

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG ELECTRONICS CO. LTD.,
SAMSUNG ELECTRONICS AMERICA, INC.,
SAMSUNG TELECOMMUNICATIONS AMERICA, LLC,
SAMSUNG SEMICONDUCTOR, INC., and
SAMSUNG AUSTIN SEMICONDUCTOR, LLC,¹
Petitioner,

v.

HOME SEMICONDUCTOR CORPORATION,
Patent Owner.

Case IPR2015-00466
Patent 6,030,893

Before JONI Y. CHANG, JON B. TORNQUIST, and
BETH Z. SHAW, *Administrative Patent Judges*.

TORNQUIST, *Administrative Patent Judge*.

FINAL WRITTEN DECISION
35 U.S.C. § 318(a) and 37 C.F.R. § 42.73

¹ Samsung Telecommunications America LLC, originally a real party-in-interest at the time of filing the Petition, no longer exists as a separate corporate entity, because it has merged with and into Samsung Electronics America, Inc. Paper 9.

I. INTRODUCTION

Samsung Electronics Co. Ltd., Samsung Electronics America, Inc., Samsung Telecommunications America, LLC, Samsung Semiconductor, Inc., and Samsung Austin Semiconductor, LLC (collectively “Petitioner”) filed a Petition (Paper 1, “Pet.”) requesting an *inter partes* review of claims 1, 2, and 4–28 of U.S. Patent No. 6,030,893 (Ex. 1001, “the ’893 patent”). Home Semiconductor Corporation (“Patent Owner”) did not file a Preliminary Response. Upon consideration of the Petition, we determined that the information presented in the Petition demonstrated a reasonable likelihood that Petitioner would prevail with respect to claims 1, 2, and 4–28 of the ’893 patent. Paper 11 (“Dec. Inst.”). Thus, pursuant to 35 U.S.C. § 314(a), we instituted trial with respect to those claims. *Id.*

Following institution of trial, Patent Owner filed a Patent Owner Response (Paper 17, “PO Resp.”), to which Petitioner filed a Reply (Paper 20, “Reply”). An oral hearing was held on February 25, 2016, and a transcript of the oral hearing is included in the record. Paper 30 (“Tr.”).

We have jurisdiction under 35 U.S.C. § 6(c). This Final Written Decision is entered pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons set forth below, we conclude that Petitioner has demonstrated by a preponderance of the evidence that claims 1, 2, and 4–28 of the ’893 patent are unpatentable.

A. *Related Matters*

The parties indicate that the ’893 patent is being asserted in *Home Semiconductor Corp. v. Samsung Electronics Co. Ltd.*, No. 1:13-cv-02033 (D. Del.), filed December 16, 2013. Pet. 2 (citing Ex. 1018, 4); Paper 7, 1. The ’893 patent is also at issue in IPR2015-00467. Paper 7, 1. A Final

Written Decision in IPR2015-00467 is entered concurrently with this Decision.

B. The '893 Patent

The '893 patent is directed to a method for forming interconnects on a semiconductor wafer. Ex. 1001, 1:7–10, Abstract. In particular, the '893 patent is directed to a method of growing low stress, void-free interconnects by depositing two separate conductive layers—the first layer having a high stress level and good step coverage, and the second layer having a lower stress level than the first conductive layer. *Id.* at 2:9–18, 3:29–45.

Figures 2 and 5, reproduced below, illustrate the deposition process of the '893 patent:

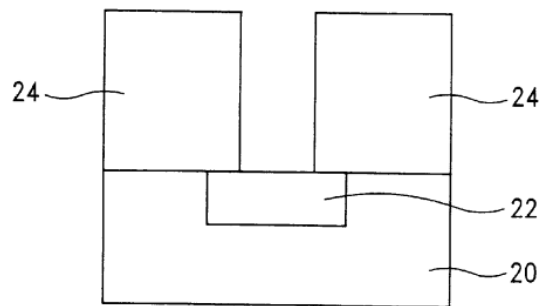


FIG.2

Figure 2 is a cross section view of a portion of a semiconductor wafer.

As depicted in Figure 2, conductive area 22, which can be a metal layer, a polysilicon layer, or a source/drain/gate, is formed in substrate 20. *Id.* at 2:47–51. Dielectric layer 24 is then deposited on substrate 20 and conductive area 22 and etched selectively to expose conductive area 22. *Id.* at 2:51–55.

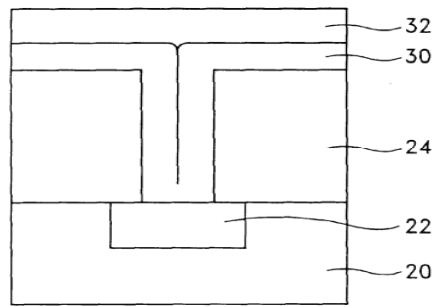


FIG. 5

Figure 5 is a cross section view illustrating the first and second conductive layers.

As depicted in Figure 5, first conductive layer 30 is formed on dielectric layer 24 and conductive layer 22 to completely fill the hole previously etched in dielectric layer 24. *Id.* at 2:60–2:67. Second conductive layer 32 is then deposited over first conductive layer 30 to fabricate interconnect lines. *Id.* at 3:15–21.

In the method of the '893 patent, the first and second conductive layers are formed in two different chambers. *Id.* at 2:60–63, 3:15–17. The deposition conditions selected for use in the first chamber, including deposition temperature, gas flow rate, and deposition time, result in a “void-free” conductive layer having “high stress” and “good step coverage.” *Id.* at 3:2–13. The deposition conditions used in the second chamber, including a lower gas flow rate and higher deposition temperature, result in a conductive layer with lower film stress. *Id.* at 3:38–41. The '893 patent instructs that the use of two separate conductive layers, the first having high stress and good step coverage and the second having low stress but poor step coverage, avoids the problem of wafer bending present in prior art systems. *Id.* at 1:54–63, 2:15–18.

C. Illustrative Claim

Challenged claims 1, 20, 27, and 28 are independent, with claims 2 and 4–19 depending, directly or indirectly, from claim 1, and claims 21–26 depending from claim 20. Claim 1 is illustrative of the challenged claims and is reproduced below:

1. A chemical vapor deposition of tungsten (W-CVD) process for growing low stress and void free interconnect, the method comprising:

forming a dielectric layer on a substrate, said substrate having a conductive area, said dielectric layer covering said conductive area;

forming a hole through said dielectric layer to uncover at least a portion of said conductive area;

forming a first conductive layer with a thickness of about 500 to 9000 Å on said dielectric layer and completely filling in said hole, wherein said first conductive layer is formed in a first chamber; and

forming a second conductive layer on said first conductive layer, wherein said second conductive layer is formed in a second chamber, wherein the temperature of said second chamber is different from the temperature of said first chamber.

Ex. 1001, 3:54–4:3.

D. Prior Art Relied Upon

U.S. Patent No. 5,843,840, iss. Dec. 1, 1998 (Ex. 1005, “Miyazaki”);

Richard C. Jaeger, VOLUME V: INTRODUCTION TO MICROELECTRONIC FABRICATION, *part of* MODULAR SERIES ON SOLID STATE DEVICES 7–9, 133–137 (Addison-Wesley Publishing Co. 1993) (Ex. 1006, “Jaeger”);

Stanley Wolf & Richard N. Tauber, SILICON PROCESSING FOR THE VLSI ERA, VOLUME 1 – PROCESS TECHNOLOGY 399–404 (Lattice Press 1986) (Ex. 1015, “Wolf”); and

P. Felix, *Interconnects for ULSI: State of the Art and Future Trends*, SOLID STATE DEVICE RESEARCH CONFERENCE 5–14 (1995) (Ex. 1016, “Felix”).

E. Instituted Grounds of Unpatentability

We instituted the instant trial based on the following grounds of unpatentability:

Challenged Claims	Basis	References
1, 2, 4–9, 11–15, 17–22, 24, 25, 27, and 28	§ 103	Miyazaki and Jaeger
10 and 23	§ 103	Miyazaki, Jaeger, Wolf, and Felix
16 and 26	§103	Miyazaki, Jaeger, and Wolf

II. ANALYSIS

A. Claim Construction

In an *inter partes* review, “[a] claim in an unexpired patent shall be given its broadest reasonable construction in light of the specification of the patent in which it appears.” 37 C.F.R. § 42.100(b). In determining the broadest reasonable construction, we presume that claim terms carry their ordinary and customary meaning. *See In re Translogic Tech., Inc.*, 504 F.3d 1249, 1257 (Fed. Cir. 2007). This presumption may be rebutted when a patentee, acting as a lexicographer, sets forth an alternate definition of a term in the specification with reasonable clarity, deliberateness, and precision. *In re Paulsen*, 30 F.3d 1475, 1480 (Fed. Cir. 1994).

In the Decision on Institution, we construed the term “on,” consistent with Petitioner’s proposed construction, to mean “in or into the position of being supported from beneath by the upper surface of something.” Dec. Inst. 6–7; Pet. 5. Patent Owner does not dispute that this construction satisfies the broadest reasonable construction standard (PO Resp. 8), and

based on our analysis of the full record developed during trial, we discern no reason to change the claim construction for purposes of this Final Written Decision.

B. Principles of Law

A patent claim is unpatentable under 35 U.S.C. § 103(a) if the differences between the claimed subject matter and the prior art are such that the subject matter, as a whole, would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 406 (2007). The question of obviousness is resolved on the basis of underlying factual determinations, including: (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the prior art; (3) the level of ordinary skill in the art;² and (4) if in the record, objective evidence of nonobviousness. *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966).

C. Obviousness over Miyazaki and Jaeger

Petitioner contends that claims 1, 2, 4–9, 11–15, 17–22, 24, 25, 27, and 28 of the ’893 patent would have been obvious under 35 U.S.C. § 103(a)

² The level of ordinary skill in the art in this case is reflected by the prior art of record. *See Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001). Moreover, although the parties disagree slightly as to the precise education and experience level possessed by a person of ordinary skill in the art, neither party asserts that resolution of the level of skill in the art between these two competing definitions would impact the outcome of this case. Ex. 1003 ¶ 11 (Master’s Degree or higher in electrical engineering and two to three years of experience in the semiconductor processing industry); Ex. 2002 ¶ 40 (Bachelors of Science degree in material science and engineering and three to four years of practical experience).

over Miyazaki and Jaeger. Pet. 12–46. In support of this argument, Petitioner relies upon the testimony of Dr. Gary Rubloff. Ex. 1003.

1. Miyazaki

Miyazaki is directed to a semiconductor device having a metal wiring film and a method for manufacturing the same. Ex. 1005, 1:8–11. In the method of Miyazaki, two conductive layers of tungsten are deposited to form a metal wiring film on a semiconductor device—the first tungsten layer having high stress and good step coverage, and the second tungsten layer having a lower internal stress than the first tungsten layer. *Id.* at 3:19–41.

Miyazaki explains that continued “microminiaturization” of semiconductor devices has led to the use of progressively smaller contact holes. *Id.* at 1:51–52. Miyazaki further explains that in order to ensure that voids do not form when these smaller contact holes are filled with a conductive material, a film with high stress and good step coverage is necessary. *Id.* at 1:51–58. A high stress film, however, may cause bowing of the silicon wafer and “suction failure” during subsequent processing. *Id.* at 1:58–64.

To lower the overall stress of the film on the semiconductor device, Miyazaki discloses that a lower stress tungsten layer may be added above the high stress tungsten layer, the thickness of which may be selected “to control the stress of the whole of the metal film to a desired value between the different stresses of the two metal films.” *Id.* at 10:33–38. Figures 8A–8D, reproduced below, depict the series of steps used in embodiments three through six of Miyazaki to manufacture a semiconductor device having a first, high stress tungsten layer with good step coverage, and a second, low stress tungsten layer with poor step coverage:

FIGURE 8A

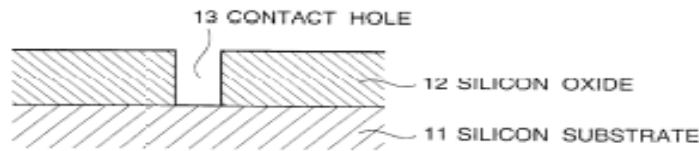


FIGURE 8B

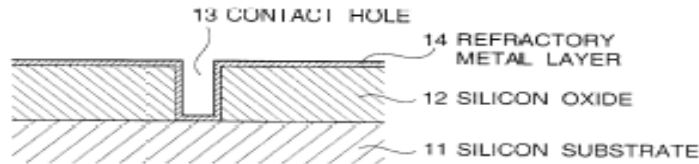


FIGURE 8C

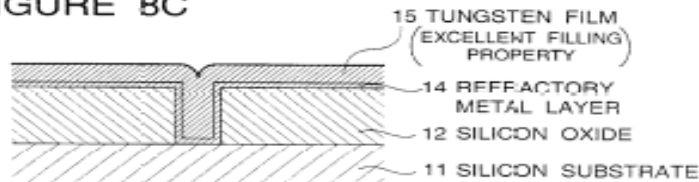
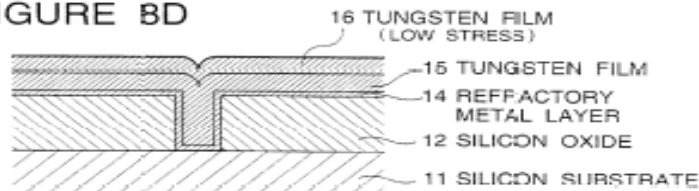


FIGURE 8D



Figures 8A to 8D are diagrammatic section views of a semiconductor device.

Id. at 7:25–8:14 (third embodiment), 8:15–8:46 (fourth embodiment), 8:47–9:7 (fifth embodiment), 9:8–9:58 (sixth embodiment).

As depicted in Figure 8A, “silicon oxide film 12 is formed on a silicon substrate 11, in which a desired circuit has been already formed.” *Id.* at 8:20–22. Silicon oxide film 12, which is a dielectric, is then selectively etched to form contact hole 13. *Id.* at 8:22–24. In Figure 8B, refractory metal layer 14 is deposited on the surface of silicon oxide film 12 and contact hole 13 by sputtering; in Figure 8C, high stress tungsten film 15 is deposited over refractory metal layer 14 to fill contact hole 13; and in Figure 8D, low stress tungsten film 16 is formed over tungsten film 15. *Id.* at 8:25–46.

Miyazaki reports that the stress level and step coverage of each tungsten layer may be selected by choosing an appropriate deposition temperature and an appropriate flow rate for the tungsten hexafluoride (“WF₆”) source gas. Figures 10A and 10B of Miyazaki, reproduced below, depict the relationship between deposition temperature and WF₆ flow rate on the one hand and film stress and step coverage on the other:

FIGURE 10A

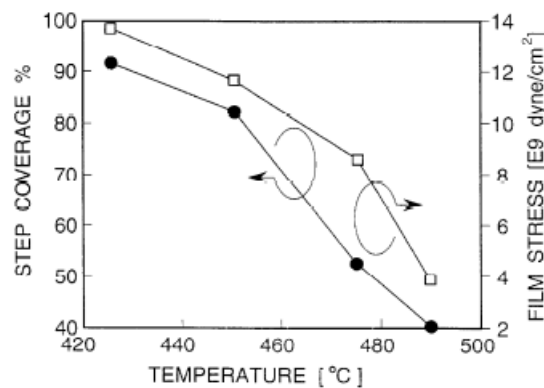


FIGURE 10B

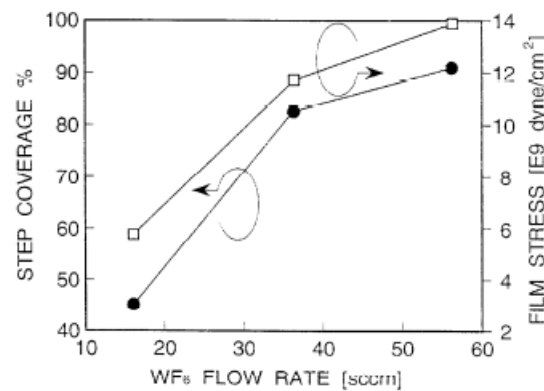


Figure 10A depicts the effect of temperature on film stress and step coverage.

Figure 10B depicts the effect of WF₆ flow rate on film stress and step coverage.

As shown in Figures 10A and 10B of Miyazaki, film stress and step coverage decrease with increasing temperature (Fig. 10A) and increase with increasing WF_6 flow rates (Fig. 10B). *Id.* at 5:24–31, 7:32–40.

In embodiments three through five of Miyazaki, lower level tungsten film 15 is deposited by chemical vapor deposition at a temperature of 400° C to 450° C using a WF_6 flow rate of either 50 sccm to 100 sccm (third and fifth embodiments) or 10 to 100 sccm (fourth embodiment). *Id.* at 7:51–57, 8:27–32, 8:56–61. In each of these embodiments, the thickness of tungsten film 15:

is controlled on such a degree as to fill the contact hole 13. For example, when the contact hole having a diameter of 0.5 μm , the thickness of the deposited film is 0.2 μm or more. In other words, this tungsten film 15 has a film thickness not smaller than 40% of a diameter of the contact hole.

Id. at 7:57–63, 8:33–36, 8:61–65.

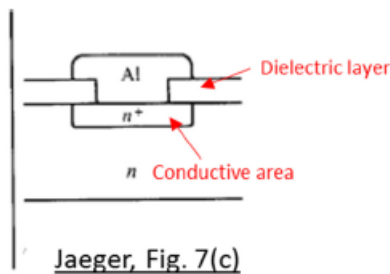
Tungsten film 16 likewise is formed by chemical vapor deposition, but the temperature and/or the WF_6 flow rate are adjusted to achieve a second tungsten layer with a lower stress level. For example, in the third embodiment of Miyazaki, the deposition temperature is maintained at 400° C to 450° C, but the WF_6 flow rate is decreased to 10 to 50 sccm; in the fourth embodiment, the WF_6 flow rate is maintained at 10 to 100 sccm, but the deposition temperature is increased to 450° C to 500° C; and in the fifth embodiment, the WF_6 flow rate is decreased to 10 to 50 sccm and the deposition temperature is increased to 450° C to 500° C. *Id.* at 7:64–8:5, 8:38–46, 8:66–9:7.

In contrast to the embodiments discussed above, the operating conditions used to deposit the tungsten layers in the sixth embodiment are not reported. Miyazaki discloses, however, that lower tungsten film 15 in

the sixth embodiment has excellent step coverage, “similarly to the third and fourth embodiments,” and tungsten film 16 has a stress level lower than tungsten film 15. *Id.* at 9:16–30. In addition, the tungsten layers in the sixth embodiment, similar to the third, fourth, and fifth embodiments, are formed continuously in the same chamber. *Id.* at 9:52–54. Miyazaki reports, however, that continuous formation in the same chamber is “not indispensable,” as the two tungsten films could “be formed in different chambers or in different deposition machines.” *Id.* at 9:52–57; *see also id.* at 4:10–11 (“*In one embodiment*, the lower level metal film and the upper level metal film are continuously formed.”) (emphasis added).

2. Jaeger

Jaeger is a textbook that discloses established methods for fabricating metal interconnects and contacts in integrated circuits. Ex. 1006, 133–136; Ex. 1003 ¶ A3. Figure 7.3(c) of Jaeger is reproduced below (annotations added by Petitioner):



In Figure 7.3(c), a conductive n^+ region is formed within an n -type substrate, with a dielectric and aluminum layer covering the conductive area. Ex. 1006, 136; Ex. 1003 ¶ A-3 (“One of ordinary skill in the art would have understood that an n^+ area is a conductive area.”).

3. Analysis

Petitioner contends Miyazaki and Jaeger disclose or suggest the subject matter of claims 1, 2, 4–9, 11–15, 17–22, 24, 25, 27, and 28 of the '893 patent.

With respect to independent claims 1, 20, 27, and 28, Petitioner identifies where Miyazaki discloses: (1) forming a silicon dioxide dielectric layer over a substrate; (2) etching a hole through the dielectric layer to form a contact hole; (3) forming a first conductive layer with a thickness of 2000 Å³ or more on⁴ the dielectric layer, such that the contact hole is completely filled in; and (4) depositing a second conductive layer on the first conductive layer using a different deposition temperature. Pet. 14–21, 35–38, 40–46 (citing Ex. 1005, 4:34–42, 8:20–24, 8:56–9:7, Abstract; Ex. 1003 ¶¶ A1–9, 14–15, 19). Petitioner also presents evidence that a person of ordinary skill in the art would have understood, in view of Miyazaki, that the deposition of the first and second tungsten layers may be accomplished in different chambers or in different deposition machines. *Id.* at 20–21 (citing Ex. 1005, 9:52–57; Ex. 1003 ¶ A15); Reply 16–23 (citing Ex. 1019 ¶¶ 5A–E).

Petitioner recognizes that Miyazaki does not disclose explicitly an exposed “conductive area” within the substrate, but provides persuasive evidence that one of ordinary skill in the art would have understood that the

³ Dr. Rubloff and Mr. Maltiel agree that a thickness of 0.2 µm is equivalent to 2000 angstroms. Ex. 1003 ¶ A9; Ex. 2002 ¶ 90.

⁴ Claim 1 requires that the first conductive layer be formed “on said dielectric layer.” Ex. 1001, 3:62–63. Although the first conductive layer of tungsten in Miyazaki is not in contact with the silicon dioxide layer, it is supported from below by this layer. Accordingly, we find that the first conductive layer is “on” the silicon dioxide layer, as we have construed that term.

“desired circuit” of Miyazaki could take the form of Jaeger’s circuit having a conductive n⁺ area within a broader source/drain/gate area. Pet. 13, 15–16, 23–24 (citing Ex. 1006, 134–137, Figs. 1.6, 7(c); Ex 1003 ¶¶ A3–5).

With respect to challenged dependent claims 2, 5, 7, 11–13, and 17, Petitioner shows where Miyazaki discloses forming a “contact hole” (claim 2) within an “oxide” dielectric layer (claim 5), depositing a second conductive layer that is 860 angstroms in thickness (claim 17), and forming first and second conductive layers using a chemical vapor deposition of tungsten (claims 7 and 11–13). *Id.* at 21–25, 27–28, 31–33 (citing Ex. 1005, 7:51–7:57, 7:65–8:1, 8:20–24, 8:47–52, 8:66–9:7, 9:35–9:51; Ex. 1003 ¶¶ A2, 5, 6, 8, 15, 20, 21).

Petitioner also shows where Miyazaki discloses: (1) WF₆ vapor flow rates that overlap with or fully encompass the ranges set forth in claims 8, 14, 21, and 24; (2) deposition temperatures that overlap with or are identical to the deposition temperatures set forth in claims 9, 15, 18–20, 22, and 25; and (3) thickness ranges for the dielectric layer that overlap with the ranges set forth in claims 4, 20, and 27. *Id.* at 22–23, 25–31, 33–39, 41 (citing Ex. 1005, 5:49–5:53, 7:51–7:57, 8:60–8:61, 8:66–9:7; Ex. 1003 ¶¶ A7, 10, 12, 16–17, 18, 22–25); *see In re Peterson*, 315 F.3d 1325, 1329–30 (Fed. Cir. 2003) (“In cases involving overlapping ranges, we and our predecessor court have consistently held that even a slight overlap in range establishes a *prima facie* case of obviousness.”).

In its response, Patent Owner argues that independent claims 1, 20, 27, and 28 would not have been obvious over Miyazaki and Jaeger because neither reference discloses: (1) a method wherein the first conductive layer completely fills the contact hole, or (2) a method for depositing two

conductive layers using two separate chambers at two different temperatures.⁵ PO Resp. 14; Ex. 2002 (testimony of Mr. Ron Maltiel).

We address Patent Owner's arguments below.

a. completely filling in said hole

Independent claims 1, 20, 27, and 28 each require “completely filling in” the contact hole with a first conductive layer. *See* Ex. 1001, 3:63–64, 4:60–61, 6:1–2, 6:19–20. Patent Owner contends Miyazaki and Jaeger do not disclose or suggest this limitation because the 0.2 μm thickness reported in Miyazaki for the first tungsten layer is insufficient to completely fill a 0.5 μm diameter contact hole. PO Resp. 15. Patent Owner further contends that a person of ordinary skill in the art would not have considered using a thickness of tungsten greater than 0.2 μm for the first tungsten layer because such a person “would not understand a thicker film” or a “completely filled hole” to be critical to the methods described in Miyazaki. *Id.* at 15–16. Finally, Patent Owner argues that the depiction in Figure 8C of contact hole 13 being completely filled by the first tungsten layer may not be relied upon to establish the presence of this claim limitation because this depiction is inconsistent with Miyazaki's disclosure of using a 0.2 μm thickness of tungsten. *Id.* at 16–17.

We do not find Patent Owner's arguments persuasive. Miyazaki discloses depositing a first tungsten layer with a thickness of 0.2 μm or more and controlling the ultimate thickness of this film so “as to fill the contact

⁵ Patent Owner does not address separately Petitioner's arguments with respect to dependent claims 2, 4–9, 11–15, 17–19, 21, 22, 24, and 25, but contends these claims would not have been obvious over Miyazaki and Jaeger because independent claims 1, 20, 27, and 28, from which they depend, would not have been obvious. PO Resp. 13–14 n.3.

hole 13.” Ex. 1005, 7:57–61, 8:33–37, 8:61–64. Contrary to Patent Owner’s arguments, these disclosures are entirely consistent with the depiction in Figure 8C of contact hole 13 being completely filled with first tungsten layer 15. *Id.* at Fig. 8C. Accordingly, we find that Miyazaki expressly discloses completely filling a contact hole with a first conductive layer, as recited in independent claims 1, 20, 27, and 28. Ex. 1003 ¶ A8.

Moreover, even if Miyazaki did not expressly disclose completely filling contact holes with a first tungsten layer, Dr. Rubloff persuasively testifies that one of ordinary skill in the art would have found it obvious to use a layer of tungsten having sufficient thickness to completely fill Miyazaki’s contact holes in view of Miyazaki’s “overarching goal” of “producing a low-stress, void-free contact.” Ex. 1019 ¶ 2A–E; Ex. 1003 ¶ A8; *see also* Ex. 1005, 2:21–30 (discussing the use of a blanket WCVD process “to fill a fine contact hole having a diameter of not greater than 0.5 μm without occurrence of” a void), 2:50–54 (noting the difficulties in filling “a fine contact of not greater than 0.5 μm ” using supply rate controlling conditions), 3:20–35 (noting that one object of the present invention is to “fill the contact hole with no void”).

In contrast, Mr. Maltiel’s counter testimony that one of ordinary skill in the art would not understand a completely filled hole to be critical to the process of Miyazaki ignores both Miyazaki’s disclosure of controlling the thickness of the deposited film so as “to fill the contact hole” and Miyazaki’s intended purpose of “fill[ing] the contact hole with no void.” Ex. 2002 ¶¶ 60–64.

Based on the foregoing, we credit the testimony of Dr. Rubloff and find that Miyazaki both expressly discloses and would have suggested to one

of ordinary skill in the art “completely filling in said hole,” as recited in independent claims 1, 20, 27, and 28 of the ’893 patent.

b. two chambers to deposit two layers at two different temperatures

Each independent claim of the ’893 patent requires formation of the second conductive layer at a different temperature and in a different chamber than the first conductive layer. *See* Ex. 1001, 3:67–4:3. As noted above, in the fourth and fifth embodiments of Miyazaki, the second layer of tungsten is deposited at a temperature that is higher than that used to deposit the first tungsten layer. Although this deposition is in a single chamber (Ex. 1005, 8:38–8:39, 8:66–8:67), Petitioner contends that one of ordinary skill in the art would have understood from the discussion of the sixth embodiment of Miyazaki that tungsten films 15 and 16 in the third, fourth, and fifth embodiments could “be formed in different chambers or in different deposition machines.” Pet. 20 (citing Ex. 1005, 9:52–57); Reply 17–18.

Patent Owner disagrees that the teachings of the sixth embodiment are applicable to the third, fourth, or fifth embodiments of Miyazaki. PO Resp. 19–20. Patent Owner reasons that, in contrast to these prior embodiments, the sixth embodiment “does not teach the management of film stress by adjusting the specific parameters of the CVD deposition,” and only teaches that “overall stress of the film can be managed by adjusting the ratio of the film thicknesses between two films having different stress levels, without actually explaining how to do so.” *Id.* (citing Ex. 1005, 9:24–51; Ex. 2002 ¶¶ 72–73; Ex. 2005, 441:3–7). According to Patent Owner, further confusion is injected into the analysis because Miyazaki discloses that the interconnects of the sixth embodiment may be formed by an unclaimed method—sputtering—“which isn’t even a CVD technique at all.” *Id.* at 20.

Patent Owner also asserts that one of ordinary skill in the art would not have found it obvious to apply the two chamber technique of the sixth embodiment in the third, fourth, or fifth embodiments because “depositing two layers [of] tungsten in a single chamber is very different from depositing those same layers in multiple chambers.” PO Resp. 23 (citing Ex. 2002 ¶ 78). Patent Owner reasons that reactions on the surface of the wafer during a continuous process will proceed as process parameters are adjusted, whereas a multi-chamber deposition will result in an instantaneous transition to the new temperature and gas flow rate, which Mr. Maltiel postulates “could affect the properties (stress and other film characteristics) of the two layers and any interface between the layers.” *Id.* at 23–24 (citing Ex. 2002 ¶ 80). Mr. Maltiel also testifies that adjusting for such effects “would be beyond the ability of a person of ordinary skill in the art without some guidance or specific teaching.” Ex. 2002 ¶ 80.

In its Reply, Petitioner reiterates that embodiments three through six of Miyazaki are part of an integrated teaching, with the third, fourth, and fifth embodiments disclosing how to form tungsten layers with a desired stress level and thickness and the sixth embodiment disclosing how to select the thickness of these layers to achieve a desired overall stress level on the semiconductor wafer. Reply 3 (“Using common sense, a POSITA would have inescapably found it obvious that the teachings of embodiments 3 to 5 provide the basis for determining the process parameters for depositing the two tungsten films in embodiment 6.”). Petitioner further contends—supported by the testimony of Dr. Rubloff—that one of ordinary skill in the art would have understood that the “reactions on the first tungsten film during any transition period would be minimal, if any” and that the desired

properties—“high stress and excellent filling for the first film and low stress and poor filling for the second film”—would be maintained using either a single or multiple chamber system. *Id.* at 22–23 (citing Ex. 1019 ¶ 6B).

As noted by Petitioner, the third, fourth, and fifth embodiments of Miyazaki disclose methods of modifying the deposition temperature and/or the WF₆ flow rate to achieve a desired thickness and stress level for tungsten layers 15 and 16. Ex. 1005, 7:51–8:5, 8:27–46, 8:56–9:7. The sixth embodiment then teaches how to vary the thickness of tungsten layers 15 and 16 to obtain a desired stress level in the combined metal film as a whole. *Id.* at 9:35–51, 10:33–38. Given the interrelated nature of these embodiments, we agree with Petitioner and Dr. Rubloff that one of ordinary skill in the art would have understood that Miyazaki contemplates depositing tungsten layers 15 and 16 in the sixth embodiment—in either a single or multi-chamber fabrication tool—using the operating conditions described in either of the third, fourth, or fifth embodiments. Ex. 1005, 9:24–34; Pet. 20; Reply 19–20; Ex. 1003 ¶¶ A13–15; Ex. 1019 ¶¶ 5C–E.

Moreover, even if the sixth embodiment were a distinct embodiment from the third, fourth, and fifth embodiments, we are persuaded that one of ordinary skill in the art would have understood—based on Miyazaki as a whole—that the deposition of tungsten in the third, fourth, and fifth embodiments could be conducted in two chambers. First, the observation in the sixth embodiment that two deposition chambers may be used to deposit the two tungsten layers is made without any limitation as to how the two tungsten layers are deposited, suggesting the broad applicability of Miyazaki’s two chamber disclosure. Second, although a multi-chamber deposition process will result in a rapid change in temperature and WF₆ flow

rate, Patent Owner presents no documentary evidence or reasoned argument tending to show that a rapid change in operating conditions in a two-chamber system would materially affect the properties of the deposited layers; Patent Owner only speculates that such a rapid change in operating conditions “could” affect the properties of the resulting layers. PO Resp. 24 (“This could affect the properties (stress and other film characteristics) of the two layers and any interface between the layers.”).

Patent Owner also provides no persuasive evidentiary support to show that one of ordinary skill in the art would have been unable to account for a change in properties, if any, caused by the modification of operating conditions in a dual chamber system. In contrast, Dr. Rubloff provides detailed analysis explaining why Patent Owner and Mr. Maltiel are incorrect in concluding that a person of ordinary skill in the art would be unable to account for the change in operating conditions when the tungsten deposition process is performed in two chambers. *Compare* Ex. 1003 ¶¶ A13–15 and Ex. 1019 ¶¶ 5A–J, *with* Ex. 2002 ¶¶ 80–82.

In view of the foregoing, we find that one of ordinary skill in the art would have found it obvious in view of Miyazaki to deposit two tungsten films at two different temperatures and in two different chambers and would have had a reasonable expectation of success in so doing. Ex. 1003 ¶¶ A13–15; Ex. 1019 ¶¶ 5D–E, 6B.

c. Conclusion

Upon review of Petitioner’s and Patent Owner’s arguments, supporting testimony, and evidence, we are persuaded that the combination of Miyazaki and Jaeger discloses or suggests every limitation of claims 1, 2, 4–9, 11–15, 17–22, 24, 25, 27, and 28 of the ’893 patent. Pet. 14–46. We

are also persuaded that Petitioner has set forth sufficient articulated reasoning with rational underpinning to explain why one of ordinary skill in the art would have combined Miyazaki and Jaeger. *Id.* at 15–16.

Accordingly, we find that Petitioner has demonstrated by a preponderance of the evidence that claims 1, 2, 4–9, 11–15, 17–22, 24, 25, 27, and 28 of the '893 patent would have been obvious under 35 U.S.C. § 103 over Miyazaki and Jaeger.

*D. Obviousness of Claims 10 and 23
over Miyazaki, Jaeger, Wolf, and Felix*

Claims 10 and 23 require that the deposition time for the first conductive layer be within “about 10–100 seconds.” Ex. 1001, 4:25–27, 5:10–12. Petitioner contends this range of deposition times would have been obvious in view of Miyazaki, Jaeger, Wolf, and Felix. Pet. 46–55.

1. Wolf

Wolf discloses methods of semiconductor manufacturing, including methods of depositing tungsten on the surface of a semiconductor wafer. Ex. 1015, 399–404; Pet. 46 (citing Ex. 1003 ¶ A22).

Figure 16 of Wolf is depicted below (red annotations by Petitioner):

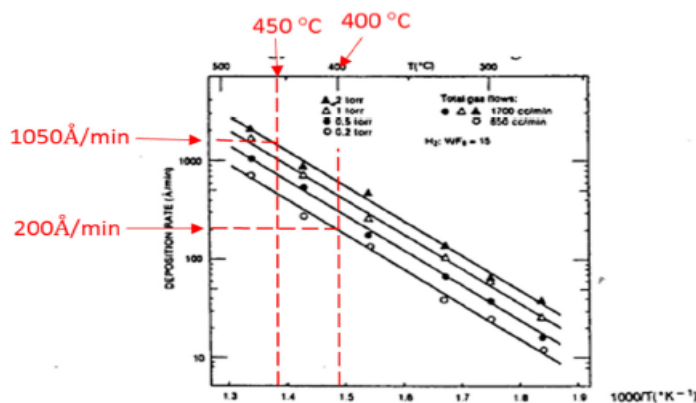


Fig. 16 Arrhenius plot of deposition rate of CVD tungsten³⁶. Reprinted with permission of Electrochemical Society.

According to Petitioner, Figure 16 “illustrates the relationship between deposition rate and temperature with the introduction of hydrogen gas to the CVD process, where the temperature ranges from 250 to 500 °C.” Pet. 47–48 (citing Ex. 1015, 401).

2. *Felix*

Felix discusses the state of the art, and future direction of, semiconductor interconnect design. Ex. 1016, Abstract. Of particular relevance to this case, Felix discloses that in 1995 contact holes on semiconductor devices were 0.35 μm in diameter or larger. *Id.*

3. *Analysis*

Miyazaki does not disclose the deposition rate for the first conductive layer of tungsten, i.e., tungsten layer 15. Relying upon the deposition rates disclosed in Wolf, however, Petitioner calculates that the first tungsten layer of Miyazaki would be deposited at a rate of 17.5 angstroms per second (at a temperature of 450° C). Pet. 49 (citing Ex. 1003 ¶ A28). Applying this deposition rate to the 2000 angstrom or greater thickness of tungsten used to fill the 0.5 μm exemplary contact holes of Miyazaki, Petitioner acknowledges that it would take at least 115 seconds to deposit Miyazaki’s first conductive layer of tungsten. *Id.*

Petitioner contends, however, that one of ordinary skill in the art would have sought to apply Miyazaki’s deposition techniques to fill not only the exemplary 0.5 μm contact holes of Miyazaki, but also other contact holes known in the art, such as the 0.35 μm diameter contact holes of Felix. *Id.* at 49–50 (citing Ex. 1003 ¶¶ A28–29); Ex. 1016, 2–4. And, applying the 17.5 angstrom per second deposition rate derived from Miyazaki and Wolf to Felix’s 0.35 μm contact holes, Petitioner calculates that only 80 seconds

would be required to completely fill these contact holes with Miyazaki's first tungsten layer. Pet. 50 (citing Ex. 1003 ¶ A29).

Patent Owner argues the combination of Miyazaki, Jaeger, Wolf, and Felix would not have rendered claims 10 and 23 obvious because Miyazaki discloses filling contact holes with a film thickness of 0.2 μm or more, which would require at least 114 seconds to deposit. PO Resp. 27–28. Patent Owner further argues that Petitioner's reliance on the smaller contact holes of Felix constitutes an impermissible attempt to "shoehorn the claimed invention into the prior art." *Id.* at 27.

Petitioner responds that Miyazaki is not limited to 0.5 μm contact holes, and specifically contemplates using the disclosed method to fill contact holes arising from advanced "microminaturization," which would include the 0.35 μm contact holes of Felix. Reply 24–25.

As noted by Petitioner, Miyazaki is not limited to 0.5 μm diameter contact holes or to the use of a first thickness of tungsten of "0.2 μm or more." Ex. 1005, 7:59–61 ("*For example*, when the contact hole having a diameter of 0.5 μm , the thickness of the deposited film is 0.2 μm or more.") (emphasis added). Indeed, Miyazaki expressly contemplates filling contact holes "not greater than 0.5 μm ." *Id.* at 2:22–25, 2:50–54.

Given that Miyazaki contemplates the filling of contact holes smaller than 0.5 μm , we find persuasive Petitioner's argument that one of ordinary skill in the art would have sought to apply Miyazaki's deposition process to the 0.35 μm contact holes of Felix. Pet. 49–50; Reply 24–25. We also find persuasive Petitioner's argument that the 0.35 μm contact holes of Felix would be filled using the method of Miyazaki within "about 10–100 seconds," as recited in claims 10 and 23.

Accordingly, we find that Petitioner has demonstrated by a preponderance of the evidence that claims 10 and 23 would have been obvious under 35 U.S.C. § 103 over Miyazaki, Jaeger, Wolf, and Felix.

E. Obviousness of Claims 16 and 26

Claims 16 and 26 require that the second conductive layer be deposited in “about 10–100 seconds.” Ex. 1001, 4:40–42, 5:19–21. Petitioner contends the subject matter of these claims would have been obvious in view of Miyazaki, Jaeger, and Wolf. Pet. 51–55

Miyazaki does not disclose the thickness of the second tungsten layer, but does disclose that the first conductive layer should be no more than 70% in the film thickness ratio of the first conductive layer and the second conductive layer. Ex. 1005, 9:35–51. Applying this film thickness ratio to the 2000 angstrom thickness of the first conductive layer in Miyazaki, Dr. Rubloff testifies that one of ordinary skill in the art would have understood that the second conductive layer of Miyazaki would need to be at least 860 angstroms thick. Ex. 1003 ¶¶ A20–21. Applying a deposition rate of 19 angstroms per second to this 860 angstrom thickness—calculated by applying the upper limit temperature of 500° C in Miyazaki to Wolf’s deposition rates—Petitioner calculates that it would take 45 seconds to deposit the second conductive layer of Miyazaki. Pet. 53. Patent Owner does not contest Petitioner’s arguments with respect to claims 16 and 26.

Upon review of Petitioner’s arguments and the supporting testimony of Dr. Rubloff, we find that Petitioner has demonstrated by a preponderance of the evidence that claims 16 and 26 would have been obvious over Miyazaki, Jaeger, and Wolf.

F. Conclusion

For the foregoing reasons, we find that Petitioner has demonstrated by a preponderance of the evidence that claims 1, 2, 4–9, 11–15, 17–22, 24, 25, 27, and 28 of the '893 patent would have been obvious under 35 U.S.C. § 103 over Miyazaki and Jaeger; that claims 10 and 23 would have been obvious over Miyazaki, Jaeger, Wolf and Felix; and that claims 16 and 26 would have been obvious over Miyazaki, Jaeger, and Wolf.

III. ORDER

For the foregoing reasons, it is:

ORDERED that claims 1, 2, and 4–28 of the '893 patent are held unpatentable; and

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

IPR2015-00466
Patent 6,030,893

PETITIONER:

W. Karl Renner
Roberto Devoto
Indranil Mukerji
David L. Holt
Joseph Colaianne
FISH & RICHARDSON P.C.
axf@fr.com
IPR39843-0012IP1@fr.com
mukerji@fr.com
dth@fr.com
PTABInbound@fr.com

PATENT OWNER:

Craig R. Kaufman
Kevin C. Jones
TECHKNOWLEDGE LAW GROUP LLP
ckaufman@tklg-llp.com
kjones@tklg-llp.com