinary skill in the art. *See, e.g., In re Boesch*, 617 F.2d 272, 276 (CCPA 1980) (“[D]iscovery of an optimum value of a result effective variable in a known process is ordinarily within the skill of the art.”); *In re Aller*, 220 F.2d 454, 458 (CCPA 1955) (“No invention is involved in discovering optimum ranges of a process by routine experimentation.”). We also determine, as urged by Petitioner (Pet. 52), that etching selectivity range of nitride over oxide is a result-effective variable, because it affects the efficiency of the etching process and/or the resulting structure.

However, it is not enough for Petitioner simply to establish that the selectivity range is a result-effective variable and that the specification of the ’044 patent does not express any “criticality” in the claimed range. The burden is not on Patent Owner to show criticality of the claimed range to avoid a conclusion of obviousness. Rather, to demonstrate obviousness, Petitioner must offer reasoning with rational underpinning for one with ordinary skill in the art to modify the selectivity range in Fujimoto from “1.3 to 2.0” to the claimed range of “10 to 40.” *See KSR*, 550 U.S. at 418. There is no overlap between the claimed range and the range disclosed by Fujimoto. Indeed, the two ranges are far apart from each other. Regarding reliance on optimization to account for obviousness, our reviewing court has instructed that there must be “some rational underpinning explaining why a person of ordinary skill in the art would have arrived at the claimed invention through routine optimization.” *In re Stepan Company*, 868 F.3d

1342, 1346 (Fed. Cir. 2017). Petitioner has not made an adequate showing of the alleged “optimization.”

Petitioner asserts that Patent Owner has not shown unexpected result or criticality in the claimed range. Reply 17. However, Patent Owner has no need to come forward with evidence of any unexpected result or criticality in the claimed range until Petitioner has shown that “optimization” of a result effective variable leads to a value within the claimed range. *See In re Geisler*, 16 F.3d 1465, 1460 (Fed. Cir. 1997) (“Only if the ‘results of optimizing a variable’ are ‘unexpectedly good’ can a patent be obtained for the claimed critical range.”).

We recognize that Petitioner has cited U.S. Patent No. 6,033,962 (Ex. 1012, “Jeng”) as an example in the prior art where the etching selectivity range of nitrides over oxides was “5 to 20.” Pet. 53 (citing Ex. 1012, 4:59–5:1). However, we observe (1) that Jeng is not an applied prior art reference in any alleged ground of unpatentability; (2) that the specific context of Jeng, relative to the applied prior art references, Fujimoto in particular, has not been explained; and (3) that Petitioner has not provided a reasoned motivation with a rational underpinning, for one of ordinary skill in the art to combine the teachings of Fujimoto and Jeng. That in some unexplained circumstance a selectivity range of 5–20 had been used in a semiconductor etching process, favoring nitrides over oxides, does not provide adequate motivation for one with ordinary skill in the art to modify Fujimoto’s etching selectivity from a value within its own disclosed range of “1.3 to 2.0” to a value within “5 to 20.” That a modification “could” have been made does not establish that one with ordinary skill in the art would have been motivated to make the modification. *Belden Inc. v. Berk-Tek LLC*, 805 F.3d 1064, 1073 (Fed. Cir. 2015) (“[O]bviousness concerns

whether a skilled artisan not only *could have made* but *would have been motivated to make* the combinations or modifications of prior art to arrive at the claimed invention.”).

Patent Owner offers several reasons why one with ordinary skill in the art would not have, in the context of Fujimoto, used an etching selectivity range of 10 to 40, for nitrides over oxides, because such a range would create problems within Fujimoto’s process. PO Resp. 39–44. Petitioner asserts, on the other hand, that either the alleged problems have not been shown to exist or the alleged problems could have been solved by one with ordinary skill in the art. Reply 17–20. We need not reach and resolve these assertions by Patent Owner that the claimed range presents a problem for the Fujimoto process, because it is not incumbent on Patent Owner to demonstrate nonobviousness. We determine that Petitioner’s articulated reasoning for modifying Fujimoto’s etching selectivity range from “1.3 to 2.0” to cover a value within the claimed range of “10 to 40” is inadequate, even without the issues of potential problems presented by Patent Owner.

At best, Petitioner has established only that etching selectivity is a result-effective variable and that a value within the claimed range of 10 to 40 could have been adopted by one with ordinary skill in the art. That is insufficient to show that it would have been obvious to one with ordinary skill in the art to modify Fujimoto’s etching selectivity range of “1.3 to 2.0” to the claimed range of “10 to 40” or to cover a value within the claimed range of “10 to 40.”

For the foregoing reasons, we determine that Petitioner has not established, by a preponderance of the evidence, that claim 7 would have been obvious over the combined teachings of Fujimoto, Yaung, and Ho.

E. Alleged Unpatentability of Claim 5 as
Obvious over Fujimoto, Yaung, Ho, and Paterson

Claim 5 depends from claim 1 and further recites: “wherein the etching step for forming a first opening comprises wet etch.” Ex. 1001, 4:60–61. As discussed above in the context of claim 6, one with ordinary skill in the art would have understood that the method disclosed by Fujimoto for forming the first opening constitutes a dry etch. *See supra* Section II.D.3. Petitioner asserts that it would have been obvious to one with ordinary skill in the art to implement the etching step, instead, with a wet etch. Pet. 60. Dr. Rubloff testifies that it would have been obvious to one with ordinary skill in the art to use a wet etch to form the first opening in Fujimoto. Ex. 1002 ¶ 139.

Dr. Rubloff explains that Paterson discloses a semiconductor device fabrication process including the step of etching a layer of multilevel dielectric 16 to form via 18 exposing silicide film 14. *Id.* ¶ 140 (cited at Pet. 60). Dr. Rubloff further explains that one with ordinary skill in the art would have understood that forming via 18 by etching dielectric 16 to expose the silicide film 14 in Paterson is analogous to forming opening 20 in Fujimoto by etching insulating film 15 to expose silicide layer 18. *Id.* ¶ 141 (cited at Pet. 59). Notably, Dr. Rubloff testifies:

Paterson discloses that its “[v]ia 18 is patterned according to conventional photolithography techniques, and **etched by conventional wet or plasma etches** for the particular material of multilevel 16.” ([Ex. 1008] at 4:5–8 (emphasis added).) A person of ordinary skill in the art would have understood that a plasma etch is a dry etch. As such, *Paterson* discloses that the via 18 can be formed using wet etch or dry etch depending on the material of the dielectric layer. As such, using dry etch or wet etch to form the via 18 in *Paterson* or the opening [20] in

Fujimoto would have simply been a mere choice among a finite number of known, predictable alternatives.

Ex. 1002 ¶ 142 (cited at Pet. 61). Dr. Rubloff further testifies:

Therefore, in my opinion, a person having ordinary skill in the art would have been motivated . . . to use wet etch or dry etch when forming the opening [20] in *Fujimoto*. Using the dry etch or wet etch to form the initial contact hole or via to expose the silicide would not be of any critical importance to the overall process of forming contact holes to the gate and source/drain regions, but would rather simply be a function of the dielectric material being etched to form the initial contact hole, as disclosed by *Paterson*. ([Ex. 1008] at 4:5–8.) As such, a person having ordinary skill in the art would have been motivated to modify the *Fujimoto-Yaung-Ho* method such that the etching of the first layer of interlayer insulating film 15 to form the opening 20 would include etching the first layer of interlayer insulating film using wet etch depending on the material of the first layer of interlayer insulating film 15 because, for example, using a wet etch would amount to no more than applying a known technique (wet etch as disclosed in *Paterson*) to a known device (the insulating film 15 in *Fujimoto*) to yield predictable results (forming the opening 20). Specifically, a person of ordinary skill in the art would have been motivated to etch the silicon oxide making up the first layer of interlayer insulating film using a wet etch as the skilled artisan would have known that silicon oxide could be etched using a wet etch or a dry etch. Additionally, given the disclosures of these prior art references, the knowledge of one skilled in the art, and that the '044 patent does not disclose any advantages or unexpected results achieved by using wet etch (as opposed to dry etch) for forming the first opening, a person having ordinary skill in the art would have found using such techniques, which I discussed above, to be a predictable implementation at the time of the alleged invention of the '044 patent. Additionally, such a skilled person would have known and had the capability to implement the above modifications in such a way to ensure the process of

manufacturing the semiconductor device disclosed by *Fujimoto*, as well as the resulting device being formed, would be workable.

Ex. 1002 ¶ 143 (cited at Pet. 61–62).

Upon review of Dr. Rubloff’s testimony, we find that it falls short of establishing that one with ordinary skill in the art would have known to use either wet etch or dry etch techniques in any and all circumstances. Instead, the testimony establishes that although both wet etch and dry etch processes are conventional techniques that would have been known to a person with ordinary skill in the art, the particular technique the person would have used depends on the circumstances, e.g., the material to be etched. For instance, Dr. Rubloff states: “*Paterson* discloses that the via 18 can be formed using wet etch or dry etch *depending on the material of the dielectric layer*.” Ex. 1002 ¶ 142 (emphasis added) (cited at Pet. 61). Patent Owner persuasively states:

The *Paterson* reference does little more than confirm that wet etching is a conventional technique that can be used to etch certain dielectric materials. Ex. 1008 at col. 4:5–8. It does not teach how wet etching could be used or when the use of wet etching (as opposed to dry etching is appropriate). *Paterson* does not teach a person of ordinary skill in the art when it should use wet etching over dry etching.

PO Resp. 45.

Fujimoto expressly describes using a dry etch to form first opening 20. Ex. 1005, 5:1–6 (cited at Pet. 50). Thus, to the extent that the choice of a dry etch or a wet etch is a decision based on the material to be etched and the particular circumstance, *Fujimoto* already has made and disclosed that choice. Petitioner must put forth reasoning for one with ordinary skill in the art to make the modification from using a dry etch to a wet etch, in the same circumstance, with the same material to be etched.

That, however, Petitioner has failed to do. Although Petitioner notes that the Patent Owner Response expresses several advantages for using a wet etch (Reply 23), Petitioner's reasoning for modifying Fujimoto does not express advantages of using wet etch in the process according to Fujimoto. Nor does Petitioner's reasoning for modifying Fujimoto express why any advantage would have provided sufficient motivation for one with ordinary skill in the art to make the modification.

Petitioner must present reasoning with a rational underpinning to make the modification in Fujimoto's process from dry etch to wet etch. It has not done so. We determine that Petitioner has not established, by a preponderance of the evidence, that claim 5 would have been obvious over the combined teachings of Fujimoto, Yaung, Ho, and Paterson.

F. Alleged Unpatentability of Claim 9–11 as
Obvious over Fujimoto, Yaung, Ho, and Sonogo

Claim 9 depends from claim 1 and further recites: “rapid thermal annealing to reflow the second layer of dielectric material to obtain a substantially planar surface.” Ex. 1001, 5:5–7. We already have discussed above, in the context of claim 1, how the method according to Fujimoto, Yaung, and Ho discloses the deposition of a second layer of dielectric material. In particular, Fujimoto discloses deposition of a second layer of dielectric material. Ex. 1002 ¶¶ 87–88 (cited at Pet. 31). The second layer of dielectric material is deposited directly over interlayer insulating film 15. Ex. 1005, 5:58–62 (cited at Pet. 31). After deposition of the second layer of dielectric material over insulating film 15, Fujimoto describes that the surface of insulating film 15 “is subjected to a flattening process.” *Id.* at 5:63–64 (cited at Pet. 62). This describes the flattening of the surface of the second layer of dielectric material on top of the insulating film 15, which

increases the thickness of insulating film 15. That understanding is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶ 145 (cited at Pet. 63). Dr. Rubloff also testifies that a person of ordinary skill in the art would have understood that flattening “refers to creating a planar, i.e., ‘flat’ surface.” *Id.*

Petitioner acknowledges that Fujimoto does not expressly disclose the details of how the second layer of dielectric material is flattened, and specifically, whether the flattening is achieved through use of rapid thermal annealing. Pet. 63. Petitioner asserts, however, that in light of the disclosure of Sonogo, it would have been obvious to one with ordinary skill in the art to use rapid thermal annealing as the technique for flattening the second layer of dielectric material. *Id.* The assertion is supported by the testimony of Dr. Rubloff. Ex. 1002 ¶¶ 146–148 (cited at Pet. 64–65).

Dr. Rubloff testifies that Sonogo discloses a second dielectric layer 18 and applying rapid thermal annealing to optimize the planarity of the second dielectric layer 18. *Id.* ¶ 146 (cited at Pet. 64). Dr. Rubloff testifies that Sonogo’s rapid thermal annealing was a known technique for achieving the flattening goal sought by Fujimoto. *Id.* Dr. Rubloff explains:

[One with ordinary skill in the art] would have looked to Sonogo for guidance regarding implementing the *Fujimoto-Yaung-Ho* method, because *Sonogo* is in the same field as *Fujimoto*, *Yaung*, and *Ho*. Having looked to *Sonogo*, such a person would have recognized the benefit of implementing *Sonogo*’s rapid thermal annealing process, because *Sonogo* expressly discloses that such an annealing process is suitable for “optimiz[ing] the planarity” of a second dielectric layer 18 which is similar to *Fujimoto*’s second layer of interlayer insulating film 15. (Ex. 1013, 5:58–61.)

In order to optimize the planarity of the second dielectric layer 18 of the BPSG type, the deposition step is followed by a thermal reflowing operation of

either rapid thermal annealing cycles or quick backings in an oven.

(*Id.*)

Ex. 1002 ¶ 147 (cited at Pet. 64). Dr. Rubloff further testifies:

Implementing such a rapid thermal annealing process was within the skill of an ordinary artisan who would have been able to implement such a process in the combined *Fujimoto-Yaung-Ho* process with a reasonable expectation of success. In fact, drawing from *Sonego's* teachings to implement *Fujimoto's* flattening step would merely have constituted the application of a known technique (*Sonego's* rapid thermal annealing) to a known device (the second layer of insulating film 15 in *Fujimoto*) ready for improvement (*Fujimoto's* device would benefit from a planar surface for the second layer of insulating film 15) to yield the expected result of obtaining a planarized surface for the second layer of interlayer insulating film 15. Additionally, given the disclosures of such prior art references and the knowledge of one skilled in the art, and that the '044 patent does not disclose any advantages or unexpected results achieved by rapid thermal annealing to reflow the second layer of dielectric material to obtain a substantially planar surface, a person having ordinary skill in the art would have found using such techniques, which I discussed above, to be a predictable implementation at the time of the alleged invention of the '044 patent. Additionally, such a skilled person would have known and had the ability to implement the above modifications in such a way to ensure the process of manufacturing the semiconductor device disclosed by *Fujimoto* would be workable, as well as the resulting device being formed.

Id. ¶ 148 (cited at Pet. 64–65).

For claim 9, Patent Owner does not present arguments other than those it has presented for claim 1, which we have discussed and rejected above in the context of claim 1. Petitioner has shown that the method according to the combined teachings of *Fujimoto*, *Yaung*, *Ho*, and *Sonego* discloses the step of “rapid thermal annealing to reflow the second layer of

dielectric material to obtain a substantially planar surface.” We determine that Petitioner has established, by a preponderance of the evidence, that claim 9 would have been obvious over Fujimoto, Yaung, Ho, and Sonogo.

Claim 10 depends from claim 9 and further recites: “wherein the rapid thermal annealing is performed at a temperature from approximately 900 to 1,000° C.” Ex. 1001, 5:8–10. Sonogo specifically describes that its thermal reflowing operation, such as that accomplished by rapid thermal annealing, is performed “under controlled temperature conditions within the range of 900° C. to 1000° C.” Ex. 1013, 5:61–65 (cited at Pet. 65).

For claim 10, Patent Owner does not present arguments other than those it has presented for claim 1, which we have discussed and rejected above in the context of claim 1. Petitioner has shown that the method according to the combined teachings of Fujimoto, Yaung, Ho, and Sonogo discloses the feature of “wherein the rapid thermal annealing is performed at a temperature from approximately 900 to 1,000° C.” We determine that Petitioner has established, by a preponderance of the evidence, that claim 10 would have been obvious over Fujimoto, Yaung, Ho, and Sonogo.

Claim 11 depends from claim 10 and further recites: “wherein the rapid thermal annealing is performed at a temperature from approximately 950 to 970° C.” Ex. 1001, 5:11–13. As discussed above in the context of claim 10, Sonogo specifically describes rapid thermal annealing at a temperature range from approximately 900° to 1,000° C. We agree with Petitioner that the claimed range of 950° C to 970° C would have been rendered obvious by the prior art range of 900° to 1000° C. *See In re Peterson*, 315 F.3d 1325, 1329–30 (Fed. Cir. 2003) (“Selecting a narrow range from *within* a somewhat broader range disclosed in a prior art reference is no less obvious than identifying a range that simply *overlaps* a

disclosed range. In fact, when, as here, the claimed ranges are completely encompassed by the prior art, the conclusion is even more compelling than in cases of mere overlap.”).

For claim 11, Patent Owner does not present arguments other than those it has presented for claim 1, which we have discussed and rejected above in the context of claim 1. Petitioner has shown that the method according to the combined teachings of Fujimoto, Yaung, Ho, and Sonogo discloses the limitation “wherein the rapid thermal annealing is performed at a temperature from approximately 950 to 970° C.” We determine that Petitioner has established, by a preponderance of the evidence, that claim 11 would have been obvious over Fujimoto, Yaung, Ho, and Sonogo.

G. Alleged Unpatentability of Claims 16, 19,
and 22 as Obvious over Fujimoto and Ho

For reasons discussed below, we find that Petitioner has established, by a preponderance of the evidence, that each of claims 16, 19, and 22 would have been obvious over Fujimoto and Ho.

1. Claim 16

Independent claim 16 recites: “A method for forming contacts in a semiconductor device including a plurality of active devices formed over a substrate.” Ex. 1001, 5:24–26. The portion of the preamble about “forming contacts” merely reflects intended use and thus is non-limiting. Nevertheless, Fujimoto specifically states that it “relates to a method for manufacturing a semiconductor device, and more particularly to a method for forming contact holes for conductive strips passing through an insulating film, such as an interlayer insulating film.” Ex. 1005, 1:9–13 (cited at Pet. 63). Dr. Rubloff testifies: “Contacts were well known at the time of *Fujimoto*’s disclosure, and a person of ordinary skill would have known that

the reason *Fujimoto* discloses forming contact holes is so that contacts can be formed at the location of the contact holes.” Ex. 1002 ¶ 152 (cited at Pet. 66). Dr. Rubloff further testifies that based on *Fujimoto*’s disclosure of forming contact holes and the knowledge of one with ordinary skill in the art, one with ordinary skill would have understood that *Fujimoto* discloses or suggests a “method for forming contacts.” *Id.* Thus, even assuming that the recitation “for forming contacts” is limiting, Petitioner has shown that *Fujimoto* discloses or at least suggests this limitation.

With respect to the portion of the preamble reciting “in a semiconductor device including a plurality of active devices formed over a substrate,” essentially the same limitation is present in claim 1 by way of this recited step in claim 1: “providing at least two active devices over a substrate.” In that regard, Petitioner relies on the same arguments it presented in the context of claim 1. Pet. 67. For the same reasons discussed above in the context of claim 1, Petitioner has shown that *Fujimoto* discloses this limitation.

Claim 16 further recites: “depositing a first layer of dielectric material over the substrate and plurality of active devices.” Ex. 1001, 5:27–28. Essentially the same limitation is present in claim 1 by way of this recited step in claim 1: “depositing a first layer of dielectric material over the substrate and active devices.” *Id.* at 4:28–29. In that regard, Petitioner relies on the same arguments it presented in the context of claim 1. Pet. 67. For the same reasons discussed above in the context of claim 1, Petitioner has shown that *Fujimoto* discloses this limitation.

Claim 16 further recites: “forming a first opening in the first layer of dielectric material.” *Id.* at 5:29–30. Essentially the same limitation is present in claim 1 by way of this recited step in claim 1: “etching the first

layer of dielectric material unmasked by the first photoresist to form a first opening.” *Id.* at 4:33–34. In that regard, Petitioner relies on the same arguments it presented in the context of claim 1. Pet. 68. For the same reasons discussed above in the context of claim 1, excluding Petitioner’s reliance on Yaung to account for a first photoresist limitation that is not present in claim 16, Petitioner has shown that Fujimoto discloses this limitation.

Claim 16 further recites: “depositing a second layer of dielectric material over the first layer of dielectric material and in the first opening.” *Id.* at 5:31–32. Exactly the same limitation is present in claim 1. *Id.* at 4:38–39. In that regard, Petitioner relies on the same arguments it presented in the context of claim 1. Pet. 68. For the same reasons discussed above in the context of claim 1, excluding reliance on Yaung to account for a first photoresist limitation that is not present in claim 16, Petitioner has shown that Fujimoto discloses this limitation.

Claim 16 further recites: “providing a mask over the second layer of dielectric material, wherein the mask is distinguishable over silicon oxides.” *Id.* at 5:33–35. The first half of the limitation is present in claim 1 by way of this recitation: “providing a mask over the second layer of dielectric material.” *Id.* at 4:40–41. The second half of the limitation is present in claim 13 by way of the recitation: “wherein the mask material is distinguishable over silicon oxides.” *Id.* at 5:17–18. In that regard, Petitioner relies on the same arguments it presented in the context of claims 1 and 13. Pet. 68–69. For essentially the same reasons discussed above in the context of claims 1 and 13, excluding Petitioner’s reliance on Yaung to satisfy a first photoresist limitation that is not in claim 16, Petitioner has

shown that this limitation is satisfied by the combined teachings of Fujimoto and Ho.

Claim 16 further recites: “forming a second opening and a third opening in the second layer of dielectric material, wherein the second opening is aligned with the first opening and exposes a first silicide of a first active device, and the third opening exposes one of diffused regions of a second active device.” *Id.* at 6:1–6. Essentially the same limitation is present in claim 1 by way of this recited step in claim 1: “forming a second opening and a third opening, wherein the second opening is aligned with the first opening and exposes the first silicide of the first active device, and the third opening exposes one of the pair of the spaced-apart diffused regions of a second active device.” *Id.* at 4:45–49. In that regard, Petitioner relies on the same arguments it presented in the context of claim 1. Pet. 69. For essentially the same reasons discussed above in the context of claim 1, excluding Petitioner’s reliance on Yaung to satisfy a first photoresist limitation that is not in claim 16, Petitioner has shown that this limitation is satisfied by the combined teachings of Fujimoto and Ho.

For claim 16, Patent Owner does not make arguments separate from those it makes for claim 1, which we have discussed and rejected above in the context of claim 1. For the foregoing reasons, we determine that Petitioner has established, by a preponderance of the evidence, that claim 16 would have been obvious over the combined teachings of Fujimoto and Ho.

2. Claims 19 and 22

Claim 19 depends from claim 16 and further recites: “wherein the step for forming a first opening comprises an etching step having a selectivity between silicon nitrides and silicon oxides of approximately 10 to 40.” Ex. 1001, 6:15–18. Essentially the same limitation is present in

claim 7 by way of this recited step in claim 7: “wherein the etching step for forming a first opening comprises an etching selectivity between silicon nitrides and silicon oxides of approximately 10 to 40.” *Id.* at 4:64–67.

For this additional limitation in claim 19, Petitioner and Patent Owner do not make arguments separate from those they have made for the additional limitation in claim 7. *See* Pet. 70. Thus, for essentially the same reasons discussed above in the context of claim 7, excluding Petitioner’s reliance on Yaung to account for a first photoresist limitation that is not present in claim 19, Petitioner has not shown that the combined teachings of Fujimoto and Ho reasonably would have suggested the limitation: “wherein the step for forming a first opening comprises an etching step having a selectivity between silicon nitrides and silicon oxides of approximately 10 to 40.” Accordingly, we determine that Petitioner has not established, by a preponderance of the evidence, that claim 19 would have been obvious over Fujimoto and Ho.

Claim 22 depends from claim 16 and further recites: “further comprising providing a layer of anti-reflection coating over the second layer of dielectric material.” *Id.* at 6:28–30. The same limitation is present in claim 12. *Id.* at 5:14–16. For this additional limitation in claim 22, Petitioner and Patent Owner do not make arguments separate from those they have made for the corresponding limitation in claim 12. *See* Pet. 71. For the same reasons discussed above in the context of claim 12, excluding Petitioner’s reliance on Yaung to account for a first photoresist limitation that is not present in claim 22, Petitioner has shown that this limitation is satisfied by the combined teachings of Fujimoto and Ho. We determine that

Petitioner has shown, by a preponderance of the evidence, that claim 22 would have been obvious over Fujimoto and Ho.

H. Alleged Unpatentability of Claims 17, 18,
and 20 as Obvious over Fujimoto, Ho, and Yaung

Claim 17 depends from claim 16 and further recites: “wherein the first layer of dielectric material may be comprised of boro-phospho silicate glass, tetraethylorthosilicate, or high-density plasma.” Ex. 1001, 6:7–10. The limitation is the same as that recited in claim 3, which depends from claim 1. Petitioner asserts that the added limitation of claim 17, like the limitation in claim 3, should not be given any weight, because it is phrased as an optional limitation by using the phrase “may be comprised.” Pet. 71. Patent Owner does not provide a response to that argument.

For the same reasons discussed above in the context of claim 3, we agree with Petitioner that this added limitation in claim 17 does not further limit claim 16. Thus, for the same reasons that Petitioner has established, by a preponderance of the evidence, that claim 16 would have been obvious over the combined teachings of Fujimoto and Ho, we determine that Petitioner has established, by a preponderance of the evidence, that claim 17 would have been obvious over Fujimoto, Ho, and Yaung.⁸

Claim 18 depends from claim 16 and further recites: “a step of planarizing the first layer of dielectric material through chemical-mechanical polishing.” Ex. 1001, 6:12–14. The same limitation is present in claim 4. *Id.* at 4:57–59. For this additional limitation in claim 18, Petitioner presents

⁸ For claim 17, Petitioner does not substantively rely on any teaching from Yaung, even though Yaung is named in the alleged ground of unpatentability. Pet. 71–72.

the same arguments it asserts for the corresponding limitation in claim 4.
Pet. 72. Patent Owner has not provided any argument for claim 18.

For the same reasons discussed above in the context of claim 4, excluding Petitioner's reliance on Yaung to account for a first photoresist limitation that is not present in claim 18, Petitioner has shown that this limitation is satisfied by the combined teachings of Fujimoto and Ho. We determine that Petitioner has shown, by a preponderance of the evidence, that claim 18 would have been obvious over Fujimoto, Ho, and Yaung.⁹

Claim 20 depends from claim 16 and further recites: "wherein the second layer of dielectric material may be comprised of boro-phospho silicate glass, tetraethylorthosilicate, or high-density plasma." *Id.* at 6:20–23. The limitation is the same as that contained in claim 8, which depends from claim 1. Petitioner asserts that the added limitation of claim 20 should not be given any weight, because it is phrased as an optional limitation by using the phrase "may be comprised." Pet. 72. Patent Owner does not provide a response to that argument.

For the same reasons discussed above in the context of claim 8, we agree with Petitioner that this added limitation in claim 20 does not further limit claim 16. Thus, for the same reasons that Petitioner has established, by a preponderance of the evidence, that claim 16 would have been obvious over the combined teachings of Fujimoto and Ho, we determine that

⁹ For claim 18, Petitioner does not substantively rely on any teaching from Yaung, even though Yaung is named in the alleged ground of unpatentability. Pet. 72.

Petitioner has established, by a preponderance of the evidence, that claim 20 would have been obvious over Fujimoto, Ho, and Yaung.¹⁰

I. Alleged Unpatentability of Claim 21
as Obvious over Fujimoto, Ho, and Sonogo

As discussed above, the combined teachings of Fujimoto and Ho render obvious the subject matter of claim 16. Claim 21 depends from claim 16 and further recites: “rapid thermal annealing to reflow the second layer of dielectric material to obtain a substantially planar surface.”

Ex. 1001, 6:25–27. The same limitation is present in claim 9, which depends from claim 1. *Id.* at 5:5–7. For the same reasons discussed above in the context of claim 9, excluding Petitioner’s reliance on Yaung to account for a first photoresist limitation that is not present in claim 21, Petitioner has shown that the combined teachings of Fujimoto, Ho, and Sonogo disclose the step of “rapid thermal annealing to reflow the second layer of dielectric material to obtain a substantially planar surface.”

For claim 21, Patent Owner does not present arguments other than those it has presented for claim 1, which we have discussed and rejected above in the context of claim 1. We determine that Petitioner has established, by a preponderance of the evidence, that claim 21 would have been obvious over Fujimoto, Ho, and Sonogo.

¹⁰ For claim 20, Petitioner does not substantively rely on any teaching from Yaung, even though Yaung is named in the alleged ground of unpatentability. Pet. 72–73.

J. Alleged Unpatentability of Claim 15 as
Obvious over Fujimoto, Yaung, Ho, and Ohkawa

Claim 15 depends from claim 1 and further recites: “wherein the step of forming the second and third openings comprises a self-aligned contact step.” Ex. 1001, 5:21–23. As discussed above, Petitioner has shown that the subject matter of claim 1 would have been obvious over the combined teachings of Fujimoto, Yaung, and Ho. Petitioner acknowledges that in the combined method of Fujimoto, Yaung, and Ho, Fujimoto’s first contact hole 21 and second contact hole 22 are formed without using a “self-aligned contact” step. Pet. 74. However, Petitioner asserts that in light of the disclosure of Ohkawa, it would have been obvious to one with ordinary skill in the art to modify the method according to the combined teachings of Fujimoto, Yaung, and Ho, such that the step of forming contact holes 21 and 22 “includes a self-aligned contact step.” *Id.*

For reasons discussed below, we determine that Petitioner has not established, by a preponderance of the evidence, that claim 15 would have been obvious to one with ordinary skill in the art over the combined teachings of Fujimoto, Yaung, Ho, and Ohkawa.

Ohkawa relates to a manufacturing method for a semiconductor device with self-aligned contacts. Ex. 1025, 1:12–15 (cited at Pet. 74). Dr. Rubloff testifies that Ohkawa discloses a semiconductor structure similar to that in Fujimoto, in that Ohkawa’s structure includes gate oxide film 3 over substrate 1, gate electrode 5G and first wiring layer 5a over gate oxide film 3, and silicon nitride film 7 over gate electrode 5G and first wiring layer 5a. Ex. 1002 ¶ 168 (cited at Pet. 74). Dr. Rubloff also testifies: “Ohkawa further discloses that ‘by using the gate electrode 5G as a mask, P (phosphorous) ions are implanted into the silicon substrate 1 to form n-type

impurity diffusion regions (not shown). The n-type impurity diffusion regions are used as the source and drain regions (not shown).” *Id.* (quoting Ex. 1025, 7:58–65).

Dr. Rubloff additionally testifies:

[G]iven the similarity in the structure of the devices disclosed by *Fujimoto* and *Ohkawa*, a person of ordinary skill in the art would have readily understood that *Fujimoto*’s polysilicon layer 12 is analogous to *Ohkawa*’s gate electrode 5G/first wiring layer 5a, *Fujimoto*’s protective film 14 is analogous to *Ohkawa*’s SiN film 7 on top of the gate electrode 5G/first wiring layer 5a, and *Fujimoto*’s first layer of interlayer insulating film 15 is analogous to *Ohkawa*’s BPSG film 9.

Ex. 1002 ¶ 169 (cited at Pet. 75). Dr. Rubloff further testifies:

[S]imilar to *Fujimoto*, *Ohkawa* discloses etching through its dielectric layer, i.e., BPSG film 9, to form two contact holes: “a contact hole 11a to the substrate between the gate electrodes 5G and a contact hole 11b to the first wiring layer 5a.” ([Ex. 1025] at 8:15–19.) *Ohkawa*’s contact hole 11a is similar to *Fujimoto*’s contact hole 21 because both are holes formed towards the source/drain contacts (circled in red in the annotated figures below) while *Ohkawa*’s contact hole 11b is similar to *Fujimoto*’s contact hole 22 because both are holes formed towards the gate (circled in blue in the annotated figures below). *Ohkawa* discloses that the contact holes 11a and 11b are both formed “by a self-aligned contact method.” (*Id.*; see also *id.* at 22–33.)

Ex. 1002 ¶ 170 (cited at Pet. 76).

Dr. Rubloff testifies that a person of ordinary skill in the art would have been motivated to modify the combined *Fujimoto*-*Yaung-Ho* method such that the step of forming contact holes 21 and 22 includes a self-aligned contact step like that disclosed by *Ohkawa*. *Id.* ¶ 171 (cited at Pet. 76). Dr. Rubloff explains that both *Fujimoto* and *Ohkawa* are directed to a technique for forming contact holes in a semiconductor device and disclose

similar structures, and that both Fujimoto and Ohkawa recognize the benefits of forming contact holes using a self-aligned contact step. *Id.* Dr. Rubloff cites Ohkawa to show that by using a self-aligned contact step, “a position alignment margin between the underlying conductive layer and a contact hole is not necessary and the cell can be made finer correspondingly.” *Id.* ¶ 172 (cited at Pet. 76). Dr. Rubloff further testifies that this well-known benefit of a self-aligned contact process is also recognized by Fujimoto. *Id.* (citing Ex. 1005, 1:23–47). Finally, Dr. Rubloff testifies:

Modifying the *Fujimoto-Yaung-Ho* method to form the contact holes 21 and 22 using a self-aligned contact step would have been nothing more than the application of a known technique (using a self-aligned contact step to form holes towards a gate and a substrate as disclosed by *Ohkawa*) to a known device (the semiconductor device of *Fujimoto*) ready for improvement (*Fujimoto*’s device would benefit from a higher tolerance to mask misalignment conferred by forming contact holes using a self-aligned contact process) to obtain the expected result of holes towards the gate and the source/drain to enable electrical connection to other parts of the device. . . . Additionally, a person having ordinary skill in the art would have known and had the capability to implement the above modifications in such a way to ensure the process of manufacturing the semiconductor device disclosed by *Fujimoto* would be workable, as well as the resulting device being formed.

Id. ¶ 173 (cited at Pet. 77).

Although it is true, as noted by Dr. Rubloff, that Fujimoto itself recognizes certain advantages of a self-aligning process, Ex. 1005, 1:23–47 (cited at Ex. 1002 ¶ 172 (cited at Pet. 76)), Patent Owner correctly notes that Fujimoto’s contact openings are formed without using the self-aligned contact process, as acknowledged by Petitioner. PO Resp. 48 (citing Pet. 74 (citing Ex. 1005, 4:49–56)). Patent Owner asserts that “[a] person of ordinary skill in the art would not modify Fujimoto to implement a self-align

contact etch process because Fujimoto's device structure is not suitable for such a process." *Id.*

Patent Owner explains:

In Fujimoto, prior to forming the contact openings, the protective film 14 located over the gate electrode is removed using the combination of the large diameter opening in the etch mask and an etching medium that etches the protective film faster than the surrounding insulating film. Ex. 1005 at col. 2:49–57. This results in the structure shown in Figure 1(d), with the removal of the protective film 14 on top of the gate “as well as upper halves of its side-wall portions 14b, which were continuous to the top portion.” *Id.* at col. 5:23–27. The self-aligned etch process relies on the existence of side-wall spacers on the gate to separate the gate electrode from contacts formed nearby. Ex. 2004 at ¶ 89. . . . With the side-wall spacers in place, perfect alignment of the contact openings is less of a concern because, even if there is some misalignment, the side-wall spacer will keep the gate electrode insulated from the surrounding contacts.

This doesn't work in Fujimoto because half of the sidewalls of the gate electrode are removed. Thus, a substrate contact formed nearby could more easily come in contact with the gate electrode, resulting in a short circuit. A person of ordinary skill in the art would understand that this is the reason Fujimoto states that its contact etch process does not utilize the self-aligned contact technique. It is the tradeoff made in order to obtain the other benefits of the Fujimoto process. Thus, even though a person of ordinary skill would recognize that there are some benefits to using a self-aligned process, they would also recognize that *such a technique is incompatible with the Fujimoto process.*

PO Resp. 49–50 (emphasis added) (footnotes omitted). In particular, Patent Owner asserts: “A person of ordinary skill in the art would recognize that without the sidewalls to protect the gate, it is not possible to implement a self-aligned contact etch process. Ex. 2004 at ¶ 89. By definition, the sidewalls protective layer must be present.” *Id.* at 49 n.17. These assertions

are supported by the testimony of Patent Owner's declarant, Mr. Brahmbhatt. Ex. 2004 ¶ 89.

In its Reply, Petitioner does not dispute Patent Owner's above-noted positions (1) that a person of ordinary skill in the art would have recognized that without the sidewalls to protect the gate, it is not possible to implement a self-aligned contact etch process; and (2) that by definition, the sidewalls protective layer must be present for a self-aligned contact etch process. PO Resp. 49 n.17. In this circumstance, we credit the corresponding testimony of Mr. Brahmbhatt (Ex. 2004 ¶ 89), and find both of these assertions of Patent Owner to be established facts.

Instead, Petitioner replies by making two arguments. First, Petitioner contends Patent Owner improperly attacks its asserted references individually where Petitioner's obviousness ground is based on the teachings of a combination of references. Reply 25. According to Petitioner, it does not matter that Fujimoto does not disclose full sidewalls allegedly required by a self-aligned contact etch, because Ohkawa discloses using a self-aligned contact etch and Patent Owner does not contend that one with ordinary skill in the art would have been incapable of leaving more gate sidewalls in tact in Fujimoto. *Id.* Second, Petitioner contends Patent Owner does not explain what benefits are provided by Fujimoto's removing half of the sidewalls of the gate, or why one would not or could not, in the context of Fujimoto, leave the sidewalls in tact like they are in Ohkawa. Reply 26. For reasons discussed below, we find both arguments to be misplaced, and that both arguments attempt improperly to shift the burden of proof to Patent Owner.

Although it is true that "[n]on-obviousness cannot be established by attacking references individually where the rejection is based upon the

teachings of a combination of references,” *In re Merck & Co., Inc.*, 800 F.2d 1091, 1097 (Fed. Cir. 1986), we do not agree that Patent Owner attacks any reference individually. Patent Owner argues persuasively that Fujimoto’s process is not compatible with a self-aligned contact step and also that Fujimoto’s device structure is not suitable for a self-aligned contact etch process. PO Resp. 48–50. These arguments represent something more than an attack on Fujimoto individually as not teaching a self-aligned contact etch.

The issues raised by Patent Owner are directed to whether there is a proper motivation to combine teachings. Neither of the two above-identified arguments of Petitioner, focusing on what Patent Owner has not asserted, provides a reasoned motivation to make the necessary modification to Fujimoto. The burden is on Petitioner to establish sufficient motivation for making the modification in Fujimoto’s process and structure. Patent Owner need not demonstrate lack of motivation.

Petitioner does not explain why, in the context of Fujimoto, non-diminished gate sidewalls would have been acceptable to one with ordinary skill in the art. It is a substantial omission for Petitioner not to account for the facially incompatible process and structure of Fujimoto with respect to implementing a self-aligned contact etch, and to place the focus solely on Ohkawa’s teachings.

Petitioner asserts that even if certain benefits of diminished sidewalls are lost by implementing full sidewalls, that does not negate obviousness. Reply 26. The statement is too broad. It depends on the role and significance of having diminished sidewalls in Fujimoto, which Petitioner has not adequately explained. The authority cited by Petitioner (Reply 26), *In re Urbanski*, 809 F.3d 1237, 1244 (Fed. Cir. 2016), does not stand for

the extreme proposition that any teaching from one reference always can be properly applied and incorporated in a process disclosed by another reference, no matter how incompatible that other process may be. The approach taken by Petitioner represents an over-simplification of the analysis for determining a sufficient motivation to combine teachings.

For the foregoing reasons, Petitioner has not presented adequate motivation for one with ordinary skill in the art to include a self-aligned contact step in the process of Fujimoto. We determine that Petitioner has not established, by a preponderance of the evidence, that claim 15 would have been obvious over the combined teachings of Fujimoto, Yaung, Ho, and Ohkawa.

K. Alleged Unpatentability of Claim 23 as
Obvious over Fujimoto, Ho, and Ohkawa

Claim 23 depends from claim 16 and further recites: “wherein the step of forming the second and third openings comprises a self-aligned contact step.” Ex. 1001, 6:31–33. We discussed and concluded above that Petitioner has established, by a preponderance of the evidence, that claim 16 would have been obvious to one with ordinary skill in the art over the combined teachings of Fujimoto and Ho. *See supra* Section II.G.

Claim 23 adds to claim 16 the same limitation that claim 15 adds to claim 1. Petitioner’s analysis for this added limitation of claim 23 is identical to its analysis of the added limitation of claim 15 (Pet. 78), and Patent Owner’s arguments for this added limitation of claim 23 are the same as its arguments for the added limitation of claim 15 (PO Resp. 47–50).

For the same reasons discussed above with respect to claim 15, we determine that Petitioner has not established, by a preponderance of the

evidence, that claim 23 would have been obvious over the combined teachings of Fujimoto, Ho, and Ohkawa.

L. Patent Owner's Motion to Strike

Patent Owner's Motion to Strike centers on an argument made by Petitioner in its Reply: "[T]hat a person of ordinary skill in the art would further modify the Fujimoto-Yaung-Ho combination to select a different, not previously disclosed hardmask material, such as the polysilicon hardmask disclosed in Nulty." Paper 24, 4 (citing Reply 15). Patent Owner asserts that this argument, together with Paragraph 10 of Dr. Rubloff's Rebuttal Declaration (Ex. 1029) and Exhibit 1030 ("Nulty") as cited in that Paragraph 10, should not be considered, because they were not a part of the initial Petition or Dr. Rubloff's initial Declaration (Ex. 1002) in support of the Petition. Paper 24, 2. In that regard, the Reply states: "Indeed, hardmasks made of other materials (e.g., polysilicon) were known to a POSITA. (Ex. 1029, ¶ 10 (citing Ex. 1030, 4:34–35).)" Reply 15. Paragraph 10 of Dr. Rubloff's Rebuttal Declaration states, in part: "For instance, a person of ordinary skill would have known of a polysilicon mask. (*Ex. 1030 (Nulty)* at 4:34–35, 11:6–8.) It was within the capability of a person of ordinary skill to select the appropriate hardmask material depending on the materials being etched and the etch chemistry being used." Paper 24, 4–5 (quoting Ex. 1029 ¶ 10).

For all the reasons presented in Petitioner's Opposition (Paper 29), we are not persuaded by Patent Owner that the specific argument and evidence relied on by Petitioner, as identified by Patent Owner, are beyond the proper scope of a reply. Petitioner's obviousness analysis is based on implementing Ho's hardmask in Fujimoto. Pet. 35–37; Ex. 1002 ¶ 94. Notably, the Petition itself relied on Ho's disclosure of the use of "other hard mask

materials” in addition to SiO₂ and Si₃N₄. Pet. 57 (citing Ex. 1007, 3:17–19). The cited portion of Ho describes that “[h]ard mask may be formed of SiO₂, Si₃N₄, or other hard mask materials, especially inorganic hard mask materials.” Ex. 1007, 3:17–19. Under these circumstances, Petitioner’s reply arguments about other hardmask materials described in Ho constitute an appropriate response to Patent Owner’s argument that one with ordinary skill in the art would not have used SiO₂ and Si₃N₄ as hardmask materials in Fujimoto (PO Resp. 32–33).

Accordingly, Patent Owner’s Motion to Strike is *denied*.

III. CONCLUSION

Petitioner has established, by a preponderance of the evidence, that each of claims 1–4, 6, 8, and 12–14 would have been obvious over Fujimoto, Yaung, and Ho;

Petitioner has established, by a preponderance of the evidence, that each of claims 9–11 would have been obvious over Fujimoto, Yaung, Ho, and Sonogo;

Petitioner has established, by a preponderance of the evidence, that each of claims 16 and 22 would have been obvious over Fujimoto and Ho;

Petitioner has established, by a preponderance of the evidence, that each of claims 17, 18, and 20 would have been obvious over Fujimoto, Ho, and Yaung;

Petitioner has established, by a preponderance of the evidence, that claim 21 would have been obvious over Fujimoto, Ho, and Sonogo;

Petitioner has not established, by a preponderance of the evidence, that claim 5 would have been obvious over Fujimoto, Yaung, Ho, and Paterson;

Petitioner has not established, by a preponderance of the evidence, that claim 7 would have been obvious over Fujimoto, Yaung, and Ho;

Petitioner has not established, by a preponderance of the evidence, that claim 15 would have been obvious over Fujimoto, Yaung, Ho, and Ohkawa;

Petitioner has not established, by a preponderance of the evidence, that claim 19 would have been obvious over Fujimoto and Ho; and

Petitioner has not established, by a preponderance of the evidence, that claim 23 would have been obvious over Fujimoto, Ho, and Ohkawa.

IV. ORDER

It is

ORDERED that each of claims 1–4, 6, 8–14, 16–18, and 20–22 of the '044 patent is unpatentable;

FURTHER ORDERED that Patent Owner's Motion to Strike is *denied*; and

FURTHER ORDERED that because this is a Final Written Decision, parties to the proceeding seeking judicial review of the decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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Patent 6,559,044 B1
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