

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

NANYA TECHNOLOGY CORPORATION,
NANYA TECHNOLOGY CORPORATION U.S.A., and
NANYA TECHNOLOGY CORPORATION DELAWARE,
Petitioner,

v.

MONTEREY RESEARCH, LLC,
Patent Owner.

IPR2021-00172
Patent 6,902,993 B2

Before JOHN F. HORVATH, JASON W. MELVIN, and
BRIAN D. RANGE, *Administrative Patent Judges*.

MELVIN, *Administrative Patent Judge*.

JUDGMENT
Final Written Decision
Determining All Challenged Claims Unpatentable
35 U.S.C. § 318(a)

I. INTRODUCTION

Nanya Technology Corporation, Nanya Technology Corporation, U.S.A., and Nanya Technology Corporation Delaware (collectively “Petitioner”) filed a Petition (Paper 1, “Pet.”) requesting institution of *inter partes* review of claims 1–19 (all claims, “the challenged claims”) of U.S. Patent No. 6,902,993 B2 (Ex. 1001, “the ’993 patent”). Pet. 3–4. Monterey Research, LLC, (“Patent Owner”) filed a Preliminary Response. Paper 6 (“Prelim. Resp.”). We instituted review. Paper 7 (“Institution Decision” or “Inst.”).

Patent Owner filed a Response (Paper 17, “PO Resp.”), Petitioner filed a Reply (Paper 20, “Pet. Reply”), and Patent Owner filed a Sur-Reply (Paper 25, “PO Sur-Reply”). We held an oral argument on March 23, 2022, and a transcript appears in the record. Paper 32.

We have authority to hear this *inter partes* review under 35 U.S.C. § 6. This Final Written Decision is issued pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons that follow, we determine that Petitioner establishes by the preponderance of the evidence that claims 1–19 of the ’993 patent are unpatentable.

A. REAL PARTIES-IN-INTEREST

Petitioner identifies the captioned parties as real parties-in-interest. Pet. 1–2. Patent Owner identifies itself and IPValue Management as real parties-in-interest. Paper 4, 1.

B. RELATED MATTERS

The parties identify a litigation involving the '993 patent, *Monterey Research, LLC v. Nanya Technology Corp. et al.*, No. 1:19-cv-02090 (D. Del. 2019). Pet. 2–3; Paper 4, 1–2.

C. THE '993 PATENT

The '993 patent is titled “Gate Electrode for MOS Transistors.” Ex. 1001, code (54). It discloses forming a gate of a transistor “by performing a first thermal treatment on a silicon layer, forming a metal stack over the silicon layer, and performing a second thermal treatment on the metal stack.” *Id.*, code (57). Through this approach, the '993 patent seeks to improve transistor switching speed by “lowering interface contact resistance between layers of the gate electrode.” *Id.* at 1:30–32.

The '993 patent describes several advantages that flow from “[r]apid thermal annealing of silicon layer 112 before formation of additional gate materials thereon.” *Id.* at 3:15–17. Namely, it asserts repair of “damage caused by the implantation step, re-crystallization of amorphous silicon, and providing a smooth interface for a subsequently formed silicide layer.” *Id.* at 3:17–20.¹

The '993 patent describes forming a gate electrode by depositing a stack comprising a first metal layer, a refractory nitride layer, and a second metal layer. *Id.* at 3:46–4:19. Once the stack has been deposited, a second thermal treatment is performed, in part forming a silicide layer at the interface with the silicon layer. *Id.* at 4:43–62.

¹ The “implantation step” refers to doping silicon with ions to form a transistor. Ex. 1001, 2:46–50.

D. CHALLENGED CLAIMS

Challenged claim 1 is reproduced below:

1. A method of forming a gate of a transistor, the method comprising:
annealing a silicon layer;
forming a metal stack over the silicon layer; and
exposing the metal stack in a heated environment comprising nitrogen to convert a portion of the metal stack to a silicide layer;
wherein forming the metal stack comprises:
forming a titanium layer over the silicon layer;
forming a tungsten nitride layer over the titanium layer;
and
forming a tungsten layer over the tungsten nitride layer.

Ex. 1001, 8:13–24. Independent claims 9 and 17 recite limitations similar to those of claim 1. *See id.* at 8:42–50, 9:4–10:5. Claims 2–8 depend, directly or indirectly, from claim 1. *Id.* at 8:25–41. Claims 10–16 depend directly from claim 9. *Id.* at 8:51–67. Claims 18 and 19 depend directly from claim 17. *Id.* at 10:6–9.

E. PRIOR ART AND ASSERTED GROUNDS

Petitioner asserts the following grounds of unpatentability:

Claims Challenged	35 U.S.C. §	References/Basis
1, 4, 7–9, 12–14	103	Yoon ² , Chern ³

² US 6,740,585 B2, issued May 25, 2004, from an application filed Jan. 9, 2002 (Ex. 1005).

³ US 6,277,719 B1, issued Aug. 21, 2001 (Ex. 1006).

Claims Challenged	35 U.S.C. §	References/Basis
1, 4, 7–9, 12–14	103	Chern, Yoon ⁴
2, 3, 10, 11	103	Yoon, Chern, Kubo ⁵
5, 6, 15, 16	103	Yoon, Chern, Weimer ⁶
17–19	103	Yoon, Chern, Weimer, Kunikiyo ⁷
1, 4, 7–9, 12–14	103	Iyer ⁸ , Chern
2, 3, 10, 11	103	Iyer, Chern, Kubo

Pet. 6. Petitioner also relies on the Declaration of Jean-Pierre Leburton, Ph.D. Ex. 1003. Patent owner relies on the Declaration of Joseph C. McAlexander III. Ex. 2006.

II. ANALYSIS

A. LEVEL OF ORDINARY SKILL IN THE ART

Petitioner proposes that a person of ordinary skill “would have been a technical person with a Bachelor’s degree in electrical engineering, materials science, applied physics, or a related field, and approximately two years of experience working in the design, development, and/or testing of semiconductor structures and dynamic random access memory (DRAM)

⁴ In the first ground, Petitioner relies on Yoon as the primary reference, modified by Chern, whereas in the second ground, Petitioner relies on Chern as the primary reference, modified by Yoon.

⁵ US 6,589,827 B2, issued July 8, 2003 (Ex. 1007).

⁶ US 6,291,868 B1, issued Sept. 18, 2001 (Ex. 1008).

⁷ US 6,500,720 B2, issued Dec. 31, 2002, from an application filed Sept. 25, 2001 (Ex. 1009).

⁸ US 6,688,584, issued Feb. 10, 2004, from an application filed May 16, 2001 (Ex. 1010).

cells” Pet. 9 (citing Ex. 1003 ¶¶ 25–26). Patent Owner takes no position on that definition. PO Resp. 10.

We adopt Petitioner’s proposed level of ordinary skill as it appears to be consistent with the record evidence.

B. CLAIM CONSTRUCTION

For an *inter partes* review petition filed after November 13, 2018, we construe claim terms “using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b).” 37 C.F.R. § 42.100(b) (2020). Petitioner submits that “all terms should be given their plain and ordinary meaning” without elaboration. Pet. 10. Patent Owner agrees that no term requires construction, but contends the preambles limit the claims. PO Resp. 10, 12–14. Petitioner disputes that contention. Pet. Reply 1–3.

The preambles of independent claims 1, 9, and 17 recite “[a] method of forming a gate of a transistor” (claims 1 and 9) or “[a] method of forming a gate electrode of a transistor” (claim 17). Patent Owner contends that the preambles limit the claims and require forming a gate. Patent Owner relies first on Petitioner’s expert, Dr. Leburton, who testified that the preambles provide context for practicing the claims and serve as claim elements. *Id.* at 12 (citing Ex. 2005, 123:12–124:2, 124:9–18, 124:22–125:7, 125:8–15). Beyond interpreting the claims’ preambles to require forming a gate, Patent Owner contends that “each of the layers recited in each independent claim must correspond to those found inside the gate or at least be utilized to make a gate.” *Id.* at 13.

Petitioner discounts the significance of Dr. Leburton’s testimony about the preamble, noting that the issue is one of law. Pet. Reply 2. We

agree with Petitioner that the expert testimony here does not demonstrate the preamble limits the claims. The testimony by Dr. Leburton confirmed his declaration statement that Yoon discloses claim 1's preamble. *E.g.*, Ex. 2005, 123:12–19. In other words, Dr. Leburton's analysis treated the preambles as limiting; however, that does not compel a conclusion that the preambles are limiting. Dr. Leburton also testified that the preamble provides context for the remainder of the claim. *Id.* at 125:8–15 (agreeing that “the phrase, for example, a method of forming a gate of a transistor is providing a context of what needs to be performed in order to practice this claim”). But providing context for the limitations in the claim body is tantamount to reciting “a purpose or intended use for the invention,” which typically does not limit the claims. *TomTom, Inc. v. Adolph*, 790 F.3d 1315, 1323 (Fed. Cir. 2015).

The claim here does not rely upon the preamble for antecedent basis of any limitation in the claim body. *E.g.*, Ex. 1001, 8:13–24. Moreover, nothing about the preamble adds to the recitation of the invention defined by the claim body—deleting the preamble would not affect the steps of the claimed invention. Thus, the relationship between the preamble and the claim body indicates that the preamble recites a nonlimiting intended use. *TomTom*, 790 F.3d at 1324 (citing *Am. Med. Sys., Inc. v. Biolitec, Inc.*, 618 F.3d 1354, 1358–59 (Fed. Cir. 2010)).

Patent Owner contends additionally that the “Examiner relied on the preamble gate (or gate electrode) of a transistor” to make a restriction requirement during prosecution. PO Resp. 13–14. Petitioner points out that the Examiner's restriction requirement identified claim groups directed to “a process of making a semiconductor device” versus a “semiconductor

device.” Pet. Reply 3 (quoting Ex. 1002, 160). Petitioner argues that the claim bodies distinguished the two sets of claims. *Id.* (citing Ex. 1002, 20–24). We agree that the groups broadly distinguished claims directed to a device from claims directed to a method for making that device. Other than distinguishing method from apparatus claims, the restriction requirement did not address whether the preamble is otherwise limiting. Ex. 1002, 160 (“Inventions II and I are related as process of making and product made.”). The prosecution history here does not demonstrate “clear reliance on the preamble during prosecution to distinguish the claimed invention from the prior art,” which would support construing the preamble to limit the claims. *See Symantec v. Computer Associates*, 522 F.3d 1279, 1288 (Fed. Cir. 2008).

We conclude that the preambles do not limit the claims to methods used to form gates, but instead recite the nonlimiting intended use of the claimed methods. We conclude further that no other claim term requires express construction for purposes of this decision. *See Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017).

C. OBVIOUSNESS OVER YOON MODIFIED BY CHERN

Yoon discloses an approach for forming a metal or metal silicide barrier layer over a silicon substrate. Ex. 1005, code (57). After a first metal layer is deposited on a silicon-containing material, the layer is “annealed to form a metal silicide layer.” *Id.* at 12:7–12. Yoon discloses that a two-step annealing process may be used, in which the first step may “partially convert the metal to a metal silicide.” *Id.* at 12:19–22. In the second annealing step, “the metal is substantially converted to the desired silicide phase.” *Id.* at 12:22–24.

In Yoon's approach, a second metal layer is deposited "to fill the feature" (*id.* at 12:12–13) and, "prior to second metal deposition, such as tungsten, a layer of a barrier material, such as titanium or titanium nitride, may be deposited on the first metal layer" (*id.* at 14:50–52). Yoon further discloses that the aforementioned "second annealing step may be performed before or after the deposition of the second metal." *Id.* at 12:33–35.

Petitioner agrees that Yoon does not disclose annealing the "silicon-containing material" on which metal layers are deposited. Pet. 14. For that step, Petitioner points to Chern. Pet. 14.

Chern discloses a "low resistance metal/polysilicon gate for use in CMOS devices." Ex. 1006, code (57). In Chern's approach, an insulating layer is formed on a silicon substrate, and then a polysilicon layer is formed over the insulating layer. *Id.* Then, "[i]n a key step, the polysilicon layer is annealed to prevent peeling of the subsequently formed diffusion barrier layer." *Id.* According to Chern, "[p]erforming the polysilicon annealing step prior to forming a diffusion barrier layer has been experimentally proven to reduce the subsequently formed diffusion barrier layer's susceptibility to peeling." *Id.* at 3:35–38.

After the annealing step, Chern discloses forming a titanium silicide layer, performing a second annealing step, then depositing a titanium nitride layer, a tungsten layer, and a cap layer to define a gate structure. *Id.* at 3:40–4:11.

Petitioner submits that annealing Yoon's silicon-containing layer would have been obvious because doing so "would reduce the interface roughness between the silicon and the other layers, and aid in creating a low resistivity path between the silicon-containing material and the other layers."

Pet. 15. Petitioner submits additionally that annealing “would also have reduced the susceptibility of the barrier layer to peeling.” *Id.*

1. Independent claims 1 and 9

Patent Owner challenges Petitioner’s contentions for all claims under grounds applying Yoon as modified by Chern (Grounds 1 and 3–5).

PO Resp. 11, 15–36. Relevant to obviousness over Yoon and Chern, those arguments apply to independent claims 1 and 9.

Patent Owner argues first that Petitioner’s contentions are deficient because Yoon does not disclose forming a gate and instead discloses making contacts that would connect with a gate, source, or drain. PO Resp. 15–20. Because, as explained above, we do not construe the preambles as limitations on claim scope, we do not agree with Patent Owner that Yoon must teach the claimed process as applied to forming a gate.⁹ *See supra* at 6, § II.B.

Patent Owner argues next that Yoon does not teach “exposing the metal stack in a heated environment comprising nitrogen to convert a portion of the metal stack to a silicide layer” as recited in claim 1 and a similar limitation in claim 17. PO Resp. 20. According to Patent Owner, Yoon’s first anneal step fully converts the initial metal layer to metal silicide; thus, the second anneal step cannot be performed on the claimed “metal stack,” which must include the initial metal layer, because that layer is no longer present after the first anneal step. *Id.* at 21.

⁹ We do not address Petitioner’s contention that Yoon discloses forming a gate and thus satisfies even a limiting construction of the preamble. *See* Pet. Reply 3–8.

As described above, Petitioner relies on Yoon's disclosure that the first anneal step may be "used to . . . partially convert the metal to a metal silicide" before, in the second anneal step, "the metal is substantially converted to the desired silicide phase." Ex. 1005, 12:19–24. In Patent Owner's view, that passage must be read to indicate that the first anneal step completely converts the metal to a first metal silicide, and the second anneal step converts what was originally metal (before the first anneal step) from the first metal silicide to a second metal silicide. PO Resp. 24. To the extent metal remains after Yoon's first anneal step, Patent Owner contends that Yoon teaches removing that unreacted metal before the second anneal step. *Id.* The problem with that argument, however, is that Yoon teaches removing unreacted metal between anneal steps only optionally, not as a required step. *E.g.*, Ex. 1005, 16:42–45 ("A selective etch of the first metal layer and metal silicide layer to remove unreacted first metal material *may be performed* between two or more annealing steps." (emphasis added)). Thus, when Yoon discloses "partially convert[ing] the metal to a metal silicide" in the first anneal step (*id.* at 12:22), that would leave metal remaining for the second anneal step. Such an understanding is consistent with Yoon's statement that, in the second anneal step, "the metal is substantially converted to the desired silicide phase" (*id.* at 12:22–24).

Patent Owner submits that Yoon's description of the second anneal step mistakenly omitted "silicide" when describing what the step converts. PO Resp. 25. Based on the foregoing arguments, we do not agree. Yoon's description includes a first anneal step that only partially converts metal to metal silicide. Ex. 2005, 12:22. Thus, Yoon's statement that, in the second anneal step, "the metal is substantially converted to the desired silicide

phase” is not inconsistent with Yoon’s other disclosures, and we decline to interpret Yoon’s disclosure in the manner Patent Owner seeks.

Patent Owner argues also that skilled artisans would not have combined Yoon’s approach with Chern’s teaching to anneal a silicon layer as asserted by Petitioner. PO Resp. 26–36. According to Patent Owner, because Yoon’s processes are directed to a transistor’s contacts, rather than to the transistor itself, skilled artisans would not have combined its teachings with Chern’s, which relate to the transistor’s gate. *Id.* at 26–27. Petitioner points out that Yoon also discusses forming a gate electrode on the silicon substrate, and encompasses more than just upper-layer contacts. Pet. Reply 11 (citing Ex. 1005, 20:55–59 (“A gate oxide layer 408 and a polysilicon gate electrode 410 are formed over silicon substrate 400 in between source and drain regions 402 and 404 with oxide spacers 412 formed on the sidewalls of polysilicon gate electrode 410.”)). We agree with Petitioner that Yoon’s disclosure of aspects beyond Chern’s discussion does not mean skilled artisans would not have looked at the two references in combination.¹⁰

Petitioner further reasons that annealing a polysilicon substrate as Chern discloses offered two distinct benefits—lower resistivity from reduced interface roughness and reduced susceptibility to peeling. Pet. 14–15 (citing Ex. 1003 ¶ 57). Although the Petition is supported by Dr. Leburton’s testimony, in the Institution Decision, we noted that his testimony regarding lower resistivity did not provide “independent evidentiary support.” Inst. 8. In light of the alternative justification for the

¹⁰ Patent Owner does not argue that Chern and Yoon are nonanalogous art.

asserted combination, we did not address the potentially reduced resistivity. *Id.* That evaluation, however, was based on the limited preinstitution evidentiary record. *Id.* at 17.

Petitioner notes that there is no dispute that annealing polysilicon reduces resistivity with additional layers. Pet. Reply 15–16. And Petitioner identifies additional record evidence to support that annealing can reduce resistivity and smooth the silicon surface. *Id.* (citing Ex. 1008, 3:37–39; Ex. 1005, 1:58–2:1; Ex. 1014, Fig. 2, 660–62 (discussing 20–30% reduced sheet resistance for films annealed before ion implantation); Ex. 1013, 181 (“The emitter resistance of annealed devices is considerably lower than unannealed ones.”); Ex. 1015, 259 (“[A] controlled annealing treatment is necessary to convert the amorphous film into a smooth polycrystalline film.”)). Patent Owner argues that Petitioner’s additional citations and evidence are too late, and should have been raised in the Petition. PO Sur-Reply 15. We do not agree. Petitioner reasonably responds to an issue discussed in the Institution Decision and Patent Owner Response. *See* Inst. 8; PO Resp. 30–31. Dr. Leburton’s testimony cited in the Petition sufficiently established Petitioner’s contention to permit elaboration during the trial, and the full record supports that annealing Yoon’s silicon substrate as taught by Chern would have reduced interface roughness and therefore the resistivity between the polysilicon and additional layers. That benefit would have sufficiently motivated skilled artisans to make the asserted combination.

Even if we were to discount that aspect of Petitioner’s proffered motivation, however, we determine that reduced susceptibility to peeling also would have motivated skilled artisans to anneal Yoon’s substrate.

Petitioner relies on Chern's statement that "[p]erforming the polysilicon annealing step prior to forming a diffusion barrier layer has been experimentally proven to reduce the subsequently formed diffusion barrier layer's susceptibility to peeling." Ex. 1006, 3:31–38; Pet. 14–15. Patent Owner argues that Chern's disclosure of reduced peeling susceptibility relates only to depositing a barrier layer on the annealed polysilicon. PO Resp. 33–34. Patent Owner identifies Dr. Leburton's testimony that the modification would reduce susceptibility of Yoon's tungsten nitride barrier layer from peeling, notwithstanding that a metal layer is between the polysilicon substrate and tungsten nitride layer. *Id.* at 34 (citing Ex. 2005, 67:23–68:6). While Patent Owner focuses on the tungsten nitride layer, we agree with Petitioner that the record supports reduced peeling for whatever material contacts the annealed substrate. Dr. Leburton testified that annealing a polysilicon substrate makes that material more "coherent and consistent" and improves its "contact with other materials." Ex. 2005, 134:24–135:25. We agree with Petitioner that reducing peeling from the polysilicon substrate is a benefit to all upper layers, as they depend on the bottom layer remaining attached. *See* Pet. Reply 14–15.

Thus, we conclude that skilled artisans had reason to anneal Yoon's polysilicon substrate both to reduce additional layers' susceptibility to peeling, and also to reduce interface roughness and resistivity.

Patent Owner raises no additional arguments against Petitioner's assertions for claims 1 and 9 as obvious over Yoon modified by Chern.¹¹

¹¹ We determine Patent Owner has waived any unraised argument. *See* Paper 8, 8 ("Patent Owner is cautioned that any arguments not raised in the response may be deemed waived."); *In re NuVasive, Inc.*, 842 F.3d 1376,

The unpatentability burden, however, remains on Petitioner. *See Dynamic Drinkware, LLC v. Nat’l Graphics, Inc.*, 800 F.3d 1375, 1378 (Fed. Cir. 2015). Petitioner provides contentions showing how claims 1 and 9 are obvious over Yoon and Chern. Pet. 10–21. We have reviewed the parties’ contentions and the evidence presented and conclude that Petitioner has shown by a preponderance of the evidence that the subject matter of claims 1 and 9 would have been obvious over Yoon and Chern.

2. Additional Claims

Petitioner provides contentions showing how dependent claims 4, 7, 8, and 12–14 are obvious over Yoon and Chern. Pet. 17–19. Other than as discussed above regarding independent claims 1 and 9, Patent Owner does not challenge Petitioner’s assertions. We have reviewed the parties’ contentions and the evidence presented and conclude that Petitioner has shown by a preponderance of the evidence that the subject matter of claims 4, 7, 8, and 12–14 would have been obvious over Yoon and Chern.

D. OBVIOUSNESS OVER YOON, CHERN, AND KUBO

Claim 2 depends from claim 1 and additionally recites “the silicon layer comprises amorphous silicon.” Ex. 1001, 8:25–26. Claim 3 depends from claim 1 and additionally recites “the silicon layer comprises a material stack comprising silicon-germanium.” *Id.* at 8:27–28. Claims 10 and 11 depend from claim 9 and recite the same limitations as claims 2 and 3, respectively. *Id.* at 8:51–54.

1380–81 (Fed. Cir. 2016); Consolidated Trial Practice Guide 52 (Nov. 2019).

Petitioner asserts that dependent claims 2, 3, 10, and 11 would have been obvious over Yoon, Chern, and Kubo, relying on Yoon and Chern in the same manner described above. Pet. 33–37. Kubo discloses a method of depositing a gate insulating film on a substrate, depositing a silicon-germanium layer, depositing an amorphous silicon layer, doping the silicon with boron ions, and then etching the stack to form a gate electrode. Ex. 1007, 8:45–9:19. Petitioner submits that it would have been obvious to skilled artisans to use Kubo’s gate electrode with Yoon’s process, and that the heavily doped gate would mean “the work function difference between the substrate and an insulating oxide layer would generally be the same as the work function difference between the insulating oxide layer and the gate, which would allow for better control of the threshold voltage.” Pet. 35 (citing Ex. 1003 ¶ 146).

Patent Owner argues that Yoon discloses a polysilicon gate electrode, and that the Petition fails to explain how to form an amorphous gate electrode. PO Resp. 37. Petitioner responds that the amorphous silicon taught by Kubo is converted to polysilicon during an anneal step after implanting the boron ions, so the combination does not pose a mismatch with Yoon. Pet. Reply 17–18 (citing Ex. 1007, 9:27–31 (“After the boron ions have been implanted into the SiGe layer 13, however, the Si layer 14 will be polycrystalline in the end because the Si layer 14 will be annealed in the process step of depositing an inter level dielectric film on the gate electrode 15, for example.”))).

We agree with Petitioner. Patent Owner does not clearly explain what modification it believes the combination requires, other than to point to amorphous silicon in Kubo and polysilicon in Yoon. PO Resp. 37. Kubo

expressly teaches annealing its amorphous silicon to form polycrystalline silicon, before completing the gate electrode. Ex. 1007, 9:27–31. The '993 patent's independent claims require annealing the silicon layer, which is also consistent with Petitioner's position that the amorphous silicon in the combination would result in polysilicon when the metal stack is formed over the silicon layer. That result is consistent with Yoon.

Patent Owner raises no additional arguments against Petitioner's assertions for claims 2, 3, 10, and 11. We have reviewed the parties' contentions and the evidence presented and conclude that Petitioner has shown by a preponderance of the evidence that the subject matter of claims 2, 3, 10, and 11 would have been obvious over Yoon, Chern, and Kubo.

E. OBVIOUSNESS OVER YOON, CHERN, AND WEIMER

Petitioner asserts that dependent claims 5, 6, 15, and 16 would have been obvious over Yoon, Chern, and Weimer, relying on Yoon and Chern in the same manner described above. Pet. 37–45.

Weimer discloses a multilayer conductive structure for semiconductor devices. Ex. 1008, code (57). As part of that structure, Weimer discloses a barrier layer that may be formed by various approaches, including “deposition followed by a high temperature anneal of a metal (e.g., tungsten or titanium) in an ambient containing nitrogen, ammonia (NH₃), or hydrazine (N₂H₄) in a rapid thermal processing (RTP) system.” *Id.* at 4:15–23. Petitioner submits that Yoon discloses an annealing step with a nitrogen environment, and that it would have been obvious to use ammonia as the nitrogen source as taught by Weimer. Pet. 40–41. Petitioner reasons further that “ammonia is a stronger reactant than molecular nitrogen (N₂), and thus results in a lower-resistivity silicide layer.” *Id.* at 41 (citing Ex. 1003 ¶ 163).

1. Claims 5 and 15

Claim 5 depends from claim 1 and further recites “exposing the metal stack in the heated environment comprising nitrogen forms a titanium silicide layer on the silicon layer and a titanium nitride layer on the titanium silicide layer.” Ex. 1001, 8:31–34. Claim 15 depends from claim 9 and further recites “converting at least the portion of the first metal layer to the silicide layer also converts another portion of the first metal layer to a diffusion barrier layer comprising titanium nitride.” *Id.* at 8:62–65. Thus claim 15 generally parallels claim 5.

For the limitations of claims 5 and 15, Petitioner asserts that Yoon discloses annealing in a nitrogen-containing environment, and that doing so would form the claimed titanium nitride and titanium silicide layers. Pet. 39 (citing Ex. 1005, 17:44–45 (“Annealing in an RTA anneal chamber may be performed by introducing a process gas including nitrogen (N₂)”)). Petitioner asserts also that Weimer discloses forming a barrier layer by depositing metal then annealing in an environment containing nitrogen, ammonia, or hydrazine, Pet. 39 (citing Ex. 1008, 4:15–23 (“[V]arious methods can be used to form the diffusion barrier layer 102, including . . . deposition followed by a high temperature anneal of a metal (e.g., tungsten or titanium) in an ambient containing nitrogen, ammonia (NH₃), or hydrazine (N₂H₂) in a rapid thermal processing (RTP) system.”)). Petitioner identifies that Yoon discloses annealing conditions of 300 to 900 °C and Weimer discloses annealing conditions of 600 to 1000 °C for 1 to 60 seconds. Pet. 40 (citing Ex. 1005, 16:6–13; Ex. 1008, 4:20–22, 4:30–37). Petitioner compares that to the ’993 patent’s stated conditions of annealing conditions of 675 to 725 °C for 30 seconds. *Id.* (citing Ex. 1001, 5:25–28).

Patent Owner argues that Weimer teaches away from forming “a titanium silicide barrier layer over a silicon layer.” PO Resp. 38. Weimer discloses that “titanium silicide (TiSix) formed on polysilicon may result in agglomeration of silicon into the TiSix grains, which can increase resistivity.” Ex. 1008, 3:8–10. Weimer provides exemplary barrier layers including metal silicides but does not include titanium silicide as an example. Ex. 1008, 3:14–23; *accord* Ex. 2005, 92:17–94:6.

We do not read Weimer as teaching away from forming a titanium silicide barrier layer. Weimer expressly states that doing so *may* result in agglomeration, and that such agglomeration *can* increase resistivity. Ex. 1008, 3:8–10. Those possibilities do not convey that titanium silicide is unlikely to work, only that it introduces additional complications. *See In re Gurley*, 27 F.3d 551, 553 (Fed. Cir. 1994) (“The degree of teaching away will of course depend on the particular facts; in general, a reference will teach away if it suggests that the line of development flowing from the reference’s disclosure is unlikely to be productive of the result sought by the applicant.”). To that point, although Weimer indicates a possible complication, Dr. Leburton explained that annealing would suppress the possible agglomeration. Ex. 2005, 136:21–137:13. As Petitioner points out, the combination in which Weimer’s teachings are used includes annealing the polysilicon layer. Pet. Reply 19. Thus, we conclude that Weimer does not teach away from a titanium silicide layer.

Patent Owner argues additionally that Petitioner’s contentions for claims 5 and 15 rely on a combination of materials that is not disclosed in Yoon. PO Resp. 40. In particular, Patent Owner submits that Yoon does not disclose “the particular three material combination” claimed, and that

disclosing those materials as possible options for the relevant layers is insufficient. *Id.* We do not agree. As the Federal Circuit has held in the anticipation context, disclosing possible options for each member of a combination can anticipate when the number of categories and components in the prior art is not so large that the claimed combination would not be immediately apparent to skilled artisans. *Wm. Wrigley Jr. Co. v. Cadbury Adams USA*, 683 F.3d 1356, 1361–62 (Fed. Cir. 2012). Petitioner contends Yoon discloses “six barrier layer materials (Ex. 1005, 14:57–60), one second metal layer material (*e.g.*, Ex. 1005, 19:13–14), and ten first metal layer materials (Ex. 1005, 12:10–12, 20:48–52), *i.e.*, sixty combinations” Pet. Reply 19–20. Patent Owner contends that Petitioner omits combinations and alloys of those materials, and the total should be nearly sixty-five thousand. PO Sur-Reply 17–18. Although Yoon discloses that combinations may be suitable, we do not read those disclosures to expand the scope of disclosed options to the extent Patent Owner asserts. At most, the specific alloys Yoon discloses as appropriate for the first metal layer should be considered, such that Yoon discloses fifteen express possibilities. Ex. 1005, 12:59–67. Viewed in that light, Yoon would include a total of ninety options for the stack (first metal layer, barrier material, second metal layer). We conclude skilled artisans would understand any of those ninety options as immediately apparent from Yoon.

Patent Owner argues also that Yoon does not necessarily disclose forming a metal nitride layer, because Yoon “lacks disclosure regarding the exact content of nitrogen in the process gas.” PO Resp. 41. Yoon states that its anneal may “may be performed by introducing a process gas including nitrogen (N₂), argon (Ar), helium (He), and combinations thereof, with less

than about 4% hydrogen (H), at a process gas flow rate greater than 20 liters/min to control the oxygen content to less than 100 ppm.” Ex. 1005, 17:44–49. As Petitioner explains, with limits on hydrogen and oxygen, Yoon’s disclosures allow for a process gas mixture of predominantly nitrogen. Pet. Reply 20–21. In such an environment, we credit Dr. Leburton’s statement that “[t]he result of Yoon’s annealing step would be to form a titanium silicide layer on the layer of silicon, and a titanium nitride layer on the titanium silicide layer.” Ex. 1003 ¶ 159; *accord* Ex. 2005, 83:10–84:1. Patent Owner argues that Dr. Leburton agreed that, even within a nitrogen environment, it would be possible that no metal is converted to metal nitride. PO Resp. 41–42. But Dr. Leburton’s agreement was made “under the condition that [he] mentioned,” which refers to “the temperature at which you expose it,” a condition that Dr. Leburton had explained was important to the process. Ex. 2005, 84:16–85:12. It is unremarkable that no metal nitride would be formed at sufficiently low temperatures.

We conclude that Yoon discloses processing conditions that would form a metal nitride layer during the second anneal step. Although Yoon discloses other conditions that may not necessarily result in the formation of a metal nitride, that does not undermine its disclosures that support formation of a metal nitride and obviousness. Additionally, Weimer expressly discloses using a nitrogen-containing environment to form a metal nitride, and Petitioner provides a rational basis that skilled artisans would have used Weimer’s disclosures in combination with Yoon.

We have reviewed the parties’ contentions and the evidence presented and conclude that Petitioner has shown by a preponderance of the evidence

that the subject matter of claims 5 and 15 would have been obvious over Yoon, Chern, and Weimer.

2. Claims 6 and 16

Claim 6 depends from claim 1 and further recites “the heated environment comprises ammonia.” *Id.* at 8:35–36. Claim 16 depends from claim 9 and further recites “performing a heat treatment comprises: heating the silicon layer, the first metal layer, the refractory nitride layer, and the second metal layer in an environment comprising ammonia.” *Id.* at 8:66–9:3. Thus claim 16 generally parallels claim 6.

Petitioner reasons that using an environment containing ammonia as taught by Weimer would have been obvious because ammonia was a known source for nitrogen in the annealing process taught by both Yoon and Weimer. Pet. 40–41. Petitioner reasons further that skilled artisans “would have understood that ammonia is a stronger reactant than molecular nitrogen (N₂), and thus results in a lower-resistivity silicide layer.” *Id.* at 41 (citing Ex. 1003 ¶ 163).

Patent Owner contends that Petitioner must “rebut the unexpectedly, superior results in utilizing ammonia in conjunction with tungsten, which is highlighted in the specification itself.” PO Resp. 43–44. According to Patent Owner, the combination of tungsten and ammonia is key to “unexpectedly superior results discussed in the specification” (PO Sur-Reply 20–21) but Patent Owner does not explain why Petitioner needed to “rebut” the specification’s supposed claim. We do not understand the legal basis for Patent Owner’s assertion, and instead agree with Petitioner that Weimer expressly discloses annealing a tungsten layer in an ammonia-containing

environment. *Boston Scientific Scimed, Inc. v. Cordis Corp.*, 554 F.3d 982, 991 (Fed. Cir. 2009); *see* Pet. Reply 21–22.

To the extent Patent Owner argues “unexpectedly superior results” as an objective indicium of nonobviousness, we further do not agree. The specification does not support that assertion. The specification states that “[a]mmonia is the preferred source of nitrogen because tungsten layer 115 promotes dissociation of ammonia, thereby providing sufficient nitrogen to convert a portion of titanium layer 113 to a nitride layer comprising a titanium nitride layer 117.” Ex. 1001, 4:48–50. It does not, however, suggest that the tungsten-ammonia interaction was either unknown or unexpected. Similarly, Patent Owner’s expert asserts only that the “patent explains that the combination of tungsten . . . and ammonia . . . provides unexpectedly superior results.” Ex. 2006 ¶ 144; *see* PO Resp. 44. Notably, Patent Owner’s witness does not testify that skilled artisans at the time would have been surprised at the result or provide other evidence indicating the result was surprising. The witness also does identify any data demonstrating superiority over the closest prior art. Thus, the witness’s assertion that the specification indicates unexpectedly superior results is, at best, weak evidence of unexpected results. Thus, we agree with Petitioner that Patent Owner “fails to demonstrate that such a combination is ‘unexpected’ relative to what was known at the time.” Pet. Reply 22.

Petitioner has persuasively explained why skilled artisans would have had reason to use Weimer’s teaching of an ammonia-containing environment, which Weimer discloses in conjunction with a tungsten layer. Ex. 1008, 4:19–22 (disclosing forming a diffusion barrier layer using “deposition followed by a high temperature anneal of a metal (e.g., tungsten

or titanium) in an ambient containing . . . ammonia (NH₃) . . . in a rapid thermal processing (RTP) system”). The preponderance of the evidence thus supports Petitioner’s position.

After considering all of the parties’ contentions and the evidence presented as a whole, including Patent Owner’s evidence of alleged unexpected results, we conclude that Petitioner has shown by a preponderance of the evidence that the subject matter of claims 6 and 16 would have been obvious over Yoon, Chern, and Weimer.

F. OBVIOUSNESS OVER YOON, WEIMER, AND KUNIKIYO¹²

1. Claim 17

Independent claim 17 recites limitations similar to those of claims 1 and 9, but requires “annealing an amorphous silicon layer to convert the amorphous silicon layer to a polycrystalline silicon layer.” Ex. 1001, 9:4–10:5. Petitioner asserts that skilled artisans would have had reason to use Kunikiyo’s teachings of depositing an amorphous silicon film, implanting hydrogen ions into that film, then heat treating it in a nitrogen atmosphere to form a polycrystalline silicon layer. Pet. 45–48 (citing Ex. 1009, 12:30–13:20). Petitioner reasons that using Kunikiyo’s process would “suppress variations in threshold voltage” by reducing “the amount of dopant reaching an interface between the gate electrode and the gate insulating film.” Ex. 1009, 8:12–17; Pet. 47–48 (citing Ex. 1003 ¶ 179).

As with the combination discussed above including Kubo (*see supra* at 15, § II.D), Patent Owner contends that Yoon’s use of a polysilicon gate

¹² As noted in the Institution Decision, Petitioner’s inclusion of Chern in the heading for this ground does not cause confusion, as the ground is clearly directed at Yoon, Weimer, and Kunikiyo. Inst. 16; *see* Pet. 45–50.

electrode is not compatible with the amorphous gate electrode in Kunikiyo. PO Resp. 36–37. As discussed above, Patent Owner’s argument is not persuasive because, like Kubo, Kunikiyo discloses a process that results in a polysilicon gate electrode after annealing the amorphous layer. Ex. 1009, 13:17–18 (“polysilicon film 44a formed by performing the heat treatment over the amorphous silicon film 21”).

We have reviewed the parties’ contentions and the evidence presented and conclude that Petitioner has shown by a preponderance of the evidence that the subject matter of claim 17 would have been obvious over Yoon, Weimer, and Kunikiyo.

2. Claims 18 and 19

Claim 18 depends from claim 17 and further recites “the silicide layer comprises titanium silicide.” Ex. 1001, 10:6–7. Claim 19 also depends from claim 17 and recites that “the environment comprises ammonia.” *Id.* at 10:8–9. Petitioner relies on Yoon’s and Weimer’s disclosures discussed above. Pet. 49–50; *see supra* at 17, § II.E. Patent Owner includes claim 18 in the arguments discussed above. PO Resp. 37–42. We need not repeat our discussion, and conclude that Petitioner’s showing is persuasive while Patent Owner’s arguments are not.

We have reviewed the parties’ contentions and the evidence presented and conclude that Petitioner has shown by a preponderance of the evidence that the subject matter of claims 18 and 19 would have been obvious over Yoon, Weimer, and Kunikiyo.

III. CONCLUSION¹³

For the reasons discussed above, we conclude:

Claim(s)	35 U.S.C. §	Reference(s)/Basis	Claim(s) Shown Unpatentable	Claim(s) Not Shown Unpatentable
1, 4, 7–9, 12–14	103	Yoon, Chern	1, 4, 7–9, 12–14	
1, 4, 7–9, 12–14	103	Chern, Yoon ¹⁴		
2, 3, 10, 11	103	Yoon, Chern, Kubo	2, 3, 10, 11	
5, 6, 15, 16	103	Yoon, Chern, Weimer	5, 6, 15, 16	
17–19	103	Yoon, Chern, Weimer, Kunikiyo	17–19	
1, 4, 7–9, 12–14	103	Iyer, Chern ¹⁵		
2, 3, 10, 11	103	Iyer, Chern, Kubo ¹⁶		

¹³ Should Patent Owner wish to pursue amendment of the challenged claims in a reissue or reexamination proceeding subsequent to the issuance of this decision, we draw Patent Owner’s attention to the April 2019 *Notice Regarding Options for Amendments by Patent Owner Through Reissue or Reexamination During a Pending AIA Trial Proceeding*. See 84 Fed. Reg. 16,654 (Apr. 22, 2019). If Patent Owner chooses to file a reissue application or a request for reexamination of the challenged patent, we remind Patent Owner of its continuing obligation to notify the Board of any such related matters in updated mandatory notices. See 37 C.F.R. § 42.8(a)(3), (b)(2).

¹⁴ We do not reach this ground because it would not change our overall outcome.

¹⁵ We do not reach this ground because it would not change our overall outcome.

¹⁶ We do not reach this ground because it would not change our overall outcome.

Claim(s)	35 U.S.C. §	Reference(s)/Basis	Claim(s) Shown Unpatentable	Claim(s) Not Shown Unpatentable
Overall Outcome			1–19	

IV. ORDER

Accordingly, it is

ORDERED that Petitioner has proven that claims 1–19 of the '993 patent are unpatentable;

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 6,902,993

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