

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MICRON TECHNOLOGY, INC.,
INTEL CORPORATION, GLOBALFOUNDRIES U.S., INC., and
SAMSUNG ELECTRONICS COMPANY, LTD.,
Petitioner,

v.

DANIEL L. FLAMM,
Patent Owner.

Case IPR2017-00406¹
Patent 5,711,849

Before CHRISTOPHER L. CRUMBLEY, JO-ANNE M. KOKOSKI, and
KIMBERLY McGRAW, *Administrative Patent Judges*.

KOKOSKI, *Administrative Patent Judge*.

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

¹ Samsung Electronics Company, Ltd. was joined as a party to this proceeding via a Motion for Joinder in IPR2017-01748.

I. INTRODUCTION

We have jurisdiction to conduct this *inter partes* review under 35 U.S.C. § 6, and this Final Written Decision is issued pursuant to 35 U.S.C. § 318(a) and 37 C.F.R. § 42.73. For the reasons that follow, we determine that Petitioner has shown by a preponderance of the evidence that claims 1–29 of U.S. Patent No. 5,711,849 (“the ’849 patent,” Ex. 1001) are unpatentable.

A. *Procedural History*

Micron Technology, Inc., Intel Corporation, and GLOBALFOUNDRIES U.S., Inc. (collectively, “the Micron Petitioners”)² filed a Petition (“Pet.”) to institute an *inter partes* review of claims 1–29 of the ’849 patent. Paper 1. Daniel L. Flamm (“Patent Owner”) filed a Preliminary Response (“Prelim. Resp.”). Paper 9. Pursuant to 35 U.S.C. § 314(a), we instituted an *inter partes* review of claims 1–29 based on our determination that the information presented in the Petition demonstrated a reasonable likelihood that Petitioner would prevail on its challenge that at least one of the challenged claims is unpatentable under 35 U.S.C. § 103 as

² On September 15, 2017, we granted the Motion for Joinder filed by Samsung Electronics Company, Ltd. (“Samsung”) in IPR2017-01748, and authorized Samsung to participate in this proceeding only on a limited basis. See Paper 14. We refer to Micron Technology, Inc., Intel Corporation, GLOBALFOUNDRIES U.S., Inc., and Samsung collectively as “Petitioner” throughout this Decision.

obvious over the combined teachings of Alkire³ and Galewski.⁴ Paper 10 (“Dec. on Inst.”), 17.

After institution of trial, Patent Owner filed a Patent Owner Response (“PO Resp.,” Paper 13), and Petitioner filed a Reply (“Reply,” Paper 15). Petitioner relies on the Declaration of Dr. David Graves (“the Graves Declaration,” Ex. 1003) and the Reply Declaration of Dr. David Graves (“the Graves Reply Declaration,” Ex. 1023). Patent Owner relies on the Declaration of Daniel L. Flamm (“the Flamm Declaration,” Ex. 2002). An oral hearing was held on March 7, 2018. A transcript of the hearing is included in the record. Paper 29.

B. Related Proceedings

The parties indicate that the ’849 patent is at issue in five related patent infringement actions. Pet. 4; Paper 7, 2. The ’849 patent previously was the subject of IPR2016-00466 (filed by Lam Research Corp., institution denied on July 19, 2016), and currently is the subject of IPR2017-00392, also filed by the Micron Petitioners (and joined by Samsung). Pet. 5.

C. The ’849 Patent

The ’849 patent, titled “Process Optimization in Gas Phase Dry Etching,” is directed to “a plasma etching method that includes determining a reaction rate coefficient based upon etch profile data.” Ex. 1001, 1:51–53. The method “includes steps of providing a plasma etching apparatus having

³ *Transient Behavior during Film Removal in Diffusion-Controlled Plasma Etching*, J. Electrochem. Soc.: Solid-State Science and Technology, Vol. 132, No. 3 (1985) 648–656 (Ex. 1005).

⁴ *Modeling of a High Throughput Hot-Wall Reactor for Selective Epitaxial Growth of Silicon*, IEEE Transaction on Semiconductor Manufacturing, Vol. 5, No. 3 (1992) 169–179 (Ex. 1007).

a substrate therein[,]” where the substrate has a film overlaying the top surface, and the film has a top film surface. *Id.* at 1:59–63. It “also includes chemically etching the top film surface to define an etching profile on the film, and defining etch rate data which includes an etch rate and a spatial coordinate from an etching profile.” *Id.* at 1:63–67. Steps of extracting a reaction rate constant from the etch rate data, and using the reaction rate constant to adjust the plasma etching apparatus are also described. *Id.* at 1:67–2:2. According to the ’849 patent, the method “provides for an easy and cost effective way to select appropriate etching parameters such as reactor dimensions, temperature, pressure, radio frequency (rf) power, flow rate and the like by way of the etch profile data.” *Id.* at 1:53–57.

Figure 1A of the ’849 patent is reproduced below:

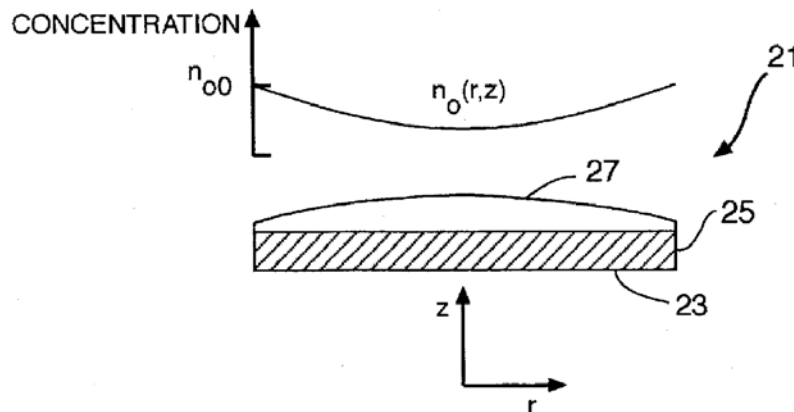


FIG. 1A

Figure 1A is an example of an etched substrate. *Id.* at 3:66–67. Substrate 21 includes bottom surface 23, sides 25, and top surface film 27, and is defined in spatial coordinates z and r . *Id.* at 3:67–4:2. “[T]op surface film [27] includes a convex region, or etching profile.” *Id.* at 4:3–4. “The etching profile occurs by way of different etch rates along the r -direction of [substrate 21], corresponding to different etchant species concentrations.” *Id.* at 4:4–6. Concentration profile $n_o(r,z)$ shows that “the greatest

concentration of reactant species exists at the outer periphery of [] top surface film [27].” *Id.* at 4:6–9.

The ’849 patent describes an embodiment of a method of extracting an etch rate constant in which a substrate with an overlying film is placed into a plasma etching apparatus, and the plasma etching step occurs at constant pressure, and, preferably, isothermally. *Id.* at 5:11–19. Plasma etching of the film stops before etching into an etch stop layer underneath the overlying film “[in order] to define a ‘clean’ etching profile.” *Id.* at 5:24–26. The plasma etching step produces an etching profile, which “converts into a relative etch rate, relative concentration ratio, a relative etch depth and the like at selected spatial coordinates.” *Id.* at 5:28–32.

Using x-y-z coordinates, the relative etch rate is in the z-direction, and x-y are the spatial coordinates. *Id.* at 5:38–40. “The etching profile is thereby characterized as a relative etch rate u , [an] x-location, and a y-location u , (x, y) ,” and an array of data points in the x-y coordinates define the etching profile. *Id.* at 5:40–41, 45–47. An etch constant over diffusivity (k_{vo}/D) and an etch rate at the substrate edge is then calculated, where “[t]he etch constant over diffusivity correlates with data points representing the etch rate profile.” *Id.* at 5:62–65. After the etch rate constant k_{vo} is extracted, the surface reaction rate constant k_s can be determined using the formula $k_s = (k_{vo})d_{gap}$, where d_{gap} is the space above the substrate, between the substrate and the adjacent substrate. *Id.* at 3:35–36, 6:58–62, 9:27–29, Fig 7.

Claims 1, 10, 20, 22, and 26 are the challenged independent claims. Claim 1 is representative, and is reproduced below.

1. A device fabrication method comprising the steps of:
 - providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;
 - etching said top film surface to define a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate which defines a position within said relatively non-uniform etching profile on said substrate, said etching comprising a reaction between a gas phase etchant and said film; and
 - extracting a surface reaction rate constant from said etch rate data, and using said surface reaction rate constant in the fabrication of a device.

Ex. 1001, 17:35–50.

II. ANALYSIS

A. *Level of Ordinary Skill in the Art*

Petitioner argues that a person of ordinary skill in the art at the time of the '849 patent would have had “a Bachelor of Science degree in chemical engineering, electrical engineering, material science, chemistry, or physics or a closely related field, along with at least 3–4 years of experience in the development of plasma etching or chemical vapor deposition.” Pet. 19.

Petitioner further argues that a person with a master’s degree “would require 2–3 years of experience in the development of plasma etching or chemical vapor deposition,” and a person with a Ph.D. “would not require additional experience.” *Id.* (citing Ex. 1003 ¶ 73). Patent Owner does not dispute Petitioner’s assessment in its Response.

Petitioner’s assessment appears consistent with the level of ordinary skill in the art at the time of the invention as reflected in the prior art in this proceeding. *See Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir.

2001) (explaining that specific findings regarding ordinary skill level are not required “where the prior art itself reflects an appropriate level and a need for testimony is not shown” (quoting *Litton Indus. Prods., Inc. v. Solid State Sys. Corp.*, 755 F.2d 158, 163 (Fed. Cir. 1985))). Accordingly, we adopt Petitioner’s assessment of the level of ordinary skill in the art.

B. Claim Interpretation

The ’849 patent has expired. Ex. 1001 at [22] (application filed on May 3, 1995); see Pet. 15. For claims of an expired patent, the Board’s claim interpretation is similar to that of a district court, i.e., consistent with *Phillips v. AWH Corp.*, 415 F.3d 1303 (Fed. Cir. 2005) (en banc). See *In re Rambus, Inc.*, 694 F.3d 42, 46 (Fed. Cir. 2012). Under the *Phillips* standard, claim terms are given their ordinary and customary meaning as would be understood by a person of ordinary skill in the art at the time of the invention, and in the context of the entire patent disclosure and prosecution history. *Phillips*, 415 F.3d at 1312–14. Only those terms in controversy need to be construed, and only to the extent necessary to resolve the controversy. See *Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017) (“we need only construe terms ‘that are in controversy, and only to the extent necessary to resolve the controversy’”) (quoting *Vivid Techs., Inc. v. Am. Sci. & Eng’g, Inc.*, 200 F.3d 795, 803 (Fed. Cir. 1999)).

For purposes of the Decision on Institution, we interpreted “surface reaction rate constant” as set forth in claims 1, 5, 10, 14, 20, 22, 26, 27, and 29 to mean “a temperature-dependent reaction rate constant for the chemical reaction between a gas phase etchant and the surface of an etchable material.” Dec. on Inst. 8. The parties do not contest our interpretation of

this term, and we see no reason to modify it in light of the record developed at trial.

C. *Principles of Law*

To prevail on its challenges to the patentability of the claims, a petitioner must establish facts supporting its challenge by a preponderance of the evidence. 35 U.S.C. § 316(e); 37 C.F.R. § 42.1(d). “In an [*inter partes* review], the petitioner has the burden from the onset to show with particularity why the patent it challenges is unpatentable.” *Harmonic Inc. v. Avid Tech., Inc.*, 815 F.3d 1356, 1363 (Fed Cir. 2016) (citing 35 U.S.C. § 312(a)(3) (requiring *inter partes* review petitions to identify “with particularity . . . the evidence that supports the grounds for the challenge to each claim”)). This burden of persuasion never shifts to the patent owner. *See Dynamic Drinkware, LLC v. Nat’l Graphics, Inc.*, 800 F.3d 1375, 1378–79 (Fed. Cir. 2015) (discussing the burdens of persuasion and production in *inter partes* review).

A claim is unpatentable under 35 U.S.C. § 103 if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious to a person having ordinary skill in the art to which the 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; and (4) objective evidence of nonobviousness. *See Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966).

A patent claim “is not proved obvious merely by demonstrating that each of its elements was, independently, known in the prior art.” *KSR*, 550 U.S. at 418. An obviousness determination requires finding “both ‘that a skilled artisan would have been motivated to combine the teachings of the prior art references to achieve the claimed invention, and that the skilled artisan would have had a reasonable expectation of success in doing so.’” *Intelligent Bio-Sys., Inc. v. Illumina Cambridge Ltd.*, 821 F.3d 1359, 1367–68 (Fed. Cir. 2016) (citation omitted); *see KSR*, 550 U.S. at 418 (for an obviousness analysis, “it can be important to identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the elements in the way the claimed new invention does”). A reason to combine or modify the prior art may be found explicitly or implicitly in market forces, design incentives, the “interrelated teachings of multiple patents,” “any need or problem known in the field of endeavor at the time of invention and addressed by the patent,” and “the background knowledge, creativity, and common sense of the person of ordinary skill.” *Perfect Web Techs., Inc. v. Info USA, Inc.*, 587 F.3d 1324, 1329 (Fed. Cir. 2009) (quoting *KSR*, 550 U.S. at 418–21).

D. Overview of the Prior Art

1. Overview of Alkire

Alkire is directed to the formulation of a mathematical model “to analyze transient behavior during film removal from closely spaced wafers in a barrel plasma etching reactor.” Ex. 1005, 1.⁵ “The analysis relates the effect of geometric and operating variables to process characteristics such as

⁵ The cited page numbers in Ex. 1005 refer to the numbers added by Petitioner in the bottom right corner of the page.

etch uniformity, over-etch exposure, and throughput.” *Id.* “Regions of operating conditions that permit etch uniformity within specified tolerances are found, and optimum settings for inter-wafer spacing and reactor pressure to achieve maximum throughput are calculated.” *Id.* Alkire teaches that “[e]tch uniformity and throughput are of particular importance in any plasma etching process,” and that “[p]arameters that affect uniformity and throughput include RF power input, chamber pressure, gas flow rate and distribution, wafer spacing, wafer diameter, and temperature.” *Id.* at 1–2.

Alkire Figure 2 is reproduced below.

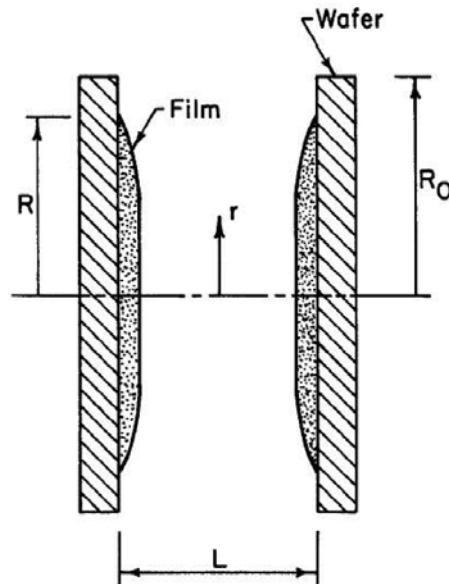


Figure 2 is a schematic of the radially symmetric region between two successive wafers that are facing each other. *Id.* at 2. Before etching begins, a uniform-thickness film exists on the wafer surface. *Id.* “To an extent that depends upon operating conditions, the etch rate is highest on the periphery of the wafer,” and, therefore, film in this region clears first. *Id.* Figure 2 illustrates this, showing that the “film has been cleared entirely from the outer portion of the wafer, while the inner region is yet to clear.” *Id.*

Alkire makes several assumptions to “preserve the salient features of the system and also streamline the task of computation,” including that “[t]he spacing between the adjacent wafers is sufficiently smaller than the wafer radius so that significant concentration variations occur only in the radial direction,” “the etching reaction is first order” and “proceeds to completion at or near the film surface,” and “[t]he concentration of etchant at the wafer remains constant during the etch cycle.” *Id.* Alkire provides two governing equations: Equation [1] that gives “the thickness of etchable material left at a certain location and time,” and Equation [2] that is the conservation equation for the etching species, as set forth below.

$$h(r, t) = h_o - \int_0^t \frac{k_2}{x} c(r, t) dt \quad [1]$$

$$D \frac{1}{r} \frac{d}{dr} \left(r \frac{dc}{dr} \right) = \frac{2k_2}{L} c + 2k_1 c^2 [A_2] + \frac{v_o w}{2L} c \quad [2]$$

with the boundary conditions

$$c = c_o \text{ at } r = R_o$$

$$\frac{dc}{dr} = 0 \text{ at } r = 0$$

Id. Alkire defines h_o as the initial film thickness (cm), k_2 as the etch rate constant (cm/s), X as the moles of etchant species consumed per cm³ of film etched (mol/cm³), c as the etchant concentration (mol/cm³), h as the film thickness (cm), r as the radial position (cm), t as time (s), D as the etchant diffusivity (cm²/s), L as the wafer separation distance (cm), k_1 as the volume recombination reaction rate constant (cm⁶/(mol)²/s), A_2 as the parent molecule, v_o as the random thermal velocity of etchant species (cm/s), w as the wall recombination coefficient, c_o as the etchant concentration at the wafer edge (mol/cm³), and R_o as the wafer radius (cm). *Id.* at 8–9.

Alkire then “rewrite[s] the governing equations in terms of dimensionless quantities” that it defines, resulting in dimensionless Equations [6] and [7]. *Id.* at 3. According to Alkire, “[b]y solving Eq. [6] and [7], the effect of process parameters (c_0 , P , D , k ’s) and of geometric factors (L , R_0) on etch uniformity, overetch exposure, and total etch time can be determined,” and, “[i]n particular, optimum conditions for high throughput can be identified.” *Id.* Alkire states that these “[d]imensionless groupings of system parameters were used to compile behavior and to reveal scale-up principles,” and that “[t]he model can be extended without much difficulty to handle more complex situations.” *Id.* at 8. Alkire concludes that “[t]he use of mathematical models can assist in organizing scientific concepts into strategies for engineering design.” *Id.*

2. *Overview of Galewski*

Galewski is directed to characterizing “[a] tubular hot-wall silicon epitaxial reactor operated in the selective deposition regime . . . for growth rate uniformity in both the radial and longitudinal directions.” Ex. 1007, Abs. Galewski explains that “[t]ypically, epitaxial deposition of silicon requires high temperatures that are not compatible with hot-wall reactors because of the severe depletion effects that result,” but “it is possible with careful consideration of the reactor design, deposition conditions, and wafer cleaning to use low deposition temperatures that reduce depletion effects while still resulting in defect-free epitaxial silicon.” *Id.* at 1.⁶ Galewski uses growth rate data produced in an experimental reactor “constructed by modifying a commercial low-pressure chemical vapor deposition (LPCVD)

⁶ The cited page numbers in Ex. 1007 refer to the numbers added by Petitioner in the bottom right corner of the page.

furnace” “to formulate a physical model that predicts the deposition uniformity in both the radial and longitudinal directions,” and uses the model “to propose improvements to the existing reactor, and to propose a design for a system that can accommodate 100 wafers of 200 mm diameter.” *Id.*

E. Obviousness over Alkire and Galewski

Petitioner contends that the subject matter of claims 1–29 is unpatentable under 35 U.S.C. § 103(a) as having been obvious over the combined teachings of Alkire and Galewski. Pet. 29–79; Reply 4–29. Petitioner relies on the Graves Declaration and the Graves Reply Declaration in support of its contentions. *Id.* Patent Owner disagrees with Petitioner’s assertions. PO Resp. 2–23.

1. Motivation to Combine Alkire and Galewski

Petitioner contends that a person having ordinary skill in the art (“PHOSITA”) “would have been motivated to combine Alkire and Galewski in order to improve the theoretical model of Alkire with the use of experimental data in order to test and validate Alkire’s theoretical model, as taught in Galewski.” Pet. 29 (citing Ex. 1003 ¶ 118–119). Petitioner contends that “a PHOSITA would have recognized that Alkire provides a robust model for the reaction between a gas phase etchant and a substrate film, but that no experimental data to test and validate the model was provided,” and that “[a] PHOSITA would have been motivated to improve the model disclosed in Alkire by using experimental data to provide independent confirmation of the accuracy of the model as taught in Galewski.” *Id.* at 29–30 (citing Ex. 1003 ¶ 119; Ex. 1006, 1). According to Petitioner, “a PHOSITA would have been motivated to combine the

teachings of Galewski with those in Alkire in order to increase the predictive capability of Alkire's model to better drive process development and reactor design to improve throughput and yield while avoiding costly trial and error." *Id.* at 30 (citing Ex. 1003 ¶ 120).

Petitioner also contends that "both Alkire and Galewski disclose the known technique of modeling a gas-phase and substrate reaction using a first-order mathematical model," and Galewski teaches "using a model tested and validated with measured experimental data to improve a reactor, and the combination of this technique with Alkire would have been understood to yield predictable results because it was well known that plasma etching and low pressure chemical vapor deposition can exhibit the same behavior." Pet. 30–31 (citing Ex. 1003 ¶ 121). Petitioner contends that "Alkire and Galewski are both directed to chemical reactors for manufacturing semiconductor devices and address non-uniformity in semiconductor plasma processing," and "Alkire teaches that similar reactors are used for the LPCVD process and that 'a similar analysis can be applied to LPCVD processes.'" *Id.* at 31 (citing Ex. 1005, Fig. 1; Ex. 1007, Fig. 1; Ex. 1003 ¶ 122).

Patent Owner argues in response that "Alkire provides a 'mathematical model' for analyzing transient behavior during film removal from closely spaced wafers facing each other in a barrel plasma etching reactor, which is incompatible with the modeling of hot wall reactor for selective epitaxial growth of silicon taught by Galewski." PO Resp. 9. Patent Owner further argues that "[a] PHOSITA would not have been motivated to improve the model disclosed in Alkire by using silicon deposition experimental data for epitaxial films given the silicon deposition

experimental data are incompatible and would in no way be expected to relate to the plasma etching taught by Alkire.” *Id.* at 10. Patent Owner also argues that “Alkire and Galewski are both directed to completely different types of reactors.” *Id.* at 11. In particular, Patent Owner argues that “Galewski teaches that the selection of (high) deposition temperature and its axial profile are critical parameters to improve silicon epitaxy and to design a production-sized reactor,” and “[n]one of these things relate to or are suggested by Alkire,” which “excludes any explicit dependence on temperature from his model.” *Id.* at 11–12.

Patent Owner argues that Alkire teaches away from the ’849 patent because it “specifically takes the position that ‘purely empirical programs of development can be time consuming’” and “uses a pure mathematical model without actual etch profile data.” PO Resp. 13 (citing Ex. 1005, 1). According to Patent Owner, “the ’849 patent discloses the surprising idea and a method of specifically using purely empirical data, acquired from non-uniform etching profiles that are particularly unsuited for device production . . . to improve the fabrication of a device based on plasma etching, rather than the theoretical modeling approach” taught in Alkire. *Id.* Patent Owner further argues that Alkire’s statement that “[a] similar analysis can be applied to LPCVD processes” “is limited to only ‘the events occurring in between the wafers’” because “[t]he boundary conditions, as well as the analysis after this passage, focuses only on a mathematical model for transient etching of films, and therefore teaches away from any combination with Galewski.” *Id.* at 13–14 (citing Ex. 1005, 4).

Based on our review of the record, we find that Petitioner has established that a PHOSITA would have had reason to combine the

teachings of Alkire and Galewski to achieve the claimed subject matter. Alkire discloses that the mathematical model developed therein “represents a simplified view by virtue of several assumptions,” but “can serve as a basis for studying more complex systems.” Ex. 1005, 8. Alkire also states that “[e]xperimental work aimed at testing the model predictions is currently in progress in our laboratory.” *Id.* Galewski teaches using growth rate data from a LPCVD experimental reactor “to formulate a physical model that predicts the deposition uniformity in both the radial and longitudinal directions.” Ex. 1007, 1. In this regard, we credit Dr. Graves’s testimony that

one of ordinary skill in the art would have understood that, and would have been motivated to, improve the theoretical model of Alkire with the use of actual measured reaction data as taught in Galewski. A person of ordinary skill in the art would have recognized that, while Alkire does teach a reliable model for an etching reaction between a gas phase etchant and a substrate film, it fails to measure and use experimental data to test and validate its model. *See also*, Ex. 1006 at p. 1 (discussing the model of Alkire and recognizing that “only model results were given with no experimental data”). The use of actual experimental data to extract the surface reaction rate constant would provide independent confirmation of the accuracy of Alkire’s model. A person of ordinary skill in the art would have been motivated to improve the model of Alkire with actual data to test and validate the model, as taught in Galewski.

Ex. 1003 ¶ 119.

We have considered Patent Owner’s arguments to the contrary and do not agree with them for the following reasons. Patent Owner contends that Alkire and Galewski are incompatible because Alkire relates to film removal and Galewski relates to film growth. PO Resp. 9–10. Petitioner, however, shows that a PHOSITA would have understood that “the same modeling

principles apply equally to etching and deposition reactions because the chemistry at the surface is the same.” Reply 17 (citing Ex. 1003 ¶¶ 30–40, 118–122 (citing Ex. 1008; Ex. 1009; Ex. 1010; Ex. 1011; Ex. 1012; Ex. 1013)). For example, Dr. Graves testifies, with citations to the evidence of record, that “the mathematical model of the low pressure chemical vapor deposition (LPCVD) reactor described by Jensen and Graves (1983) originated as a model of a packed bed chemical reactor used in the chemical and petroleum refining industries, among others,” which demonstrates “[t]he generality of the principles of chemical reaction engineering.” Ex. 1003 ¶ 32 (citing Ex. 1009, 1).

Dr. Graves further testifies that “[b]y the late 1980s, it was well known that there are substantial similarities between plasma etching and chemical vapor deposition,” and that “[m]odels for one process (e.g. chemical vapor deposition) can often be easily adapted to, and in some cases identical to, the models for another process (e.g. plasma etching).” Ex. 1003 ¶ 34. In that regard, Dr. Graves testifies that

Hess and Graves write: “etching or deposition processes are merely chemical reactions that yield a volatile or involatile product, respectively” Ex. 1010 at p. 12 (D. W. Hess and K. F. Jensen, eds., *Microelectronics Processing*, 221 (7–8): 362, 377–440 (May 5, 1980)). Plasmas can be used to either deposit or etch films.

Id. ¶ 35. Dr. Graves also states that “it is well known that both deposition and etching usually take place simultaneously in plasma reactors” (*id.* ¶ 36), and that

Jensen in 1987 noted that the chemical aspects of plasma etching (including diffusion controlled plasma etching that neglects plasma effects) can be modeled in the same manner as chemical vapor deposition: “Since the plasmas used in microelectronics

processing are weakly ionized gases, plasma reactor modelling may be separated into two subproblems: the discharge structure as a function of electric parameters, and the transport and reaction of neutral species governing the deposition/etch performance. *The latter problem is equivalent to those of conventional reaction engineering and CVD as discussed.*”

Id. ¶ 37 (quoting Ex. 1011, 24) *see also id.* ¶ 38 (describing figure in Jensen that “illustrate[s] the components of plasma processes” and stating that equations modeling plasma chemistry and the processes occurring in chemical vapor deposition reactors “are correspondingly identical”).

Patent Owner, in contrast, does not provide sufficient explanation or evidence to support its contention that Alkire and Galewski are incompatible. In particular, we note that Patent Owner states that it has “supplemented” its arguments with the Flamm Declaration (PO Resp. 1, 9), but does not provide any citations to or discussion of the Flamm Declaration in its Response. It is improper to incorporate by reference arguments from one document into another document. 37 C.F.R. § 42.6(a)(3); *see also DeSilva v. DiLeonardi*, 181 F.3d 865, 866–67 (7th Cir. 1999) (“A brief must make all arguments accessible to the judges, rather than ask them to play archeologist with the record.”); *Cisco Sys., Inc. v. C-Cation Techs., LLC*, Case IPR2014-00454, slip op. at 7–10 (PTAB August 29, 2014) (Paper 12) (informative) (discussing incorporation by reference).

Nevertheless, we have reviewed the Flamm Declaration and determine that it is virtually identical to Patent Owner’s arguments as they appear in the Patent Owner Response, and does not provide any additional explanation or objective evidence in support of those arguments. *See Ashland Oil, Inc. v. Delta Resins & Refractories, Inc.*, 776 F.2d 281, 294 (Fed. Cir. 1985) (stating a lack of objective support for an expert opinion

“may render the testimony of little probative value in [a patentability] determination”). Therefore, even if it had been presented properly, we would not credit Dr. Flamm’s testimony on this issue because it is conclusory in nature. Ex. 2002 ¶¶ 14–15, 18–19; *see* 37 C.F.R. § 42.65(a) (“Expert testimony that does not disclose the underlying facts or data on which the opinion is based is entitled to little or no weight.”).

Next, we do not agree with Patent Owner that “a PHOSITA would not have been motivated to improve the model of Alkire since Alkire taught a model without actual etch data” and “Alkire never suggests improving its model with any actual data.” PO Resp. 5–6. As Petitioner notes, “Alkire *encourages* testing and validating a model with empirical data, and describes an ongoing effort to do so, stating that ‘[e]xperimental work aimed at testing the model predictions is currently in progress in our laboratory.’” Reply 21 (quoting Ex. 1006, 8); *see also* Ex. 1003 ¶ 119 (Dr. Graves testifying that “[t]he use of actual experimental data to extract the surface reaction rate constant would provide independent confirmation of the accuracy of Alkire’s model,” and a PHOSITA “would have been motivated to improve the model of Alkire with actual data to test and validate the model, as taught in Galewski.”).

Moreover, Patent Owner’s argument that “[a] PHOSITA would not have been motivated to improve the model disclosed in Alkire using silicon deposition experimental data” from Galewski is inapposite. PO Resp. 10. Petitioner does not argue that Galewski’s data would be combined with Alkire’s model; instead, Petitioner argues a PHOSITA would have been motivated to combine the model of Alkire with the specific teachings of Galewski. *See, e.g.*, Pet. 30 (“A PHOSITA would have been motivated to

improve the model disclosed in Alkire by using experimental data to provide independent confirmation of the accuracy of the model as taught in Galewski.”), 37 (“[C]ombining the teaching from Galewski of using experimentally measured data in modeling the reaction would have been an obvious improvement of the theoretical Alkire model to a PHOSITA.”); Ex. 1003 ¶ 119 (Dr. Graves’s testimony that a PHOSITA “would have been motivated to improve the model of Alkire with actual data to test and validate the model, as taught in Galewski.”).

Next, we do not agree with Patent Owner that “Alkire specifically teaches away from the ’849 patent.” PO Resp. 13. We credit Dr. Graves’s testimony that

Alkire does not criticize or disparage the alleged invention, and [Patent Owner] does not identify any teachings in Alkire that teach away from the alleged invention. Indeed, Alkire encourages testing and validating a model with empirical data, as does Galewski, and describes an ongoing effort to do so, stating that “[e]xperimental work aimed at testing the model predictions is currently in process in our laboratory.” Ex. 1006 at 8. In addition, I do not see any criticism in Alkire of empirical programs such as Galewski’s. At most, Alkire merely acknowledges what was well known to a person of skill: that “it is invariably difficult to translate successful experience with one system to a new system on the basis of intuition alone” and “purely empirical programs of development can be time consuming.” Ex. 1005 at 1. Accordingly, Alkire proposed using mathematical models to “assist in organizing scientific concepts into strategies for engineering design” (*id.* at 8) but did not eschew validating, testing, and improving a model with experimental data. Rather, Alkire expressly stated that his laboratory would undertake experimental work to test his model. Ex. 1006 at 8.

Ex. 1023 ¶ 24.⁷ We agree with Petitioner that “[n]othing in these disclosures would cause a PHOSITA to ‘be discouraged from following the path’ of combining empirical data with a mathematical model.” Reply 22 (quoting *In re Fulton*, 391 F.3d 1195, 1201 (Fed. Cir. 2004)).

Additionally, we find persuasive Petitioner’s argument that the ’849 patent “describes a method for determining the surface reaction rate constant by fitting etch rate data to the mathematical model disclosed in the specification.” Reply 19. As Dr. Graves explains,

Figure 3 of the ’849 Patent illustrates “a method of extracting a rate constant 100 for a plasma etching step according to the present invention.” Ex. 1001, 5:8–11. Figure 3 depicts a flow diagram comprising a sequence of three functional blocks directed to determining the surface reaction rate constant k_s : “Measure etch profile,” “**Fit to model** with k_{vo}/D and etch rate as parameters,” and “Calculate D and with it k_{vo} & k_s .” Ex. 1001, Fig. 3 (emphasis added).

Ex. 1023 ¶ 25. Dr. Graves goes on to explain that “[t]he analytical model referenced in Fig. 3 (at step 105)” is described in the ’849 patent “at col. 5, line 62 to col. 6, line 62.” *Id.* (citing Ex. 1003 ¶¶ 57–61). Patent Owner, in contrast, fails to provide any evidence to support its claim that the ’849 patent “relies upon using actual etch profile data from a non-uniform profile to determine a reaction rate coefficient” without prior mathematical modeling. PO Resp. 13. Most notably, Patent Owner does not provide any citations to the ’849 patent in support of its argument, and the Flamm

⁷ In two places in this paragraph, Dr. Graves includes cites to Ex. 1006 when quoting Alkire, which is Ex. 1005. Because the text is clear that the quotations are from Alkire, we understand these to be typographical errors.

Declaration includes the same conclusory argument without further explanation or support. *See* Ex. 2002 ¶ 23.

We also find that the evidence of record contradicts Patent Owner's assertion that Dr. Flamm "never recognized" that "the mathematical models disclosed in the '849 Patent apply equally to etching and deposition." PO Resp. 10. As Petitioner notes (Reply 18), during prosecution of the '849 patent, Dr. Flamm argued to the Patent Office that "[n]umerous advantages are achieved by way of the invention of claim 1," including that "[i]n the semiconductor industry, the surface reaction rate constant can be used to design a reactor such as a plasma etching reactor or even a chemical vapor deposition reactor," and "can be used for designing other types of reactors which are generally know[n]." Ex. 1002, 135–136.

Lastly, we do not agree with Patent Owner that Petitioner has "mischaracterized" Alkire's statement that "[a] similar analysis can be applied to LPCVD processes," and that "[a] correct reading of the passage requires that such passage be limited to only the 'events occurring in between the wafers.'" PO Resp. 13–14 (citing Pet. 30–31; Ex. 1005, 4). Petitioner establishes, with support from Dr. Graves, that the analysis in Alkire on which Petitioner relies "falls entirely within the analysis that Alkire teaches 'can be applied to LPCVD processes.'" Reply 23; *see* Pet. 30–31, 39–46; Ex. 1003 ¶¶ 93–98, 121–122; Ex. 1023 ¶¶ 14–17. In that regard, we credit Dr. Graves's testimony that

Alkire's full statement reads as follows: "The analysis up to this point has concentrated on events occurring in between the wafers. A similar analysis can be applied to LPCVD processes." Ex. 1005 at 4. [Patent Owner] ignores that the "analysis up to this point" is the same analysis that I relied upon in showing that Alkire discloses "essentially the same mathematical model for

the etch rate reaction, with the same surface rate reaction as the '849 Patent.” Ex. 1003 ¶¶ 93–98. In other words, the model disclosed by Alkire—which I demonstrated would have been combined with the specific teachings of Galewski to arrive at the claimed invention—falls entirely within the analysis that Alkire teaches “can be applied to LPCVD processes.” See Ex. 1003 ¶¶ 118–122. Moreover, Alkire’s model, like that of the '849 Patent, focuses on “events occurring in between the wafers,” where etchant species diffuse to the surface of the etchable film and undergo a surface chemical reaction, and ignores plasma species. See Ex. 1001 at 3:3–34, Fig. 1; Ex. 1003 ¶¶ 45, 49, 51, 92–93. By contrast, the discussion in Alkire that begins in the paragraph following his statement that “[t]he analysis up to this point has concentrated on events occurring in between the wafers” relates to plasma species outside the region between the wafers. Ex. 1005 at 4–5.

Ex. 1023 ¶ 26; *see also* Ex. 1003 ¶ 122 (Dr. Graves’s testimony that a PHOSITA “would have known that comparable LPCVD processes can use similar or identical models, as acknowledged by Alkire, Dr. Flamm’s previous patent applications, and multiple prior articles and books.” (citing Ex. 1005, 1, 4; Ex. 1012; Ex. 1013; Ex. 1012, 2; Ex. 1008)). Patent Owner’s arguments to the contrary are conclusory and not supported by the evidence of record. See PO Resp. 13–14; Ex. 2002 ¶ 24.

2. *Claim 1*

Petitioner contends that the combination of Alkire and Galewski discloses or suggests all of the elements of claim 1. Pet. 32–46. The parties focus their arguments on two elements in claim 1: (1) “etching said top film surface to define a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate which defines a position within said relatively non-uniform etching profile on said substrate;” and (2) “extracting a surface reaction rate constant from

said etch rate data, and using said surface reaction rate constant in the fabrication of a device.” As to the other elements of claim 1, we have reviewed the evidence and arguments presented in the Petition and find that Petitioner has shown sufficiently that those elements are disclosed and arranged as in the claim. Pet. 32–34. We address the arguments regarding the disputed elements in turn.

- a. *etching said top film surface to define a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate which defines a position within said relatively non-uniform etching profile on said substrate*

Petitioner contends that Alkire discloses “etching the top surface to define a relatively non-uniform etching profile” because it teaches that “the rate of film removal depends on the concentration distribution in the interwafer gap” and “[t]he etch rate is highest on the periphery of the wafer.” Pet. 35 (quoting Ex. 1005, 2). Petitioner contends that Alkire discloses “defining etch rate data comprising an etch rate and a spatial coordinate which defines a position within said relatively non-uniform etching profile” because “[t]he thickness of etchable material as a function of time disclosed in Alkire is etch rate data, where the change in $h(r,t)$ as a function of time is an etch rate at a spatial coordinate (given by r in cylindrical coordinates) over time (t).” *Id.* at 36 (citing Ex. 1005, 2).

Petitioner acknowledges that “Alkire does not explicitly disclose measuring the etch rate data at any spatial coordinates.” Pet. 36. In that regard, Petitioner contends that “Galewski teaches measuring the reaction rate data for a reaction between a gas-phase deposition precursor and a film on a substrate at a number of spatial coordinates.” *Id.* at 36–37 (citing Ex. 1007, 3–4) (internal footnote omitted). According to Petitioner,

“[a]pplying Galewski’s empirical rate measurement and use of empirical data in extracting the surface reaction rate constant in the model teaching to the plasma etching model of Alkire would allow a PHOSITA to use empirical data to improve the Alkire model for plasma etching.” *Id.* at 37–38 (citing Ex. 1003 ¶ 119).

Patent Owner argues that “Alkire teaches to have a uniform profile, not any nonuniform profile, and the only drawing (Fig. 2) discloses a flat etch profile, which is not a relatively non-uniform etching profile as claimed.” PO Resp. 14–15. Patent Owner also argues that “[n]o etch rate data including etch rate and spatial coordinate was disclosed by Alkire,” and that “Galewski also fails to show or teach any etch rate data as claimed [in the ’849 patent], but rather discusses silicon based epitaxial film growth rates using thermally driven feed gas deposition in LPCVD.” *Id.* at 15. Patent Owner argues that “[a] PHOSITA would never have used or even understood any way in which silicon based epitaxial film growth rates would be useful in connection with the mathematical model related to film removal in a barrel plasma etching reactor.” *Id.*

Petitioner replies that “Alkire discloses that ‘the etch rate is highest on the periphery of the wafer,’ thereby expressly teaching that the etch rate across the wafer is non-uniform.” Reply 5–6 (citing Ex. 1005, 2). Petitioner asserts that “Alkire discloses an equation for the thickness of the film as a function of the radial distance and time,” which “provides the thickness of the film at a given spatial coordinate at a given time” and therefore defines etch rate data. *Id.* at 10–11 (citing Ex. 1003 ¶¶ 134–135; Ex. 1005, 2; Pet. 34–38). Petitioner further asserts that Patent Owner “attacks the Alkire

and Galewski references separately, and never addresses the combination as explained by” Petitioner. *Id.* at 25.

Based on our review of the record, we find Petitioner’s argument that the combination of Alkire and Galewski discloses the “etching said top film surface to define a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate which defines a position within said relatively non-uniform etching profile on said substrate” limitation of claim 1 to be persuasive. Pet. 34–38; Reply 4–11, 24–27; Ex. 1003 ¶¶ 92, 131–139; Ex. 1023 ¶¶ 8–13. Alkire teaches that Figure 2, which is “not drawn to scale, is a schematic representation of the radially symmetric cell formed by two wafers facing each other,” and, “[p]rior to the onset of etching, a film of uniform thickness exists on the wafer surfaces.” Ex. 1005, 2. Alkire further teaches that “the etch rate is highest on the periphery of the wafer” and “[f]ilm in this region thus clears first.” *Id.* Alkire explains that “Figure 2 illustrates the situation part way through the process, where film has been cleared entirely from the outer portion of the wafer, while the inner region is yet to clear.” *Id.*

Moreover, Dr. Graves testifies that “a profile that tapers at the edges, as shown in Alkire Figure 2, is by definition non-uniform” and that “Alkire makes clear that Figure 2 is meant to represent a diffusion-limited regime in which etching occurs at variable rates along the wafer radius, the highest rate being at the wafer’s edge.” Ex. 1023 ¶ 10. We further credit Dr. Graves’s testimony that

[a] person of skill considering Alkire would have been aware not only of Figure 2 but also of Figure 6, which also shows a non-uniform thickness profile:

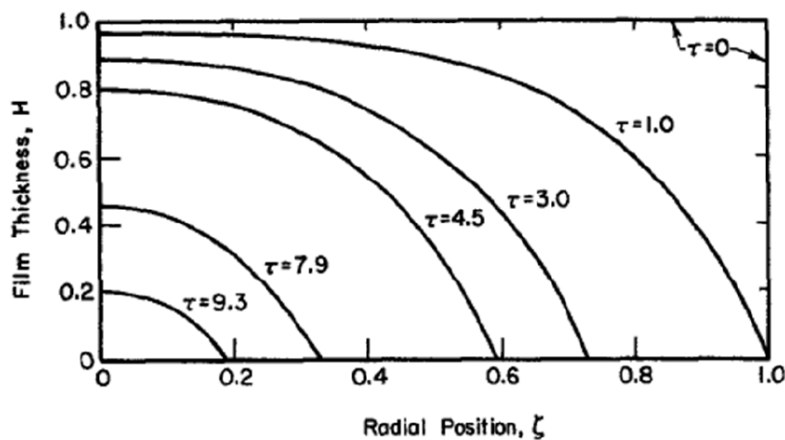


Fig. 6. Film thickness distribution at different cumulative etch times τ ($\alpha = -1$, $\beta = 10$, $\gamma = 0$, $\phi_o^2 = 25$ and total etch time $\tau_o = 10.1$).

Figure 6 shows the “film thickness distribution” as a function of radial position on the wafer for five different etch times ($\tau = 1.0$ through 9.3). Ex. 1005 at 6. The film initially has a uniform thickness (shown by the horizontal and vertical line segments labeled “ $\tau = 0$ ”). During etching, as the radial position on the wafer increases from the center of the wafer (0 on the ζ -axis) toward the edge of the wafer (positive values on the ζ -axis), the thickness of the film decreases as shown by the five curves corresponding to five different etch times. *Id.* Each curve represents the non-uniform etching profile on the film at a particular time. *Id.* at 2, 6; *cf.* Ex. 1001 at 3:66–4:9, Fig. 1A; Ex. 1003 ¶ 92. Accordingly, Alkire teaches a non-uniform film and etch profile, contrary to Dr. Flamm’s statements.

Ex. 1023 ¶ 11. That a PHOSITA would understand Alkire to be teaching a non-uniform etch profile is further confirmed by Kao,⁸ which identifies Alkire as a published paper that discusses “the problem of etch nonuniformities,” and recognizes that Alkire “examined the *nonuniform* stripping of photoresist with O_2 in a barrel reactor” wherein the transport of etching species to the wafer “relies predominately on diffusion, with little

⁸ *Analysis of Nonuniformities in the Plasma Etching of Silicon with CF_4/O_2* , J. Electrochemical Soc., Vol. 137, No. 3 (1990) 954–960 (Ex. 1006).

convective influences,” which “results in a depletion of the etching species across the wafer, thus causing *nonuniform* etching.” Ex. 1006, 1 (emphasis added). Accordingly, the evidence of record supports Petitioner’s contention that Alkire discloses a non-uniform etch profile.

We also agree with Petitioner that Alkire “discloses ‘defining etch rate data comprising an etch rate and a spatial coordinate which defines a position within said relatively non-uniform etching profile on said substrate.’” Pet. 35–36. In particular, Alkire teaches that “during etching, the thickness of the etchable material left at a certain location and time will be given by

$$h(r, t) = h_o - \int_o^t \frac{k_2}{x} c(r, t) dt \quad [1]$$

The concentration distribution $c(r, t)$ varies with time during the etching process and is calculated by application of transport laws to the movement of etchant species.” Ex. 1005, 2. Dr. Graves explains that “the thickness of etchable material as a function of time disclosed in Alkire is etch rate data, where $h(r, t)$ is [] an etch rate at a spatial coordinate (given by r in cylindrical coordinates) and a time (t).” Ex. 1003 ¶ 135. In contrast, Patent Owner’s argument that “[n]o etch rate data including etch rate and spatial coordinate was disclosed by Alkire” is conclusory and not supported by the evidence of record. See PO Resp. 15.

We further find that “Galewski teaches measuring the reaction rate data for a reaction between a gas-phase deposition precursor and film on a substrate at a number of spatial coordinates” as Petitioner asserts. Pet. 36–37 (citing Ex. 1007, 3–4). As Dr. Graves explains:

Galewski discloses measuring “[f]ilm thicknesses . . . with a stylus profiler.” [Ex. 1007, 3]. This thickness represents the

growth of silicon on a substrate through a deposition reaction. Nonetheless, this reaction rate data is directly analogous to etch rate data. As discussed above, the models for LPCVD and plasma etching are the same and represent the same values. See Sections IV and VIII(B) above. This is because, in both cases, the gas phase reactant—either the ‘etchant’ in a plasma etch reactor or the ‘deposition precursor’ in the CVD reactor—are lost at surfaces with the identical first order chemical reaction model. See Section VIII (B) above. The result is a mathematical model that is identical in precursor or reactant concentration profile.

Ex. 1003 ¶ 137. Dr. Graves further explains that Galewski’s Figure 3(a) “plots the reaction (or film growth) rate data against the radial component of cylindrical coordinates,” where “the reaction rate is represented on the y-axis, and the radial position of the reaction rate measurement ‘corresponds to a left (negative) to right (positive) diameter as viewed facing the wafer from an upstream position inside the reactor.’” *Id.* ¶¶ 137–138 (citing Ex. 1007, 3, Fig. 3(a)). We also credit Dr. Graves’s testimony that

[c]ombining Alkire with Galewski so that the model for the barrel plasma etching reactor process of Alkire would use measured etch rate data at a number of spatial coordinates, as taught by Galewski, would have been an obvious improvement of the Alkire model to one of ordinary skill in the art. Applying Galewski’s empirical rate measurement process to the plasma etching techniques of Alkire would allow a person of ordinary skill in the art to use empirical data to test, validate, and improve the Alkire model for plasma etching. Alkire explicitly teaches that an LPCVD reactor as used in Galewski is similar to the reactor used in Alkire, and that “similar analys[es] can be applied to [the plasma etching model in Alkire and] to LPCVD processes,” as in Galewski. Galewski discloses a reaction rate measurement process for a non-uniform reaction rate of a reaction between a gas-phase reactant and a film on a substrate in an LPCVD reactor. In my opinion, it would have been obvious to improve the model of Alkire by using the experimental measurement teachings in Galewski. This combination would

connect the purely mathematical model of Alkire to the empirical data for the reaction rate data to extract the surface reaction rate for defined process conditions to test, validate, and improve Alkire's model.

Id. ¶ 139 (internal citations omitted).

Patent Owner's arguments in this regard generally attack Alkire and Galewski individually, rather than in combination. PO Resp. 4–5, 14–15. Nonobviousness cannot be established by attacking the references individually when the ground of unpatentability is predicated upon a combination of prior art disclosures. *See In re Merck & Co., Inc.*, 800 F.2d 1091, 1097 (Fed. Cir. 1986); *see also In re Keller*, 642 F.2d 413, 426 (CCPA 1981) (“But one cannot show non-obviousness by attaching references individually where, as here, the [ground of unpatentability] are based on combinations of references.”).

Furthermore, as set forth above, we disagree with Patent Owner's contention that a PHOSITA would not combine Galewski with Alkire. *See supra* Section II.E.1. Additionally, with respect to Patent Owner's argument that a PHOSITA would not use Galewski's experimental data in Alkire's model, we note that an obviousness analysis does not require bodily incorporation of one reference into another. *Allied Erecting & Dismantling Co. v. Genesis Attachments, LLC*, 825 F.3d 1373, 1381 (Fed. Cir. 2016) (“[I]t is not necessary that [the cited references] be physically combinable to render obvious [the challenged patent]. The test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference. . .” (internal quotations omitted)). Rather, the test for obviousness is “whether a skilled artisan would have been motivated to combine the teachings of the prior art references to

achieve the claimed invention.” *Id.* Here, Petitioner argues a PHOSITA would have been motivated to combine the model of Alkire with the specific teachings of Galewski, not to use Galewski’s data in Alkire’s model. *See, e.g.*, Pet. 30, 37; Ex. 1003 ¶ 119.

Accordingly, we determine that the combined teachings of Alkire and Galewski disclose “etching said top film surface to define a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate which defines a position within said relatively non-uniform etching profile on said substrate” as recited in claim 1.

- b. *extracting a surface reaction rate constant from said etch rate data, and using said surface reaction rate constant in the fabrication of a device*

Petitioner contends that “Alkire in view of Galewski discloses ‘extracting a surface reaction rate constant from said etch rate data’” because “[b]oth Alkire and Galewski disclose a reaction rate constant for the surface etching reaction (k_2 in Alkire, k_s' in Galewski); that is a temperature-dependent reaction rate constant for the chemical reaction between a gas phase etchant and the surface of an etchable material.” Pet. 39 (citing Ex. 1003 ¶¶ 98, 142–147; Ex. 1005, 3–4; Ex. 1007, 2). Petitioner contends that Galewski teaches “the relationship between the surface rate constant and the deposition as follows:

$$R_{dep} = k_s' C$$

where R_{dep} is the rate of deposition and C is the concentration of the gas-phase reactant.” *Id.* Petitioner also contends that “Galewski discloses that the surface reaction rate constant for deposition divided by diffusivity can be obtained by performing a best fit analysis of the reaction rate data,” and,

“[o]nce k_s'/D has been determined from the best fit analysis, k_s' can be derived by multiplying k_s'/D by the estimated diffusivity (D_{AB}).” *Id.* at 43 (citing Ex. 1007, 4).

Petitioner further contends that “Alkire and Galewski teach ‘using said surface reaction rate constant in the fabrication of the device.’” Pet. 44. Petitioner contends that “Alkire teaches the use of a mathematical model using an etch rate constant to analyze the effect of etching parameters ‘on etch uniformity, overetch exposure, and throughput [], and [to identify] optima.’” *Id.* (quoting Ex. 1005, 8). Petitioner contends that Alkire teaches using this analysis “to find ‘[r]egions of operating conditions that permit etch uniformity within specified tolerances,’ and to calculate ‘optimum settings for interwafer spacing and reactor pressure to achieve maximum throughput’ in fabricating devices in a plasma etcher.” *Id.* (quoting Ex. 1005, 1). Petitioner also contends that “Galewski discloses using the calculated surface-rate reaction constant to improve an existing reactor or design a production-sized reactor for the fabrication of semiconductor wafers,” and “describes designing the second reactor using the surface reaction rate constant and certain specific design constraints.” *Id.* (citing Ex. 1007, 8–10).

First, Patent Owner argues in response that “each of Alkire or Galewski is silent on extracting a surface reaction rate constant from the etch rate data, and using the surface reaction rate constant in the fabrication of a device.” PO Resp. 16. As an initial matter, Petitioner does not rely on Alkire as disclosing the extraction of the surface reaction rate constant from the etch rate data. *See, e.g.*, Pet. 42 (“A PHOSITA, would have been motivated to use, and would have found it obvious to use, the teaching of

Galewski of extracting the surface reaction rate constant from the empirical data (as described below) to improve the theoretical model of Alkire through testing and validation.”). Petitioner relies on Alkire with respect to its mathematical model for the etch rate reaction, and its disclosure of a reaction rate constant for the surface etching reaction. *See id.* at 39. Petitioner contends that Galewski “teaches a method for extracting the surface-rate constant from the reaction rate data for the reaction between the gas-phase etchant and the film on the surface.” *Id.* at 42.

In that regard, Petitioner demonstrates, with support from Dr. Graves, that Galewski teaches extracting a surface reaction rate constant from empirical data. *See* Pet. 42–44; Ex. 1003 ¶¶ 108–115, 148–151. Petitioner and Dr. Graves convincingly explain that Galewski discloses “a temperature-dependent reaction rate constant for the chemical reaction between a gas phase and the surface of an etchable material,” and shows how the ’849 patent “discloses the same basic relationship between the etch rate and the surface reaction rate constant.” Pet. 39–40 (citing Ex. 1003 ¶¶ 98, 142–147; Ex. 1007, 2; Ex. 1001, 7:18–19). Petitioner and Dr. Graves further set forth how Galewski extracts a “surface-rate constant from the reaction rate data for the reaction between the gas-phase reactant and the film on the substrate” using “similar steps and equations” as the ’849 patent. *Id.* at 42–44 (citing Ex. 1007, 2, 4; Ex. 1001, 5:62–64, 6:31–38, 6:50–53, 6:58–62; 15:57–59; Ex. 1003 ¶ 151); Ex. 1003 ¶¶ 148–151.

Patent Owner further argues that “Alkire actually excludes any explicit dependence on temperature from his model,” and “also mentions in his conclusions that ‘Since chemical reactions are affected by temperature,

the reaction rate constant k_2 may not be a constant.” PO Resp. 11–12.

Dr. Graves convincingly explains, however, that

Alkire’s overall model is temperature dependent. The surface reaction rate constant will in general depend on temperature but other factors in the model also depend on temperature. Temperature is therefore one of the parameters used in extracting the surface reaction rate constant from the overall model, as in the ’849 Patent. Equations 8, 19, and 20 of Alkire expressly depend on the variable T, which Alkire defines as temperature. . . . That is, Alkire’s mathematical model, as can be seen from equations 8, 19, and 20 above, is expressly dependent on the temperature in Kelvin, although the explicit temperature dependence of k_2 is not included in these equations. A person of ordinary skill would know that the surface reaction rate constant k_2 would normally depend on temperature in the conventional Arrhenius (i.e. exponential) form, as I explained in my Opening Declaration. Ex. 1003 ¶¶ 24–29. Alkire specified the temperature (“T = 400 K”) at which all of the curves calculated from his model are calculated. Ex. 1005, p.6 at Table I. The reason for doing so is, as a person of skill would have realized, that Alkire’s model is temperature dependent in the same way as the ’849 Patent’s.

Ex. 1023 ¶ 20. Patent Owner’s arguments to the contrary are conclusory and not supported by the evidence of record. See PO Resp. 16–17; Ex. 2002 ¶ 21.

Lastly, Patent Owner repeats its argument that “Alkire illustrates a flat etch profile, which cannot extract a surface reaction rate, using any type of model whether the model is from Alkire, Galewski, or even [the ’849 patent].” PO Resp. 16. We already determined, however, that Alkire teaches a non-uniform etch profile. See *supra* Section II.E.2.a. Patent Owner also reiterates its arguments that a PHOSITA would not have been motivated to combine “the teaching of Galewski of extracting the surface reaction rate constant from empirical data . . . to improve the theoretical

model of Alkire through testing and validation,” and that Petitioner “misleadingly rel[ies] upon the passage [in Alkire] that the same modeling applies to both plasma etching in a barrel etcher and to the LPCVD deposition process,” which we do not find persuasive, as set forth above. See supra Section II.E.1.

Accordingly, we determine that the combined teachings of Alkire and Galewski disclose “extracting a surface reaction rate constant from said etch rate data, and using said surface reaction rate constant in the fabrication of a device” as required by claim 1.

c. Conclusion

After considering Petitioner’s and Patent Owner’s positions, as well as their supporting evidence,⁹ we determine that Petitioner has shown by a preponderance of the evidence that independent claim 1 would have been obvious over the combined teachings of Alkire and Galewski.

3. Claims 2–9 and 14

Claims 2–9 and 14 depend, directly or indirectly, from independent claim 1. Patent Owner does not address separately Petitioner’s explanations and supporting evidence as to how the teachings of Alkire and Galewski account for all of the limitations of these dependent claims. PO Resp. 23 (arguing that because Petitioner fails “to show any basis to invalidate” the independent claims, “[a]s a matter of law, the petition should also be denied as to all of the” dependent claims). We have reviewed the evidence and arguments presented in the Petition and find that Petitioner has shown sufficiently that the combined teachings of Alkire and Galewski account for

⁹ Patent Owner did not introduce any evidence of objective indicia of nonobviousness.

all the limitations recited in claims 2–9 and 14. Pet. 59–71; Ex. 1003 ¶¶ 203–230.

4. *Claims 10–13 and 15–19*

The limitations of independent claim 10 are substantially similar to those in independent claim 1. *Compare* Ex. 1001, 18:4–18 *with id.* at 17:35–50. As a result, Petitioner relies on the same disclosures in Alkire and Galewski and makes similar arguments with respect to the elements of claim 10 as it does with respect to the elements of claim 1. Pet. 47–49. Patent Owner reiterates its arguments that “Alkire does not show or suggest defining etch rate data,” and “Galewski does not disclose any etch rate data.” PO Resp. 18. For the reasons set forth above with respect to claim 1, we do not find Patent Owner’s arguments to be persuasive. *See supra* Section II.E.2. Patent Owner further argues that Galewski “teaches away from any combination with Alkire, and the invention itself,” but provides no explanation or evidence in support of that contention. PO Resp. 18–22. Accordingly, after considering Petitioner’s and Patent Owner’s positions, as well as their supporting evidence, we determine that Petitioner has shown, by a preponderance of the evidence that independent claim 10 would have been obvious over the combined teachings of Alkire and Galewski. Pet. 47–49; Ex. 1003 ¶¶ 156–166.

Claims 11–13 and 15–19 depend, directly or indirectly, from independent claim 10. Patent Owner does not address separately Petitioner’s explanations and supporting evidence as to how the teachings of Alkire and Galewski account for all of the limitations of these dependent claims. PO Resp. 23 (arguing that because Petitioner fails “to show any basis to invalidate” the independent claims, “[a]s a matter of law, the petition should

also be denied as to all of the” dependent claims). We have reviewed the evidence and arguments presented in the Petition and find that Petitioner has shown sufficiently that the combined teachings of Alkire and Galewski account for all the limitations recited in claims 11–13 and 15–19. Pet. 59–65, 67–69, 72–74; Ex. 1003 ¶¶ 203–216, 220–226, 231–236.

5. *Claims 20 and 21*

Petitioner contends, with supporting testimony from Dr. Graves, that the combined teachings of Alkire and Galewski disclose all of the elements of independent claim 20. Pet. 49–51; Ex. 1003 ¶¶ 167–176. Patent Owner responds that the combination of Alkire and Galewski “does not disclose[] ‘extracting a surface reaction rate constant from said etch rate data, and using said surface reaction rate constant’ in the fabrication of a device above, and in the design of a second plasma etching reactor.” PO Resp. 19–20.

For the reasons set forth above, we determined that the combined teachings of Alkire and Galewski disclose extracting a surface reaction rate constant from etch rate data. See *supra* Section II.E.2.b. With respect to the “using said surface reaction rate constant” limitation of claim 20, Galewski teaches that “[g]rowth rate from this [experimental LPCVD reactor] is used to formulate a physical model that predicts the deposition uniformity in both the radial and longitudinal directions,” and that “[t]he model is used to propose improvements to the existing reactor, and to propose a design for a system that can accommodate 100 wafers of 200 mm diameter.” Ex. 1007, 1. We credit Dr. Graves’s testimony that

Galewski steps through the design of a reactor for the fabrication of 200 mm wafers using its reactor simulation model incorporating the surface reaction rate constant given specific

design constraints. [Ex. 1007, 9.] Given a specific interwafer gap (d_{gap} in 849 Patent, δ in Galewski) and using the mathematical relationship in Galewski developed between interwafer gap and k_s'/D , Galewski calculates a range of temperatures and pressures that can achieve a maximum uniformity value by using k_s' , the surface reaction rate constant. *Id.* In Figure 10, Galewski illustrates the possible design space for the fabrication of wafers of diameter of 200 mm and a radial uniformity of $\pm 2\%$ calculated based on the surface reaction rate constant k_s' .

Ex. 1003 ¶ 153. Dr. Graves further explains that “Galewski discloses that from this analysis, a ‘temperature of 850°C and pressure of 0.5 torr is chosen to satisfy’ the design constraints for the fabrication of the device.” *Id.* ¶ 154. In addition, as Petitioner notes, “Alkire specifically states that the analysis is intended to find ‘[r]egions of operating conditions that permit etch uniformity within specified tolerances,’ and to calculate ‘optimum settings for interwafer spacing and reactor pressure to achieve maximum throughput’ in fabricating devices in a plasma etcher.” Pet. 44 (quoting Ex. 1005, 1). Patent Owner does not address these disclosures in Galewski and Alkire.

Accordingly, after considering Petitioner’s and Patent Owner’s positions, as well as their supporting evidence, we determine that Petitioner has shown, by a preponderance of the evidence that independent claim 20 would have been obvious over the combined teachings of Alkire and Galewski. See Pet. 49–51; Ex. 1003 ¶¶ 167–176.

Claim 21 depends from claims 1, 10, or 20. Ex. 1001, 18:60–62. Patent Owner does not address separately Petitioner’s explanations and supporting evidence as to how the teachings of Alkire and Galewski account for all of the limitations of dependent claim 21. PO Resp. 23 (arguing that because Petitioner fails “to show any basis to invalidate” the independent

claims, “[a]s a matter of law, the petition should also be denied as to all of the” dependent claims). We have reviewed the evidence and arguments presented in the Petition and find that Petitioner has shown sufficiently that the combined teachings of Alkire and Galewski account for all the limitations recited in claim 21. Pet. 75–77; Ex. 1003 ¶¶ 237–242.

6. *Claims 22–25*

Petitioner contends, with supporting testimony from Dr. Graves, that the combined teachings of Alkire and Galewski disclose all of the elements of independent claim 22. Pet. 52–57; Ex. 1003 ¶¶ 177–191. For example, Petitioner contends that Galewski teaches the “defining etching parameters providing said uniformity value” element of claim 22 because “[i]n Figure 10, Galewski discloses the relationship between reaction parameters (temperature, pressure, and d_{gap}) that will produce a uniformity value of 98%.” Pet. 53 (citing Ex. 1007, 9–10).

Patent Owner makes three arguments in response to Petitioner’s contentions. First, Patent Owner argues that neither Alkire nor Galewski disclose “defining etching parameters providing said uniformity value.” PO Resp. 20. In particular, Patent Owner argues that Galewski’s Figure 10 “merely discloses the relationship between reaction parameters (temperature, pressure, and spacing) that will produce a uniformity value of 98% for silicon based epitaxial films, which are not etching parameters as claimed.” *Id.* Patent Owner, however, does not provide adequate explanation or evidence demonstrating that a PHOSITA would understand Galewski in this manner. In contrast, Petitioner and Dr. Graves provide sufficient explanation supported by the evidence of record showing that Galewski “discloses ‘providing a uniformity value’ based on the surface reaction

rate.” Pet. 53. Petitioner points to Figure 10 in Galewski, which “illustrates the design constraints to fabricate semiconductor wafers with, among other requirements, a radial uniformity value of $\pm 2\%$.” *Id.* at 54 (citing Ex. 1007, 10). Petitioner states that “[t]he three-dimensional envelope illustrated with the plane of squares in Figure 10 illustrates the defined reaction parameters that provided the desired uniformity value.” *Id.* (citing Ex. 1007, 10); see Ex. 1003 ¶¶ 184–185. Dr. Graves further explains that “Galewski teaches that ‘it is possible to predict the uniformity [value] once the ratio k_s/D is known.’” *Id.* ¶ 182 (citing Ex. 1007, 3 (“Because of the first-order rate assumption . . . the radial uniformity model [is] independent of longitudinal depletion.”)). Patent Owner does not address these disclosures in Galewski.

Second, Patent Owner argues that neither Alkire nor Galewski discloses “adjusting at least one of said etching parameters using said surface reaction rate constant to produce a selected etching rate” as recited in claim 22. PO Resp. 21–22. Patent Owner argues that Alkire “fail[s] to show or suggest adjusting one of the [process] parameters using the surface reaction rate to produce a selected etching rate.” *Id.* at 21 (citing Ex. 1005, 3). Patent Owner also argues that “Galewski suffers from additional deficiencies” such as “not showing or suggesting any etching parameters or producing a selected etch rate.” *Id.*

We disagree with Patent Owner. Alkire teaches that its models can be used to determine “the effect of process parameters (c_0 , P , D , k ’s) and of geometric factors (L , R_0) on etch uniformity, overetch exposure, and total etch time,” and, “[i]n particular, optimum conditions for high throughput can be identified.” Ex. 1005, 3. Alkire further states that “the efficient design and scale-up of plasma systems is usually difficult to accomplish by intuition

alone,” and “[t]he use of mathematical models can assist in organizing scientific concepts into strategies for engineering design.” *Id.* at 8; *see also* Ex. 1003 ¶ 187 (“Alkire teaches that these process parameters can be adjusted to produce a selected etching rate.”).

Additionally, Galewski describes using its reactor simulator to determine the effects of increasing the SiH_2Cl_2 flow rate, increasing the H_2 flow rate, simultaneously increasing the SiH_2Cl_2 and H_2 flow rates, and adding “injectors that add SiH_2Cl_2 towards the rear of the reactor.” Ex. 1007, 8. In Figure 9, Galewski plots the simulated growth-rate profiles “that result from adding either increased flow rates” or injectors as described. *Id.* at 9. Dr. Graves explains that

Figure 9 illustrates the growth rate for different reaction parameters (e.g. Experiment 196 versus Experiment 196 with 5x flow rate). Based on Figure 9, reaction parameters (i.e. flowrate) can be chosen to produce a desired growth rate. As described above a person having ordinary skill in the art would have been motivated to combine Galewski with Alkire in order to increase the predictive capability of Alkire’s model to better drive process development to improve throughput and yield while avoiding costly trial and error. It would have been obvious to take the teachings of adjusting the reaction parameters to obtain a desired growth rate from Galewski and apply them to the plasma etching parameters of Alkire to obtain a desired etch rate and thus a desired throughput and yield.

Ex. 1003 ¶ 189.

Third, Patent Owner argues that “neither Alkire nor Galewski show or suggest that the etching rate provides an etching condition for fabrication of an integrated circuit device.” PO Resp. 21. According to Patent Owner, “[e]ach of these references is silent on the point and, in fact, Galewski teaches fabrication of epitaxial silicon films using hot wall reactors, rather

than any etching process as claimed.” *Id.* at 21–22. We note that Patent Owner’s arguments in this regard generally attack Alkire and Galewski individually, rather than in combination. Nonobviousness cannot be established by attacking the references individually when the ground of unpatentability is predicated upon a combination of prior art disclosures. *See In re Merck & Co.*, 800 F.2d at 1097; *In re Keller*, 642 F.2d at 426.

We find persuasive Petitioner’s arguments that the combination of Alkire and Galewski teaches or suggests “wherein said etching rate provid[es] an etching condition for fabrication of an integrated circuit device” as required by claim 22. Pet. 33–34, 52, 57; Ex. 1003 ¶¶ 124–125, 167–168, 177–178, 190–191. Dr. Graves explains that “Alkire discloses analyzing and modeling ‘film removal from closely spaced wafers in a barrel plasma etching reactor’ in view of ‘[i]mportant goals for plasma processing [that] include yield, throughput, and uniformity’” and “teaches modeling ‘transient removal of a film from a wafer stacked in a barrel plasma etcher.’” Ex. 1003 ¶ 124 (quoting Ex. 1005, 1–2). Based on these disclosures, Dr. Graves testifies that “by disclosing a method for removing film from a semiconductor wafer in a barrel plasma etcher, Alkire discloses a device fabrication method” (*id.* ¶ 125), and because the barrel plasma etching apparatus contains “wafers, with each wafer having a film on the wafer’s surface, each film surface having a surface furthest from the wafer,” Alkire also discloses a plasma etching apparatus comprising a substrate (*id.* ¶ 130).

We further credit Dr. Graves’s testimony, which is unrebutted by Patent Owner, that “it would have been common knowledge to a person of ordinary skill in the art that fabrication of a semiconductor substrate is one step in the fabrication of an integrated circuit device.” Ex. 1003 ¶ 177.

Moreover, as Petitioner notes, “Galewski teaches a low cost-approach to reactor design for ‘the complex integrated circuits of the futures.’” Pet. 52 (quoting Ex. 1007, 1). We also credit Dr. Graves’s testimony that a PHOSITA “would thus understand that Galewski teaches a method that can be used to fabricate an integrated circuit on a semiconductor substrate.” Ex.1003 ¶ 178.

After considering Petitioner’s and Patent Owner’s positions and their supporting evidence, we determine that Petitioner has shown, by a preponderance of the evidence that independent claim 22 would have been obvious over the combined teachings of Alkire and Galewski. See Pet. 52–57; Ex. 1003 ¶¶ 177–191. Claims 23–25 depend directly from independent claim 22. Patent Owner does not address separately Petitioner’s explanations and supporting evidence as to how the teachings of Alkire and Galewski account for all of the limitations of these dependent claims. PO Resp. 23 (arguing that because Petitioner fails “to show any basis to invalidate” the independent claims, “[a]s a matter of law, the petition should also be denied as to all of the” dependent claims). We have reviewed the evidence and arguments presented in the Petition and find that Petitioner has shown sufficiently that the combined teachings of Alkire and Galewski account for all the limitations recited in claims 23–25. Pet. 77–78; Ex. 1003 ¶¶ 243–246.

7. *Claims 26–29*

The limitations of independent claim 26 are substantially similar to those in independent claim 1, and Petitioner largely relies on the same disclosures in Alkire and Galewski and makes similar arguments with respect to the elements of claim 26 as it does with respect to the elements of

claim 1. Pet. 57–59. Patent Owner repeats its arguments that “Alkire does not show or suggest defining etch rate data,” and, “[l]ikewise, Galewski does not disclose any extracting from the etch rate data a surface reaction rate constant for the temperature, as claimed.” PO Resp. 22. We have already considered these arguments, and do not agree with them for the reasons set forth above. See *supra* Sections II.E.1, II.E.2. As to the other elements of claim 26, we have reviewed the evidence and arguments presented in the Petition and find that Petitioner has shown sufficiently that those elements are disclosed and arranged as in the claim. Pet. 57–59; Ex. 1003 ¶¶ 192–202.

Claims 27–29 directly depend from independent claim 26. Patent Owner does not address separately Petitioner’s explanations and supporting evidence as to how the teachings of Alkire and Galewski account for all of the limitations of these dependent claims. PO Resp. 23 (arguing that because Petitioner fails “to show any basis to invalidate” the independent claims, “[a]s a matter of law, the petition should also be denied as to all of the” dependent claims). We have reviewed the evidence and arguments presented in the Petition and find that Petitioner has shown sufficiently that the combined teachings of Alkire and Galewski account for all the limitations recited in claims 27–29. Pet. 75–79; Ex. 1003 ¶¶ 237–241, 247–250.

III. CONCLUSION

After reviewing the record and weighing the evidence offered by both parties, we determine that Petitioner has shown, by a preponderance of the evidence, that claims 1–29 of the ’849 patent would have been obvious over the combined teachings of Alkire and Galewski.

IV. ORDER

In consideration of the foregoing, it is

ORDERED that claims 1–29 of the '849 patent are determined to be *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.

IPR2017-00406
Patent 5,711,849

PETITIONER:

Jonathan McFarland
Chad Campbell
Philip A. Morin
PERKINS COIE LLP
jmcfarland@perkinscoie.com
cscampbell@perskincoie.com
pmorin@perskinscoie.com

Jeremy Jason Lang
Jared Bobrow
ORRICK, HERRINGTON & SUTCLIFFE
PTABDocketJJL2@orrick.com
PTABDocketJ3B3@orrick.com

David M. Tenant
Nathan Zhang
WHITE & CASE LLP
dtenant@whitecase.com
nathan.zhang@whitecase.com

Naveen Modi
Joseph E. Palys
Chetan R. Bansal
PAUL HASTINGS LLP
naveenmodi@paulhastings.com
josephpalys@paulhastings.com
chetanbansal@paulhastings.com

PATENT OWNER:

Justin J. Lesko
LAW OFFICES OF STEVEN G. LISA, LTD.
justinlesko@patentit.com

Rolf O. Stadheim
STADHEIM & GREAR
stadheim@stadheimgrear.com