

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

GLOBALFOUNDRIES U.S., INC. and GLOBALFOUNDRIES, INC.,
Petitioners,

v.

OAK IP, LLC,
Patent Owner.

Case No. IPR2025-01052
Patent No. 9,905,691

**PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 9,905,691**

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1042	Exhibit E to Acorn’s Preliminary Infringement Contentions, <i>Acorn Semi, LLC v. Samsung Elecs. Co., Ltd.</i> , No. 2:19-cv-00347 (Mar. 9, 2020)
1043	Redacted Acorn’s Opposition to Samsung’s Motion for Judgment, <i>Acorn Semi, LLC v. Samsung Elecs. Co., Ltd.</i> , No. 2:19-cv-00347, ECF No. 401 (E.D. Tex. Sept. 2, 2021)
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1089	Petition, <i>Samsung Electronics Co., Ltd. v. Acorn Semi, LLC</i> , IPR2020-01206, Paper 2 (P.T.A.B. June 29, 2020)
1090	Decision Granting Institution, <i>Samsung Electronics Co., Ltd. v. Acorn Semi, LLC</i> , IPR2020-01206, Paper 22 (P.T.A.B. Jan. 13, 2021)
1091	Final Written Decision, <i>Samsung Electronics Co., Ltd. v. Acorn Semi, LLC</i> , IPR2020-01206, Paper 49 (P.T.A.B. Jan. 12, 2022)
1092	Trial Transcript, <i>Acorn Semi, LLC v. Samsung Elecs. Co., Ltd.</i> , No. 2:19-cv-00347 (E.D. Tex. May 14, 2021)
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1096	Petition, <i>Samsung Electronics Co., Ltd. v. Acorn Semi, LLC</i> , IPR2020-01282, Paper 2 (P.T.A.B. July 13, 2020)
1097	Final Written Decision, <i>Samsung Electronics Co., Ltd. v. Acorn Semi, LLC</i> , IPR2020-01282, Paper 56 (P.T.A.B. Feb. 9, 2022)
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Exhibit	Description
1122	Samsung's Opening Brief, <i>Samsung-Electronics Co. v. Acorn Semi, LLC</i> , No. 2022-1539, Doc. 19 (Fed. Cir. Jun. 24, 2022)
1123	Acorn's Corrected Response Brief, <i>Samsung-Electronics Co. v. Acorn Semi, LLC</i> , No. 2022-1539, Doc. 19 (Fed. Cir. Oct. 11, 2022)
1124	May 17, 2021 Trial Transcript, <i>Acorn Semi, LLC v. Samsung Electronics Co., et al</i> , No. 2:19-cv-000347-JRG (E.D. Tex.) (Redacted)
1125	Final Written Decision, <i>Samsung-Electronics Co. v. Acorn Semi, LLC</i> , IPR2020-01207, Paper 49 (P.T.A.B. Feb. 9, 2022)
1126	U.S. Patent No. 7,727,882 ("Wu")

All citations to specific pages of exhibits follow the pagination added to those exhibits per 37 C.F.R. § 42.63(d)(2)(i).

I. INTRODUCTION

GlobalFoundries U.S., Inc. and GlobalFoundries, Inc. (collectively, “Petitioners” or “GF”) request *inter partes* review of Claims 5-12, 14-19, 21, 23-24, and 26-29 (“the Challenged Claims”) of U.S. Patent No. 9,905,691 (Ex.1001, “the ’691 Patent”) assigned to Oak IP, LLC (“PO” or “Oak”). The ’691 Patent relates to metal-semiconductor junctions with a metal oxide layer and a passivating dielectric tunnel barrier layer between the metal and the semiconductor. (Ex.1001, 1:25-29, Claims 6 and 26.) The ’691 Patent purports to claim a priority date of August 12, 2002 through a series of parent applications, the earliest of which issued as U.S. Patent No. 7,084,423. (Ex.1001, Cover, 1:8-21; Ex.1003.)

Oak filed a Complaint against Petitioners on February 4, 2025 alleging infringement of three patents, including the ’691 Patent.¹ (Ex.1095, ¶¶20-23.) This is Petitioners’ first petition challenging the ’691 Patent claims.² The Challenged

¹ Oak asserts that it is the sole owner of the ’691 Patent. (Ex.1095, ¶20.)

² In October 2019, Acorn Semi, LLC (“Acorn”) filed a Complaint against Samsung Electronics Co., Ltd. (“Samsung”) alleging infringement of the ’691 Patent. Samsung filed a petition (IPR2020-01206) in June 2020, and the Board issued a final written decision in January 2022. (Ex.1091). Samsung filed another petition

Claims requiring an “oxide of titanium” (i.e., Claims 6-12, 15-19, and 26-29) are not entitled to the 2002 priority date because the specification does not provide adequate written description support to the “oxide of titanium” genus. Both Oak and Acorn (the prior patent owner) have asserted that the “oxide of titanium” genus includes ternary compounds, such as, titanium silicon oxide (TiSiO_x). (Ex.1095, ¶¶52-54, 68, 78.) Though the Challenged Claims requiring an “oxide of titanium” purportedly cover any binary or ternary compound containing oxygen and titanium (*id.*), the specification discloses *only one* example of such a compound: titanium dioxide (TiO_2), which is binary. The single disclosed species— TiO_2 —is not representative of the entire “oxide of titanium” genus and does not describe features common to all members of the claimed genus. Thus, the “oxide of titanium” limitation lacks adequate written description support in the specification of the ’691 Patent.

Not all of the ancestor applications of the ’691 Patent describe the “oxide of titanium” genus. Indeed, the first time the patentee even arguably described an “oxide of titanium” was in the originally filed claims of the application (U.S. Patent App. No. 15/048,877) that issued as the ’691 Patent—which was not filed until February 19, 2016. (Ex.1020, 61-64.) As a result, no Challenged Claim requiring an

(IPR2020-1279) in July 2020, and the decision was issued in January 2022. (Ex.1097).

“oxide of titanium” can obtain a priority date earlier than February 19, 2016. Thus, Grupp ’483 qualifies as prior art to Claims 6-12, 15-19, and 26-29.

Regarding Claims 18 and 26-29, the Board has previously found that Claims 18 and 25-29 are not entitled to a priority date earlier than February 19, 2016 because the ’691 Patent and its ancestor applications do not enable the breadth of the recited range of “a specific contact resistivity . . . less than $1 \Omega\text{-}\mu\text{m}^2$.” (Ex.1091, 27-39.) Thus, the Board concluded that Grupp ’483 is prior art for each of challenged Claims 18 and 25–29 but did not find Claims 18 and 26-29 unpatentable.³ Thus, lack of disclosure of the claimed range of resistivity is another independent reason as to why the priority date of these claims is not earlier than February 19, 2016.

Claims 5, 9, and 14 (which depend from claim 1) require “a metal or a stack of metals.” None of the ancestor applications describe “a stack of metals.” Thus, these claims cannot obtain a priority date earlier than February 19, 2016, and Grupp ’483 qualifies as prior art to Claims 5, 9, and 14.

³ As explained in **Section X.C** below, though the Board found that Grupp ’483 is prior art for Claims 18 and 26-29, (Ex.1091, 39), the Board erroneously concluded that the claims were nevertheless patentable. (*Id.*, 50.) Samsung appealed the decisions noting that Board’s finding of no anticipation for Claims 18 and 26-29 was an oversight, (Ex.1122, 48-50), and Acorn concurred. (Ex.1123, 82.)

Claim 21 (which depends from Claim 1) requires a dielectric tunnel barrier layer comprising “a metal oxide,” as recited in Claim 1. This claim does not narrow that genus of “metal oxide” further, and the Board has previously found that Claim 1 is not entitled to a priority date earlier than February 7, 2011 because the genus “metal oxide” lacked adequate written description support. (Ex.1091, 24.) Thus, Claim 21 is also not entitled to a priority date earlier than February 7, 2011, and Grupp ’483 qualifies as prior art to Claim 21.

Finally, Claims 23 and 24 require a “metal electrical contact” that comprises an “oxide of titanium.” In addition to not providing adequate written description support to the “oxide of titanium” genus, the specification fails to disclose use of such an oxide in a “metal electrical contact.” Thus, Claims 23 and 24 are not entitled to a priority date earlier than February 19, 2016, and Grupp ’483 qualifies as prior art to Claims 23 and 24.

As shown herein and as further explained in the declaration of Dr. E. Fred Schubert, an expert in metal-semiconductor junctions (Ex.1022, ¶¶8-21), Grupp ’483 (Ex.1021) anticipates every Challenged Claim except Claims 23 and 24, which are rendered obvious by Grupp ’483 in view of Wu (Ex.1126).

II. MANDATORY NOTICES

A. Real Parties-in-Interest (37 C.F.R. § 42.8(b)(1))

Petitioners identify the following as the real parties-in-interest:

GLOBALFOUNDRIES Inc. and GLOBALFOUNDRIES U.S., Inc.

B. Related Matters (37 C.F.R. § 42.8(b)(2))

1. Judicial Matters

The following judicial matters may affect or be affected by this proceeding:

Oak IP, LLC v. GlobalFoundries U.S., Inc. and GlobalFoundries, Inc., Civil Action No. 25-142 (MN) (D. Del.) (“the Oak Litigation”), in which PO filed a complaint alleging that Petitioners and their real parties-in-interest infringe the ’691 Patent (Ex.1095, ¶¶1-2). Oak first served the complaint on GlobalFoundries U.S., Inc. on February 18, 2025 (Ex.1095), and GlobalFoundries, Inc., waived service on March 4, 2025. (Ex.1109.)

2. Administrative Matters

Petitioners have filed a petition, IPR2025-00889, for *inter partes* review against U.S. Patent No. 10,090,395 and will be filing one or more petitions for *inter partes* review against U.S. Patent No. 10,937,880. Those proceedings may affect or be affected by this proceeding. Further, Oak has asserted those two patents against Petitioners in addition to the ’691 Patent. (Ex.1095, ¶¶1-2.)

C. Lead and Back-Up Counsel:

Lead Counsel	Back-Up Counsel
<p>Scott C. Weidenfeller (Reg. No. 54,531) sweidenfeller@cov.com <u>Postal and Hand-Delivery Address:</u> Covington & Burling LLP One CityCenter, 850 Tenth Street NW Washington, DC 20001 T: (202) 662-5923; F: (202) 778-5923</p>	<p>Anupam Sharma (Reg. No. 55,609) asharma@cov.com <u>Postal and Hand-Delivery Address:</u> Covington & Burling LLP 3000 El Camino Real 5 Palo Alto Square Palo Alto, California 94306 T: (650) 632-4709; F: (650) 632-4809</p> <p>Peter P. Chen (Reg. No. 39,631) pchen@cov.com <u>Postal and Hand-Delivery Address:</u> Covington & Burling LLP 3000 El Camino Real 5 Palo Alto Square Palo Alto, California 94306 T: (650) 632-4720; F: (650) 632-4820</p>
	<p>Dr. W. Kiersten Choi (Reg. No. 73,012) wchoi@cov.com <u>Postal and Hand-Delivery Address:</u> Covington & Burling LLP One CityCenter, 850 Tenth Street NW Washington, DC 20001 T: (202) 662-5240; F: (202) 778-5240</p>

Pursuant to 37 C.F.R. § 42.10(b), Petitioners have filed a power of attorney with the above designation of counsel.

D. Service Information:

Please address correspondence to counsel at the address above. Petitioners consent to electronic service to: GF-Oak-IPR@cov.com and the email addresses listed above. Service information is provided in the designation of counsel above.

III. PAYMENT OF FEES

This Petition is accompanied by the fees set forth in 37 C.F.R. § 42.15(a). Please charge or credit Deposit Account No. 60-3160 with any shortage or overpayment of fees associated with this Petition and any other fees incurred by Petitioners.

IV. GROUNDS FOR STANDING

Petitioners certify that the '691 Patent is available for *inter partes* review. Petitioners further certify that neither Petitioners nor any real party-in-interest or privy is estopped or barred from requesting *inter partes* review of the challenged claims on the grounds identified in this Petition.

V. PRECISE RELIEF REQUESTED AND GROUNDS RAISED

Petitioners request *inter partes* review and cancellation of Claims 5-12, 14-19, 21, 23-24, and 26-29 of the '691 Patent.

A. Identification of Prior Art⁴

1. Grupp '483 (Ex.1021)

As discussed in **Section X**, Claims 5-12, 14-19, 23-24, and 26-29 are not entitled to a priority date earlier than February 19, 2016, the filing date of U.S. Patent App. No. 15/048,877. Claim 21 is not entitled to a priority date earlier than February 7, 2011, the filing date of U.S. Patent App. No. 13/022,522. Thus, U.S. Patent No. 7,176,483 (Ex.1021, “Grupp ’483”), issued on February 13, 2007, qualifies as prior art to Claims 5-12, 14-19, 21, 23-24, and 26-29 under at least pre-AIA 35 U.S.C. § 102(b).

2. Wu (Ex.1126)

As discussed in **Section X**, Claims 23 and 24 are not entitled to a priority date earlier than February 19, 2016. Thus, U.S. Patent No. 7,727,882 (Ex.1126, “Wu”) filed on Dec. 17, 2007 and issued on June 1, 2010 is prior art to Claims 23 and 24 under at least pre-AIA 35 U.S.C. § 102(b).

B. Statutory Grounds of Unpatentability

Ground I: Grupp ’483 anticipates Claims 5-12, 14-19, 21, and 26-29 under at least pre-AIA 35 U.S.C. § 102(b) or under AIA 35 U.S.C. § 102(a)(1).

⁴ If Oak argues that the ’691 Patent is governed by the AIA, Grupp ’483 and Wu qualify as prior art under AIA 35 U.S.C. § 102(a)(1).

Ground II: Grupp '483 in view of Wu renders Claims 23 and 24 obvious under at least pre-AIA 35 U.S.C. § 103(a) or under AIA 35 U.S.C. § 103.

VI. OVERVIEW OF PRIOR ART

A. Grupp '483

Grupp '483 is a continuation-in-part of an August 2002 application that issued as U.S. Patent No. 7,084,423. (Ex.1021, Cover, 1:8-19.) The '691 Patent purports to claim priority to that same August 2002 application through a chain of ancestor applications. (Ex.1001, Cover, 1:8-29.) Thus, Grupp '483 and the '691 Patent and its ancestor applications have significantly overlapping disclosures. Unsurprisingly, Grupp '483 anticipates Claims 5-12, 14-19, 21, and 26-29. (Ex.1022, ¶¶197-204.)

B. Wu

Wu pertains to diffusion barrier films used in the field of integrated circuit fabrication. (Ex.1126, 1:7-8.) It describes “methods and apparatus for depositing titanium-containing diffusion barrier layers for use as copper diffusion barrier films in Damascene processing.” (Ex.1126, 1:10-12.)

VII. OVERVIEW OF THE '691 PATENT

A. Technical Background

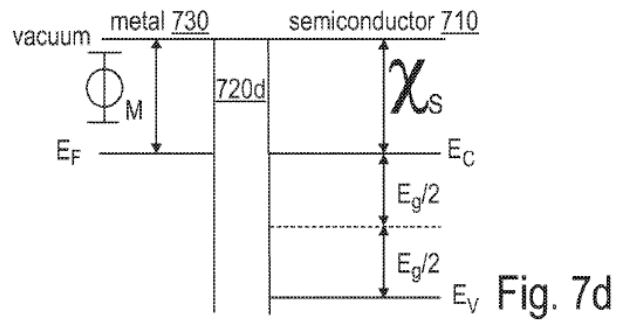
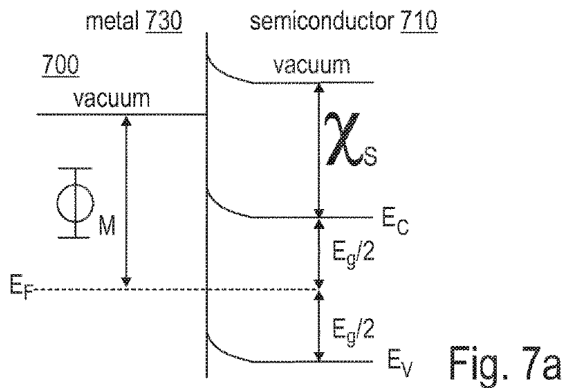
Metal-semiconductor junctions are basic electronic components. (Ex.1022, ¶38; Ex.1001, 1:25-29.) Those junctions are generally characterized by a barrier to the movement of charge carriers at the interface between the metal and the semiconductor, called a Schottky barrier. (Ex.1023, 1; Ex.1001, 1:46-48; Ex.1022,

¶¶39-40.) The barrier's width and height each affect the junction's specific contact resistance.⁵ (Ex.1024, 545-546; Ex.1022, ¶¶41-47.)

The Schottky barrier height of a metal-semiconductor junction can become fixed at a particular height in a phenomenon known as Fermi-level pinning. (Ex.1001, 2:4-61, 5:24-27, 7:44-48; Ex.1022, ¶¶48-51.) Electron states can cause the Fermi level to become pinned between the semiconductor's conduction and valence bands, typically at or near the midgap.⁶ (Ex.1001, 2:35-3:3, 16:52-55; Ex.1022, ¶52.) Fig. 7a depicts that the pinned Fermi level E_F in the metal-semiconductor junction is not aligned with the conduction band edge E_C of the semiconductor at the interface:

⁵ Height of the barrier represents the energy an electron needs to overcome to move from the semiconductor to metal or vice versa, and width of the barrier is the width of the depletion region created when the electrons deplete (or move) from the semiconductor and transition to metal. (Ex.1022, ¶125.)

⁶ Energy states refers to states, such as Bardeen states that are created by dangling bonds at the semiconductor surface and metal-induced gap states (MIGS) that are energy states in the bandgap of the semiconductor that become populated due to the proximity of the metal. (Ex.1022, ¶¶45-47.)



(Ex.1001, Figs. 7a and 7d, 16:52-55, 16:67-17:12; Ex.1022, ¶52.)

However, as Fig. 7d depicts, “when the interface layer 720d is sufficient to both eliminate or reduce the effect of MIGS and to passivate the semiconductor surface, we see the Fermi level of the metal aligning with the conduction band of the semiconductor” and “vacuum level is now continuous as there is no charged dipole at the interface.” (Ex.1001, 16:67-17:12; Ex.1022, ¶53.)

“The importance of the barrier height at a metal-semiconductor interface is that it determines the electrical properties of the junction. Thus, if one were able to control or adjust the barrier height of a metal-semiconductor junction, one could produce electrical devices of desired characteristics.” (Ex.1001, 3:4-8.) According to the ’691 Patent, depinning a Fermi level is one technique for accomplishing that. (*Id.*, 16:23-44, Ex.1022, ¶¶54-55.)

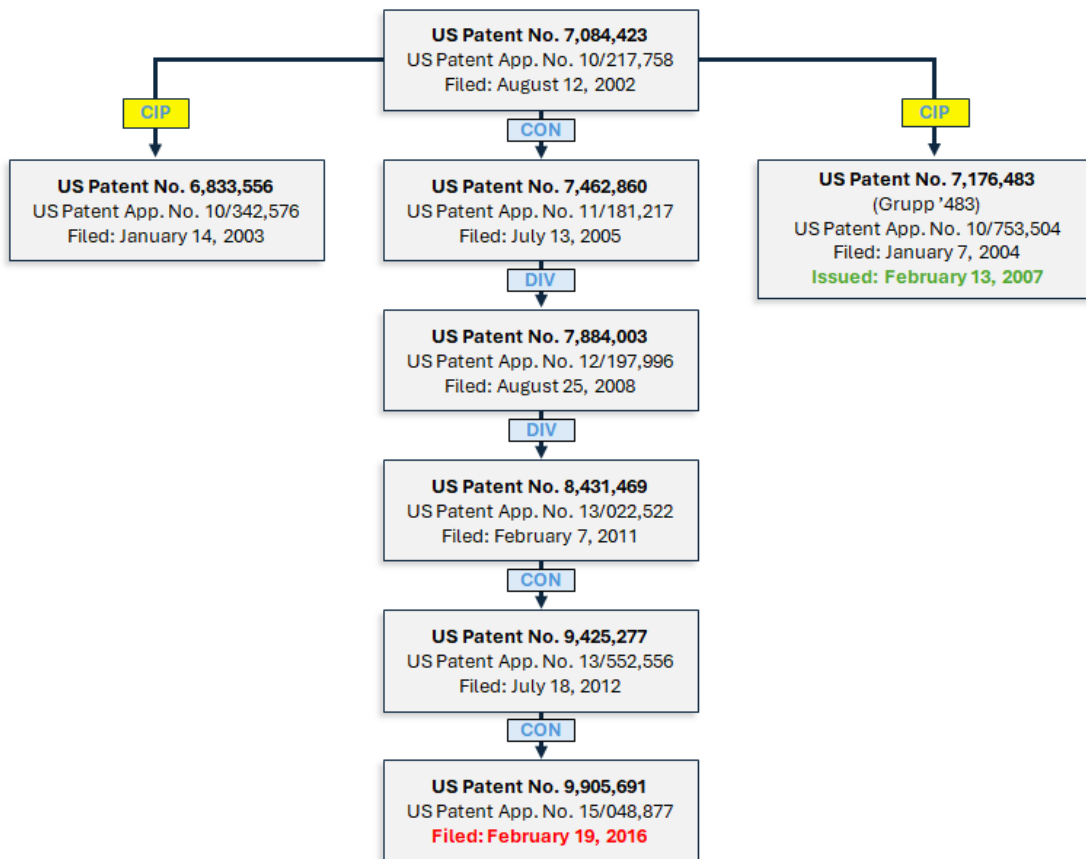
As Dr. Schubert explains, even before the earliest alleged priority date of August 2002 of the Challenged Claims, techniques for depinning a Fermi level and controlling barrier height were well-known. (Ex.1022, ¶¶56-68.)

B. The Purported Invention of the '691 Patent

The purported invention of the '691 Patent involves providing an interface layer between the metal and the semiconductor in a metal-semiconductor junction. (Ex.1001, 1:25-29.)

C. Prosecution History

The '691 Patent began as U.S. Patent App. No. 15/048,877 (“the '877 Application,” filed on February 19, 2016. (Ex.1020, 3-65.) The '691 Patent purports to claim a priority date of August 12, 2002 through a series of parent applications, as shown in the partial family tree below:



(Ex.1005, Cover; Ex.1020, 5; Ex.1021, Cover, 1:8-19.)

Each challenged claim was among the originally filed claims of the '877 Application. (Ex.1020, 61-64.) In June 2016, the Examiner allowed the originally filed claims on the first action. (Ex.1020, 118-130, 142-152.) The reasons for allowance tracked the language of originally filed Claims 1 and 25. (Ex.1020, 123-124.)

In February 2018, the Examiner entered a corrected notice of allowance with an Examiner's amendment to Claims 1, 6, 15, and 19. (Ex.1020, 163-168.) The patentee requested a certificate of correction to effect the Examiner's amendment, and the Office granted that request. (Ex.1020, 183-187, 191.) This Petition addresses the claims as corrected.

Notably, the Examiner did not cite any prior art against any claim during the prosecution and did not expressly determine any priority dates.

D. Prior Litigation and IPR Petitions

1. District Court

On October 23, 2019, Acorn filed a Complaint against Samsung, alleging infringement of several patents, including the '691 Patent. (Ex.1038) ("the Acorn Litigation"). The parties apparently settled the dispute. (Ex.1104.)

2. PTAB

On June 29, 2020, Samsung filed a petition for an *inter partes* review of claims 1-4, 6, 8, 10-13, 15-20, 22, and 25-30 of the '691 patent. (Ex.1089.) On October 14, 2020, Acorn disclaimed Claim 30. (Ex.1106.) On February 9, 2022, the Board issued

a final written decision determining that claims 1-4, 13, 20, 22, and 25 were unpatentable. (Ex.1091, 50.) The Board held, *inter alia*, that Acorn was not entitled to the benefit of any pre-2011 priority applications for claims 1-4, 13, 20, 22, and 25 (i.e., claims that require a “metal oxide”), and Grupp ’483 was prior art for those claims. (Ex.1091, 24.) The petition did not challenge Claims 5, 7, 9, 14, 21, 23, and 24, and the Board did not consider priority arguments regarding Claims 6, 8, 10-12, 15-17, and 19 (i.e., claims that require an oxide of titanium), noting that the arguments were not present in the petition. (Ex.1091, 26.) Though the Board noted that “Grupp ’483 is prior art for each of the challenged claims 18 and 25-29,” (Ex.1091, 39), it did not find Claims 18 and 26-29 unpatentable.

On July 10, 2020, Samsung filed another petition for *inter partes* review of Claims 1-4, 6, 8, 10-13, 15-20, 22, and 25-30 of the ’691 patent, based primarily on Goodnick (Ex.1025) and Jammy (Ex.1101). (Ex.1096.) On January 12, 2022, the Board issued a final written decision determining that Claims 1-4 and 13 were unpatentable under 35 U.S.C. § 102(b) and Claims 6, 8, 10-12, 15-20, 22, and 25-29 were not unpatentable under 35 U.S.C. § 103(a). (Ex.1097, 52.)

VIII. CLAIM CONSTRUCTION

For petitions filed after November 13, 2018, the Board “constru[es] the claim in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the

patent.” 37 C.F.R. § 42.100(b); *see also Phillips v. AWH Corp.*, 415 F.3d 1303 (Fed. Cir. 2005) (en banc). The Board need only construe claim terms to the extent necessary to resolve a controversy. *See Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017) (citing *Vivid Techs., Inc. v. Am. Sci. & Eng’g, Inc.*, 200 F.3d 795, 803 (Fed. Cir. 1999)).

The district court in the Eastern District of Texas issued a *Markman* order on October 16, 2020, construing several terms from the ’691 Patent, and the pertinent constructions are listed below:

Term	Claims	Construction
“a metal oxide layer, and a passivating dielectric tunnel barrier layer”	1	“a metal oxide layer, and a distinct dielectric tunnel barrier layer that terminates all or substantially all dangling bonds that may be present at the surface of the semiconductor region without the layer present”
“interface layer”	26-29	Plain and ordinary meaning
“the interface layer comprising a metal oxide separation layer and a semiconductor oxide passivation layer”	26-29	“the interface layer comprising a metal oxide separation layer and a distinct layer of a semiconductor oxide that terminates all or substantially all dangling bonds that may be present at the surface of the semiconductor without the layer present”
“configured to”	20	Plain and ordinary meaning

(Ex.1100, 27-31.)

In the prior *inter partes* reviews filed by Samsung, the Board also has construed the terms “specific contact resistivity” and “specific contact resistance” to be interchangeable. (Ex.1091, 8-9; Ex.1097, 8.)

The term “specified contact resistivity” that appears in Claim 21 has not been construed. As Dr. Schubert opines, the term “specified contact resistivity” is not commonly used in the art. (Ex.1022, ¶77.) Nor does it appear in the specification of the '691 Patent—however, the specification does discuss “specific contact resistance” in the context of the purported invention in Claim 21. (Ex.1001, 17:41-54; Ex.1022, ¶77.) Thus, a POSITA would have understood the term “specified contact resistivity” in Claim 21 to refer to “specific contact resistance” or “specific contact resistivity.” (Ex.1022, ¶77.)

The Petitioners have applied the constructions enumerated above. The Board need not expressly construe any term at this stage.⁷

⁷ Petitioners reserve all rights to raise claim construction arguments and other arguments in the Oak Litigation or other proceedings involving the '691 Patent. For example, Petitioners have not raised all of their challenges to the '691 Patent here, including invalidity under 35 U.S.C. § 112. Further, comparing the claims to the

IX. LEVEL OF ORDINARY SKILL

Any of the following combinations of education and experience would have qualified someone as an ordinarily skilled artisan in the field of the '691 Patent:

- a Ph.D. in electrical engineering, physics, materials science, or chemical engineering, with two years of practical experience with semiconductor research and design;
- a Master's degree in electrical engineering, physics, materials science, or chemical engineering, with four years of practical experience with semiconductor research and design; or
- a Bachelor's degree in electrical engineering, physics, materials science, or chemical engineering, with six to eight years of practical experience with semiconductor research and design.

(Ex.1022, ¶¶80-87.) Further, additional education could make up for less practical experience, and vice versa. (Ex.1022, ¶¶80-87.) The same level of ordinary skill would have been applicable in August 2002, February 2011, or February 2016.

accused products in the Oak Litigation may raise controversies that require claim construction in that litigation, but not here.

(Ex.1022, ¶88.) The Board applied the above description of the level of skill in its Institution Decisions pertaining to the '691 Patent.⁸ (Ex.1090, 10; Ex.1098, 10-11.)

X. PRIORITY DATE OF THE CHALLENGED CLAIMS

The '691 Patent purports to claim priority to August 12, 2002, the filing date of the application that issued as U.S. Patent No. 7,084,423. (Ex.1001, Cover, 1:8-21; Ex.1003, Cover.) For the Challenged Claims to receive the benefit of the priority of that August 12, 2002 filing date, every application in the priority chain leading to the application that issued as the '691 Patent must support (i.e. both enable and describe) every limitation of the challenged claims under 35 U.S.C. § 112 ¶1. *In re NTP, Inc.*, 654 F.3d 1268, 1277 (Fed. Cir. 2011); *Fiers v. Revel*, 984 F.2d 1164, 1169-70 (Fed. Cir. 1993).

A. Claims 6-12, 15-19, 23-24, and 26-29

Claims 6-12, 15-19, 23-24, and 26-29 have at least one limitation that the parent applications fail to support: *an oxide of titanium*. The parent applications are substantively identical to the '691 Patent, including in their incorporation by reference of U.S. Patent No. 6,833,556. (Ex.1005.) Thus, if the limitation lacks support in the specification of the '691 Patent, it also lacks support in the disclosures

⁸ The Board did not comment on the level of ordinary skill in the Final Written Decisions of the prior IPRs pertaining to the '691 Patent. (Ex.1091; Ex. 1097.)

of the ancestor applications, and vice versa. (Ex.1002, 5-52; Ex.1003; Ex.1006, 3-42; Ex.1007; Ex.1008, 8-48; Ex.1009; Ex.1010, 14-51; Ex.1011; Ex.1012, 6-46; Ex.1013.)

The only differences among the parent applications and the '691 Patent are their respective abstracts and claims. But, even those abstracts and claims cannot provide the challenged claims with any priority date earlier than February 19, 2016. In particular, the patentee did not even arguably disclose a generic “oxide of titanium” limitation until February 19, 2016, in the originally filed claims of U.S. Patent App. No. 15/048,877. (Ex.1020, 61; Ex.1022, ¶¶90-100.) Thus, the priority date of claims listed above is no earlier than February 19, 2016.

B. Claims 5, 9, and 14

Claims 5, 9, and 14 of the '691 Patent are not entitled to a priority date earlier than February 19, 2016. Mirroring Claims 5, 9, and 14, Claim 30 requires a “stack of metals.” In earlier petitions, Samsung challenged Claim 30, which Acorn disclaimed. (Ex.1106.)

C. Claims 18 and 26-29

The Board has found that Claims 18 and 26-29 are not entitled to a priority date earlier than February 19, 2016 because the ancestor applications of the '691 Patent do not enable the breadth of the recited range of “a specific contact resistivity . . . less than $1 \Omega\text{-}\mu\text{m}^2$.” (Ex.1091, 27-39.) However, as the Board also agreed, Grupp

'483 enables the upper part of the range for purposes of anticipation. (Ex.1091, 27-39.) Thus, the Board has concluded that Grupp '483 is prior art for each of challenged Claims 18 and 26–29. (Ex.1091, 39.)

The Board also found that these claims were not anticipated by Grupp '483. (Ex.1091, 39, 50). The Board noted that these claims require a layer of “oxide of titanium” and the petitioner (i.e., Samsung) had “failed to demonstrate that the oxide of titanium claims are not entitled to the priority date of Grupp '483” (*Id.*, 43, 44-46). As explained in **Section XIV.C** below, this was erroneous because Grupp '483 is prior art to these claims, which require “specific contact resistivity,” a limitation that is not supported by the specification. Thus, Grupp '483 anticipates these claims irrespective of whether they require a layer of “oxide of titanium,” and Acorn eventually conceded that the Board made a clerical error. (Ex.1123, 82.)

D. Claim 21

The Board has found that Claim 1 of the '691 Patent is not entitled to a priority date earlier than February 7, 2011 because the earlier filed ancestor applications do not describe the “metal oxide” genus. (Ex.1091, 24.) Because Claim 21 (which depends from Claim 1) does not narrow that genus further, the priority date of Claim 21 can be no earlier than February 7, 2011.

E. Claims 23 and 24

As discussed in **Section X.A** above, the parent specifications fail to support the “oxide of titanium” limitation. Claims 23 and 24 also require that the “metal electrical contact” comprise an “oxide of titanium” whereas the sole disclosure of an “oxide of titanium” in the specification is limited to such use in an interface layer and not for a “metal electrical contact.” (Ex.1001, 17:60-62.) Thus, the priority date of Claims 23 and 24 cannot be earlier than February 19, 2016.

XI. '691 PATENT AND ITS PARENT APPLICATIONS DO NOT ADEQUATELY DESCRIBE THE GENUS OF “OXIDE OF TITANIUM”

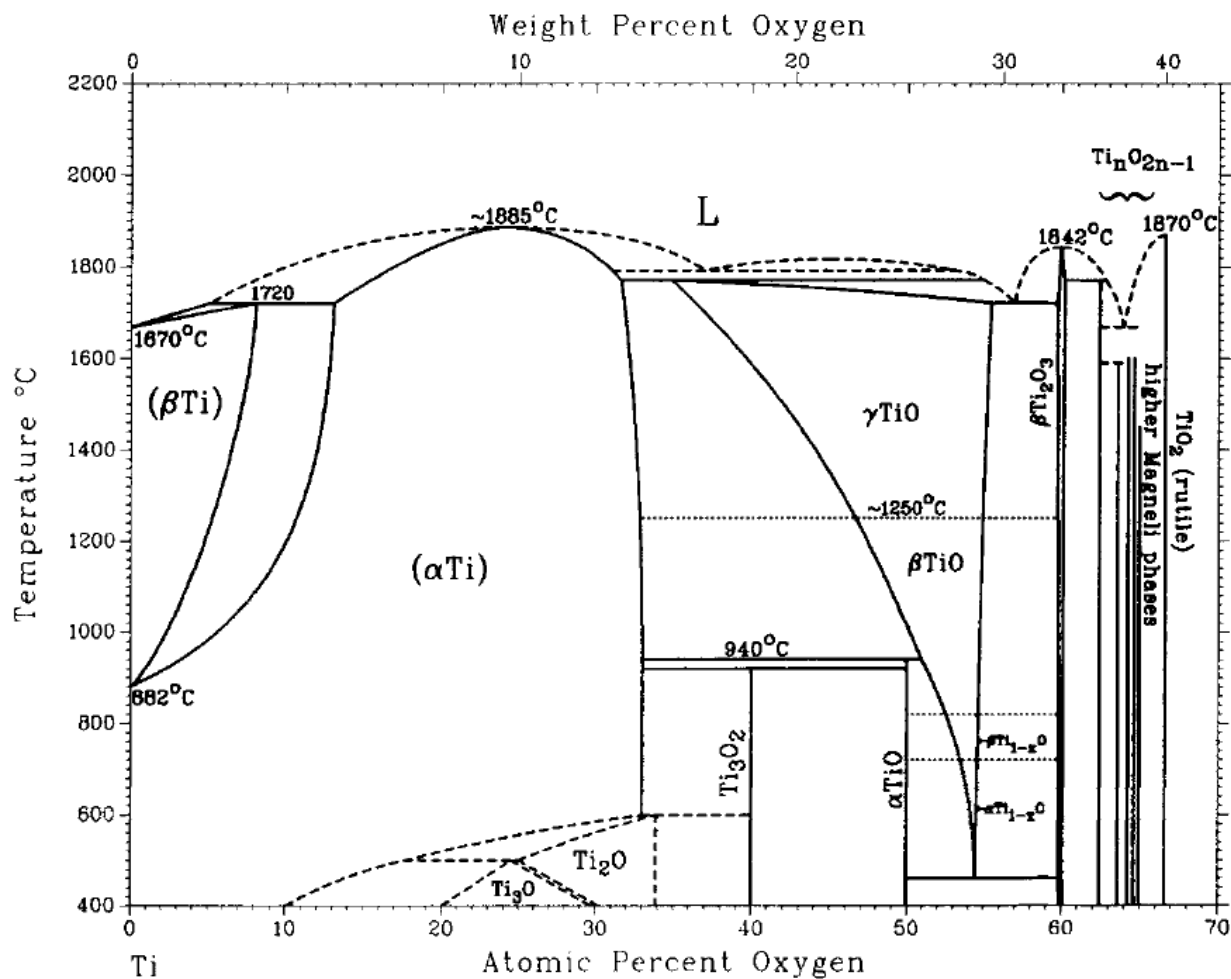
A. Genus of “oxide of titanium” is extremely broad

The genus of “oxide of titanium” is broad and is not adequately described by disclosure of a single species, TiO₂. The genus encompasses (i) numerous binary compounds (compounds composed of two elements) composed of varying ratios of titanium and oxygen and (ii) numerous ternary compounds (compounds composed of three elements) composed of titanium, oxygen, and one other element. (Ex.1022, ¶¶101-105.) These binary and ternary compounds have drastically diverse physical, structural, and electrical properties that are vastly different than the properties of TiO₂. (Ex.1022, ¶¶110-169.) Thus, Challenged Claims requiring an “oxide of titanium” *cannot* obtain a priority date earlier than February 19, 2016 because the specification fails to provide adequate written description support to the entire genus. *See In re NTP*, 654 F.3d at 1276-77. (Ex.1022, ¶¶168-170.)

1. Genus of “oxide of titanium” includes numerous binary compounds composed of oxygen and titanium

Like generic metal oxides, there are numerous oxides of titanium, yet the Priority Applications disclose only *one*:⁹ TiO₂. (Ex.1001, 17:60-62; Ex.1022, ¶¶91-100.) As shown below, some (but not all) titanium oxide species include TiO, Ti₂O, Ti₃O, TiO₂, Ti₂O₃, Ti₃O₅, and Ti₄O₇, among others. (Ex.1022, ¶¶101-102.)

⁹ Indeed, when deposed during the earlier IPR proceedings, Acorn’s expert could not even identify all of the titanium oxide species. Ex.1048, 114:10-18 (“Q. Dr. Kuhn, what are the different species in the titanium oxide genus? A. ... I don’t know how many chemical compounds exist within the Ti oxide family.”).



(Ex.1056, Figure 1; Ex.1022, ¶102.)

Moreover, in the semiconductor industry, titanium oxides are not limited to the equilibrium compounds discussed above; they can also include non-equilibrium compounds. (Ex.1048, 50:25-51:13; Ex.1022, ¶103.) In other words, a large number of different types of oxide of titanium species can be used in semiconductor devices. (Ex.1022, ¶103.)

2. Genus of “oxide of titanium” includes numerous ternary compounds composed of oxygen, titanium, and another element

Ternary compounds are three-element compounds that include titanium, oxygen, and another element. (Ex.1022, ¶¶104-105.) There may be at least ten to twenty such compounds with different characteristics, making them suitable for multiple applications. (Ex.1022, ¶¶104-105 (listing ternary compounds comprising titanium, oxygen and one of the following: nitrogen, carbon, germanium, chromium, strontium, aluminum, barium, magnesium, calcium, and lithium).)

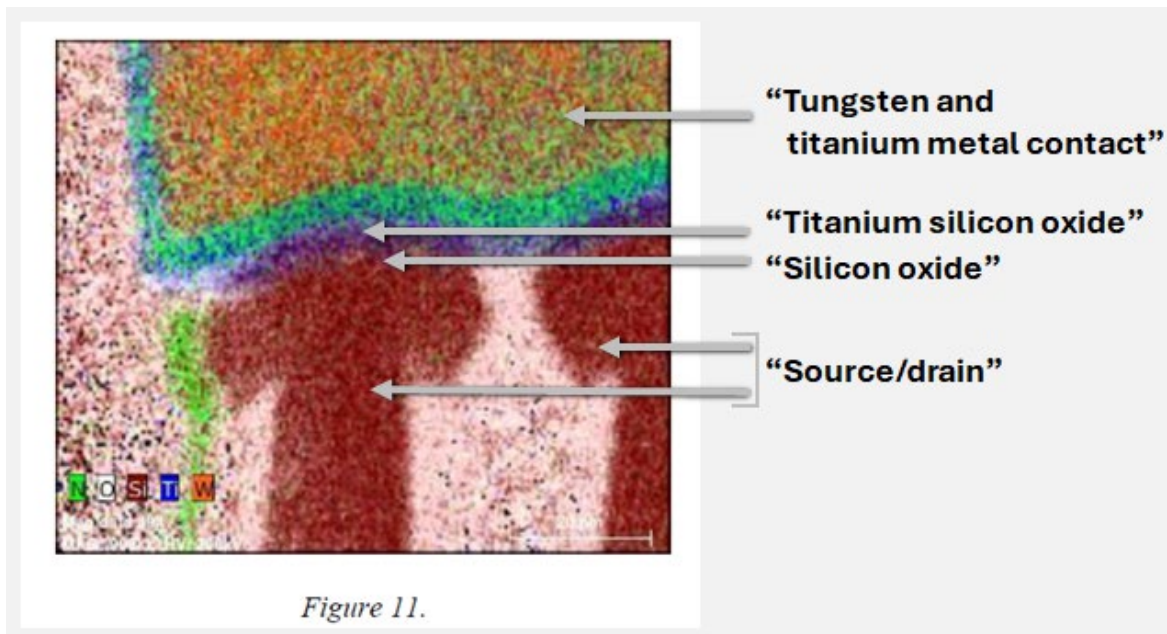
a) Oak argues that “oxide of titanium” includes ternary compounds composed of oxygen, titanium, and silicon

In the Oak Litigation, Oak contends that the genus of “oxide of titanium” includes “titanium silicon oxide.” (Ex.1095, ¶¶52-54, 68, 78) In the Complaint, with respect to the “metal oxide” term of Claim 19 of the ’691 Patent that requires an *oxide of titanium*, Oak alleges that each product of the Petitioners “comprises passivating dielectric tunnel barrier layer of *titanium silicon oxide* and silicon dioxide.”¹⁰(Ex.1095, ¶52.)¹¹ Specifically, Oak alleges that in “the microscopic

¹⁰ Emphasis added unless noted.

¹¹ In its Complaint, Oak is apparently relying upon the as-issued version of Claim 19 that required “the metal oxide of the dielectric tunnel barrier layer comprises an

image . . . of a chip” fabricated by the Petitioners, “the *titanium silicon oxide* and silicon oxide interface layer can be seen in purple and pink (or maroon-white) between the tungsten and titanium nitride metal contact and the silicon semiconductor source/drain.” (Ex.1095, ¶52.)

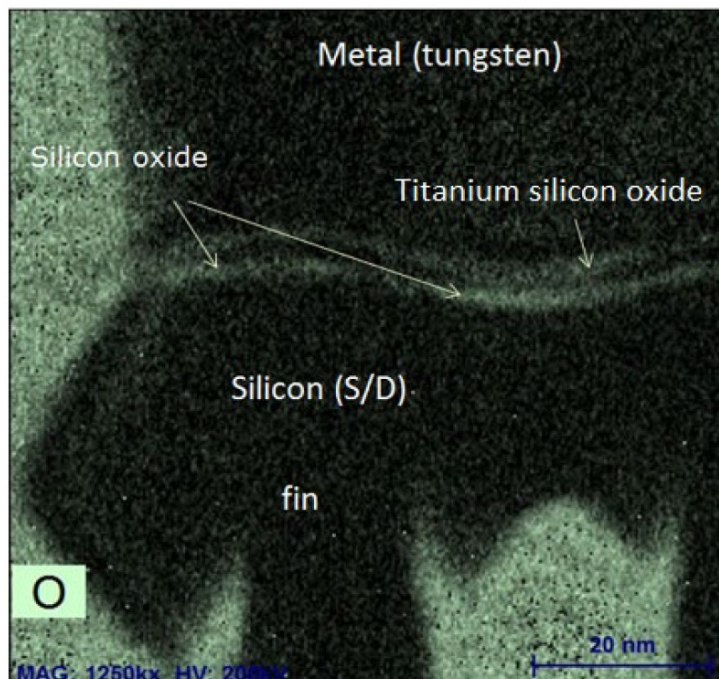


(Ex.1095, 21, Fig. 11 (annotated).) Thus, Oak asserts that “oxide of titanium” genus is not limited to binary compounds but also includes ternary compounds that include titanium, silicon, and oxygen.

Likewise, in the Acorn Litigation, Acorn expressly interpreted the genus of “oxide of titanium” to encompass ternary compounds. Referring to the image below,

oxide of titanium.” That claim was subsequently amended to require “the metal oxide layer comprises an oxide of titanium.” (Ex.1020, 191.)

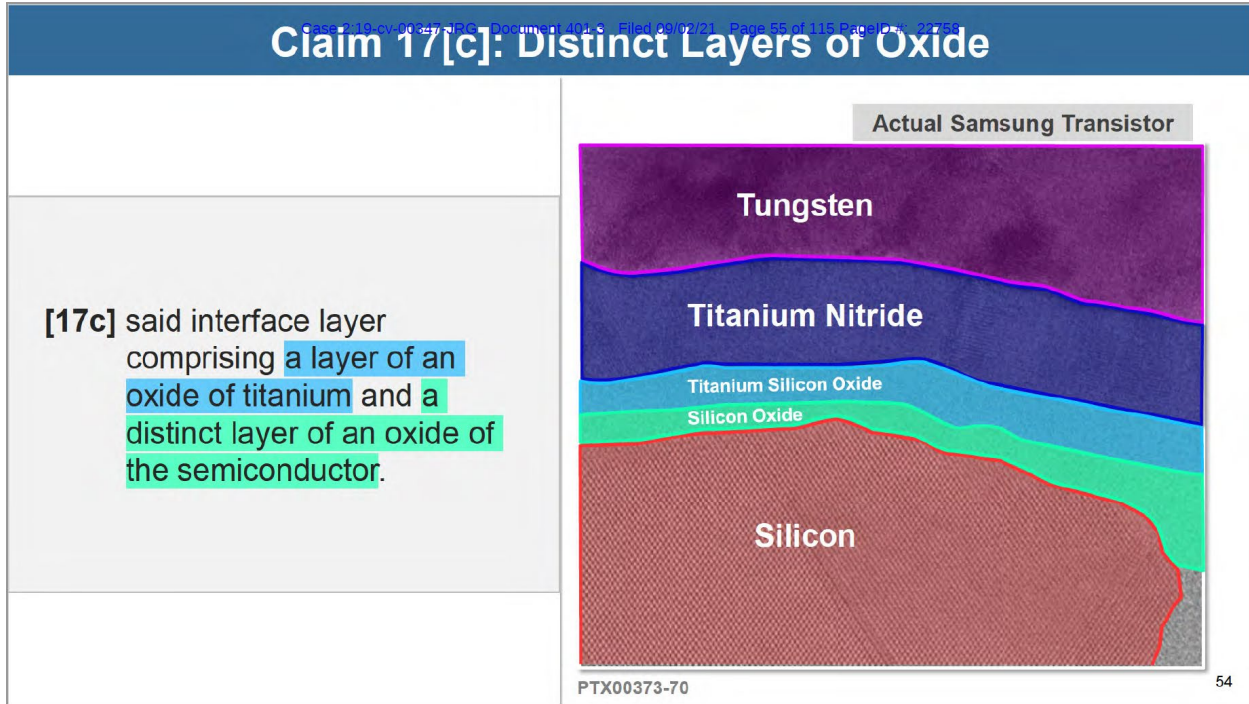
Acorn argued that the accused products infringe Claim 19 of the '691 Patent because “the metal oxide comprises *titanium silicon oxide*, which comprises an oxide of *titanium*.” (Ex.1042, 19.)



Samsung 14nm LPE - Exynos 7420 (Galaxy S6)

(Ex.1042, 11, 20.)

At trial in the Acorn Litigation, Acorn explicitly argued that the “oxide of titanium” genus includes ternary compounds that contain silicon in addition to oxygen and titanium. During his testimony at trial, Acorn’s expert, Dr. Piner, relied upon the demonstrative below to argue that the “layer of an oxide of titanium” present in Limitation [c] of Claim 17 of '395 Patent, (Ex.1014, Claim 17), corresponds to the “Titanium Silicon Oxide” layer in the accused products:

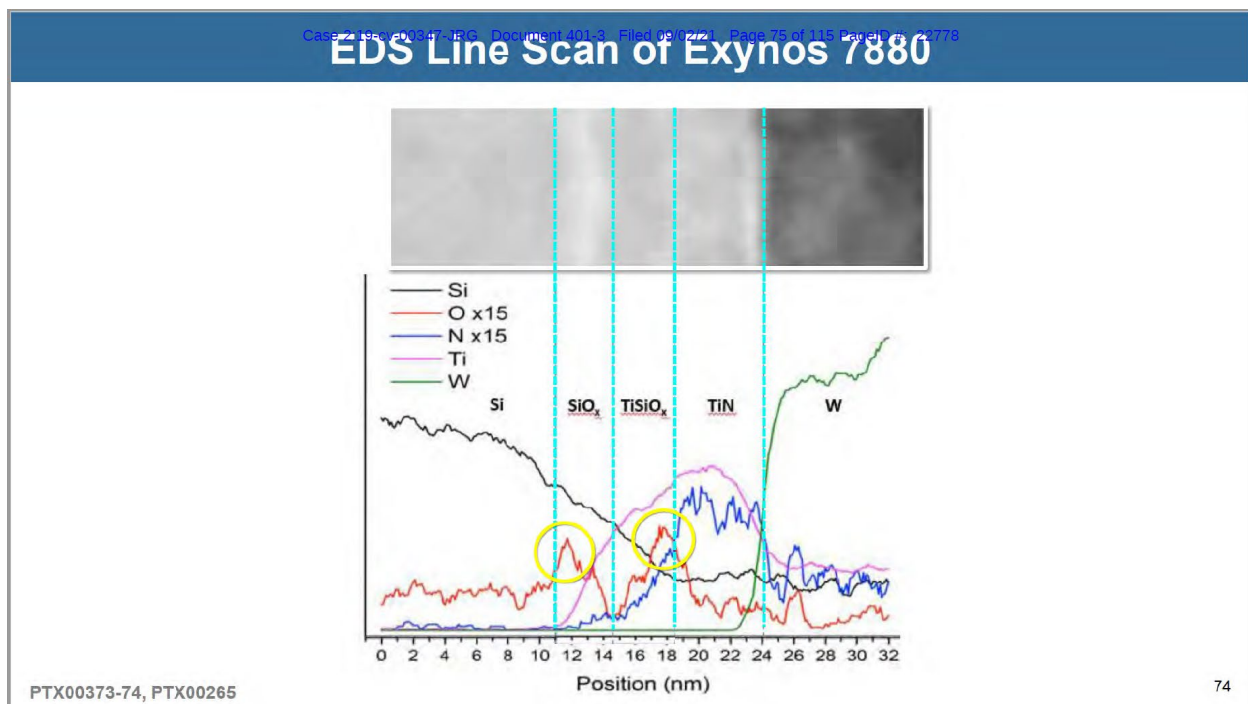


(Ex.1044, 55.) When discussing the demonstrative slide above, Dr. Piner testified the term “a layer of an oxide of titanium” corresponds to the layer of “Titanium Silicon Oxide” in blue. (Ex.1092, 476-77) (“And so the interface layer needs to include a *layer of an oxide of titanium*, which I highlighted in the light blue here to correspond to what I’m showing in the image as *titanium silicon oxide*.”)

At trial in the Acorn Litigation, Acorn asserted Claims 6, 8 and 19 of the '691 Patent. (Ex.1044, 21; Ex.1045, 4.) Like Claim 17 of the '395 Patent, Claims 6-12,15-19, and 26-29 of the '691 Patent require a layer of “oxide of titanium,” (Ex.1014, Claim 17; Ex. 1001, Claims 6, 15, 19, 26), and both patents share a common specification. Thus, Acorn’s allegations and Dr. Piner’s testimony regarding “oxide of titanium” layer in context of the '395 Patent are equally applicable to that layer

in the '691 Patent. (See Ex.1124, 857-858 (Dr. Piner testifying at trial that he found the “oxide of titanium” requirement in both the '395 Patent and the '691 Patent.).)

Acorn’s expert, Dr. Piner, did not limit the scope to a particular composition of titanium silicon oxide. Through the demonstrative slide below, Dr. Piner equated “oxide of titanium” to $TiSiO_x$, a compound of oxygen, titanium, and silicon in which the amount of oxygen can be arbitrary:



(Ex.1044, 75.) In other words, Acorn argued to the jury that the “oxide of titanium” includes all compounds of titanium, silicon, and oxygen, irrespective of the amount of oxygen content. (Ex.1043, 23) (“[Samsung’s] argument is based on the idea that an oxide of titanium requires 33% oxygen, while an oxide of silicon requires 50% oxygen. . . . [Acorn’s expert] never agreed with either point, and [Samsung’s

expert's] testimony on these points was conclusory, at best. There was certainly not anything at trial *requiring* the jury to believe in Samsung's claimed percentage requirements.") (emphasis in original) (internal citations omitted).

Acorn also argued that a compound containing "more than mere trace amounts" of oxygen, and as little as 5% or 15%, meets the "oxide of titanium" limitation. (Ex.1043, 23) ("[Samsung's expert's] charts *did* show peaks of 5% and 15% oxygen at the accused interface layer, which are more than mere trace amounts.") (emphasis in original.) During post-trial phase, while relying upon the above demonstrative, (Ex.1044, 75), Acorn did not limit $TiSiO_x$ to a particular level of oxygen; instead it asserted that "Dr. Piner had identified the layer of silicon oxide and a *layer of titanium silicon oxide*." (Ex.1043, 9.)

Relying upon the testimony of Dr. Piner, the jury found that Samsung infringes Claim 17 of the '395 Patent and also Claims 6, 8 and 19 of the '691 Patent. (Ex.1045, 4.) The District Court entered a final judgment shortly thereafter noting, *inter alia*, that Samsung infringed Claims 6, 8 and 19 of the '691 Patent. (Ex.1093, 2.)

b) Oak is estopped from arguing that ternary compounds containing titanium, silicon, and oxygen do not fall within the scope of "oxide of titanium"

By virtue of Acorn's infringement allegations during the Acorn Litigation regarding the scope of the "oxide of titanium" genus, the doctrine of judicial estoppel

now estops Oak from arguing a narrower scope of that genus. As the present assignee of the '691 Patent, Oak is bound by the acts of Acorn, the previous assignee of that patent. *See Worely v Loker Tobacco Co.*, 104 U.S. 340, 344 (1881) (“[T]he assignee of a patent right takes it subject to the legal consequences of the previous acts of the patentee.”); *In re Galaz*, 841 F.3d 316, 326 (5th Cir. 2016) (“Because Galaz is Vernon’s successor-in-interest, [Galaz] inherits the positions that [Vernon] has taken throughout the litigation. [Galaz] cannot now contend that Oshita has an ownership interest in WSG, because that position is plainly inconsistent with Vernon’s prior position.”); *Adelphia Recovery Tr. v. Goldman, Sachs & Co.*, 748 F.3d 110, 120 (2d Cir. 2014) (finding appellants judicially estopped by actions of predecessors in interest); *see also Int’l Nutrition Co. v. Horphag Rsch., Ltd.*, 220 F.3d 1325, 1329 (Fed. Cir. 2000) (“[A] judgment with respect to a particular property interest may be binding on a third party based on a transfer of the property in issue to the third party after judgment.”).

The doctrine of judicial estoppel prevents a party who relied on one argument to prevail in a legal proceeding from advancing a contradictory argument in another proceeding. *See New Hampshire v. Maine*, 532 U.S. 742, 749 (2001). The doctrine’s purpose is “to protect the integrity of the judicial process by prohibiting parties from deliberately changing positions according to the exigencies of the moment[.]” *Id.* at

749–50 (quotations and citations omitted). To determine whether judicial estoppel should apply, the Federal Circuit considers three non-exclusive factors:

(1) whether the party’s position is clearly inconsistent with its earlier position; (2) whether the party has succeeded in persuading a [tribunal] to accept that party’s earlier position, so that judicial acceptance of an inconsistent position in a later proceeding would create the perception that either the first or the second [tribunal] was misled; (3) whether the party seeking to assert an inconsistent position would derive an unfair advantage or impose an unfair detriment on the opposing party if not estopped.

(*Trs. in Bankr. of N. Am. Rubber Thread Co. v. United States*, 593 F.3d 1346, 1354 (Fed. Cir. 2010) (citing *New Hampshire*, 532 U.S. at 749).)

Because all three judicial estoppel factors are present, Oak should be estopped from arguing for a different scope of the “oxide of titanium” genus than it obtained in the litigation against Samsung. *First*, any argument from Oak that the “oxide of titanium” genus does not include TiSiO_x would contradict Acorn’s earlier position that the “oxide of titanium” genus does include TiSiO_x . *Second*, Acorn prevailed in the infringement trial based on the interpretation that the “oxide of titanium” genus includes TiSiO_x . *Third*, Oak would derive an unfair advantage if it were permitted to advocate for inconsistent constructions of its patent claims. Thus, Oak should be precluded from asserting that the “oxide of titanium” genus does not include ternary compounds, such as, TiSiO_x . *See Trs. in Bankr.*, 593 F.3d at 1356; *see also Trs. of*

Columbia Univ. v. NortonLifeLock, Inc., No. 3:13cv808, 2019 WL 7040931, at *3–6 (E.D. Va. Dec. 20, 2019).

B. Ancestor applications of the '691 Patent fail to adequately describe an “oxide of titanium”

As discussed above, Claims 6-12, 15-19, 23-24, and 26-29 cannot obtain their alleged August 12, 2002 priority date unless all of the '691 Patent's ancestor applications provide written description support for every limitation of these claims. *In re NTP*, 654 F.3d at 1277. “[T]he test for sufficiency is whether the disclosure of the application relied upon reasonably conveys to those skilled in the art that the inventor had possession of the claimed subject matter as of the filing date.” *Ariad Pharm., Inc. v. Eli Lilly & Co.*, 598 F.3d 1336, 1351 (Fed. Cir. 2010) (en banc); *see also Juno Therapeutics, Inc. v. Kite Pharma, Inc.*, 10 F.4th 1330, 1336 (Fed. Cir. 2021) (finding that the “written description fails to provide a representative sample of species within, or defining characteristics for, [an] expansive genus” when the patent-at-issue discloses only two species). Thus, “[a] disclosure in a parent application that merely renders the later-claimed invention obvious is not sufficient to meet the written description requirement; the disclosure must describe the claimed invention with all its limitations.” *Tronzo v. Biomet, Inc.*, 156 F.3d 1154, 1158 (Fed. Cir. 1998).

To support a claim to a genus, the specification must disclose “either a representative number of species falling within the scope of the genus or structural

features common to the members of the genus so that one of skill in the art can ‘visualize or recognize’ the members of the genus.” *Ariad*, 598 F.3d at 1350 (citation omitted); *see also Juno*, 10 F.4th at 1336. Here, Claims 6-12, 15-19 and 26-29 require an “oxide of titanium” in a metal oxide layer or a metal oxide separation layer and Claims 23-24 require an “oxide of titanium” in a “metal electrical contact.” (Ex.1001, Claims 6-12, 15-19, 23-24, and 26-29.) The only possible example of an “oxide of titanium” described in any earlier parent application is a ***TiO₂ spacer layer***. (Ex.1001, 17:60-62; Ex.1022, ¶96.)¹² Thus, the relevant question is whether the statement in earlier parent applications that “[s]pacer layers may be used with lower barriers (e.g., TiO₂ has a barrier of less than 1 eV)” provides written description of

¹² The Board has found that although incorporated-by-reference U.S. Patent No. 6,833,556 describes a generic metal oxide and four example metal oxides, those metal oxides are only used to electrically isolate a transistor’s gate from its channel “such that essentially no current flows between the gate 270 and the channel 220”—not for an interface layer through which current does flow, as is claimed. Moreover, none of the examples disclosed (zinc oxide, aluminum oxide, zirconium oxide, and hafnium oxide) is an oxide of titanium. (Ex.1125, 18; Ex.1005, 7:60-8:22; *see also id.*, 13:44-14:20; Ex.1001, 14:33-45; Ex.1022, ¶99.)

the entire “oxide of titanium” genus. (Ex.1001, 17:60-62.) And the answer is no, as further explained below:

First, although Claims 6-12, 15-19, 23-24 and 26-29 of the '691 Patent purport to cover any “oxide of titanium,” the Priority Applications provide a *single* example: titanium dioxide (TiO₂). “[A] patentee will not be deemed to have invented species sufficient to constitute the genus by virtue of having disclosed a single species.” *In re Curtis*, 354 F.3d 1347, 1358 (Fed. Cir. 2004); *see also Juno*, 10 F.4th at 1336.

Second, the single disclosed species—TiO₂—is not representative of the entire genus of “oxide of titanium,” and the specification does not describe features common to all members of the claimed genus. (Ex.1022, ¶100.) There are numerous materials that fall within the “oxide of titanium” genus, including several binary and ternary compounds as discussed above, and these materials exhibit a very broad range of properties. (Ex.1022, ¶¶101-105, 110-164.) Specifically, the “oxide of titanium” genus includes not only dielectric compounds (i.e., insulators), but also metallic compounds and semiconductive compounds because different species of “oxide of titanium” have vastly different electrical and structural properties. (Ex.1022, ¶¶110-164.) The genus of “oxide of titanium” encompasses all of them.

There are many different properties that affect the characteristics of the compounds within the “oxide of titanium” genus and the applications for which

those compounds may be employed. (*Id.*) Some of the non-limiting exemplary properties of the species of the genus include: (a) electrical (tunneling and bulk) conductivity (*or* resistivity); (b) barrier height; (c) electron affinity; (d) bandgap energy; (e) dielectric constants; (f) structural characteristics; (g) melting point; and (h) optical transparency. (Ex.1022, ¶108.) As discussed below, none of these properties exhibit a characteristic that is common to all the species in the “oxide of titanium” genus.

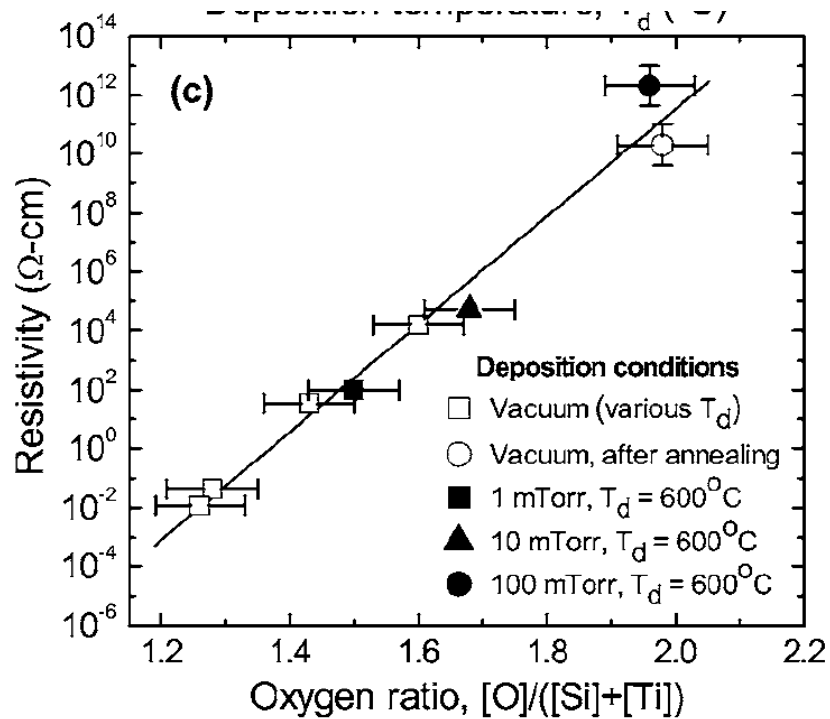
1. Electrical conductivity (or resistivity)

The electrical conductivity (or resistivity)¹³ of an “oxide of titanium” as used in an interface layer in a metal-semiconductor junction directly affects the specific contact resistivity of the junction. (Ex.1022, ¶¶113-114.) The Board also recognized that “[t]he electrical conductivity of a metal oxide is an important property for the recited genus because electrical conductivity directly affects the specific contact resistance of a junction, which is an important property for the ’395 patent’s disclosure.” (Ex.1125, 20 n.3.) Because the ’395 and ’691 Patents share the specification, the electrical conductivity of an oxide of titanium is an important property for the purported invention of the ’691 Patent as well.

¹³ Electrical conductivity is the reciprocal of electrical resistivity. (Ex.1022, ¶112.)

That TiO_2 is insufficient to represent the full scope of the claimed genus is evident when only a *single* property—electrical conductivity—is compared between different species of oxides of titanium. TiO_2 (titanium dioxide) is an oxide of titanium with *semi-conductive* properties (which may vary depending on the impurity content). (Ex.1022, ¶117.) Mirroring the semi-conductive property, the electrical resistivity (ρ) of TiO_2 ranges from 1×10^4 to $1 \times 10^7 \Omega \text{ m}$. (Ex.1078, 88; Ex.1022, ¶117.)

Based upon their *composition*, the conductivity of compounds within the “oxide of titanium” genus varies considerably and ranges from *conductors* at one end to *insulators/dielectrics* at the other end. (Ex.1022, ¶117.) For example, the conductivity of oxides of titanium composed of titanium, silicon, and oxygen (i.e., TiSi_xO_y) varies widely depending on the level of oxygen of the compound. (*Id.*, ¶118.) Fig. 6(c) of 2005-Brassard shows that titanium silicates (TiSi_xO_y) with high levels of oxygen content are insulators whereas titanium silicates with low levels of oxygen are conductors:



(Ex.1035, 054912-6, Fig. 6(c).) When oxygen and titanium are present in equal proportion (e.g., TiO), the compound acts like a *conductor* or has metallic properties. However, when oxygen content is high (e.g., 60% or more as in TiSiO₄) the compound acts like an *insulator*. (Ex.1022, ¶¶119-122.)

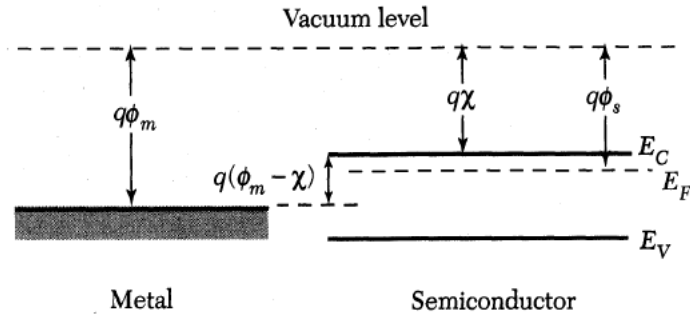
In addition to *composition*, the electrical conductivity of compounds in the “oxide of titanium” genus varies significantly based on *environmental conditions*, such as temperature (*Id.*, ¶123.) For example, Ti₃O₅ behaves like a semiconductor at room temperature, but becomes conductive at higher temperatures. (*Id.*) The conductivity of oxides of titanium also varies based on their *growth or film deposition conditions*, such as oxygen pressure and deposition temperature. (*Id.*, ¶¶124-126.) For example, the conductivity is low when the films are deposited at

low oxygen pressure, but when oxygen pressure is increased, the resistivity increases rapidly and highly insulating films are obtained. (*Id.*, ¶125.) The resistivity of titanium silicate films deposited under vacuum decreases when the deposition temperature is increased. (*Id.*, ¶126.)

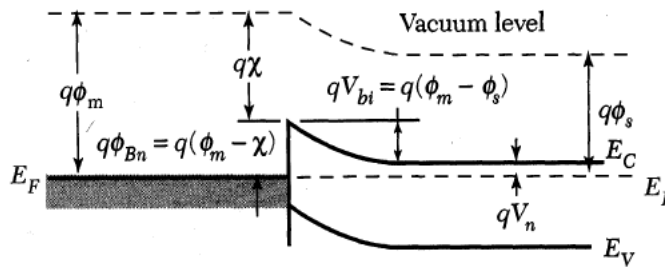
In light of the broad range of variation in the conductivity within the “oxide of titanium” genus depending on the composition, environmental conditions, and growth (deposition) conditions, the disclosure of “TiO₂” with “a barrier less than 1 eV” alone does not convey to a POSITA the entire “oxide of titanium” genus. (*Id.*, ¶127.)

2. Barrier height

In a metal-semiconductor junction, the barrier height represents the energy an electron needs to overcome to move from the semiconductor to the metal or vice versa. Thus, barrier height influences the electrical characteristics of the junction, and impacts the specific contact resistivity. (Ex.1107, 72-74; Ex.1022, ¶128.) Fig. 2(a) from the Sze Textbook (excerpted below) is the energy band diagram of an isolated metal adjacent to an isolated n-type semiconductor and Fig. 2(b) is a diagram for a metal-semiconductor junction:



(a)



(b)

(Ex.1107, Figs. 2(a), 2(b), and 226.) The concept of barrier height is related to work function and electron affinity, and as shown in Fig. 2(b), barrier height ($q\phi_{Bn}$) of a metal-semiconductor junction is the difference between the metal's work function and the semiconductor's electron affinity:

$$q\phi_{Bn} = q\phi_m - q\chi$$

(Ex.1107, 226). The electron affinity $q\chi$ is the energy difference between the conduction band edge E_c and the vacuum level in the semiconductor (i.e., level at which an electron has no potential energy). (*Id.*) The work function $q\phi_s$ is the energy difference between the Fermi level E_F and the vacuum level in the semiconductor. (*Id.*) The work function of a metal $q\phi_m$ is an inherent property of the metal and does not vary (for a given metal). Thus, the barrier height varies along with the electron

affinity $q\chi$. (Ex.1022, ¶128.) The choice of metal and the semiconductor to form the junction influences barrier height, which in turn influences the specific contact resistance. (*Id.*)

Species within the “oxide of titanium” genus can have a broad range of barrier heights. Some species can exhibit a barrier height that is equal to or higher than 1 eV. (*Id.*, ¶¶130-131.) For example, the barrier heights of some species of titanium aluminates relative to silicon conduction band (or the aluminum Fermi level) are higher than or equal to 1 eV and not less than 1 eV in some instances. (*Id.*) Further, metallic compounds, such as TiO (and likely Ti₃O and Ti₂O), do not have a barrier height because they behave like metals.¹⁴ (*Id.*, ¶133.) Accordingly, the species of the oxide of titanium genus cannot be characterized as fitting the description of having “a barrier of less than 1 eV.” (*Id.*, ¶¶129, 134.) The limited disclosure in the specification of the ’691 Patent does not convey the entire genus to a POSITA. (*Id.*)

¹⁴ When a dielectric is deposited on a semiconductor, a barrier forms at the semiconductor-dielectric interface. For Si and TiO₂, the ’691 Patent discloses a barrier of less than 1 eV. Such a barrier is absent when TiO₂ (a semiconductor / dielectric) is replaced by TiO (a metallic compound).

3. Electron affinity

As discussed above, in a metal-semiconductor junction, electron affinity $q\chi$ is the energy required to move an electron from the semiconductor's conduction band to the vacuum level. (Ex.1022, ¶135.) Electron affinity, along with the work function of a metal $q\phi_m$, determines the barrier height of the junction and the resistance of the junction. (*Id.*; *see also id.*, ¶¶136-137.)

The electron affinity of TiO_2 (a semiconductor) is 4.0 eV. (Ex.1087, 3; Ex.1022, ¶139.) Different compounds in the “oxide of titanium” genus have different electron affinities. (*Id.*, ¶138.) If, in terms of electrical conductivity, a compound in the “oxide of titanium” genus behaves like a metal (e.g., TiO), then its properties are more appropriately described by a metal work function. (*Id.*, ¶139.) Further, electron affinities of some of the oxides of titanium (e.g., Ti_2O_3 and TiSiO_4) are not even known. (*Id.*) Thus, the electron affinity of TiO_2 does not convey the entire genus to a POSITA. (Ex.1022, ¶140.)

4. Bandgap energy

The bandgap energy E_g is the gap between the bottom of the conduction band and top of the valence band ($E_c - E_v$), as shown below in Fig. 15. (Ex.1107, 29; Ex.1022, ¶141.)

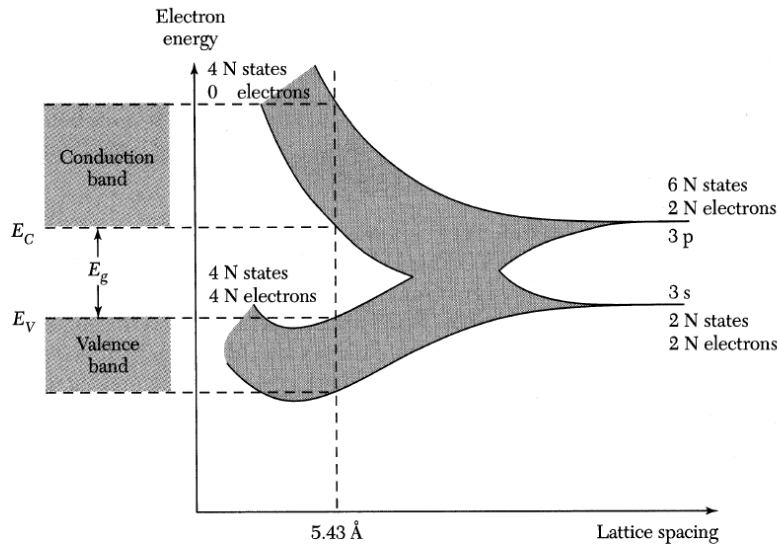


Fig. 15 Formation of energy bands as a diamond lattice crystal is formed by bringing isolated silicon atoms together.

(Ex.1107, 30.) E_g is the energy required to break a bond in the semiconductor to free an electron to the conduction band and leave a hole in the valence band. (*Id.*; Ex.1022, ¶141.) Higher bandgap energy E_g implies higher resistivity and smaller bandgap implies lower resistivity. Thus, the bandgap energy is a key factor in determining a material’s electrical conductivity—a material’s conductivity is inversely related to its bandgap energy. (*Id.*; see also *id.*, ¶¶142-144.)

The bandgap energy of TiO_2 is about 3.0 to 3.4 eV. (Ex.1074; Ex.1058; Ex.1022, ¶145.) Compounds in the “oxide of titanium” genus have different bandgap energies. (*Id.*) For example, TiO does not have a bandgap energy because it behaves like a metal, and the bandgap energies of Ti_2O_3 and TiSiO_4 are 0.1 eV and 1.75-2.68 eV, respectively. (*Id.*) Thus, the bandgap energy of TiO_2 does not convey the entire genus to a POSITA. (*Id.*, ¶146.)

5. Dielectric constant

The dielectric constant of a material is the ratio of the electrical permittivity of the material to the permittivity of vacuum. Permittivity of a material is its ability to store electrical energy in an electrical field. The dielectric constants are used to describe characteristics of insulators and thus determine the applications for which the insulators can be employed. (*Id.*, ¶147; *see also id.*, ¶148.)

TiO₂ is known to have a high dielectric constant with *k* values in excess of 80. (*Id.*, ¶149.) The dielectric constant also varies widely between different species in the “oxide of titanium” genus when compared to the dielectric constant of TiO₂. (*Id.*) For example, the dielectric constant of TiSiO₄, Ti_{0.5}Si_{0.5}O₂, and Ti_{0.51}Si_{0.49}O₂ is around “16.5,” “higher than 20,” and “as high as 26,” respectively. (*Id.*) Thus, the dielectric constant of TiO₂ fails to convey the entire genus to a POSITA. (*Id.*, ¶150.)

6. Structural properties

Structural properties of a compound are associated with the spatial arrangement of its atoms, which in turn can affect the movement of charge carriers within the material. (Ex.1022, ¶¶151-153.)

TiO₂ crystallizes in three different structures: the rutile structure, anatase structure, and brookite structure. (*Id.*, ¶153.) Atoms in a crystal structure have specific positional relationships with each other. In each of the three crystal structures (rutile, anatase, and brookite), the constituent atoms have distinct

positional relationships with each other. (*Id.*) The compounds in the “oxide of titanium” genus have different structural properties. (*Id.*, ¶¶154-155.) For example, many binary compounds, such as TiO, Ti₂O₃, Ti₄O₇, and Ti₃O₅, are known to have different crystal structures. (*Id.*, ¶154.) Some ternary titanate compounds were also known to have a glass-like structure (e.g., TiSiO₄, TiSi_xO_y). (*Id.*, ¶155.) Thus, no one structural property is common to all compounds that fall within the genus. (*Id.*, ¶156.)

7. Melting point

The melting point of an “oxide of titanium” is important when considering its usefulness in semiconductor manufacturing because it is indicative of high-temperature structural stability and affects the reliability and manufacturability of the device employing the compound. (Ex.1022, ¶¶157-158.)

The melting point of TiO₂ is 1,855° C. (Ex.1022, ¶157) The melting point of different species of the genus can vary, from 1,700° C to 2,130° C. (Ex.1022, ¶157.) Thus, the melting point of TiO₂ does not convey the entire genus to a POSITA. (Ex.1022, ¶159.)

8. Optical transparency

The optical transparency gives an indication of the bandgap energy, with opaque materials having a lower bandgap energy, and transparent materials having

a higher bandgap energy. (Ex.1022, ¶160.) The optical transparency may have a significant influence in semiconductor manufacturing. (Ex.1022, ¶161.)

TiO₂ is optically transparent in the visible wavelength range (corresponding to high optical transparency). (Ex.1022, ¶162.) The species of the genus can have different optical reflectivity, absorbency, opacity, and transparency—from transparent or partially transparent to opaque or black. (Ex.1022, ¶162.) Thus, the optical transparency of TiO₂ does not describe the entire genus to a POSITA. (Ex.1022, ¶163.)

* * *

The table below compares just a handful of binary and ternary compounds of oxides of titanium that could be used in semiconductor devices with the seven exemplary properties to illustrate their disparate nature, including properties that are diametrically opposite, exhibited by different oxides of titanium.¹⁵

Properties	TiO	TiO ₂	Ti ₂ O ₃	Ti ₃ O ₅	TiSiO ₄
Electrical conductivity	Conductor	SemiC	SemiC at RoomT exhibiting SemiC-to-M	SemiC at RoomT exhibiting SemiC-to-M	Insulator

¹⁵ SemiC refers to semiconductor; RoomT refers to room temperature; SC-to-M refers to transition from semiconductor properties to metal properties. The blank entries in the table indicate that data is not available.

Properties	TiO	TiO ₂	Ti ₂ O ₃	Ti ₃ O ₅	TiSiO ₄
			at higher temp.	at higher temp.	
Electron affinity	None	4 eV	Probably unknown	Probably unknown, but relatively small	Probably unknown
Bandgap energy	None (metallic)	3.0-3.4 eV	0.1 eV	Small bandgap with semiconductor-to-metal transition at 440 K	1.75-2.68 eV
Dielectric constant		80			16.5
Structural properties	Monoclinic and cubic	Rutile, anatase and brookite	Corundum	Anosovite and monoclinic	Glass-like (no structure)
Melting point	1,700 °C	1,855 °C	2,130 °C	1,700 °C	
Optical transparency	Reflective (similar to a metal)	Transparent (high)	Optically absorbing and opaque (“dark violet”)	Optically absorbing and opaque (black colored)	Partially transparent

(Ex.1022, ¶164.)

The table above does not even consider all the equilibrium and non-equilibrium species¹⁶ of the binary and the ternary species of genus that collectively exhibit even broader disparities in the characteristics. (Ex.1022, ¶¶101-105.) For example, titanium silicate (TiSi_xO_y) is a ternary compound of oxide of titanium, and its electrical conductivity changes considerably—from a metal to an insulator—depending upon growth conditions (e.g., film deposition conditions), including oxygen pressure and deposition temperature. (Ex.1022, ¶¶117-121.) Further, properties of some of the species of “oxide of titanium”—such as TiO_2 and non-stoichiometric compounds—were not entirely well understood. (Ex.1022, ¶¶165-169.) Thus, a POSITA would not have known whether certain species in the “oxide of titanium” genus would be suitable as an interface layer. (Ex.1022, ¶¶165-169.)

The variations show that neither TiO_2 nor “lower barriers” represents the full genus of oxides of titanium. Those disclosures, whether taken alone or together, do not reflect the full variation across the genus of oxide of titanium. Thus, no

¹⁶ In the semiconductor fabrication process, nonequilibrium compounds can form because the products are fabricated in nonequilibrium conditions. (Ex.1022, ¶101; Ex.1048, 50:25-51:13.) In the Acorn Litigation, Acorn argued that the oxide of titanium includes nonequilibrium compounds. (Ex.1043, 5, 9 (identifying “ TiSiO_x ” in the interface layer).)

application prior to U.S. Patent App. No. 15/048,877 provides written description of a generic “oxide of titanium” interface layer.

Indeed, “[a] patentee will not be deemed to have invented species sufficient to constitute the genus by virtue of having disclosed a single species when, as is the case here, the evidence indicates ordinary artisans could not predict the operability in the invention of any species other than the one disclosed.” *In re Curtis*, 354 F.3d 1347, 1358 (Fed. Cir. 2004). The Federal Circuit held *In re Curtis* that a lone disclosed example a dental floss could not support a claim to a genus of friction-enhancing coatings. *See id.* at 1358; *see also Juno*, 10 F.4th at 1336.

Like the lone example in *In re Curtis*, TiO₂ is the only “oxide of titanium” layer disclosed in the parent applications predating the ’877 Application. Acorn alleged that the operability of the claimed interface layers was unpredictable; indeed, it alleged that using *any* interface layer was “counter-intuitive.” (Ex.1038 ¶¶6, 48; Ex.1022, ¶100.) Oak also alleges that the inventors found this result “remarkable.” (Ex.1095, ¶¶37-39.) Thus, just as the lone example in *In re Curtis* could not support a claim to the genus of friction-enhancing coatings, the previous parent applications’ lone example of TiO₂ as a spacer layer cannot support claims to a generic “oxide of titanium” for an interface layer. Accordingly, no Challenged Claim requiring an “oxide of titanium” can possibly obtain a priority date earlier than February 19, 2016, the filing date of the ’877 Application. (Ex.1022, ¶¶90, 92-100.)

In light of prior arguments made by Acorn, Oak may argue that the disclosure of TiO₂ is sufficient to support the “oxide of titanium” genus. (Ex.1091, 15.) Oak may argue that because the “oxide of titanium” is in the spacer layer, a common structural feature of oxides of titanium used for such purpose is that they are dielectrics. (Ex.1091, 16-24.) The Board should reject Oak’s arguments for the same reason it rejected Acorn’s arguments. The Board noted that “[t]he ’423 patent [parent of ’691 Patent with same specification] does not discuss any properties of metal oxides (other than the lower barrier of the metal oxide TiO₂) or design considerations concerning the selection of particular oxides to use in the claimed structure, particularly in the context of MIGS separation.” (Ex.1091, 22.) Thus, the Board did not credit Acorn’s analysis that a skilled artisan would have found that the inventors possessed the recited genus. (Ex.1091, 22 (citing *Martin v. Meyer*, 823 F.2d 500, 505 (Fed. Cir. 1987) (holding that the written description is “not a question whether one skilled in the art *might* be able to construct the patentee’s device from the teachings of the disclosure Rather, it is a question whether the application necessarily discloses that particular device.”) (emphasis in original).)

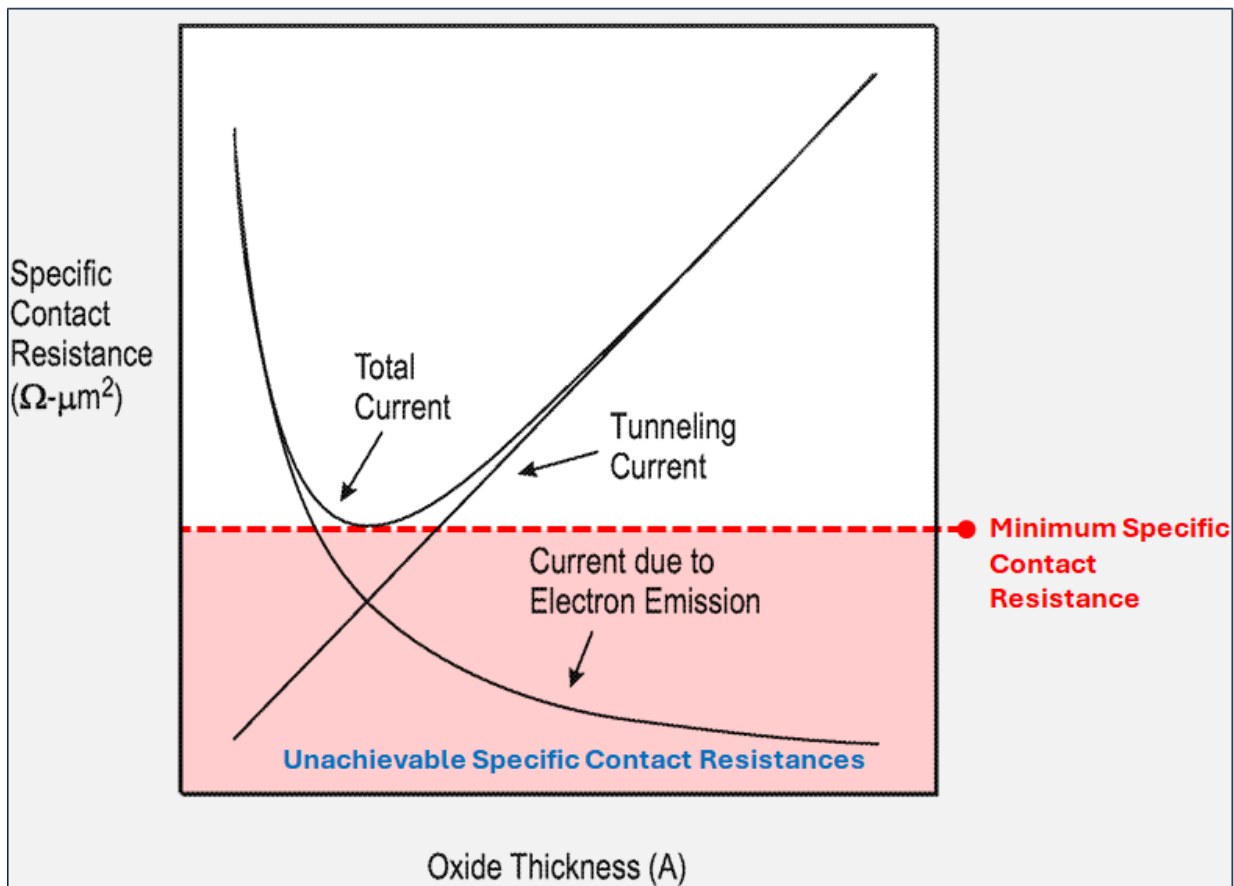
XII. ANCESTOR APPLICATIONS OF THE ’691 PATENT FAIL TO ENABLE A SPECIFIC CONTACT RESISTIVITY LESS THAN 1 Ω-μM²

Claims 18 and 26-29 require “a specific contact resistivity . . . less than 1 Ω-μm².” However, none of the ancestor applications enable a specific contact

resistivity less than $1 \Omega\text{-}\mu\text{m}^2$. (Ex.1022, ¶¶ 170-176.) The Board has found that that the ancestor applications of the '691 Patent do not enable the full breadth of the recited range of “less than $1 \Omega\text{-}\mu\text{m}^2$.” (Ex.1091, 37-39.) “The enablement requirement asks whether ‘the specification teach[es] those in the art to make and use the invention without undue experimentation.’” *Enzo Life Scis., Inc. v. Roche Molecular Sys., Inc.*, 928 F.3d 1340, 1345 (Fed. Cir. 2019), *cert. denied*, 206 L.Ed.2d 513 (Mar. 30, 2020) (quoting *In re Wands*, 858 F.2d 731, 737 (Fed. Cir. 1988); *see also Magsil Corp. v. Hitachi Global Storage Techs., Inc.*, 687 F.3d 1377, 1380-81 (Fed. Cir. 2012). Thus, “the specification must teach those of skill in the art how to make and how to use the invention as broadly as it is claimed.” *In re Goodman*, 11 F.3d 1046, 1050 (Fed. Cir. 1993).

The disclosure that the '691 Patent shares with its ancestor applications falls well short of that mark. Claims 18 and 26-29 recite or include “a specific contact resistivity . . . less than $1 \Omega\text{-}\mu\text{m}^2$.” As written, that claim limitation has no lower bound on specific contact resistivity. The specification imposes no lower bound on specific contact resistivity, either, as it does not quantify or describe any lower bound for the “minimum specific contact resistance” that it purports to describe. (Ex.1001, Fig. 8, 4:9-22, 14:29-49.) Thus, the “less than $1 \Omega\text{-}\mu\text{m}^2$ ” part of that limitation encompasses specific contact resistivities down to and including approximately zero. Such a lower bound cannot be achieved according to the '691 Patent or its ancestor

applications. Their shared disclosure purports to describe an interface layer that minimizes the total specific contact resistance (specific contact resistivity) of a metal-semiconductor junction, represented below by the “total current” curve that sums (1) resistance to tunneling current and (2) resistance to current by electron emission:



(Ex.1001, Fig. 8 (annotations added), 14:29-49; Ex.1022, ¶¶ 170-174.)

As can be seen from the annotated figure above, the nadir of Fig. 8’s “total current” curve indicates a range of specific contact resistivities down to and including approximately zero that an ordinarily skilled artisan could not have

attained by following the teachings of the '691 Patent and its ancestor applications. Thus, those parent applications fail to enable the *full* scope of the “specific contact resistivity . . . less than $1 \Omega\text{-}\mu\text{m}^2$ ” limitations in Claims 18 and 26-29. (Ex.1022, ¶¶175-176.)

Nor should the Board constrain “less than $1 \Omega\text{-}\mu\text{m}^2$ ” to some lower bound in order to enable Claims 18 and 26-29. That would be tantamount to redrafting those claims, and Federal Circuit precedent discourages that. *Chef America, Inc. v. Lamb-Weston, Inc.*, 358 F.3d 1371, 1374 (Fed. Cir. 2004); *see also Magsil Corp. v. Hitachi Global Storage Techs., Inc.*, 687 F.3d 1377, 1381 (Fed. Cir. 2012) (noting that a patentee chooses broad claims at its own peril.)

Claims 18 and 26-29 are no better off than the non-enabled claims in *Magsil*. The '691 Patent and its ancestor applications do not describe any working examples of an electrical junction with a specific contact resistivity under $1 \Omega\text{-}\mu\text{m}^2$, down to and including approximately zero. Worse still, despite the '691 Patent and its ancestor applications expressly teaching that the disclosed techniques cannot reduce specific contact resistivity below some unspecified minimum, the patentee nonetheless drafted open-ended claims with no lower bound on specific contact resistivity. (Ex.1001, Fig. 8, 14:29-49; Ex.1022, ¶¶ 175-176.)

Because Claims 18 and 26-29 encompass a range of specific contact resistivities down to and including approximately zero that cannot be achieved

according to the '691 Patent's ancestors applications, those parent applications cannot enable the full scope of the challenged claims. *Magsil*, 687 F.3d at 1382. And when the breadth of a claim alone indicates that the claim is not enabled—as is the case here—that disposes of the enablement issue in its entirety, as it did in *Magsil*. *CommVault Sys., Inc. v. Realtime Data, LLC*, IPR2017-01710, Paper 11, at 20 (PTAB Jan. 18, 2018) (citing *Magsil*, 687 F.3d at 1382). Because no ancestor application enables the full scope of the challenged claims, their priority date is the filing date of the '691 Patent: February 19, 2016.

In light of Acorn's arguments in earlier petitions, Oak may argue that the specification provides adequate support. (Ex.1091, 29-32.) However, the Board has already found these arguments to be “off the mark” because the issue is “whether the disclosure enables the specific numerical ranges recited in the claims.” (Ex.1091, 32.) As the Board observed, “[a]s for the recited ranges, Patent Owner [Acorn] does not dispute, and the evidence shows, that the disclosure does not enable specific contact resistance down to zero.” (Ex.1091, 32-33.) The Board also rejected Acorn's argument and held that “[e]nablement under section 112, which is required for priority under section 120, requires enablement of the *full breadth of a claim*” (emphasis added). (Ex.1091, 33-34, 38.) The Board concluded that the ancestor applications of the '691 Patent do not enable the breadth of the recited range of “less than $1 \Omega\text{-}\mu\text{m}^2$.” (Ex.1091, 37-39; *see also* Ex.1022, ¶¶177-184.)

As the Board reiterated, enablement for anticipation “requires only enablement of an embodiment or embodiments that fall within the scope of the claim.” (Ex.1091, 38 (citing *Chester v. Miller*, 906 F.2d 1574, 1577 (Fed. Cir. 1990)).) The Board noted that Acorn did not deny that the upper part of the recited range (just below $1\Omega\text{-}\mu\text{m}^2$) is enabled by either the priority applications or Grupp ’483. (Ex.1091, 38.) Accordingly, as the Board found, Grupp ’483 enables the upper part of the range for purposes of anticipation and thus is prior art for each of challenged claims 18 and 25–29. (Ex.1091, 38-39; *see also* Ex.1022, ¶202.)

XIII. ANCESTOR APPLICATIONS OF THE ’691 PATENT FAIL TO ENABLE A “METAL ELECTRICAL CONTACT” THAT IS A “STACK OF METALS”

Claims 5, 9, and 14 of the ’691 Patent are not entitled to a priority date earlier than February 19, 2016 because none of the ancestor applications describe “a stack of metals deposited on the interface layer.” (Ex.1022, ¶185.) Although the ’691 Patent and its ancestor applications describe depositing a metal on an interface layer and various examples of metals for depositing on the interface layer, none describes depositing a stack of metals on an interface layer. At most, they describe depositing a single body of metal or alloy on an interface layer. (Ex.1001, Fig. 6, Figs. 7a-7d, 11:15-19, 13:45-67.) The same is true of the incorporated-by-reference disclosure of U.S. Patent No. 6,833,556. (Ex. 1005, Figs. 1-3, Fig. 6B, 4:64-67, 7:8-12, 7:49-53, 8:67-9:6, 14:54-67.)

XIV. THE CHALLENGED CLAIMS ARE UNPATENTABLE

A. Ground I: Grupp '483 anticipates Claims 6-8, 10-12, 15-17, and 19

1. Claim 6

a) The structure of claim 3,

The Board has found that Claims 1 and 3 are anticipated by Grupp '483. (Ex.1091, 39-40.)

b) wherein the metal oxide layer comprises an oxide of titanium.

Grupp '483 discloses this limitation. Grupp '483 discloses an interface layer that includes (1) a passivation layer, which can be a semiconductor oxide; and (2) a separation layer, which can be titanium dioxide. Specifically, Grupp '483 discloses that the separation layer can be a “spacer layer” of TiO₂, which is a metal oxide layer comprising an oxide of titanium: “[s]pacer layers may be used with lower barriers (e.g., TiO₂ has a barrier of less than 1 eV).” (Ex.1021, 18:65-67; *see also id.*, 18:45-65.)

2. Claim 7

a) The structure of claim 6,

Grupp '483 discloses the structure of Claim 6, as discussed above in **Section XIV.A.1.**

- b) wherein the semiconductor oxide of the dielectric tunnel barrier layer has a thickness of approximately less than 1 nm.**

Grupp '483 discloses this limitation. "The interface layer includes a passivating material, for example, a nitride, a fluoride, an oxide, an oxynitride, a hydride and/or an arsenide of the semiconductor, and in some cases may also include a separation layer." (Ex.1021, 3:53-56; *see also id.*, 4:28-31, 4:53-55, 8:64-9:10, 9:39-43, 10:34-44, 10:48-54, 10:60-63, 11:35-38, 13:41-46.) Grupp '483 further discloses that the semiconductor oxide passivation layer can have a thickness of approximately less than 1 nm: "the interface layer 520 includes or is made up of a passivation layer with a thickness of between approximately 0.1 nm and about 5 nm. For example, depending upon the particular implementation, the thickness may be less than about 1 nm." (Ex.1021, 10:66-11:3.)

3. Claim 8

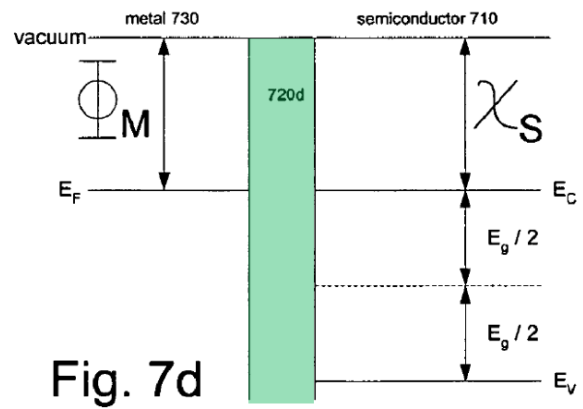
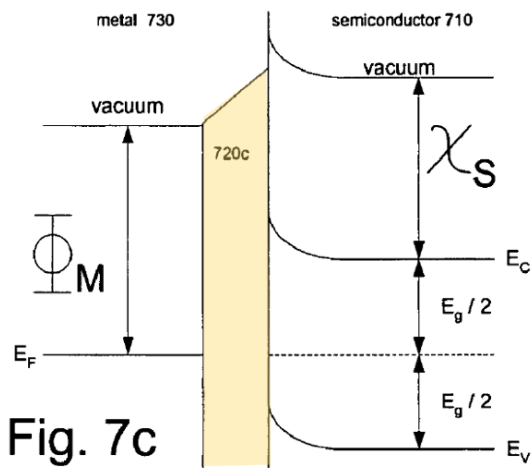
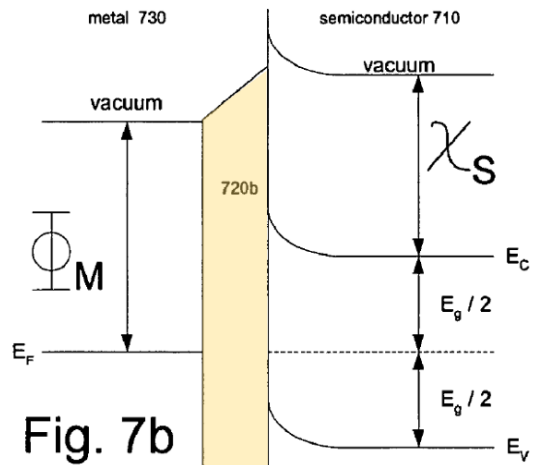
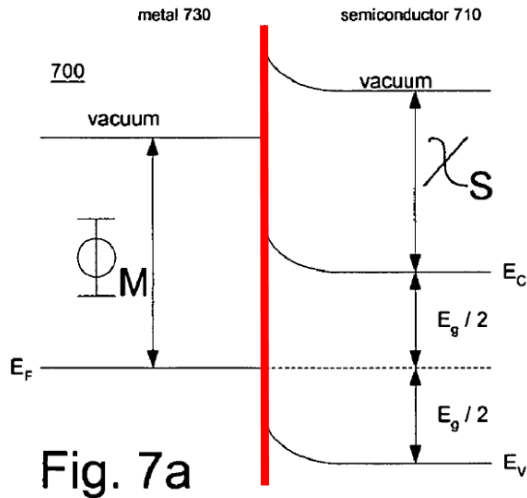
- a) The structure of claim 6,**

Grupp '483 discloses the structure of Claim 6, as discussed above in **Section XIV.A.1.**

- b) wherein the semiconductor region comprises an n-type doped source or drain of a transistor.**

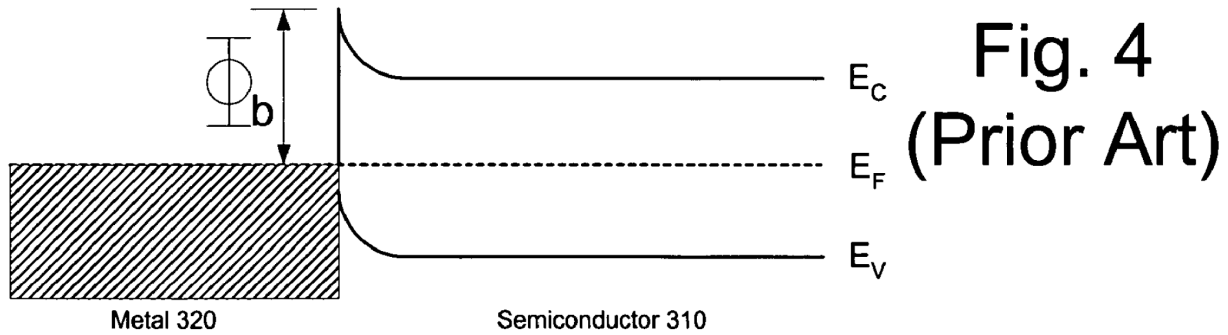
Grupp '483 discloses this limitation. Grupp '483 discloses that the semiconductor can be an n-type doped semiconductor. (Ex.1021, 6:5-9.)

Further, Fig. 7d of Grupp '483 shows a metal-interface layer-semiconductor junction, in which the semiconductor is an n-type semiconductor. (Ex.1021, Fig. 4, Fig. 7a, Fig. 7d, 5:22-23, 5:37-40, 18:4-10.) In particular, Grupp '483 depicts a series of band diagrams for metal-semiconductor junctions in Figs. 7a-7d, where the metal can be aluminum, and where the semiconductor can be n-type silicon. (Ex.1021, 5:33-40, 17:50-18:17.) In contrast to Figs. 7b-7d, which depict interface layers 720b, 720c, and 720d between the metal 730 and the semiconductor 710, Fig. 7a does not depict any interface layer, indicating that the metal 730 and the semiconductor 710 are in **direct contact with no interface layer** in Fig. 7a.



(Ex.1021, Figs. 7a-7d (annotations added), 5:33-40, 17:50-18:17.)

As Dr. Schubert explains, Fig. 7a of Grupp '483 depicts the same band bending as Grupp '483's Fig. 4, which is described as a junction between a metal and an n-type semiconductor:



(Ex.1021, Fig. 4, 5:22-23, 8:10-15; Ex.1022, ¶¶198-199.)

Grupp '483 explains that Fig. 4 depicts a junction between an n-type semiconductor and a metal with barrier height ϕ_b , which is the difference between the Fermi level of the metal E_F and the conduction band edge of the semiconductor E_C at the interface. (Ex.1021, 5:22-23, 8:10-15.) In light of Fig. 4 and its accompanying description, an ordinarily skilled artisan would have recognized that Figs. 7a-7d also depict a junction of an n-type semiconductor and a metal. (Ex.1021, Fig. 4, Fig. 7a, 5:22-23, 8:10-15, 18:4-17.) In particular, Fig. 7a, Fig. 7b, and Fig. 7c all depict band bending identical to that shown in Fig. 4, which depicts a metal to n-type semiconductor junction.

Grupp '483 additionally discloses “wherein said region in the semiconductor substrate comprises a source or drain of a transistor.” Grupp '483 describes that its invention is generally applicable to a broad category of metal-semiconductor contacts, which can include contacts to the source or drain of a transistor. (Ex.1021, 18:32-35.)

Further, in a section entitled “Transistors Containing Passivated Semiconductor Surfaces,” Grupp ’483 discloses that “the junction of the present invention can be used in making contacts to source or drain implanted wells and will have the advantage of reducing the need for high doping levels (which are now reaching their limits of solid solubility).” (Ex.1021, 18:19-20, 19:11-15; *see also id.*, 18:32-35.) In a transistor, a ‘well’ is a doped region of a semiconductor in which source and drain regions are formed by implanting dopants; the source and drain regions have a doping opposite that of the well. (Ex.1022, ¶197.)

In sum, Grupp ’483 discloses that the region in the semiconductor substrate can be both (1) n-type doped and (2) the source or drain of a transistor. Accordingly, Grupp ’483 discloses the limitation “wherein the semiconductor comprises an n-type doped source or drain of a transistor.”

4. Claim 10

a) The structure of claim 6,

Grupp ’483 discloses the structure of Claim 6, as discussed above in **Section XIV.A.1.**

b) wherein the semiconductor oxide comprises an oxide of silicon.

Grupp ’483 discloses this limitation. Grupp ’483 discloses two semiconductor oxides as passivating dielectric tunnel barrier layers: silicon oxide and silicon dioxide. (Ex.1021, 10:27-34, 10:48-54, 10:60-63 (silicon oxide); *id.*, 8:64-9:10

(silicon dioxide.) Both silicon oxide and silicon dioxide are oxides of silicon.
(Ex.1022, ¶197.)

5. Claim 11

a) The structure of claim 6,

Grupp '483 discloses the structure of Claim 6, as discussed above in **Section XIV.A.1.**

b) wherein the semiconductor oxide of the dielectric tunnel barrier layer is adjacent the semiconductor region.

Grupp '483 discloses this limitation. Grupp '483 discloses two semiconductor oxides as passivating dielectric tunnel barrier layers: silicon oxide and silicon dioxide. (Ex.1021, 10:27-34, 10:48-54, 10:60-63 (silicon oxide); Ex.1021, 8:64-9:10 (silicon dioxide).) Turning to silicon oxide, Grupp '483 further discloses forming a passivation material such as silicon oxide on a silicon surface such that it is adjacent to the semiconductor region made of silicon and bonds to the silicon. (Ex.1021, 10:27-34.) Turning to silicon dioxide, Grupp '483 discloses forming a silicon dioxide layer by exposing the silicon to oxygen so that the oxygen bonds to the silicon's surface, forming silicon dioxide adjacent to the silicon. (Ex.1021, 8:64-9:10.)

6. Claim 12

a) The structure of claim 6,

Grupp '483 discloses the structure of Claim 6, as discussed above in **Section XIV.A.1.**

b) wherein the metal electric contact comprises titanium.

Grupp '483 discloses this element. Grupp '483 discloses a metal electrical contact. Further, Grupp '483 discloses using titanium (Ti) as the metal electrical contact. (Ex.1021, 4:13-20, 14:58-15:2, Claim 7.) Though the claim recites *electric* contact, a POSITA would interpret claim to recite metal *electrical* contact thereby mirroring Claim 16, which recites metal *electrical* contact.

7. Claim 15

a) The structure of claim 13,

The Board has found that claim 13 is anticipated by Grupp '483. (Ex.1091, 41-42.)

b) wherein the metal oxide layer comprises an oxide of titanium.

Grupp '483 discloses this limitation, as discussed in **Section XIV.A.1.b).**

8. Claim 16

a) The structure of claim 15,

Grupp '483 discloses the structure of Claim 15, as discussed above in **Section XIV.A.7.**

- b) wherein the metal electrical contact comprises titanium.**

Grupp '483 discloses this limitation, as discussed above in **Section XIV.A.6.b).**

9. Claim 17

- a) The structure of claim 15,**

Grupp '483 discloses the structure of Claim 15, as discussed above in **Section XIV.A.7.**

- b) wherein the semiconductor comprises an n-type doped source or drain of a transistor.**

Grupp '483 discloses this limitation, as discussed in **Section XIV.A.3.b).**

10. Claim 19

- a) The structure of claim 1,**

The Board has found that Claim 1 is anticipated by Grupp '483. (Ex.1091, 39.)

- b) wherein the semiconductor region comprises silicon,**

Grupp '483 discloses this limitation. For example, Grupp '483 discloses that “[t]he present inventors have determined that for thin interface layers disposed between a metal and a semiconductor (e.g., C, Ge, Si [silicon], SiC and SiGe), so as to form a metal—interface layer—semiconductor junction, there exist corresponding minimum specific contact resistances.” (Ex.1021, 3:18-22.)

- c) **the semiconductor oxide comprises an oxide of silicon,**

Grupp '483 discloses this limitation, as discussed in **Section XIV.A.4.b).**

- d) **the metal oxide layer comprises an oxide of titanium,
and**

Grupp '483 discloses this limitation, as discussed in **Section XIV.A.1.b).**

- e) **the metal electrical contact comprises titanium.**

Grupp '483 discloses this limitation, as discussed in **Section XIV.A.6.b).**

As Dr. Schubert notes, he has reviewed Ground I and has concluded that Grupp '483 anticipates Claims 6-12, 15-17, and 19 of the '691 Patent. (Ex.1022, ¶¶197.)

B. Ground I: Grupp '483 anticipates claims 5, 9, and 14

1. Claim 5

- a) **The structure of claim 3,**

The Board has found that Claims 1 and 3 are anticipated by Grupp '483. (Ex.1091, 40.)

- b) **wherein the metal electrical contact is a metal or a stack of metals deposited on the dielectric tunnel barrier layer.**

Grupp '483 discloses this limitation. Although to satisfy this limitation Grupp '483 only needs to disclose either (1) a metal deposited on the interface layer or (2) a stack of metals deposited on the interface layer, Grupp '483 teaches both alternatives.

First, Grupp '483 discloses a contact metal that is a metal deposited on the interface layer. “An interface layer formed in this fashion may be best suited for applications where a subsequent metal layer is deposited over the interface layer in a generally non-invasive fashion, for example using a thermally evaporated source.” (Ex.1021, 11:66-12:3.) “The use of non-invasively deposited metals may allow for forming the metal on a thin interface layer without disrupting the passivation properties of the layer.” (Ex.1021, 14:32-34.)

Second, Grupp '483 discloses a contact metal that is a stack of metals deposited on the interface layer. As discussed previously, Grupp '483 describes depositing metals on an interface layer. (Ex.1021, 11:66-12:3, 14:32-34.) Further, “[a] conductor may also consist of one conductor at the interface covered by a second conductor.” (Ex.1021, 14:50-51; *see also id.*, Claim 10.) For example, “[a] submonolayer metal covered by a different metal may result in a workfunction different than either individual metal.” (Ex.1021, 14:38-40.)

2. Claim 9

a) The structure of claim 6,

Grupp '483 discloses the structure of Claim 6, as discussed in **Section XIV.A.1.**

b) wherein the metal electrical contact is a metal or a stack of metals deposited on the dielectric tunnel barrier layer.

Grupp '483 discloses this limitation, as discussed in **Section XIV.B.1.b).**

3. Claim 14

a) The structure of claim 13,

The Board has found that Claim 13 is anticipated by Grupp '483. (Ex.1091, 41-42.)

b) wherein the metal electrical contact is a metal or a stack of metals deposited on the dielectric tunnel barrier layer.

Grupp '483 discloses this limitation, as discussed in **Section XIV.B.1.b).**

As Dr. Schubert notes, he has reviewed Ground I and has concluded that Grupp '483 anticipates Claims 5, 9 and 14 of the '691 Patent. (Ex.1022, ¶200.)

C. Ground I: Grupp '483 anticipates claims 18 and 26-29

Claims 18 and 26-29 require a specific contact resistivity “less than $1 \Omega\text{-}\mu\text{m}^2$.” The Board has found that Grupp '483 is prior art for each of challenged claims 18 and 26–29 and treated “Grupp '483 as enabling the upper part of the range for purposes of anticipation.” (Ex.1091, 39.)

In the Acorn Litigation, after the conclusion of the IPRs, Samsung appealed the decisions to the Federal Circuit, and noted that Board’s finding of no anticipation for Claims 18 and 26-29 was an oversight in view of the Board’s finding that the claims were not enabled. (Ex.1122, 48-50.) In response, Acorn conceded that the Board “should have listed those claims as unpatentable because the Board found them unenabled. That was a simply typographical error.” (Ex.1123, 82.)

1. Claim 18

a) The structure of claim 17,

Grupp '483 discloses the structure of Claim 17, as discussed above in **Section XIV.A.9.**

b) wherein a specific contact resistivity between the n-type doped source or drain and the metal electric contact is less than $1 \Omega\text{-}\mu\text{m}^2$.

Grupp '483 discloses this limitation.

Grupp '483 discloses that the source or drain can be an n-type doped semiconductor, as discussed in **Section XIV.A.3.b).**

As discussed above in **Section VIII**, “specific contact resistivity” is interchangeable with “specific contact resistance,” so the analysis for this limitation focuses on specific contact resistance.

Grupp '483 discloses that “the present inventors have determined that for thin interface layers disposed between a metal and a semiconductor, so as to form a metal-interface layer-semiconductor junction, there exist corresponding minimum specific contact resistances.” (Ex.1021, 5:64-6:1.) “Indeed, minimum specific contact resistances of . . . even less than or equal to approximately $1 \Omega\text{-}\mu\text{m}^2$ may be achieved for such junctions in accordance with the present invention.” (Ex.1021, 6:1-5; *see also id.*, 3:40-43, 5:64-6:1, 8:58-61, 10:44-47; 15:52-57.) Grupp '483 therefore discloses some non-zero specific contact resistivity of less than $1 \Omega\text{-}\mu\text{m}^2$,

such as a specific contact resistivity just under $1 \Omega\text{-}\mu\text{m}^2$, between the n-type doped source or drain and the metal electric contact. (Ex.1022, ¶202.)

2. Claim 26

a) The electrical junction of claim 25,

The Board has found that Claim 25 is anticipated by Grupp '483. (Ex.1091, 44.)

b) wherein the metal oxide separation layer comprises an oxide of titanium.

Grupp '483 discloses this limitation, as discussed in **Section XIV.A.1.b)**.

3. Claim 27

a) The electrical junction of Claim 26,

Grupp '483 discloses the electrical junction of claim 26, as discussed above in **Section XIV.C.2.**

b) wherein the semiconductor oxide passivation layer is adjacent the semiconductor.

Grupp '483 discloses this limitation, as discussed in **Section XIV.A.5.b)**.

4. Claim 28

a) The electrical junction of Claim 27,

Grupp '483 discloses the electrical junction of claim 27, as discussed above in **Section XIV.C.3.**

- b) wherein the semiconductor oxide passivation layer has a thickness of approximately 0.1 nm to 5 nm.**

Grupp '483 discloses this limitation. Specifically, Grupp '483 discloses that “the interface layer 520 includes or is made up of a passivation layer with a thickness of between approximately 0.1 nm and about 5 nm.” (Ex.1021, 10:66-11:1.)

5. Claim 29

- a) The electrical junction of claim 27,**

Grupp '483 discloses the electrical junction of claim 27, as discussed above in **Section XIV.C.3.**

- b) wherein the semiconductor oxide passivation layer is adjacent the semiconductor.**

Grupp '483 discloses this limitation, as discussed in **Section XIV.A.5.b).**

As Dr. Schubert notes, he has reviewed Ground I and has concluded that Grupp '483 anticipates Claims 18 and 26-29 of the '691 Patent. (Ex.1022, ¶201.)

D. Ground I: Grupp '483 anticipates claim 21

1. Claim 21

- a) The structure of claim 1,**

The Board has found that Claim 1 is anticipated by Grupp '483. (Ex.1091, 39.)

- b) **wherein for a specified contact resistivity of the structure the dielectric tunnel barrier layer has a thickness less than that which would exist for a silicide layer at a contact junction between the metal electrical contact and the semiconductor region.**

Grupp '483 discloses this limitation. As discussed in Section VIII, a POSITA would have understood the term “specified contact resistivity” to refer to “specific contact resistance” or “specific contact resistivity.”

Grupp '483 discloses that “[t]he thinner interface layers provided by the present invention permit higher current across the junction (i.e., *lower junction specific contact resistance*).” (Ex.1021, 18:56-59.) Grupp '483 further discloses that “the present junction can be fabricated with a much thinner interface layer as compared to the thickness of the silicide layer used previously. Indeed, thickness of an order of magnitude less than the silicide thickness can be expected.” (Ex.1021, 18:47-50.) Because the dielectric tunnel barrier layer is part of the interface layer, as discussed in **Section XIV.A.2.b)**, the dielectric tunnel barrier layer cannot be thicker than the interface layer. Accordingly, the dielectric tunnel barrier layer has a thickness less than that which would exist for a silicide layer at a contact junction between the metal electrical contact and the semiconductor region. Thus, Grupp '483 discloses that for a lower *specified contact resistivity* (i.e., “specific contact resistance” or “specific contact resistivity”) across the junction, the dielectric tunnel barrier layer can have a thickness less than that which would exist for a silicide layer

at a contact junction between the metal electrical contact and the semiconductor region. (Ex.1022, ¶204.)

As Dr. Schubert notes, he has reviewed Ground I and has concluded that Grupp '483 anticipates Claim 21 of the '691 Patent. (Ex.1022, ¶203.)

E. Ground II: Grupp '483 in view of Wu renders obvious claims 23 and 24

1. Claim 23

a) The structure of claim 1,

The Board has found that Claim 1 is anticipated by Grupp '483. (Ex.1091, 39.)

b) wherein the semiconductor oxide of the dielectric tunnel barrier layer comprises an oxide of silicon having a thickness of approximately 0.1 nm to 5 nm,

Grupp '483 discloses this limitation. Specifically, Grupp '483 discloses that “the interface layer 520 includes or is made up of a passivation layer with a thickness of between approximately 0.1 nm and about 5 nm.” (Ex.1021, 10:66-11:1.) Grupp '483 discloses two semiconductor oxides as passivating dielectric tunnel barrier layers: silicon oxide and silicon dioxide. (Ex.1021, 10:27-34, 10:48-54, 10:60-63 (silicon oxide); *id.*, 8:64-9:10 (silicon dioxide).) Both silicon oxide and silicon dioxide are oxides of silicon.

- c) the semiconductor region comprises an n-type doped source or drain of a transistor, and**

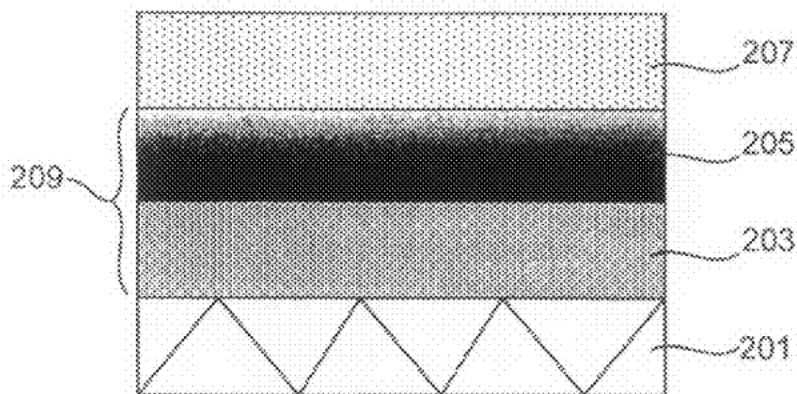
Grupp '483 discloses this limitation, as discussed above in **Section XIV.A.3.b).**

- d) the metal electrical contact comprises an oxide of titanium.**

Wu discloses this limitation. Grupp '483 discloses a diode with “an interface layer 620 disposed between and attached to both a semiconductor 610 and a conductor 630.” (Ex.1021, Fig. 6, 13:65-66, 5:29-32.) Grupp '483 further discloses that the conductor can be a metal, such as copper (Cu). (Ex.1021, 14:58-15:5.). Thus, Grupp '483 discloses that a metal electrical contact can comprise copper (Cu).

When following the disclosure of Grupp '483, a POSITA would appreciate the benefit of using copper as a metal electrical contact in a semiconductor device. (Ex.1022, ¶¶205-206; *see also* Ex.1107, 396-397 (disclosing benefits of copper as interconnect).) However, a POSITA would also be aware that because copper atoms tend to diffuse, implementing the device disclosed in Grupp '483 with copper contacts requires a suitable barrier layer to prevent such diffusion. (Ex.1022, ¶207.) For example, Wu discloses that when copper is used, the underlying silicon devices and dielectric layers should be protected from diffusion or migration of copper atoms. (Ex.1126, 7:27-33.)

Wu also discloses that traditional tantalum-based barrier layers exhibit poor performance when employed in conjunction with certain dielectrics, such as ultra low-k (ULK), having residual moisture. Wu mentions that “ULK dielectric materials are usually porous and often contain residual moisture.” (Ex.1126, 9:65-67.) Thus, Wu recommends using a titanium-based barrier layer when employing copper with such dielectric materials. (Ex.1126, 9:67-10:2.) (“for any dielectric materials containing residual moisture, *titanium-based diffusion barriers are particularly advantageous.*”) (Ex.1022, ¶208.) Wu explains that titanium oxide forms on the surface of the dielectric and “has good adhesion to the dielectric and exhibits good diffusion barrier properties.” (Ex.1126, 10:4-5) Thus, Wu recommends forming a layer of TiO_x on the surface of the dielectric. (Ex.1126, 10:5-9.) (Ex.1022, ¶209.) Wu also discloses depositing a graded TiN_x layer to serve both as a diffusion barrier and as an adhesion layer. (Ex.1126, 10:10-11; Ex.1022, ¶¶210-211.) The resulting titanium-based diffusion barrier layer is depicted in Fig. 2 of Wu (below):



(Ex.1126, Fig. 2.) The structure in Fig. 2 includes “a layer of dielectric 201; a Ti/TiO_x layer, 203; a layer of compositionally graded TiN_x, 205; and a layer of metal, 207. The layers are stacked in the recited order, with the dielectric layer 201 being the bottom layer of the stack.” (Ex.1126, 9:25-30.)

Fig. 1A of Wu depicts a portion of a device using copper. In the figure, substrate 100 includes a “preformed dielectric layer 103 . . . in which a Ti-based diffusion layer 105 . . . has been deposited, followed by inlaying with copper conductive routes 107 (‘copper plugs’).” (Ex.1126, 7:18-23.)

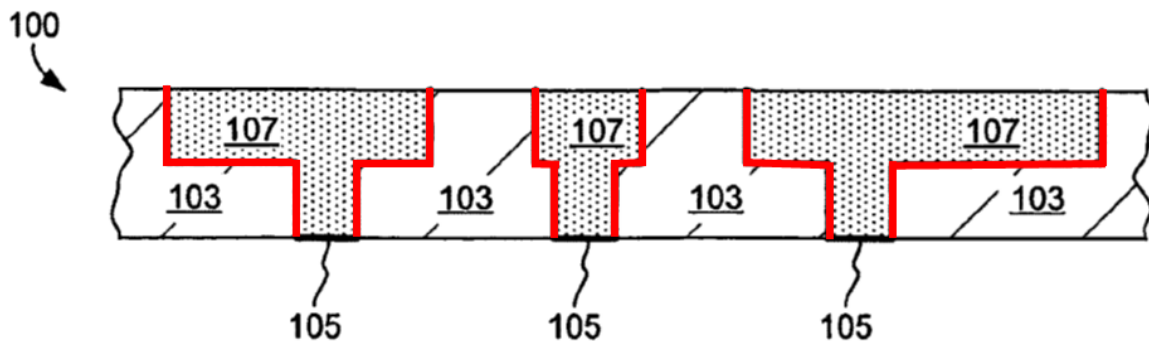


Figure 1A

(Ex. 1126, Fig. 1A (annotated).) Wu mentions that “[t]he **diffusion barrier film 105** includes a Ti/TiO_x layer adjacent to dielectric 103.” (Ex.1126, 7:40-41.) Wu discloses that the Ti/TiO_x layer is formed by “depositing a titanium-containing material capable forming TiO_x . . . on top of the dielectric.” (Ex.1125, 10:5-9.) As

Dr. Schubert explains, the Ti/TiO_x layer 203 is formed in the sidewalls where copper 107 abuts dielectric 103, as depicted in red as part of the diffusion barrier layer above. (Ex.1022, ¶¶212-213.) TiO_x may not form at the bottom of the plug because the opening exposes semiconductor substrate and not a dielectric layer. (*Id.*) When the Ti-based diffusion barrier layer disclosed in Wu is incorporated in the copper-based metal contacts disclosed in Grupp '483, then such "metal electrical contacts" will comprise a Ti/TiO_x layer 203 and graded TiN_x 205 layer in addition to copper 207.

In implementing the structures disclosed in Grupp '483, a POSITA would have been aware of the diffusion problems associated with copper, and would have consulted analogous art, such as Wu. (Ex.1022, ¶214.) Like the '691 Patent, both Grupp '483 and Wu pertain to improving quality and reliability of semiconductor devices. Grupp '483 uses an interface to reduce resistance. (Ex.1021, Abstract; Summary of the Invention.) Wu recommends using a diffusion barrier layer when using copper to ameliorate problems due to migration of copper atoms and to improve adhesion. (Ex.1126, Abstract; Summary of the Invention.) Thus, '691 Patent, Wu and Grupp '483 are analogous references. Because of the problems associated with the use of copper and the benefits that titanium-based barrier layers offer when using copper as a metal electrical contact, before the priority date of Claims 23 and 24, a POSITA would have been motivated to improve the copper

metal electrical contact disclosed in Grupp '483 by incorporating a TiO_x-based diffusion barrier layer disclosed by Wu. (Ex.1022, ¶214.) As Dr. Schubert explains, around the priority date of Claims 23 and 24, use of ultra low-k dielectric was becoming prevalent in view the shrinking feature size of IC devices, and traditional tantalum-based barriers were not sufficient. (Ex. 1022, ¶214.) In addition, integrating the TiO_x-based diffusion barrier disclosed in Wu into the metal electrical contact of the semiconductor structure disclosed in Grupp '483 would have been a combination of prior art elements according to known methods to yield predictable results. (Ex.1022, ¶215.) Thus, a POSITA would have had a reasonable expectation of success when incorporating Wu's TiO_x-based diffusion barrier layer into the copper metal electrical contact of the semiconductor structures disclosed in Grupp '483 to render Claim 23 obvious. (Ex.1022, ¶215.)

2. Claim 24

a) The structure of claim 23,

Grupp '483 discloses the structure of claim 23, as discussed above in **Section XIV.E.1.**

b) wherein the semiconductor oxide of the dielectric tunnel barrier layer is adjacent the semiconductor region.

Grupp '483 discloses this element, as discussed above in **Section XIV.A.5.b).**

XV. THE DISCRETIONARY FACTORS

Petitioners will address discretionary factors per the guidelines provided by the Board. *See* Acting USPTO Director Coke Morgan Stewart, Memorandum, “Interim Processes for PTAB Workload Management” at 2 (Mar. 26, 2025).

XVI. CONCLUSION

Petitioners respectfully request that the Board institute *inter partes* review, hold the Challenged Claims unpatentable, and cancel the Challenged Claims.

Date: June 2, 2025

Respectfully submitted,

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CERTIFICATE OF COMPLIANCE

Pursuant to 37 C.F.R. § 42.24(d), the undersigned certifies that the foregoing Petition for *Inter Partes* Review of U.S. Patent No. 9,905,691 contains, as measured by the word-processing system used to prepare this paper, 13,886 words. This word count does not include the items excluded by 37 C.F.R. § 42.24 as not counting towards the word limit.

Date: June 2, 2025

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CERTIFICATE OF SERVICE

I hereby certify that on June 2, 2025, I caused a true and correct copy of the foregoing Petition for *Inter Partes* Review of U.S. Patent No. 9,905,691 and supporting exhibits to be served on the Patent Owner via in person delivery at the following correspondence address of record as listed on PAIR:

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