

UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE PATENT TRIAL AND APPEAL BOARD

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Renesas Electronics Corporation and  
Renesas Electronics America, Inc.,

Petitioners

v.

Lone Star Silicon Innovations, LLC,

Patent Owner

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CASE IPR2017-01868  
Patent No. 6,326,231

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**EXHIBIT 1007**

**DECLARATION OF DEAN NEIKIRK, Ph.D.**

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I, Dean Neikirk, Ph.D., declare as follows:

**I. INTRODUCTION AND QUALIFICATIONS**

1. I understand that Renesas Electronics Corporation and Renesas Electronics America, Inc. (“Petitioners”) are petitioning the United States Patent and Trademark Office (“PTO”) for *inter partes* review of claims 1-5 and 7 of U.S. Patent No. 6,326,231 (“the ‘231 patent”). I have been retained by Petitioners to offer technical opinions relating to the ‘231 patent and certain prior art references relating to its subject matter.

2. I have over thirty years of experience with semiconductor fabrication, including practical experience related specifically to semiconductor modeling and fabrication as well as experience teaching fabrication techniques to undergraduate and graduate students.

3. I received a B.S. in Physics and Mathematics from Oklahoma State University in 1979; a M.S. in Applied Physics from California Institute of Technology in 1981; and a Ph.D. in Applied Physics from California Institute of Technology in 1984. Since receiving my Ph.D., I have been continuously involved in academia. I am currently a Professor in the Department of Electrical & Computer Engineering at The University of Texas at Austin, and I hold the Cullen Trust for Higher Education Endowed Professorship in Engineering.

4. My curriculum vitae, which is Exhibit 1008, contains a more detailed description of my background.

5. I am being compensated at my usual consulting rate of \$500 per hour for my technical analysis in this matter. My compensation is not contingent upon the results of my work.

## **II. MATERIALS REVIEWED**

6. I have reviewed various documents in forming my opinions, including the documents referenced herein and the following listed documents:

<b>Description</b>	<b>Exhibit</b>
Subramaniam, et al., U.S. Patent No. 6,326,231 B2	1001
Prosecution History of Application s.n. 09/207,562, granted as U.S. Patent No. 6,326,231	1005
Foote, et al., U.S. Patent No. 5,710,067	1006
Shibata, Japanese Unexamined Patent Application Publication No. Hei 08-191068	1010
Certified Translation of Shibata, Japanese Unexamined Patent Application Publication No. Hei 08-191068	1011
Cheung, U.S. Patent No. 6,562,544	1012
Foote, et al., U.S. Patent No. 6,903,007	1013
Text comparison of U.S. Patent No. 6,903,007 to U.S. Patent No. 5,710,067	1014

Description	Exhibit
Konjuh, et al., U.S. Patent No. 6,051,282, filed as U.S. Patent application s.n. 09/090,848 on June 4, 1998	1015
Ogawa, et al., “Practical Resolution Enhancement Effect by New Complete Anti-Reflective Layer in KrF Excimer Laser Lithography,” SPIE Optical/Laser Microlithography, v. 1927, pp 263-274 (1993)	1016
Joesten, et al., “Footing Reduction of Positive Deep-UV Photoresists on Plasma Enhanced ARL (PEARL) SiON Substrates,” SPIE Advances in Resist Technology and Processing XV, pp. 960-971 (June 29, 1998)	1017
Lee, et al., “ARC for Sub-0.18μm Logic and Gigabit DRAM Frontend and Backend Processes,” Symp. VLSI Technology, pp. 86-87 (June 1998)	1018

### III. THE APPLICABLE LAW

7. I am not an attorney, and I am not providing any expert opinions on the law. However, I have been advised of certain basic legal principles applicable to my analysis in this report, and I have applied those principles in forming my opinions. Those principles are provided below:

#### A. General Patent Law

8. I understand that determining the validity of a patent requires a two-step analysis. First, the meaning and scope of the patent claims are construed, and then the construed claims are compared to the prior art.

9. I understand that, in the context of an *inter partes* review, the prior art may comprise patents or printed publications. I also understand that the phrase “printed

publication” means publications sufficiently accessible to the public interested in the art and depends upon dissemination and accessibility.

**B. Level of Ordinary Skill in the Art**

10. I understand there is a concept in patent law known as the “person having ordinary skill in the art.” I understand that this concept refers to a person who is trained in the relevant technical field of a patent without possessing extraordinary or otherwise exceptional skill. I further understand that factors such as the educational level of those working in the field, the sophistication of the technology, the types of problems encountered in the art, prior art solutions to those problems, and the speed at which innovations are made may help establish the level of skill in the art. I understand the level of skill of the persons of ordinary skill is to be assessed at the time of the claimed invention.

**C. Principles of Claim Construction**

11. I understand that in an *inter partes* review, claims that are likely to expire during the *inter partes* review are to be interpreted in accordance with district court claim construction standards. I have been informed that the ‘231 patent is scheduled to expire on December 8, 2018 which would occur before an *inter partes* review on the ‘231 patent would conclude. Therefore, I have applied district court claim construction standards in preparing this opinion.

12. I understand that to construe the meaning of a claim term under such standards, a court will first look to the claim language itself and its usage in context with other claim terms. I understand that courts will defer to the ordinary and customary meaning that the terms would have to a person of ordinary skill in the art at the time of the alleged invention.

13. I also understand that a court will look to intrinsic evidence if the meaning of the term to a person having ordinary skill in the art at the time of the alleged invention is not apparent. I have been informed that this intrinsic evidence includes the context of the works in the claim, the specification of the patent, and the prosecution history of the patent. In fact, I understand that the specification is considered the single best guide to the meaning of a disputed term.

14. Also, I have been informed that a patentee can become their “own lexicographer” by defining terms within the patent however they wish, as long as they do so explicitly. For evidence that the patentee intended to become their own lexicographer, I understand that the court may look to the intrinsic evidence.

15. I understand that the prosecution history is an important source of intrinsic evidence and generally relevant to the proper interpretation of a claim. For example, I have been informed that the prosecution history can provide additional context that, in addition to the written description, is helpful in interpreting the claims. Further, I have been informed that prosecution history is useful in



determining what the patentee believed they originally claiming, and whether the patentee has narrowed a potential claim construction in an amendment or argument to distinguish the claims over the prior art. Thus, I understand prosecution history is generally relevant in claim construction.

16. If the meaning of a term is clear from the claim language and the intrinsic evidence, I understand that the claim construction must stop there. I have been informed that only if the meaning of the asserted claims cannot be determined after assessing the intrinsic evidence, may extrinsic evidence be considered. I have been informed that such extrinsic evidence may include expert testimony, dictionaries, and well-known treatises. Even if extrinsic evidence is considered, the claim construction may not be inconsistent with the construction mandated by the intrinsic evidence.

**D. Anticipation**

17. It is my understanding that to prove anticipation under 35 U.S.C. § 102 (the pre-America Inventions Act version), the challenger of the patent's validity must show that all of the requirements of that claim were present in a previous method or system that was described in a single previously printed publication or patent. To anticipate a claim, the prior art does not have to use the same words as the claim, but all of the requirements of the claim must have been disclosed, either stated expressly or inherently, to a person having ordinary skill in the art at the

time of the alleged invention, so that looking at that one reference, that person could make and use the claimed invention.

18. I understand that a prior art document anticipates a claim, when it expressly discloses every limitation of the claim within the four corners of the document and those limitations are arranged or combined in the same way as recited in the claim. To be anticipatory, a prior art reference must further enable one skilled in the art to make the anticipating subject matter.

19. I further understand that even when a prior art document does not expressly disclose every limitation of the claim, it may inherently anticipate the claim when the reference's disclosure makes it clear to persons of ordinary skill that the missing descriptive matter is necessarily present in the thing described in the reference. I understand that the question of whether missing descriptive matter is inherent in a prior art reference may be answered by looking to extrinsic evidence. I further understand that inherency may not be established by probabilities or possibilities, and the mere fact that a certain thing may result from a given set of circumstances is not sufficient.

**E. Obviousness**

20. It is my understanding that to prove that a claim is invalid for obviousness under 35 U.S.C. § 103 (the pre-America Invents Act version), the challenger of its validity must prove that, for example, two or more prior art references in

combination disclose, expressly or inherently, every claim limitation and also that the claim, as a whole, would have been obvious to a person of ordinary skill in the art at the time the alleged invention was made.

21. It is my understanding that the relevant standard for obviousness under 35 U.S.C. § 103(a) is as follows:

A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102, 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 at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

22. In determining whether or not a patented invention would have been obvious, I understand that the following so-called “*Graham*” factual inquiries must be made: (1) the scope and content of the prior art; (2) the differences between the prior art and the claims at issue; (3) the level of ordinary skill in the pertinent art at the time the alleged invention was made; and (4) any secondary considerations, including commercial success, long felt but unsolved needs, failure of others, etc.

23. I understand that a patent composed of several elements is not proved obvious merely by demonstrating that each of its elements was independently known in the prior art. Most, if not all, inventions rely on building blocks of prior

art. The challenger of a patent's validity must prove that, at the time of the claimed invention, there was a reason that would have prompted a person having ordinary skill in the field of the invention to combine the known elements in a way the claimed invention does, taking into account such factors as:

- a. whether the claimed invention was merely the predictable result of using prior art elements according to their known function(s);
- b. whether the claimed invention amounted to nothing more than using a known technique to improve similar devices or methods in the same way;
- c. whether the claimed invention provides an obvious solution to a known problem in the relevant field;
- d. whether the prior art teaches or suggests the desirability of combining elements claimed in the invention;
- e. whether the prior art teaches away from combining elements in the claimed invention;
- f. whether it would have been obvious to try the combinations of elements, such as when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions; and
- g. whether the change resulted more from design incentives or other market forces.

To find the invention obvious in light of a prior art combination, the prior art combination must have provided a reasonable expectation of success.

24. I further understand that it is not permissible to use hindsight in assessing whether a claimed invention is obvious. Rather, I understand that, to assess obviousness, you must place yourself in the shoes of a person having ordinary skill in the relevant field of technology at the time the alleged invention was made who is trying to address the issues or solve the problems faced by the inventor, considering only what was known at the time of the invention and ignoring the knowledge you currently now have of the inventions.

25. Regarding the fourth step in the four-step process for assessing obviousness (the so-called *Graham* inquiries), specifically the step involving “objective considerations,” I have been told that some of the factors that may be considered are those of copying, a long felt but unsolved need, failure of others, commercial success, unexpected results created by the claimed invention, unexpected properties of the claimed invention, licenses showing industry respect for the invention, and skepticism of skilled artisans before the invention was made. I have no reason to believe that any of these factors apply to the challenged claims of the ‘231 patent.

26. I understand that when evidence of simultaneous invention by others is present, it suggested that claimed subject matter is obvious. As described herein, I

believe such evidence is present. Four separate prior art references have been identified that disclose the same subject matter as described by claims 1-5 and 7, namely dual antireflection coatings created by silicon oxynitride and an oxide layer. *See*, Shibata (Ex. 1011), Cheung (Ex. 1012), Konjuh (Ex. 1015) and Joesten (1017), discussed below. Thus, the number of references describing this subject matter indicates that the claimed subject matter is obvious.

#### **IV. THE ‘231 PATENT**

##### **A. The Disclosure of the ‘231 Patent**

27. The ‘231 patent is directed to semiconductor manufacturing techniques and, in particular, to techniques for forming antireflection coatings over highly reflective materials in a semiconductor substrate.

28. By 1998, microlithography was a well-known technique for fabricating features in a substrate. Microlithography involves placement of a photoresist over the substrate, which is chemically active in the presence of radiation. Selective portions of the photoresist are exposed to radiation, which causes a transformation in the exposed portions of the photoresist. After exposure, either exposed (positive resist) or unexposed (negative resist) regions of the photoresist are dissolved by a developer, which causes features to be formed in the photoresist. *See*, Ex. 1001,

Col. 1:18-35. The photoresist is then used as a mask for etching of features in the material(s) below the photoresist.

29. FIG. 1 below provides a simple example of a microlithography technique. In this example, it is desired to form features in a substrate (*blue*). As shown in FIG. 1(a), the photoresist (*gray*) is placed over the substrate. Select portions of the photoresist are exposed to radiation (*red*) based on a mask image, also shown in FIG. 1 (a). The radiation exposure causes a chemical transformation in the photoresist, which, in this example, causes exposed portions of the photoresist to be dissolved readily by a developer (not shown) but unexposed portions of the photoresist remain resistant to the developer.

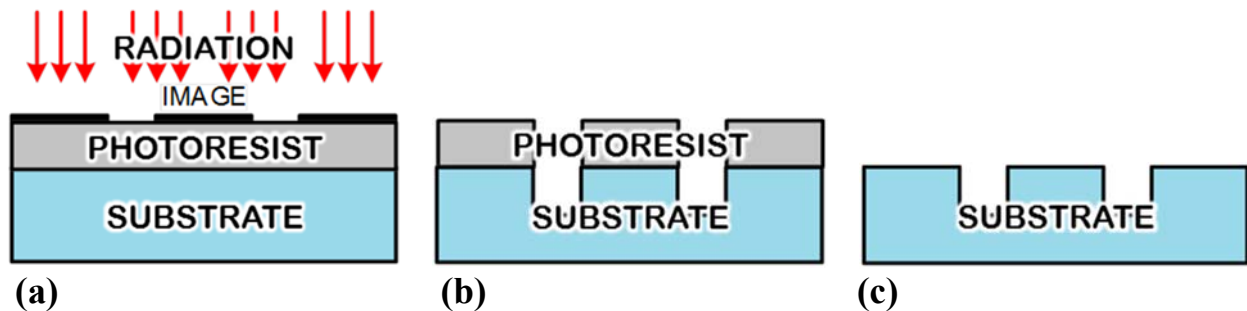


FIG. 1

30. As shown in FIG. 1(b), after the developer has been used to create openings in the photoresists, the remaining portion of the photoresist then acts as a mask for another etch process to form features in the layer below the resist (shown here as the “substrate”). Thereafter, the remaining portions of the photoresist are removed, as shown in FIG. 1(c), leaving the substrate with features formed therein.

31. The example of FIG. 1 provides only a rudimentary illustration of microlithography practices that had been developed by 1998. By then, microlithography was a mature field of study, and a wide variety of fabrication techniques had been developed. For example, a variety of photoresist materials had been developed. Where the example above illustrates an exemplary material that normally is hardened against removal by the developer and becomes amenable to removal only when exposed to radiation, other photoresist materials had been developed that normally were amenable to removal by a developer but become hardened against removal when exposed. Further, microlithography techniques were widely used not only for manufacture of semiconductor features in silicon wafers, they also were used to form circuit structures over the wafer's surface in many other layers, such as conductors and intervening dielectrics. Thus, by 1998, microlithography techniques were widely used to build features in silicon wafers, in dielectric layers and in metal layers.

32. The '231 patent acknowledges this depth of knowledge in the background description where it states:

Microlithography processes for making miniaturized electronic components, such as in the fabrication of computer chips and integrated circuits, involve using photoresists.

Generally, a coating or film of a photoresist is applied to a substrate material, such as a silicon wafer used for making integrated circuits. The



substrate may contain any number of layers or devices thereon. The photoresist coated substrate is baked to evaporate any solvent in the photoresist composition and to fix the photoresist coating onto the substrate. The baked coated surface of the substrate is next subjected to selective radiation; that is, an image-wise exposure to radiation.

This radiation exposure causes a chemical transformation in the exposed areas of the photoresist coated surface. Types of radiation commonly used in microlithographic processes include visible light, ultraviolet (UV) light, electron beam and X-ray radiant energy. After selective exposure, the photoresist coated substrate is treated with a developer solution to dissolve and remove either the radiation-exposed or the unexposed areas of the photoresist.

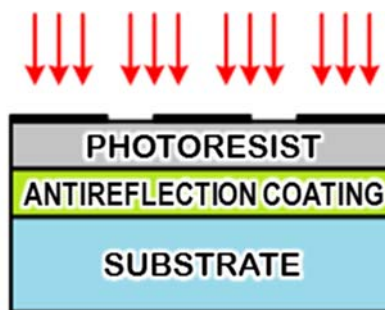
*See*, Ex. 1001, Col. 1:13-35.

33. By 1998, it had been recognized that microlithography techniques also presented certain complications. One such complication arises when portions of photoresist that should not be exposed to radiation become exposed inadvertently or, in other cases, interference effects cause some portions of photoresist that should be exposed to be underexposed. The '231 patent explains that such inadvertent exposure can occur due to back reflection of light from highly-reflective surfaces in the substrate. Ex. 1001, Col. 1:36-49. The '231 patent identifies two deleterious effects of back reflectivity, thin film interference and reflective notching. The patent explains:

Thin film interference results in a changes [sic] in critical linewidth dimensions caused by variations in the total light intensity in the photoresist film as the thickness of the photoresist changes. Reflective notching becomes severe as the photoresist is patterned over substrates containing topographical features, which tend to scatter light through the photoresist film, leading to linewidth variations, and in extreme cases, forming regions with complete photoresist loss.

*Id.*, Col. 1:36-49.

34. By 1998, antireflection coatings were well-known solutions to microlithography problems involving patterning errors in photoresists. An antireflection coating (**green**) is placed between the substrate (**blue**) and the photoresist layer (**gray**), for example, as shown in the example of FIG. 2. An antireflection coating helps solve patterning error issues by absorbing radiation that passes through the photoresist before it reaches the reflective surfaces and before it can be reflected from the substrate back into the photoresist. *See*, Ex. 1001, Col. 1:58-2:7.



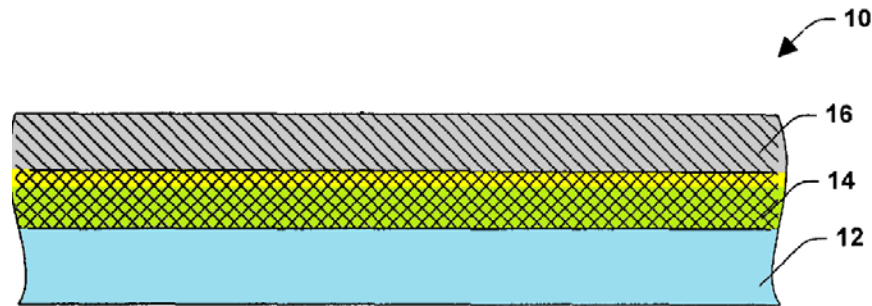
**FIG. 2: Example of Antireflection Coating**

35. The '231 patent identifies certain problems with antireflection coatings, including: incomplete removal of the coating and undesirable interaction between the antireflection coating and either the photoresist or the substrate; selecting an antireflection coating that bonds firmly to the substrate; and selecting an antireflective coating that has desirable properties at the wavelengths used for the exposure radiation. *Id.*, at 2:8-26.

36. The '231 patent identifies titanium nitride as a conventional antireflection coating. *Id.* at 2:27-43. The '231 patent identifies problems with titanium nitride coatings, including inability to reduce reflectivity when used with certain metals and “poisoning” of deep UV photoresists. Poisoning occurs when nitrogen migrates from the titanium nitride antireflection coating into the photoresist, which desensitizes the photoresist to deep ultraviolet light.

37. The '231 patent proposes an antireflective coating 14 that contains two layers: a silicon oxynitride layer (**green**) and a thin oxide layer (**yellow**). *Id.* at Cols. 2:44-49; 6:13-34. The silicon oxynitride layer is formed on an underlying substrate 12 (**blue**) that includes reflective metal surfaces. *Id.* 6:13-34. The oxide layer is formed over the silicon oxynitride layer. *Id.* at 3:43-4:60, 6:13-34. Thereafter, a photoresist 16 (**gray**) is formed over the oxide layer of the antireflective coating 14. *Id.* at 5:65-6:9, 6:35-48. The oxide layer prevents

nitrogen from migrating from the silicon oxynitride layer to the photoresist 16. *Id.* at 7:60-65. The antireflective coating 14 and photoresist are to be used with radiation at 248 nm. *Id.*, at 3:17-29.



**Ex. 1001, FIG. 1 (annotated)**

38. The '231 patent does not contain a drawing that illustrates the silicon oxynitride layer and the thin oxide layer separately from each other. Thus, FIG. 1 above is color-coded with **green** and **yellow** sub-layers to represent these two components of the antireflection coating 14.

39. The '231 patent explains that the silicon oxynitride layer (**green**) has a thickness of 100-1,500 Å. The patent discloses several ranges of thickness for the silicon oxynitride layer, including 125-1,400 Å, 150-1,300 Å, and 125-600 Å. *Id.* at 4:66-5:8.

40. Specifically, the '231 patent states:

In one embodiment, the initial silicon oxynitride layer has a thickness from about 100 Å to about 1500 Å. In another embodiment, the initial silicon oxynitride layer has a thickness from about 125 Å to about 1400

Å. In yet another embodiment, the initial silicon oxynitride layer has a thickness from about 150 Å to about 1300 Å.

*Id.*, at 4:33-39.

41. It further states:

The silicon oxynitride ARC is formed to a suitable thickness to exhibit a desired reflectivity. In one embodiment, the silicon oxynitride ARC formed in accordance with the present invention has a thickness from about 100 Å to about 1500 Å. In another embodiment, the silicon oxynitride ARC has a thickness from about 125 Å to about 1400 Å. In yet another embodiment, the silicon oxynitride ARC has a thickness from about 150 Å to about 1300 Å. In a preferred embodiment, the silicon oxynitride ARC has a thickness from about 125 Å to about 600 Å.

*Id.* at 4:66-5:8. Although the patent states that the range 125-600 Å is preferred, it does not say why. For example, the '231 patent does not identify any advantages that are obtained either by the preferred range or by any of the other disclosed ranges.

42. The '231 patent explains that the thin oxide layer (**yellow**) has a thickness between 5-50 Å. It discloses several ranges of oxide layer thickness, including 10-40 Å and 15-35 Å. *Id.* at 4:66-5:8.

43. Specifically, the '231 patent states:

In one embodiment, the thin oxide layer has a thickness from about 5 Å to about 50 Å. In another embodiment, the thin oxide layer has a thickness from about 10 Å to about 40 Å. In yet another embodiment, the thin oxide layer has a thickness from about 15 Å to about 35 Å.

*Id.*, Col. 4:61-65

44. Here, again, the ‘231 patent does not identify any particular thickness value as providing any specific advantage over another value within the stated ranges, nor does it identify any one range as advantageous over another range. *Id.*

45. Instead, the ‘231 patent states that reflectivity of the resultant antireflective layer 14 will depend on a variety of factors, including the relative amounts of oxygen and nitrogen of the silicon oxynitride layer, initial thickness of the silicon oxynitride layer, thickness of the oxide layer, and thickness of the resultant antireflection coating.

46. Specifically, the ‘231 patent states:

The reflectivity of the resultant silicon oxynitride ARC depends upon a number of factors including the ratio of silicon oxynitride components (the relative amounts of oxygen and nitrogen), the thickness of the initial silicon oxynitride layer, the thickness of the thin oxide layer and the thickness of the resultant silicon oxynitride ARC.

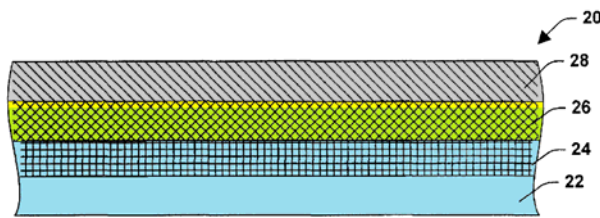
*Id.* at 5:9-15.

47. This discussion suggests that the range of thicknesses of the silicon oxynitride layer (“a thickness from about 100Å to about 1500Å”) and the oxide layer (“a thickness from about 5Å to about 50Å”) identified by independent claim 1 are not critical features of the patent. The ‘231 patent identifies these ranges merely as among several alternatives. Moreover, the ‘231 patent explains that the thicknesses of these layers are two factors among many others that will influence reflectivity of the antireflection coating. Therefore, the ‘231 patent suggests that the claimed thicknesses are not critical features of the patent.

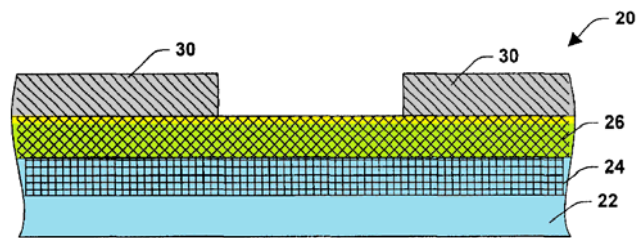
48. The ‘231 patent states that the silicon oxynitride layer (**green**) can be fabricated by any suitable technique, including chemical vapor deposition (“CVD”), low pressure chemical vapor deposition (“LPCVD”) or plasma enhanced chemical vapor deposition (“PECVD”). *Id.*, at 4:10-25. The patent states that the oxide layer (**yellow**) may be formed by contacting the silicon oxynitride layer either with an oxygen plasma or a nitrogen plasma or by depositing the oxide layer by CVD techniques. *Id.*, at 4:50-60.

49. The ‘231 patent illustrates a specific embodiment of the fabrication technique in FIGS. 3 and 4. In FIG. 3, the ‘231 patent illustrates a structure 20 with a semiconductor layer 22 (**blue**) and an aluminum layer 24 (also **blue**), an antireflective coating 26 (**green, yellow**), and a photoresist layer 28 (**gray**). The

semiconductor layer 22 represents a variety of layers including substrate layers, diffusion regions, dielectrics, and the like. The patent states that although the aluminum layer 24 is shown as continuous, it also may be intermittent. The antireflection coating 26 is made by a two-step process that includes forming a silicon oxynitride layer (*green*) followed by exposing the silicon oxynitride layer to an oxygen plasma to form an oxide layer (*yellow*). The photoresist 28 may be formed by spin coating a deep UV photoresist over the antireflection coating 26. *Id.*, at Col. 6:60-7:13.



**Ex. 1001, FIG. 3 (annotated)**



**Ex. 1001, FIG. 4 (annotated)**

50. FIG. 4 of the '231 patent illustrates the photoresist 28 having been patterned by photolithographic techniques to form a pattern 30. The pattern 30 is formed using radiation at a wavelength of 248 nm. The photoresist pattern 30 is used as a mask to pattern the antireflection coating and the aluminum layer 24. *Id.*, at Col. 7:14-26.



**B. Prosecution History of the '231 Patent**

51. The '231 patent was filed as U.S. application s.n. 09/207,562 on December 8, 1998. It makes no claim of priority to any other filing. Accordingly, I have used December 8, 1998 as the invention date of the '231 patent in my analysis.

52. When it was originally filed, the '562 application contained twenty (20) claims. Claim 1 initially They recited:

1. A method of forming a silicon oxynitride antireflection coating over a metal layer, comprising:  
providing a semiconductor substrate comprising the metal layer over at least part of the semiconductor substrate;  
depositing a silicon oxynitride layer over the metal layer having a thickness from about 100Å to about 1500 Å; and  
forming an oxide layer having a thickness from about 5Å to about 50Å over the silicon oxynitride layer to provide the silicon oxynitride antireflection coating.

Ex 1005, p. 28.

53. Claims from the '562 application were rejected four times over prior art.

54. A first rejection was issued in July 2000. The pending claims were rejected as obvious over Roman, U.S.P. 5,639,687, Ionov, U.S.P. 6,013,582 and, for some claims, Fuse, U.S.P. 4,527,007. Roman disclosed an antireflective coating made of a silicon nitride layer and an oxide layer. The Office Action concluded it would

have been obvious to use silicon oxynitride as a substitute for Roman's silicon nitride layer. Fuse was cited for disclosure of an oxide layer formed from N<sub>2</sub>O or O<sub>2</sub> plasmas. Ex. 1005, pp. 49-54.

55. The applicants argued against the rejection in an October 2000 response. *Id.*, pp. 56-61. The applicants argued the prior art did not teach use of an integral antireflective coating layer formed from silicon oxynitride and an oxide layer. With respect to Roman, the applicants argued that the oxide layer was not an integral part of an antireflective coating because Roman discloses an intervening layer provided between the oxide layer and the silicon nitride layer. The applicants also characterized Ionov's silicon oxynitride layer as relating to etching, not antireflective coatings.

56. The Office issued a final rejection in response to the applicants' arguments, in January 2001. *Id.*, pp. 64-70. The Office concluded that Roman discloses an oxide film that was deposited over an antireflective coating, which is exactly what the then-pending claims recited. The Office also concluded that Ionov discloses silicon oxynitride for use as an antireflective coating.

57. Applicants conducted an interview with the Office in January 2001. *Id.*, pp. 71-72. An interview summary indicates that applicants and the Examiner identified use of an oxide layer as a nitrogen barrier as a feature that might overcome the prior art.

58. Applicants filed a Response After Final Action in January 2001 that amended the claims to recite that an “oxide layer forms a barrier to migration of nitrogen atoms from the silicon oxynitride layer.” Specifically, independent claim 1 was amended as follows:

1. A method of forming a silicon oxynitride antireflection coating over a metal layer, comprising:  
providing a semiconductor substrate comprising the metal layer over at least part of the semiconductor substrate;  
depositing a silicon oxynitride layer over the metal layer having a thickness from about 100Å to about 1500Å; and  
forming an oxide layer having a thickness from about 5Å to about 50Å over the silicon oxynitride layer to provide the silicon oxynitride antireflection coating,  
wherein the oxide layer forms a barrier to migration of nitrogen atoms from the silicon oxynitride layer.

*Id.*, pp. 73-83.

59. The Office issued an Advisory Action in February 2001, and the applicants filed a Continuing Prosecution Application in March 2001 to have the new amendment entered for examination. *Id.*, pp. 85-91.

60. The Office issued another Office Action in April 2001, rejecting all claims over art – Adkisson, U.S.P. 6,030,541, Roman (above), and Puchner, U.S.P. 6,156,620. *Id.*, pp. 92-98. The Office Action identified Adkisson as a primary

reference that discloses a silicon oxynitride layer and an oxide layer, both having thicknesses as claimed. The Office Action acknowledged that Adkisson does not disclose forming an antireflective coating over a metal layer. Instead, Adkisson stated that the antireflective coating may be formed over “any substrate.”

61. The applicant amended the claims in May 2001 to recite that a silicon oxynitride layer is deposited “*on* the metal layer.” *Id.*, pp. 99-106. The amendment removed an earlier recitation that the silicon oxynitride layer was “over” the metal layer. The amendment to independent claim 1 is shown below:

1. A method of forming a silicon oxynitride antireflection coating over a metal layer, comprising:  
providing a semiconductor substrate comprising the metal layer over at least part of the semiconductor substrate;  
depositing a silicon oxynitride layer [over] on the metal layer having a thickness from about 100Å to about 1500Å; and  
forming an oxide layer having a thickness from about 5Å to about 50Å over the silicon oxynitride layer to provide the silicon oxynitride antireflection coating;  
wherein the oxide layer forms a barrier to migration of nitrogen atoms from the silicon oxynitride layer.

*Id.*, p. 100.

62. The applicants argued that the amendment distinguishes an arrangement disclosed in Adkisson which requires an intermediate layer between the substrate and the antireflective coating. The applicants stated:

Applicants' claims are amended herein to specify that the ARC layer is formed on the metal layer, rather than "over" the metal layer. This amendment distinguishes the present invention from that of Adkisson et al, which requires the presence of a hard mask layer between the substrate and the ARC layer. *See* Adkisson et al, col. 3, lines 60-62.

*Id.*, p. 103.

63. The applicants also argued that there is no disclosure in Adkisson that would lead a person of skill to conclude that the method is applicable to a metal surface.

*Id.* Applicants did not reconcile this statement with its admission that titanium nitride antireflective coatings were used with metals having high reflectivity. Ex. 1001, Col. 2:27-35.

64. The Office issued a Final Rejection, rejecting the claims again based on Adkisson, Roman and Puchner. Ex. 1005, pp. 110-117. The Office rejected applicants' prior argument, identifying teachings from both Roman and Adkisson that support a conclusion that it would have been obvious to form an antireflective coating on a metal layer. Following an interview and a Response After Final Rejection, however, the Office reversed itself and allowed the application. *Id.*, pp.

118-131. A Notice of Allowance included a statement of reasons for allowance, which indicated “the prior art does not teach a process wherein an antireflective coating (ARC) layer is formed directly on a metal layer.” *Id.*, at 129-130. The Office granted the ‘231 patent in December 2001.

65. The prosecution history includes an information disclosure statement that identifies Foote, U.S.P 5,710,067 (“Foote ‘067,” Ex. 1006). Ex. 1005, p. 47. The prosecution history indicates the Patent Office did not rely on Foote ‘067 in any prior art rejection.

**V. THE LEVEL OF SKILL IN THE ART TO WHICH THE ‘231 PATENT PERTAINS.**

66. In reviewing the ‘231 patent to determine the level of ordinary skill in the art, I have arrived at my opinion that the “art” found in the ‘231 patent pertains primarily to semiconductor fabrication techniques and, in particular, to techniques for forming antireflection coatings for photolithography in semiconductor devices.

67. The discussions in the ‘231 patent about methods for forming an antireflection coatings are topics that would have been well known to a student studying for a graduate degree in physics, material science, electrical engineering, or a related degree with some emphasis in semiconductor device fabrication by the time they graduated in the 1998 time period (the year the ‘231 patent was filed). At that timeframe, these topics also would have been well known to someone with an

undergraduate degree in these fields with two years' work experience in semiconductor device design and fabrication.

68. Taking the relevant factors into consideration, it is my opinion that a person of ordinary skill in the art as of the effective filing date of the '231 patent (December 8, 1998) would have had a graduate's degree in physics, material science, electrical engineering, or a related degree, with some emphasis in semiconductor device fabrication, or an undergraduate degree in one of these fields and two to three years' experience in semiconductor device design and fabrication. Such a person would have also had at least a basic understanding, through education or experience, of the materials that comprise photoresist layers and antireflection layers and how those materials interact with each other.

69. In my opinion, as of 1998, I would qualify as a person with at least ordinary skill under this standard. As of 1999, I held multiple college degrees, including two post-graduate degrees in applied physics and over fifteen years of experience in semiconductor fabrication.

70. Further, at least through my work as an educator, I am familiar with the level of ordinary skill in the art as of 1998 under this standard. As explained above and in my curriculum vitae, as of 1998, I had over a decade of experience teaching semiconductor fabrication courses to undergraduate and graduate students pursuing degrees in electrical engineering or related fields. Through my teaching, I was

familiar with the ordinary skill level of those with experience in semiconductor fabrication.

## **VI. CLAIM CONSTRUCTIONS OF THE ‘231 PATENT**

71. It is my opinion that the following constructions should apply to the claims of the ‘231 patent:

The clause “depositing a silicon oxynitride layer *on* the metal layer” requires direct contact between the silicon oxynitride layer and the metal layer.

This construction is dictated by the May 2001 amendment that substituted “on” for [[over]] and accompanying remarks that explain the amendment was intended to require this direct contact. Ex 1005, p. 103.

72. In my opinion, the other terms and phrases recited in claims 1-5 and 7 do not need construction. The meaning of the other terms and phrases would be apparent to a person of ordinary skill in the art as of December 8, 1998. These terms and phrases should be given their plain and ordinary meaning, and I have applied these constructions in the analyses presented in this report.

## **VII. OVERVIEW OF OPINION**

73. I was asked to provide my opinion as to whether claims 1-5 and 7 of the ‘231 patent were invalid as anticipated by or obvious in view of the prior art. In my



opinion, those claims are invalid because a person of ordinary skill in the art as of December 8, 1998, would have found the subject matter of each of those claims anticipated by, and obvious in view of, the prior art. To summarize, it is my opinion that:

- a.     **Ground 1:** Claims 1-5 are anticipated by Shibata.
- b.     **Ground 2:** Claim 7 is obvious over Shibata, Lee, Cheung and Joesten.
- c.     **Ground 3:** Claims 1-3 and 5 are anticipated by Foote '007.
- d.     **Ground 4:** Claims 1-5 are obvious over Konjuh and Ogawa.
- e.     **Ground 5:** Claim 7 is obvious over Konjuh, Ogawa, Lee, Joesten and Cheung.

74. In following the legal framework for anticipation and obviousness that has been explained to me, I will discuss the scope and content of the prior art, then analyze each claim to show where the limitations of the claim are present in the prior art. I will also discuss why one of skill would have been motivated to combine the prior art accordingly. I have already set forth above the level of skill for a person skilled in the art in the time frame of the '231 patent.

## **VIII. OVERVIEW OF PRIOR ART**

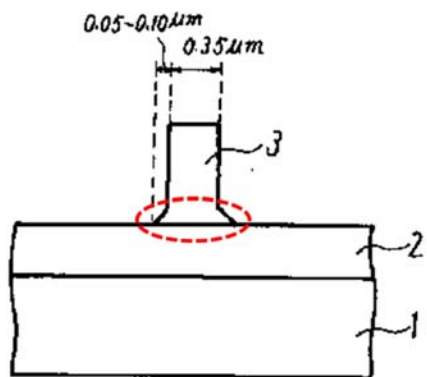
### **A. State of Prior Art in General**

75. I have provided an explanation of general principles of photolithography and the role of antireflection coatings in § IV.A of this report (pp. 11-16 above). As discussed, photolithography involves formation of patterns in photoresist material by selectively exposing those photoresists to radiation, then removing some portion of the photoresist and leaving other portions. Control of radiation exposure can be problematic in photolithography when radiation is reflected back to the photoresist from surfaces of an underlying substrate. And, while antireflection coatings were well known solutions to the back reflection problems, they created other complications.

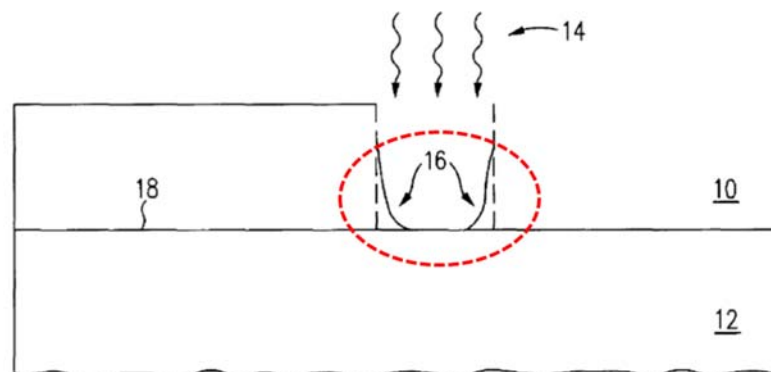
76. The '231 patent identifies titanium nitride as a conventional antireflection coating, and describes problems with titanium nitride. Ex. 1001, Col. 2:27-35. The '231 patent fails to recognize that silicon oxynitride antireflection coatings had been proposed in several references, including another patent filing submitted by Advanced Micro Devices, the original assignee of the '231 patent. *See*, Foote '007 (Ex. 1013). Silicon oxynitride antireflection coatings also had been reported in several other prior art references prior to the filing of the '231 patent, including Ogawa (Ex. 1016), Lee (Ex. 1018), Shibata (Ex. 1011), Cheung (Ex. 1012), Konjuh (Ex. 1015) and Joesten (1017), which are discussed below.

77. Ogawa reported a silicon oxynitride antireflection coating in 1993, over five years before the '231 patent was filed. Lee describes such films in 1998. The remaining references – Shibata (Ex. 1011), Cheung (Ex. 1012), Konjuh (Ex. 1015) and Joesten (1017) – all discuss “footing” problems that arise from using silicon oxynitride antireflection coatings. They explain that silicon oxynitride chemically interacts with the photoresist materials that are laid on top of them. Specifically, nitrogen from the silicon oxynitride antireflection coating interacts with the photoresist. As a result, features are not well defined in the photoresist. Instead, unintended features are defined, called “footings.”

78. These references illustrate various footing features such as shown below:



**Shibata (Ex. 1011),  
FIG. 5b (annotated)**



**Konjuh (Ex. 1015), FIG. 1 (annotated)**

Ideally, the photoresists 3 (Shibata) and 10 (Konjuh) would have sharply-defined edges that intersect with the underlying layers 2 (Shibata) and 18 (Konjuh) at right angles. The footing effects inhibit formation of such sharp edges.

79. The references propose an oxide layer interposed between a silicon oxynitride antireflection layer and a photoresist to prevent chemical interaction between the silicon oxynitride layer and the photoresist. Specifically, these references explain that the presence of the oxide layer prevents migration of nitrogen, sometimes expressed as “amines,” from the silicon oxynitride layer to the photoresist.

80. The term “amines” refers to nitrogen-hydrogen compounds. *See, for example*, Ex. 1015, Col. 1:34-43. Nitrogen from amines chemically reacts with photoresists and contributes to footing problems in semiconductor processing. Thus, skilled people would recognize chemical reaction between amines from silicon oxynitride layers and photoresist as a migration of nitrogen, as claimed.

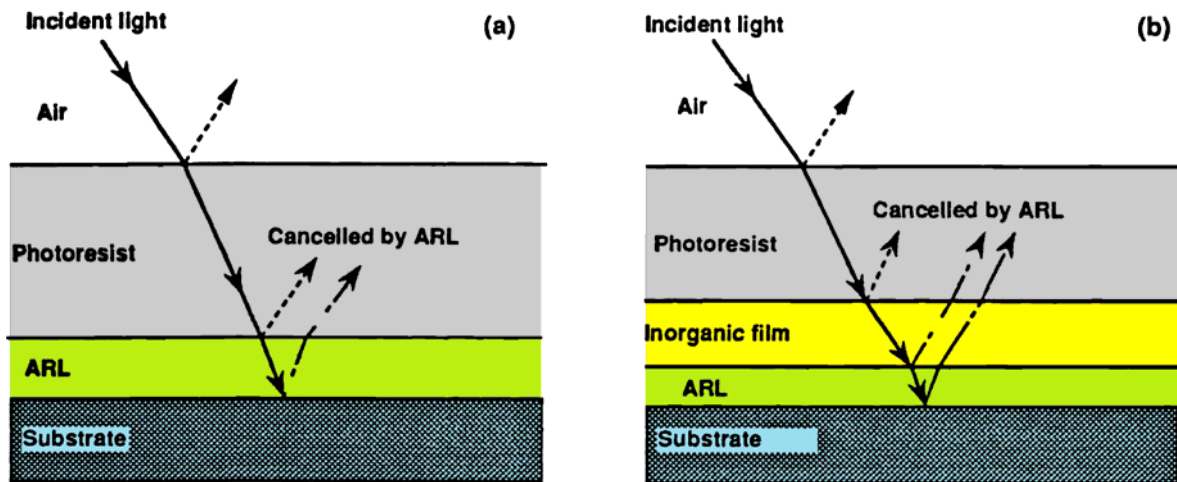
81. Below, I have summarized the teachings from these references that are relevant to my opinions.

**B. Ogawa (Ex. 1016)**

82. Ogawa is an article that was published in 1993. I understand that Ogawa is prior art to the ‘231 patent under 35 U.S.C. § 102(b).

83. Ogawa describes semiconductor processing techniques using silicon oxynitride antireflective layers, which he calls “ARLs.” Ogawa describes several

different structures using ARLs, including three-layer and four-layer structures, shown in FIG. 1(a) and (b), respectively:



Ogawa (Ex. 1016), FIGS. 1(a), 1(b) (annotated)

In both cases, the antireflective layer ARL (**green**) is silicon oxynitride. Ex. 1016, § 2.1.

84. The ARL is formed on a substrate (**blue**) that is made either of tungsten-silicide (W-Si) or aluminum silicon (Al-Si, which is a metal). Ogawa states that, for a W-Si substrate, the ARL film may have a thickness of 300Å and, for an Al-Si substrate, the ARL may have a thickness of 250Å. Specifically, Ogawa states:

This new ARL, whose material is a type of hydro silicon oxynitride film ( $\text{SiO}_x\text{N}_y\text{H}$ ), can be applied to tungsten silicide (W-Si) and even to aluminum silicon (Al-Si) substrates by controlling deposition conditions in plasma enhanced chemical vapor deposition systems. Using this  $\text{SiO}_x\text{N}_y\text{H}$  film with 30nm and 25nm thicknesses on W-Si and Al-Si

substrates respectively, critical dimension (CD) variations for both substrates are drastically reduced to within  $0.02\mu\text{m}$  for  $0.30\mu\text{m}$  imaging.

*Id.*, Abstract. The thicknesses of the hydro silicon oxynitride films are expressed in nanometers. When converted to angstroms, the thicknesses are 300 angstroms (W-Si) and 250 angstroms (Al-Si), respectively.

85. FIG. 1(a) shows a three-layer structure where a photoresist (**gray**) is placed on the ARL (**green**). The ARL cancels reflective light from the interface between the photoresist and the ARL. *Id.*, § 2.2.

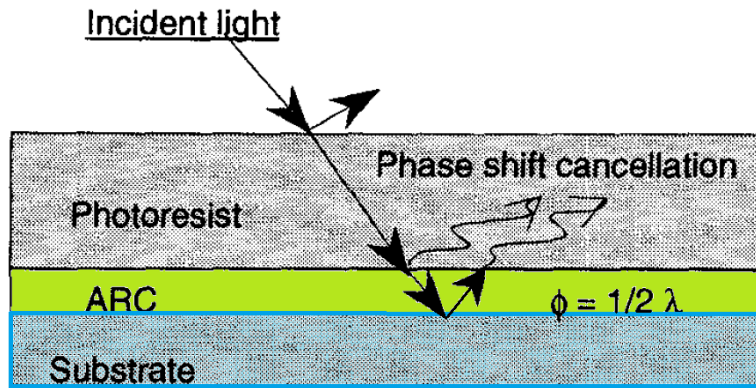
86. FIG. 1(b) shows a four-layer structure where an inorganic film, such as silicon dioxide (**yellow**), is formed on the ARL (**green**) and the photoresist (**gray**) is formed on the inorganic film. Ogawa characterizes the inorganic film as “clear.” *Id.* Here, the ARL cancels reflective light from the interface between the photoresist and the inorganic film. *Id.*

87. Ogawa teaches that the three-layer and four-layer structures find application with a variety of wavelengths. Ogawa refers to 248 nm radiation as an example. *Id.*

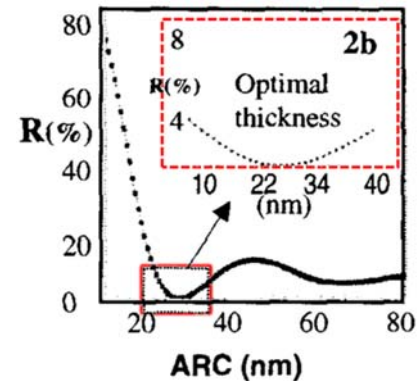
### C. Lee (Ex. 1018)

88. Lee also describes silicon oxynitride antireflection layers. Lee describes such antireflection layers (**green**) provided over metal substrates (**blue**) such as

interconnects. Ex. 1018, p. 1. Lee explains that the antireflection layer ARC finds application with aluminum (Al) substrates. Ex. 1018, p. 1 (ARC Design and Lithography). The antireflection coatings are proposed for “deep-UV lithography,” which indicates use of radiation at 248 nm or less. *Id.*, Abstract.



Lee (Ex. 1018), FIG. 1 (annotated)



Lee (Ex. 1018), FIG. 2b (annotated)

89. Lee illustrates reflectivity of the silicon oxynitride antireflection layers over a variety of ARC layer thicknesses. *Id.*, FIG. 2b. Lee’s FIG. 2b illustrates in an inset (*red*) that the reflectivity *R* is less than 10% over an ARC film thickness between 10-40 nm (100-400Å). *Id.* For ARC thicknesses between 120Å-360Å reflectivity of the ARC changes less than 2%.

90. Lee also describes application to transistor gate fabrication and DRAM circuitry. *Id.*

**D. Shibata (Ex. 1010)**

91. Shibata is Japanese Unexamined Patent Application Publication No. Hei 08-191068. I understand that it was published on July 23, 1996, and it is prior art to the '231 patent under 35 U.S.C. § 102(b). I have used a certified translation of Shibata (Ex. 1011) for purposes of the analysis in this report.

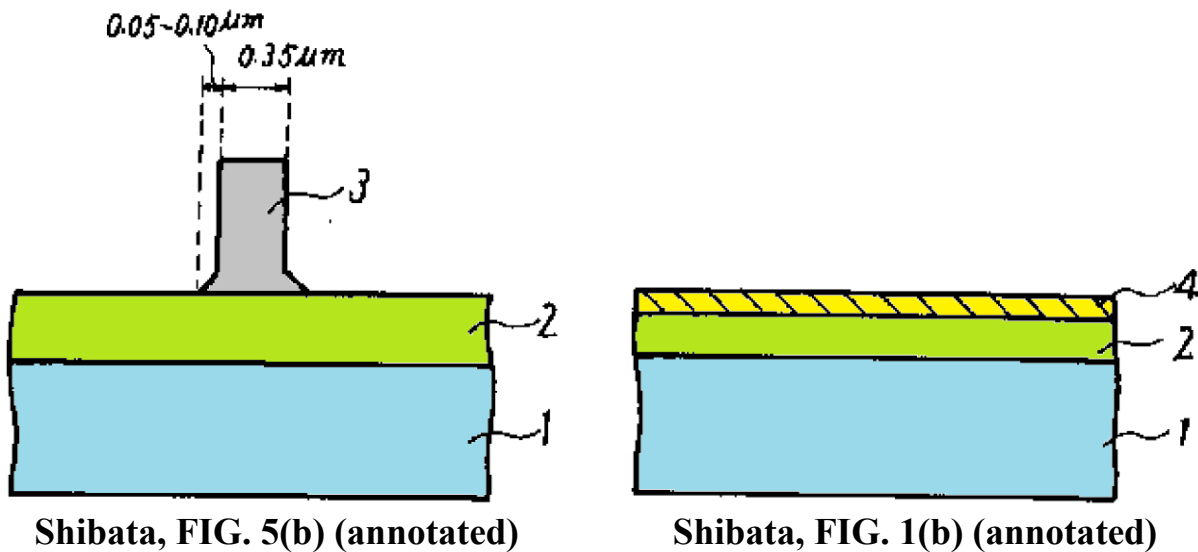
92. Shibata proposes use of an oxide layer (called an “oxide film” 4) interposed between a silicon oxynitride antireflection layer (“antireflection film” 2) and a photoresist 3 to prevent chemical interaction between the silicon oxynitride layer and the photoresist.

93. Shibata describes semiconductor manufacturing techniques that improve patterning precision of photoresists when antireflection films are used. Ex. 1011, ¶¶ 0005-6. Shibata teaches that antireflection films made of silicon nitride or silicon oxynitride (which he calls “P-SiN” and “P-SiON” films, respectively) conventionally were used with highly-reflective surfaces such as aluminum or tungsten. *Id.*, ¶¶ 0002-4. Shibata indicates these antireflection films caused patterning problems because nitrogen atoms from the P-SiN and P-SiON films react with hydrogen atoms in resist films, which lowered patterning accuracy. *Id.*, ¶ 0005.

94. Shibata illustrates a manufacturing process in FIG. 5(b) that Shibata identified as prior art. There, a highly-reflective film 1 (**blue**) is provided on a



semiconductor substrate (not shown). The antireflection film 2 (**green**) is formed on the first film 1, having a thickness of 100-1,000 Å. Resist 3 (**gray**) is provided on the anti-reflective film 2.



95. Shibata states:

[0002] [Prior Art] Figure 5 is a cross-sectional view showing a manufacturing process of a conventional semiconductor device. In the figure, 1 is a first film made of a material having high reflectance such as aluminum, tungsten or the like formed on a semiconductor substrate (not shown,) 2 is a plasma nitride film formed on first film 1 for example, as an antireflection film formed with a thickness of 100–1000 angstroms (hereinafter referred to as a P-SiN film,) and 3 is a positive chemically amplified resist film formed on P-SiN film 2.

[0003] Next, the manufacturing process of the conventional semiconductor device configured as described above will be described. First, P-SiN film 2 is laminated on first film 1 on the semiconductor

substrate. At this time, impurities such as nitrogen atoms and nitrogen molecules adhere to the upper surface of the P-SiN film 2 (Figure 5 (a.)) Next, a chemically amplified resist is applied on P-SiN film 2 and patterned to form a positive chemically amplified resist film 3 (Figure 5 (b.)) At this time, nitrogen atoms and nitrogen molecules adhering to P-SiN film 2 react with hydrogen atoms in chemically amplified resist film 3, for example when a pattern of 0.35  $\mu\text{m}$  is formed, tugging of 0.05–0.10  $\mu\text{m}$  occurs on the side of chemically amplified resist film 3, which is in contact with P-SiN film 2 as shown in Figure 5 (b.)

[0005] [Problem to be Solved by the Invention] The conventional semiconductor device is configured as described above, and is provided with P-SiN film 2 or a P-SiON film as an antireflection film for improving the accuracy of patterning a chemically amplified resist on first film 1. However, since nitrogen atoms and nitrogen molecules adhere to the upper surface of P-SiN film 2 or the P-SiON film and nitrogen atoms in P-SiN film 2 react with hydrogen atoms in the chemically amplified resist film, there is a problem that the accuracy of patterning of the chemically amplified resist is lowered.

Ex. 1011, ¶¶ 0002-05.

96. As shown in FIG. 1(b), Shibata proposes to apply a plasma treatment to the antireflection film 2 (*green*) to form an oxide film 4 (*yellow*) thereon. *Id.*, ¶ 0007.

Formation of the oxide film 4 causes nitrogen to be removed, which prevents reaction between the nitrogen and the resist. Removal of nitrogen causes the oxide

film 4 to function as a barrier to migration of nitrogen which remains present in the remaining portion of the antireflection film 2.

97. Shibata states:

[0010] [Effect] Since the method for manufacturing a semiconductor device according to Claim 1 of the present invention is such that a plasma nitride film or plasma oxynitride film is laminated on a first film, plasma treatment using a gas having oxidizing power is applied to the upper surface of the plasma nitride film or plasma oxynitride film to form an oxide film and a chemically amplified resist is coated on the oxide film and patterned, nitrogen is removed from the plasma nitride film or the plasma oxynitride film so as to *prevent reaction between the nitrogen and the chemically amplified resist*.

[0012] In addition, since the method for manufacturing a semiconductor device according to Claim 3 of the present invention is such that a plasma oxynitride film is laminated on a first film, a sputter etching of argon or nitrogen is performed on the upper surface of the plasma oxynitride film, and a chemically amplified resist is applied on the plasma oxynitride film for patterning, the nitrogen on the plasma oxynitride film is removed to *prevent reaction between this nitrogen and the chemically amplified resist*.

[0018] In other words, if the above process conditions are satisfied, oxide film 4 can be formed to a thickness of 40 angstroms or more on the upper surface of P-SiN film 2, the nitrogen atoms at the upper part (depth of 40 angstroms) of P-SiN film 2 are removed, and *it is possible to reliably prevent the reaction with the chemically amplified resist film 5*. In

addition, since the thickness of oxide film 4 can be suppressed to 100 angstroms or less, there is no influence on the reflectance of the lower P-SiN film 4 as an anti-reflection film.

[0019] Since, in the manufacturing method of the semiconductor device of Embodiment 1 manufactured as described above, nitrogen atoms and nitrogen molecules adhering to the upper surface of P-SiN film 2 and nitrogen atoms in P-SiN film 2 are removed and oxide film 4 are formed, *it is possible to prevent reaction with chemically amplified resist film 5 without impairing the function of P-SiN film 2 as an antireflection film is not impaired*, and accordingly it is possible to perform accurate patterning. In addition, since oxide film 4 can be formed continuously in the same apparatus as the film formation of P-SiN film 2, the increase in the number of steps can be minimized.

*Id.*, ¶ 0010, 0012, 0018-0019 (emphases added).

98. Shibata's manufacturing process, therefore, includes an anti-reflective film 2 (**green**) provided on a highly-reflective film 1 (**blue**) of aluminum or tungsten. *Id.*, ¶ 0002.

99. The anti-reflective film 2 may be plasma nitride or plasma oxynitride and may have a thickness of 100-1,000 Å. Shibata states:

[0002] [Prior Art] Figure 5 is a cross-sectional view showing a manufacturing process of a conventional semiconductor device. In the figure, 1 is a first film made of a material having high reflectance such as aluminum, tungsten or the like formed on a semiconductor substrate (not

shown,) 2 is a plasma nitride film formed on first film 1 for example, as *an antireflection film formed with a thickness of 100–1000 angstroms* (hereinafter referred to as a P-SiN film,) and 3 is a positive chemically amplified resist film formed on P-SiN film 2.

[0022] Embodiment 4. Figure 4 is a diagram for explaining the principle of the manufacturing process of the semiconductor device in Embodiment 4 of the present invention. In the figure, 6 is *a P-SiON film formed as an antireflection film on first film 1 at a thickness of, for example, 100–1000 angstroms*, 11 is an argon atom, 12 is a nitrogen atom, and 13 is a nitrogen molecule.

*Id.*, ¶ 0002, 0022 (emphases added). *See also*, ¶¶ 0009-0010, 0017, 0027, 0029.

Shibata discloses that the oxynitride is silicon oxynitride. The “S” in P-SiON demonstrates presence of silicon.

100. The oxide layer 4 is formed on the anti-reflective film 2 by exposing a top surface of the anti-reflective film to a plasma. *Id.*, ¶¶ 0007, 0015, 0017, 0021. The oxide film 4 may have a thickness of 40-100 Å. Shibata states:

[0017] The following experiment was attempted using the apparatus of Figure 2. Plasma treatment using nitrous oxide as a gas having oxidizing power after forming a P-SiN film to a thickness of 450 angstroms on a silicon substrate was performed under varying the processing conditions of the apparatus of Figure 2, the formation of an oxide film having a thickness of a few angstroms was examined by XPS (abbreviation of X-ray Photoelectron Spectroscopy,) and the results are shown in Figure 3.

According to Figure 3, it was found that suitable processing conditions are as follows: the distance between the electrodes is 5–15 mm, the pressure in the chamber is 1.6–6 Torr, the flow rate of nitrous oxide is 1–5 l/min, the plasma output is, for example, for a wafer 8 inches in diameter, 0.3–3 w/cm<sup>2</sup>, and the processing time is 5–180 sec. In addition, it can be inferred that the same result can be obtained regardless of whether P-SiON film is used instead of P-SiN film or a gas having oxidizing power is used instead of nitrous oxide.

[0018] In other words, if the above process conditions are satisfied, oxide film 4 can be formed to a ***thickness of 40 angstroms or more*** on the upper surface of P-SiN film 2, the nitrogen atoms at the upper part (depth of 40 angstroms) of P-SiN film 2 are removed, and it is possible to reliably prevent the reaction with the chemically amplified resist film 5. In addition, since the thickness of oxide film 4 can be suppressed to ***100 angstroms or less***, there is no influence on the reflectance of the lower P-SiN film 4 as an anti-reflection film.

*Id.*, ¶¶ 0017-18 (emphases added). *See also*, ¶ 0013.

101. In FIG. 3 (below), Shibata provides several examples of oxide thickness, including variants with 35Å and 40Å thicknesses (**yellow**):

Plasma output (W)	Processing time (sec)	Distance between electrodes (mm)	Chamber pressure (Torr)	N <sub>2</sub> O flow rate (l/min)	Thickness of oxide film (angstroms)
300	30	12.5	4.25	1	40
600	30	12.5	4.25	1	54
600	60	12.5	4.25	1	59
900	30	12.5	4.25	1	63
900	60	12.5	4.25	1	68
300	180	12.5	4.25	1	70
300	30	12.5	1.6	1	70
300	30	12.5	6.0	1	70
300	30	12.5	4.25	3	40
300	30	12.5	4.25	5	40
300	30	5	4.25	1	60
300	30	15	4.25	1	35

Shibata, FIG. 3 (annotated)

102. Shibata discloses that the plasma may be either a nitrogen plasma or an oxygen plasma. Shibata states:

[0015] Next, the upper surface of P-SiN film 2 is formed by using the same apparatus subsequently to the formation of P-SiN film 2, and oxide film 4 is formed by plasma treatment with a gas having oxidizing power such as *nitrous oxide* (Figure 1 (b.)) At this time, nitrogen atoms and nitrogen molecules on the upper surface of P-SiN film 2 and nitrogen atoms in P-SiN film 2 are removed by oxygen atoms in the nitrous oxide, oxygen atoms are introduced instead and oxide film 4 is formed. Next, a chemically amplified resist is coated on oxide film 4 and patterned to form positive chemically amplified resist film 5 (Figure 1 (c.))

Ex. 1011, ¶ 0015 (emphasis added).

[0021] Embodiment 3. Although nitrous oxide was used as a gas having oxidizing power for plasma processing in each of the above-described embodiments, it goes without saying that any gas may be used as long as

it has oxidizing power, and it goes without saying that the same effect is exhibited even if, for example, *oxygen, is used*.

*Id.*, ¶ 0021 (emphasis added).

103. Shibata, therefore, disclose an antireflection coating comprising a silicon oxynitride layer and an oxide layer for use over metal substrates.

104. Shibata also discloses that, as long as the thickness of the oxide layer 4 is kept below 100 angstroms, the oxide layer 4 does not affect reflectivity of the underlying P-SiN or P-SiON antireflection film. Shibata states:

[0018] In other words, if the above process conditions are satisfied, oxide film 4 can be formed to a thickness of 40 angstroms or more on the upper surface of P-SiN film 2, the nitrogen atoms at the upper part (depth of 40 angstroms) of P-SiN film 2 are removed, and it is possible to reliably prevent the reaction with the chemically amplified resist film 5. In addition, *since the thickness of oxide film 4 can be suppressed to 100 angstroms or less, there is no influence on the reflectance of the lower P-SiN film 4 as an anti-reflection film*.

*Id.*, ¶ 0018 (emphasis added).

105. Shibata explains that the characteristics of the antireflection film may be adjusted along with other processing conditions to achieve a predetermined reflectance with respect to a wavelength of light used for exposure. *Id.*, ¶ 0026.

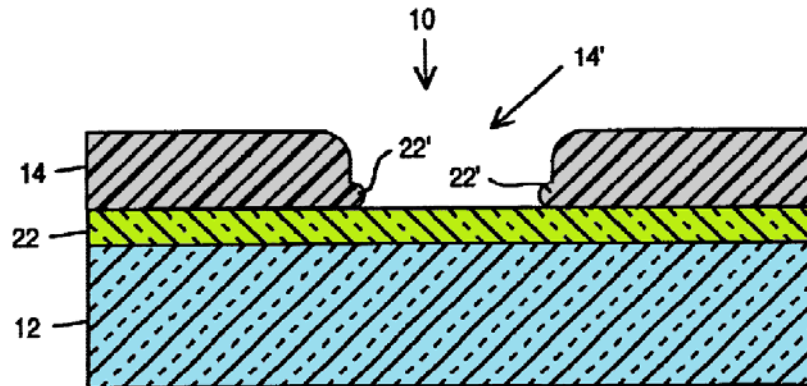


**E. Foote ‘007 (Ex. 1013)**

106. Foote ‘007 is a United States patent that was filed on May 15, 1997. I understand that Foote ‘007 is prior art to the ‘231 patent under 35 U.S.C. § 102 (e).

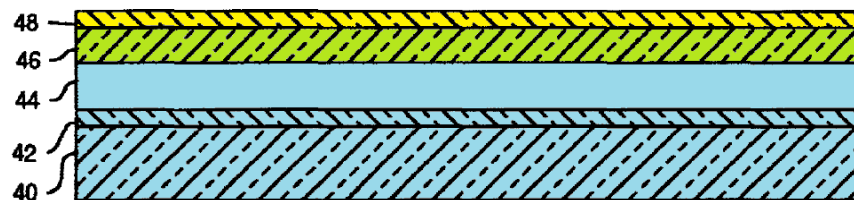
107. Foote ‘007 describes an antireflective coating for use in semiconductor fabrication. Ex. 1013, *Abstract*. The antireflective coating includes an anti-reflective layer of silicon oxime, silicon oxynitride, or silicon nitride, and a barrier layer of silicon dioxide. *Id.* The barrier layer prevents interaction between the anti-reflective layer and a photoresist layer that overlies the antireflective coating, which contributes to a phenomenon called “footing.” *Id.*

108. Foote ‘007 explains that footing degrades resolution of photolithography processes. *Id.*, FIG. 4 (below). Footing is caused by chemical interaction between an anti-reflective layer 22 (**green**) and a photoresist 14 (**gray**). *Id.* at 2:55-67. Specifically, amines (hydrogen-nitrogen bonds) in a silicon oxime anti-reflective layer 22 interact with the photoresist material. The footing appears as enlarged portions 22’ of the photoresist layer 14 in FIG. 4. *Id.*



Ex. 1013, FIG. 4 (annotated)

109. Foote '007 explains, by the time his patent was filed (May 1997), it was already known that footing can be inhibited by forming a silicon dioxide barrier layer (not shown in FIG. 4) on the surface of the anti-reflective layer 22 before the photoresist 14 is formed. *Id.*, at 3:1-6. This barrier layer prevents the amines from interacting with the photoresist 14. Foote '007 explains that, before advent of his proposal, prior art fabrication techniques created silicon dioxide barrier layers that either were too thick (100 Å or more) or too thin (less than 10 Å) to be practical. *Id.*, at 3:7-21.



Foote '007, FIG. 5b (annotated)

110. Foote '007 describes a semiconductor structure having a substrate 40, a gate oxide layer 42, and a polysilicon layer 44 (all *blue*). *Id.* at 6:25-31, FIG. 5(b)

(above). Foote '007 describes the polysilicon layer 44 as “any suitable semiconductor, metal, or other material layer” *Id.*, 1:22-27, 6:31-35, 12:30-46.

111. An anti-reflective layer 46 (**green**) is formed on the metal layer 44 (**blue**), and is made of silicon oxime, silicon oxynitride or silicon nitride. *Id.*, 6:25-45.

112. A silicon dioxide barrier layer 48 (**yellow**) is formed on the anti-reflective layer 46 using a nitrous oxide (N<sub>2</sub>O) plasma, which converts a surface portion of the anti-reflective layer 46 to silicon dioxide. *Id.*, 6:25-30, 6:55-7:7.

113. Foote '007 states:

FIG. 5 a illustrates a semiconductor structure at an intermediate step in the overall fabrication process, including a silicon substrate 40, a gate oxide layer 42 formed on the substrate 40, a polysilicon material layer 44 formed on the gate oxide layer 42, and an anti-reflective layer 46 formed on the polysilicon layer 44.

In the illustrated example, the polysilicon layer 44 is to be patterned to form a conductive gate for a field-effect transistor using photolithography. However, the present invention is not so limited, and ***can be applied to patterning*** any suitable semiconductor, ***metal***, or other material layer.

The anti-reflective layer 46 is preferably formed of silicon oxime (SiNO:H), ***silicon oxynitride*** (SiON:H), or silicon nitride (Si<sub>3</sub>N<sub>4</sub>:H). An anti-reflective layer of any of these materials is suitable for ***deep ultraviolet (DUV) photolithography at a wavelength of typically 248***

*nanometers*, or more conventional i-line ultraviolet photolithography at longer wavelengths.

Ex. 1013, Col. 6:25-43 (emphases added).

114. The anti-reflective layer 46 (**green**) has a thickness of approximately 200-400 angstroms. Foote '007 states:

In a preferred embodiment of the present invention, the anti-reflective layer 46 is formed of silicon oxime in a Plasma Enhanced Chemical Vapor Deposition (PECVD) reactor to *a thickness  $t$  of approximately 200 to 400, preferably 300 angstroms*. The values of refractive index  $n$  and extinction coefficient  $k$  for the anti-reflective layer 46 are optimized for DUV photolithography at a wavelength of 248 nanometers. Preferred values of these parameters are  $n=2.1$  to  $2.2$ , and  $k=0.5$  to  $0.7$ . The relative proportions of silicon, oxygen and nitrogen in the anti-reflective layer 46 are selected to produce these values.

Ex. 1013, Col. 6:44-54 (emphasis added).

115. The silicon dioxide barrier layer 48 (**yellow**) has a thickness of 10-40 Å.

Foote '007 states:

The present barrier layer is not formed by deposition as in the prior art. Instead, the barrier layer is grown by bombardment of the anti-reflective layer by ion species from the nitrous oxide plasma such that a portion of the surface of the anti-reflective layer is consumed by the reaction and converted into silicon dioxide. *This enables the barrier layer to be*

*grown to a thickness on the order of 10 to 40 (more preferably 15 to 25) angstroms*, which is substantially thinner than can be formed by deposition of silicon dioxide (100 angstroms or more).

*Id.*, at 5:12-21 (emphasis added).

The plasma growth process is continued for approximately 20 seconds which enables the silicon dioxide barrier layer 48 to be grown to a thickness on the order of *10 to 40 (more preferably 15 to 25) angstroms*.

*Id.*, at 7:4-7 (emphasis added).

116. Foote '007 explains that the silicon dioxide barrier layer 48 prevents interaction between the antireflective layer 46 and the photoresist layer 50 that causes footing. Foote '007 states:

The *barrier layer* prevents interaction between the anti-reflective layer and the photoresist layer that could create footing.

Ex. 1013, Abstract (emphasis added).

It is known that this interaction, and thereby the footing, can be inhibited by forming a silicon dioxide barrier layer on the surface of the silicon oxime layer before forming the photoresist thereon. *The barrier layer acts as a seal or cap which separates the amines in the silicon oxime layer from the photoresist layer 14.*

Ex. 1013, Col. 3:1-6 (emphasis added).

The anti-reflective coating includes an anti-reflective layer of silicon oxime (SiNO:H), silicon oxynitride (SiON:H), or silicon nitride. (Si<sub>3</sub>N<sub>4</sub>:H), and a barrier layer which is grown on the anti-reflective layer using a nitrous oxide plasma discharge to convert a surface portion of the anti-reflective layer into silicon dioxide.

*The barrier layer prevents interaction between the anti-reflective layer and the photoresist layer that could create footing.* The anti-reflective layer is deposited on the material layer using Plasma Enhanced Chemical Vapor Deposition (PECVD) in a reactor. The barrier layer is grown on the anti-reflective layer in-situ in the same reactor, thereby maximizing throughput.

Ex. 1013, Col. 4:66-5:11 (emphasis added).

117. I understand that Foote '007 (Ex. 1013) may not be available for use in obviousness analysis because it is assigned to Advanced Micro Devices, the original assignee of the '231 patent. In my analysis, I limited my consideration of Foote '007 only to anticipation analyses. I did not consider Foote '007 as part of an obviousness analysis. Foote '007 does not factor into my analyses, for example, of the state of the art, general teachings within the art or analyses of motivation to combine.

**F. Cheung (Ex. 1012)**

118. Cheung is a United States patent that was filed on November 4, 1996. I understand that Cheung is prior art to the '231 patent under 35 U.S.C. § 102(e).

119. Cheung proposes use of an oxide layer (called a “capping layer” 240) interposed between a silicon oxynitride antireflection layer (antireflection coating 210) and a photoresist layer 220 to prevent chemical interaction between the silicon oxynitride layer and the photoresist.

120. Cheung explains that antireflective coatings are well known solutions to problems of back reflection in photolithography. Cheung, for example, states:

Reflections from the underlying layer also may cause a phenomenon known as standing waves. When a photoresist layer is deposited on a reflective underlying layer and exposed to monochromatic radiation (e.g., deep ultraviolet (UV) light), standing waves may be produced within the photoresist layer. In such a situation, the reflected light interferes with the incident light and causes a periodic variation in light intensity within the photoresist layer in the vertical direction. ... The existence of standing waves in the photoresist layer during exposure causes roughness in the vertical walls formed when the photoresist layer is developed, which translates into variations in line widths, spacing and other critical dimensions.

One technique helpful in achieving the necessary dimensional accuracy is the use of an antireflective coating (ARC). An ARC's optical characteristics are chosen to minimize reflections occurring at interlayer interfaces. ...

FIG. 1A illustrates another phenomenon often encountered in photolithography, known as footing. In a traditional photolithographic process, a layer 110, which is to be patterned, is deposited or grown on a

substrate 120. In a traditional patterning process, a photoresist layer 130 is first deposited on layer 110. Photoresist layer 130 is then developed (i.e., patterned). This pattern is exemplified in FIG. 1A by a gap 140. Once photoresist layer 130 has been developed, the exposed areas of layer 110 may then be subjected to further processing, such as doping, etching or the like.

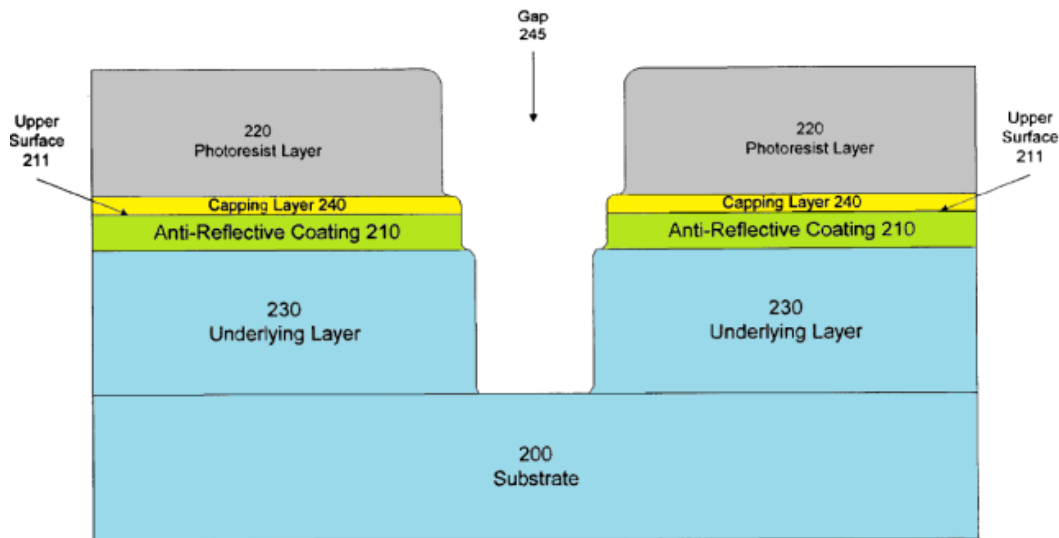
As is illustrated in FIG. 1A, after photoresist layer 130 is patterned, residual photoresist material may remain in junction areas 150 and 160. This residue, or footing, can cause variations in line width. Footing is underexposed photoresist material, which may remain at the foot of the vertical walls that are formed during the developing of photoresist layer 130. Footing is caused by the existence of amino groups ( $\text{NH}_4^+$ ) at the surface of layer 110, and therefore is related to the amount of nitrogen contained in layer 110. Amino groups are slightly basic, and can form bonds with the photoresist material (which is slightly acidic) at a bottom portion of photoresist layer 130. When this occurs, the affected photoresist material is desensitized to radiant energy. Given this reduced photosensitivity, the bottom portion of photoresist layer 130 resists developing completely, and so may remain after the photoresist layer is developed. Some desensitized areas, such as areas in the center of gaps and large open areas, can be fully exposed by simply increasing the exposure's duration.

Ex. 1012, Col. 2:12-3:7.

121. Cheung proposes a semiconductor processing technique that uses an antireflective coating having a silicon oxynitride layer 210 (**green**) and a silicon



oxide capping layer 240 (**yellow**). The antireflective coating is provided on an underlying layer 230 (**blue**) and substrate 200 (also **blue**).



**Cheung, FIG. 3A (annotated)**

122. Cheung explains that the capping layer addresses the footing problem experienced in the prior art. Cheung states:

According to the method of the present invention, a low nitrogen content layer is deposited over the upper surface of an ARC to reduce the number of amino groups presented to a subsequently applied photoresist layer, thereby reducing footing experienced in the photoresist layer. The method of the present invention begins by depositing an ARC, which is preferably a layer of silicon oxynitride ( $\text{SiO}_x\text{N}_y$ ) or silicon nitride ( $\text{SiN}_x$ ), over a substrate. The ARC is deposited to reduce the reflection and refraction of incident radiant energy occurring in a subsequently applied photoresist layer. Next, a low nitrogen content layer, such as a silicon oxide layer, is deposited. This layer is referred to herein as a capping layer. The capping layer passivates amino groups that may exist at the

upper surface of the ARC, thereby improving the accuracy with which the substrate is patterned. The capping layer's thickness is selected so that it does not substantially adversely alter the ARC's optical qualities. The photoresist layer is then deposited over the capping layer, after which a traditional patterning process is followed, including developing the photoresist, patterning the substrate, and removing the remaining photoresist, capping layer and ARC material after the substrate has been patterned.

Ex. 1012, Col. 4:48-5:3.

123. Cheung teaches use of a silicon oxynitride layer 210 (**green**) having a thickness between 50 Å and 1000 Å. Cheung states:

A silicon oxynitride ( $\text{SiO}_x\text{N}_y$ ) ARC (or DARC) was used in these simulations because the use of such an ARC is preferred in the present invention. The simulated DARC was tuned for deep UV, and exhibited a refractive index of 2.15 and absorptive index of 0.53, again at a wavelength of 248 nm. The DARC's thickness was selected by simulating various DARC thicknesses between 50 Å and 1000 Å. This was done for a DARC layer applied over both tungsten silicide and polysilicon. As expected, the minimum reflectivity at the photoresist/DARC interface occurred at a DARC thickness of about 300 Å.

Ex. 1012, Col. 17:29-39.

124. Cheung teaches use of a capping layer 240 (**yellow**) having a thickness of 50-150Å

Capping layer 240 is a layer of low nitrogen content material, such as silicon oxide, deposited between ARC 210 and photoresist layer 220 to reduce footing in photoresist layer 220. Preferably, capping layer 240 is deposited to a thickness of between about 50 Å and 150 Å when the wavelength of radiant energy used to develop photoresist layer 220 is about 248 nm.

Ex. 1012, Col. 12:66-5. This range abuts the range recited in claim 1, namely 5-50 Å.

125. Cheung explains that the underlying layer 230 (**blue**) may contain aluminum, polysilicon or tungsten silicide. Ex. 1012, Col. 13:40-44.

126. Cheung exposes the photoresist to radiation at a wavelength of 248 nm and develops the photoresist. *Id.*, Col. 12:64-13:8.

127. Cheung's manufacturing techniques achieve patterns that varied between about 0.275 µm and 0.310 µm, averaging about 0.289 µm. *Id.*, Col. 18:10-14.

128. Cheung discloses use of oxide layers as a barrier to prevent chemical interaction between silicon oxynitride (also silicon nitride) anti-reflection coatings and photoresist. Ex. 1012, Col. 4:48-5:3. Cheung provides an oxide layer to reduce footing in photoresist (*Id.*, at 12:64-13:8) – the same reason that Foote '007

provides his oxide layer. Ex. 1013, at 3:1-6. Cheung also discloses forming the oxide layer using an N<sub>2</sub>O plasma. Ex. 1012, at 16:11-60.

129. Cheung teaches that, as an alternative for an N<sub>2</sub>O plasma, oxygen plasmas may be used:

These process gases preferably include silane (SiH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O). Nitrous oxide is an acceptable process gas because little or none of the nitrogen therein is incorporated into the resulting film. However, other processes for depositing a silicon oxide film may be used, as long as the process selected provides the necessary control of thickness. Examples of acceptable processes includes *a PECVD process using TEOS and oxygen (O<sub>2</sub>)*, a thermal CVD process using TEOS and ozone (O<sub>3</sub>), and growing a silicon oxide layer. Of primary importance is the film's rate of formation, which should allow for the necessary control over the film's thickness and uniformity.

Ex. 1012, at 16:19-31 (emphasis added). *See also*, 6:40-45 (“PECVD” refers to plasma-enhanced chemical vapor deposition).

**G. Konjuh (Ex. 1015)**

130. Konjuh is U.S. Patent No. 6,051,282, which was filed as U.S. Patent application s.n. 09/090,848 on June 4, 1998. I understand that Konjuh is prior art to the ‘231 patent under 35 U.S.C. § 102(e).

131. Konjuh proposes use of an oxide layer interposed between a silicon oxynitride antireflection layer (called an “ARL”) and a photoresist layer 10 to prevent chemical interaction between the silicon oxynitride layer and the photoresist.

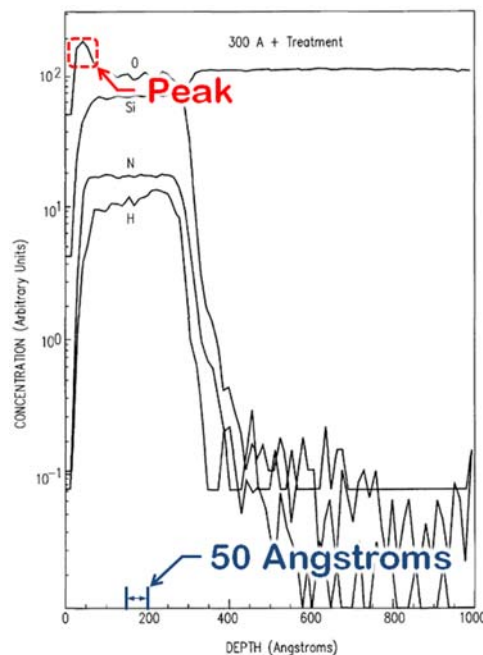
132. Konjuh cites Ogawa as describing an example of deep ultraviolet antireflective layers. Ex. 1015, Col. 1:26-40. As part of this discussion, Konjuh describes inorganic ARLs as being thinner than organic ARLs (300Å vs. 1500Å) and being formed by chemical vapor deposition. *Id.* Konjuh cites silicon oxynitride as an example of an inorganic ARL. Konjuh, however, explains that silicon oxynitride ARLs have problems, namely that amines (NH<sub>2</sub> groups), which form on the surface of the ARL layer, inhibit development of the photoresist, which leads to footing. *Id.*, Col. 1:4-63.

133. Konjuh proposes forming a surface layer on an ARL to counteract the effect of amines. *Id.*, Col. 2:36-67. The ARL is exposed to a nitrous oxide gas (N<sub>2</sub>O) in the presence of radio frequency power. *Id.* This describes a nitrous oxide plasma.

134. Elsewhere, Konjuh describes that other oxygen-containing gases such as pure oxygen can be substituted for the N<sub>2</sub>O plasma. *Id.*, Col. 4:6-15. Konjuh explains that use of pure oxygen, however, will increase the number of process steps because other process gases, such as silane, would react with oxygen. Thus

the process gases would have to be flushed from processing chambers before the oxygen is introduced. *Id.* Nevertheless, Konjuh teaches use of oxygen plasmas.

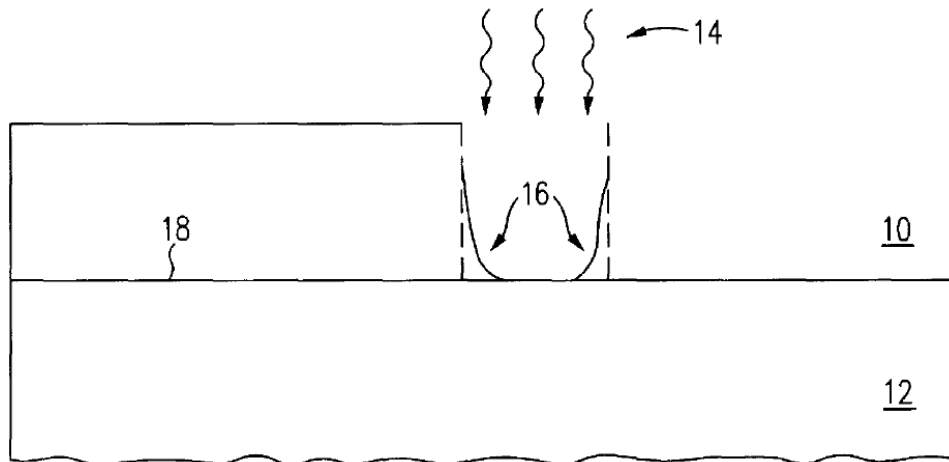
135. Konjuh teaches that the surface treatment creates a silicon dioxide layer at the surface of the silicon oxynitride antireflective layer. *Id.*, Col. 2:36-67. Konjuh does not expressly identify the thickness of her oxide layer. Instead, Konjuh explains that the oxide layer corresponds to the peak of the oxygen concentration illustrated in FIG. 3. *Id.*, Col. 2:58-67. In FIG. 3, the peak has a width of approximately 50Å.



**Konjuh, FIG. 3 (annotated)**

136. Konjuh explains that the surface layer provides a barrier that prevents the amines from migrating into the photoresist layer. *Id.*, Col. 2:35-39.

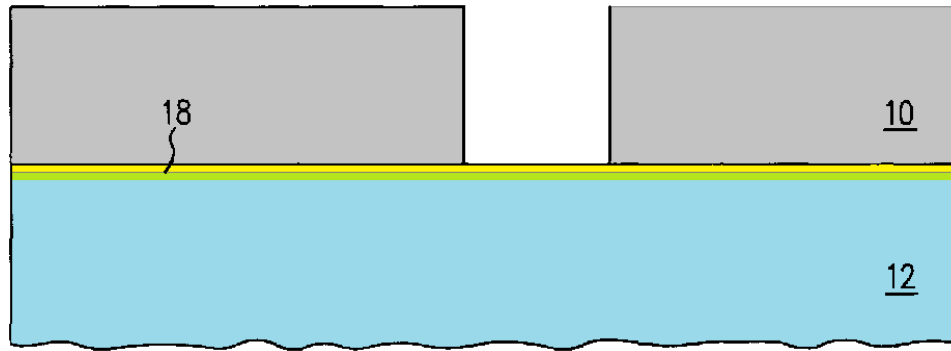
137. Konjuh does not provide a drawing that illustrates her structure after surface treatment. Konjuh illustrates a prior art structure in FIG. 1, which illustrates footing problems with conventional silicon oxynitride ARLs.



**Konjuh (Ex. 1015), FIG. 1 (PRIOR ART)**

138. In FIG 1, a substrate 12 possesses a silicon oxynitride ARL 18. A photoresist 10 is placed on the silicon oxynitride ARL 18. Konjuh illustrates photoresist footing 16 as a portion that remains after developing the photoresist layer. *Id.*, Col. 1:50-63.

139. The figure below illustrates an antireflection coating that is formed as a result of the surface treatment.



**Konjuh (Ex. 1015), FIG. 1 (annotated, modified)**

140. Above, Konjuh's FIG. 1 has been altered to illustrate the oxide layer created by the surface treatment of the ARL 18. FIG. 1 identifies the substrate 12 (*blue*), the ARL 18 (*green*) and the photoresist 10 (*gray*) from the prior art structure. *Id.*, at 1:50-63. The surface layer has been added, shown in *yellow*. Also, the footing effects 16 from FIG. 1 have been removed because Konjuh explains that the surface layer prevents amines from migrating into the photoresist. *Id.*, at 2:45-47.

141. Konjuh does not identify the material composition of the substrate 12 (*blue*). Again, Konjuh cites to Ogawa (*Id.*, Col. 1:28-32), which describes applications to tungsten-silicide (W-Si) and aluminum-silicon (Al-Si) substrates.

#### **H. Joesten (Ex. 1017)**

142. Joesten is an article that was published in June 1998. I understand that Joesten is prior art to the '231 patent under 35 U.S.C. § 102(a). Kathy Konjuh of Novellus Systems, the first named inventor of Konjuh (Ex. 1015, assigned to Novellus Systems) is a co-author of Joesten. All authors of Joesten are identified as



working for either Novellus Systems (a semiconductor equipment manufacturer) or Shipley Company (a photoresist manufacturer).

143. Joesten describes various techniques for reducing footing in deep ultraviolet photoresists caused by silicon oxynitride antireflection layers. Joesten, like Konjuh, explains that footing arises due to formation of amines at the surface of the silicon oxynitride layer, which contaminate photoresists. Ex. 1017, § 1.

144. Joesten describes several experiments with the antireflection layer, including applying surface treatments of the silicon oxynitride layer and varying reflectivity. *Id.*, Abstract. The surface treatments include forming an oxide cap on the silicon oxynitride layer, post-ash treatment and several nitrous oxide plasma treatments. *Id.*

145. With respect to the nitrous oxide plasma experiments, Joesten describes a plasma treatment performed on a silicon oxynitride layer having a thickness of 300Å. Joesten concludes that the plasma treatment forms a thin oxide layer at the surface of the silicon oxynitride layer (although Joesten had difficulty confirming the exact composition of the film).

146. Joesten states:

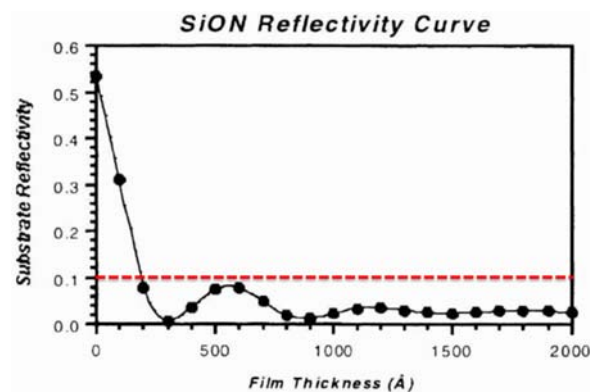
Nitrous oxide plasma treatments on a 300Å SiON film are also examined. The treatments involve nitrous oxide flow, high frequency power and time. A nitrous oxide plasma treatment is also thought to form a thin

oxide on the surface, the exact composition of the films is not known as surface analysis has proven difficult. ... In general, the nitrous oxide plasma treatments result in at least a 2X improvement in footing over a baseline film.

*Id.*, § 3.3.2.

147. The plasma treatment improves footing by 2X as compared to a baseline film. *Id.*

148. Joesten also reports various experiments altering reflectivity of her antireflection coatings to determine if reflectivity is related to footing. *Id.*, Abstract. In FIG. 10, for example, Joesten describes reflectivity of silicon oxynitride films based on the films' thicknesses. Reflectivity is shown to be less than 10% (*red*) for all silicon oxynitride thicknesses greater than 100Å.



**Joesten (Ex. 1017), FIG. 10 (annotated)**

149. Elsewhere, Joesten reports altering reflectivity of specific experimental samples to test for footing. Experiments are reported varying reflectivity of the antireflection coating from 1-22%:

An additional experiment is performed to determine if the degree of footing is dependent upon the total reflectivity, the standing wave phase at the substrate interface or a combined effect of the two. The experiment consists of five runs *varying reflectivity from 1.0% to 22.0%*. The resulting substrates have similar n and k values, except for *the 267Å film of 1% reflectivity*, and have a phase relationship relative to the reflectivity minimum at 300Å varying from -0.67 to 2.68 radians.

*Id.*, § 3.3.3 (emphases added).

150. Joesten describes that the antireflection coating is designed for deep ultraviolet photoresists that are to be exposed to radiation from KrF lasers. *See, Id.*, Abstract, § 2. KrF lasers generate radiation at 248 nm wavelengths.

# **I. Motivation to Combine Teachings**

151. In my opinion, the prior art references contain teachings that would motivate a skilled worker to consider the teachings of Ogawa, Lee, Shibata, Cheung, Konjuh and Joesten together.

152. All of these references are directed to use of antireflection coatings with the same material composition – silicon oxynitride.

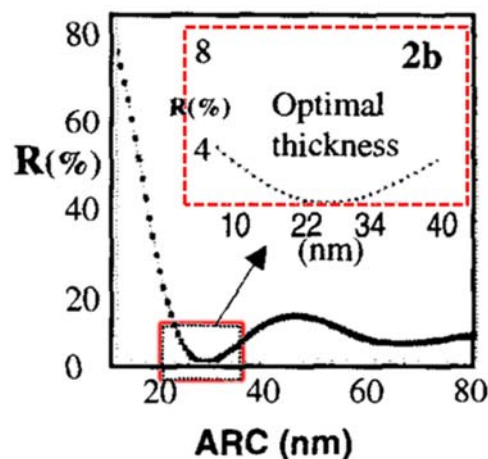
153. Shibata, Cheung, Konjuh and Joesten are directed at techniques for solving the footing problems that silicon oxynitride antireflection layers cause. Moreover, they describe nearly the same technique for solving this problem – forming of an oxide layer on the top surface of the silicon oxynitride to prevent chemical

interaction between the silicon oxynitride and a photoresist. Thus, a worker of skill would have ample motivation to consider the teachings of these references together.

154. Moreover, the prior art references contain teachings that motivate a skilled worker to vary thicknesses (claim 1) and reflectivity (claim 7) parameters of the antireflection coating to meet the claimed ranges.

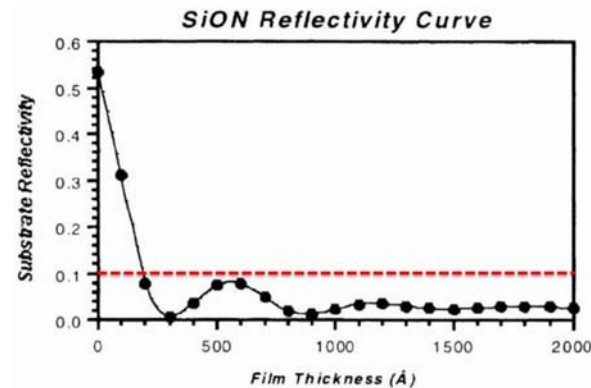
155. Ogawa and Shibata both teach that optimal thicknesses of the silicon oxynitride layer can be determined to suit individual circumstances, such as exposure wavelength. Ex. 1016, § 2.1; Ex. 1011, ¶ 0026.

156. Lee demonstrates that silicon oxynitride antireflection layers can reduce reflectivity to less than 10% for metal substrates. Lee illustrates a reflectivity curve in FIG. 2b:



Lee (Ex. 1018), FIG. 2b (annotated)

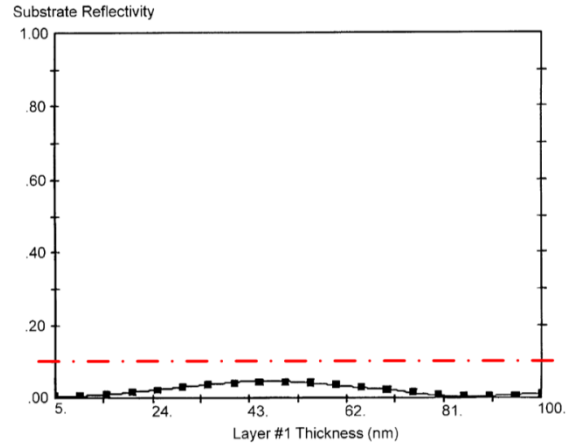
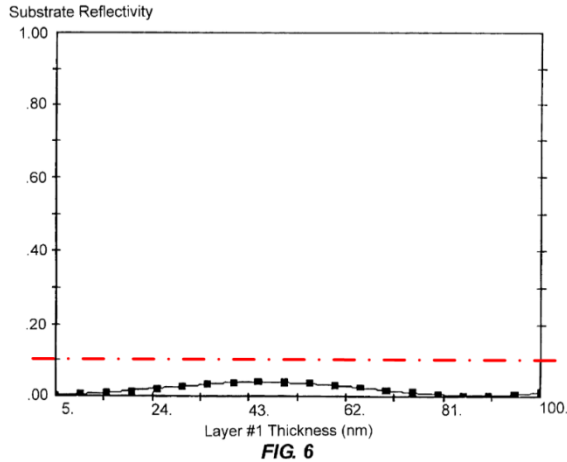
157. Joesten also analyzes performance of the silicon oxynitride layers across a range of surface treatments and reflectivity values, and assesses their effect on footing performance. Ex. 1017, §§ 3.3.2-3.3.4. Joesten also illustrates reflectivity in a graph:



**Joesten (Ex. 1017), FIG. 10 (annotated)**

158. Lee's and Joesten's reflectivity curves follow a common pattern. This suggests that the performance of silicon oxynitride antireflection coatings exhibit well understood, predictable patterns. Accordingly, it would be within the capability of an ordinarily skilled worker to design antireflection coatings with layer thicknesses that achieve desired reflectivity characteristics, such as reflectivities less than 10% at 248 nm wavelengths.

159. Similarly, Cheung simulates thicknesses of antireflection layers with oxide capping layers across a range of oxide thicknesses and estimates reflectivities that are obtained therefrom. Cheung illustrates reflectivity curves, as shown in FIGS. 6 and 7:



**Cheung (Ex. 1012), FIGS. 6, 7 (annotated)**

160. Cheung's simulations suggest that thin oxide layers will not disturb reflectivity characteristics of silicon oxynitride layers. In this regard, Cheung's simulations support Shibata's assertion that oxide layers that have thicknesses less than 100Å do not affect reflectivity. Ex. 1011, ¶ 0018

161. These teachings suggest that performance of dual layer silicon oxynitride / oxide antireflection coatings was a well understood, predictable field of endeavor by the time the '231 patent was filed. The references demonstrate that it was within the capability of a skilled worker to develop such antireflection coatings with the claimed layer thicknesses (claim 1) and reflectivities (claim 7).

## **IX. CLAIMS 1-5 ARE ANTICIPATED BY SHIBATA**

162. As stated above, it is my opinion that claims 1-5 are anticipated by Shibata, Exs. 1010, 1011. In this portion of my declaration, I explain the bases for my opinion.

**A. Shibata Anticipates Claim 1**

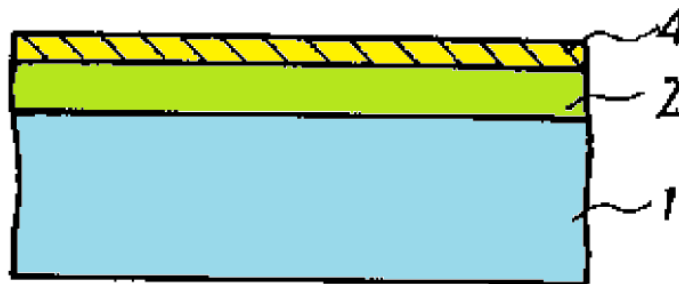
**1. Shibata discloses element [1.0]**

163. The preamble of claim 1, labeled element [1.0], states:

A method of forming a silicon oxynitride antireflection coating over a metal layer, comprising:

Shibata discloses this subject matter.

164. Shibata discloses a silicon oxynitride antireflection coating that is formed over a metal layer. These elements are shown in Shibata, FIG. 1(b), where the antireflection coating is formed from a silicon oxynitride layer 2 (*green*) and an oxide layer 4 (*yellow*). The silicon oxynitride antireflection coating is formed over metal layer 1 (*blue*).



**Shibata, FIG. 1(b) (annotated)**

165. Shibata describes the antireflection film as formed from silicon oxynitride, which Shibata describes as “P-SiON.” Shibata states:

The conventional semiconductor device is configured as described above, and is provided with P-SiN film 2 or *a P-SiON film as an antireflection*

*film* for improving the accuracy of patterning a chemically amplified resist on first film 1. However, since nitrogen atoms and nitrogen molecules adhere to the upper surface of P-SiN film 2 or the P-SiON film and nitrogen atoms in P-SiN film 2 react with hydrogen atoms in the chemically amplified resist film, there is a problem that the accuracy of patterning of the chemically amplified resist is lowered.

Ex. 1011, Col. 2 (Problem to be Solved by the Invention) (emphasis added).

166. Shibata also explains that the antireflection film is formed on a metal layer (film 1). Shibata states:

[0002] [Prior Art] Figure 5 is a cross-sectional view showing a manufacturing process of a conventional semiconductor device. In the figure, *1 is a first film made of a material having high reflectance such as aluminum, tungsten or the like* formed on a semiconductor substrate (not shown,) 2 is a plasma nitride film formed on first film 1 for example, as an antireflection film formed with a thickness of 100–1000 angstroms (hereinafter referred to as a P-SiN film,) and 3 is a positive chemically amplified resist film formed on P-SiN film 2.

Ex. 1011, ¶ 0002 (emphasis added).

167. Thus, Shibata discloses the subject matter of element [1.0].

## 2. Shibata discloses element [1.1]

168. The next element of claim 1, which is labeled element [1.1], states:



providing a semiconductor substrate comprising the metal layer over at least part of the semiconductor substrate;

Shibata discloses this subject matter.

169. Shibata discloses providing a semiconductor substrate (not shown in Shibata's drawings) comprising a metal layer 1 (*blue*) over at least part of the semiconductor substrate.



Shibata (Ex. 1011), FIG. 1(a) (annotated)

170. Again, Shibata explains that the antireflection film is formed on a metal layer (film 1). Shibata states:

[0002] [Prior Art] Figure 5 is a cross-sectional view showing a manufacturing process of a conventional semiconductor device. In the figure, *1 is a first film made of a material having high reflectance such as aluminum, tungsten or the like formed on a semiconductor substrate (not shown),* 2 is a plasma nitride film formed on first film 1 for example, as an antireflection film formed with a thickness of 100–1000 angstroms (hereinafter referred to as a P-SiN film,) and 3 is a positive chemically amplified resist film formed on P-SiN film 2.

Ex. 1011, ¶ 0002 (emphasis added).

171. Although the description of ¶ 0002 is made with reference to a prior art structure in FIG. 5, Shibata explains that the proposed structure also possesses the metal film 1. *See*, ¶ 0013 (components in FIG. 1 with same reference numerals as in the prior art design are the same).

172. Thus, Shibata discloses the subject matter of element [1.1].

### 3. Shibata discloses element [1.2]

173. The next element of claim 1, which is labeled element [1.2], states:

depositing a silicon oxynitride layer on the metal layer having a thickness from about 100 Å to about 1500 Å; and

Shibata discloses this subject matter.

174. Shibata discloses depositing a silicon oxynitride layer 2 (**green**) on the metal layer 1 (**blue**) having a thickness from about 100Å to about 1500Å.

175. Shibata states:

[0002] [Prior Art] Figure 5 is a cross-sectional view showing a manufacturing process of a conventional semiconductor device. In the figure, 1 is a first film made of a material having high reflectance such as aluminum, tungsten or the like formed on a semiconductor substrate (not shown,) *2 is a plasma nitride film formed on first film 1 for example, as an antireflection film formed with a thickness of 100–1000 angstroms (hereinafter referred to as a P-SiN film,)* and 3 is a positive chemically amplified resist film formed on P-SiN film 2.

Ex. 1011, ¶ 0002 (emphasis added).

[0022] Embodiment 4. Figure 4 is a diagram for explaining the principle of the manufacturing process of the semiconductor device in Embodiment 4 of the present invention. In the figure, 6 is a P-SiON film formed as an antireflection film on first film 1 at a thickness of, for example, 100–1000 angstroms 11 is an argon atom, 12 is a nitrogen atom, and 13 is a nitrogen molecule.

Ex. 1011, ¶ 0022.

176. Shibata's range of thickness falls squarely within the claimed range.

177. Shibata explains that the film 2 may be made of silicon oxynitride. Shibata states:

In addition, although the example of the P-SiN film was shown as the antireflection film in the above conventional example, *the same phenomenon also occurs in plasma oxynitride film (hereinafter referred to as P-SiON film.)*

Ex. 1011, ¶ 0004 (emphasis added). *See also*, ¶¶ 0017, 0020, 0022 (discussing silicon oxynitride (P-SiON) films).

178. Although the descriptions of ¶¶ 0002 and 0004 are made with reference to the prior art structure in FIG. 5, Shibata explains that the proposed structure also possesses the metal film 1. *See*, ¶ 0013 (components in FIG. 1 with same reference numerals as in the prior art design are the same).

179. Shibata also explains that the antireflection film 2 is provided directly on the metal layer (film 1). Shibata states:

First, P-SiN *film 2 is laminated on first film 1* on the semiconductor substrate. At this time, impurities such as nitrogen atoms and nitrogen molecules adhere to the upper surface of P-SiN film 2 (Figure 1 (a.)) At this time, P-SiN film 2 is formed by a parallel plate type plasma chemical vapor deposition apparatus as shown in Figure 2, using a gas system such as silane, nitrous oxide and nitrogen.

Ex. 1011, ¶ 0014 (emphasis added). Thus, Shibata explains that the silicon oxynitride film is placed on a reflective surface under construction of the term “on” above. *See*, § VI (p. 29).

180. Thus, Shibata discloses the subject matter of element [1.2].

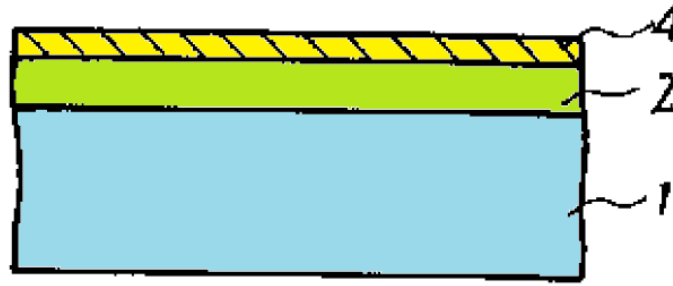
#### **4. Shibata discloses element [1.3]**

181. The next element of claim 1, which is labeled element [1.3], states:

forming an oxide layer having a thickness from about 5 Å to about 50 Å over the silicon oxynitride layer to provide the silicon oxynitride antireflection coating,

Shibata discloses this subject matter.

182. Shibata discloses forming an oxide layer 4 (**yellow**) having a thickness from about 5Å to about 50Å over the silicon oxynitride layer 2 (**green**) to provide the silicon oxynitride antireflection coating.



**Shibata (Ex. 1011), FIG. 1(a) (annotated)**

183. Shibata describes that the oxide film 4 has a thickness between 40-100 angstroms. Ex. 1011, ¶¶ 0013, 0017-18.

184. Shibata also illustrates several examples of oxide films in FIG. 3 with thicknesses of 35Å and 40Å:

Plasma output (W)	Processing time (sec)	Distance between electrodes (mm)	Chamber pressure (Torr)	N <sub>2</sub> O flow rate (l/min)	Thickness of oxide film (angstroms)
300	30	12.5	4.25	1	40
600	30	12.5	4.25	1	54
600	60	12.5	4.25	1	59
900	30	12.5	4.25	1	63
900	60	12.5	4.25	1	68
300	180	12.5	4.25	1	70
300	30	12.5	1.6	1	70
300	30	12.5	6.0	1	70
300	30	12.5	4.25	3	40
300	30	12.5	4.25	5	40
300	30	5	4.25	1	60
300	30	15	4.25	1	35

**Shibata, FIG. 3 (annotated)**

185. Shibata states:

[0018] In other words, if the above process conditions are satisfied, *oxide film 4 can be formed to a thickness of 40 angstroms* or more on the upper surface of P-SiN film 2, the nitrogen atoms at the upper part (depth of 40 angstroms) of P-SiN film 2 are removed, and it is possible to reliably prevent the reaction with the chemically amplified resist film 5. In addition, since the thickness of oxide film 4 can be suppressed to 100 angstroms or less, there is no influence on the reflectance of the lower P-SiN film 4 as an anti-reflection film.

Ex. 1011, ¶ 0018 (emphasis added).

186. While referring to SiN film above, Shibata clarifies that the oxide layer 4 may be formed on silicon oxynitride film as well:

[0020] Embodiment 2. Although the example of P-SiN film 2 was described in Embodiment 1 above, *it goes without saying that the same effects as in the above-described Embodiment 1 can also be obtained also in the case of using a P-SiON film.*

Ex. 1011, ¶ 0020 (emphasis added).

187. Thus, Shibata discloses the subject matter of element [1.3].

## **5. Shibata discloses element [1.4]**

188. The final element of claim 1, which is labeled element [1.4], states:

wherein the oxide layer forms a barrier to migration of nitrogen atoms from the silicon oxynitride layer.

Shibata discloses this subject matter.

189. Shibata discloses that the oxide layer 4 (**yellow**) forms a barrier to migration of nitrogen atoms from the silicon oxynitride layer 2 (**green**).

190. Shibata describes that the oxide layer 4 prevents reaction between the silicon oxynitride layer 2 and the photoresist because nitrogen has been removed from the oxide layer 4. Shibata states:

Since the method for manufacturing a semiconductor device according to Claim 1 of the present invention is such that a plasma nitride film or plasma oxynitride film is laminated on a first film, plasma treatment using a gas having oxidizing power is applied to the upper surface of the plasma nitride film or plasma oxynitride film to form an oxide film and a chemically amplified resist is coated on the oxide film and patterned, *nitrogen is removed from the plasma nitride film or the plasma oxynitride film so as to prevent reaction between the nitrogen.*

Ex. 1011, ¶ 0010 (effect) (emphasis added). This disclosure indicates that the oxide layer 4 is a barrier to migration of nitrogen between the silicon oxynitride layer 2 and the photoresist 3.

191. Elsewhere, Shibata confirms that the oxide layer 4 prevents reaction between the silicon oxynitride layer 2 and the photoresist. Shibata states:

In other words, if the above process conditions are satisfied, oxide film 4 can be formed to a thickness of 40 angstroms or more on the upper

surface of P-SiN film 2, the nitrogen atoms at the upper part (depth of 40 angstroms) of P-SiN film 2 are removed, and *it is possible to reliably prevent the reaction with the chemically amplified resist film 5*. In addition, since the thickness of oxide film 4 can be suppressed to 100 angstroms or less, there is no influence on the reflectance of the lower P-SiN film 4 as an anti-reflection film.

Ex. 1011, ¶ 0018 (emphasis added). *See also*, ¶¶ 0012, 0019, 0024.

192. Thus, Shibata discloses the subject matter of element [1.4].

193. As described above, Shibata discloses all elements of claim 1. Accordingly, I conclude that Shibata anticipates claim 1 of the ‘231 patent.

## **B. Shibata Anticipates Claim 2**

194. Claim 2 of the ‘231 patent depends from claim 1 and recites:

The method of claim 1, wherein the metal layer comprises at least one of aluminum, copper, gold, nickel, palladium, platinum, silver, tantalum, titanium, tungsten, zinc, aluminum-copper alloys, aluminum alloys, copper alloys, titanium alloys, tungsten alloys, titanium-tungsten alloys, gold alloys, nickel alloys, palladium alloys, platinum alloys, silver alloys, tantalum alloys, zinc alloys, and metal silicides.

Shibata discloses this subject matter.

195. Shibata discloses all elements of claim 1 as explained above.



196. Shibata also discloses that the metal film 1 (*blue*) comprises aluminum, tungsten or the like. Shibata states:

In the figure, *1 is a first film made of a material having high reflectance such as aluminum, tungsten or the like* formed on a semiconductor substrate (not shown), 2 is a plasma nitride film formed on first film 1 for example, as an antireflection film formed with a thickness of 100–1000 angstroms (hereinafter referred to as a P-SiN film,) and 3 is a positive chemically amplified resist film formed on P-SiN film 2.

Ex. 1011, Col. 1 (Prior Art) (emphasis added). Aluminum and tungsten both are included in the list of materials recited in claim 2.

197. Shibata discloses all elements of claim 2. Thus, Shibata anticipates claim 2.

### **C. Shibata Anticipates Claim 3**

198. Claim 3 of the ‘231 patent depends from claim 1 and recites:

The method of claim 1, wherein the metal layer comprises at least one of aluminum, copper, aluminum-copper alloys, aluminum alloys and copper alloys.

Shibata discloses this subject matter.

199. Shibata discloses all elements of claim 1 as explained above.

200. Shibata also discloses that the metal film 1 (*blue*) comprises aluminum.

Shibata states:

In the figure, *1 is a first film made of a material having high reflectance such as aluminum*, tungsten or the like formed on a semiconductor substrate (not shown), 2 is a plasma nitride film formed on first film 1 for example, as an antireflection film formed with a thickness of 100–1000 angstroms (hereinafter referred to as a P-SiN film,) and 3 is a positive chemically amplified resist film formed on P-SiN film 2.

Ex. 1011, Col. 1 (Prior Art) (emphasis added). Aluminum is included in the list of materials recited in claim 3.

201. Shibata discloses all elements of claim 3. Thus, Shibata anticipates claim 3.

#### **D. Shibata Anticipates Claim 4**

202. Claim 4 of the '231 patent depends from claim 1 and recites:

The method of claim 1, wherein the oxide layer is formed by contacting the silicon oxynitride layer with oxygen plasma.

Shibata discloses this subject matter.

203. Shibata discloses all elements of claim 1 as explained above.

204. Shibata discloses that the oxide layer 4 (**yellow**) is formed by contacting the silicon oxynitride layer with N<sub>2</sub>O plasma. Shibata states:

Next, the upper surface of P-SiN film 2 is formed by using the same apparatus subsequently to the formation of P-SiN film 2, and *oxide film 4 is formed by plasma treatment with a gas having oxidizing power such as nitrous oxide (Figure 1 (b.))* At this time, nitrogen atoms and nitrogen

molecules on the upper surface of P-SiN film 2 and nitrogen atoms in P-SiN film 2 are removed by oxygen atoms in the nitrous oxide, oxygen atoms are introduced instead and oxide film 4 is formed. Next, a chemically amplified resist is coated on oxide film 4 and patterned to form positive chemically amplified resist film 5 (Figure 1 (c.))

Ex. 1011, ¶ 0015 (emphasis added).

205. Shibata also states:

In addition, it can be inferred that *the same result can be obtained regardless of whether P-SiON film is used instead of P-SiN film or a gas having oxidizing power is used instead of nitrous oxide.*

Ex. 1011, ¶ 0017 (emphasis added).

206. Shibata further discloses that, instead of using nitrous oxide as described in ¶ 0015, an oxygen plasma may be used:

Although nitrous oxide was used as a gas having oxidizing power for plasma processing in each of the above-described embodiments, it goes without saying that any gas may be used as long as it has oxidizing power, and *it goes without saying that the same effect is exhibited even if, for example, oxygen, is used.*

Ex. 1011, ¶ 0021 (emphasis added). This description indicates use of an oxygen plasma.

207. Shibata discloses all elements of claim 4. Thus, Shibata anticipates claim 4.

**E. Shibata Anticipates Claim 5**

208. Claim 5 of the '231 patent depends from claim 1 and recites:

The method of claim 1, wherein the oxide layer is formed by contacting the silicon oxynitride layer with N<sub>2</sub>O plasma.

Shibata discloses this subject matter.

209. Shibata discloses all elements of claim 1 as explained above.

210. Shibata discloses that the oxide layer 4 (**yellow**) is formed by contacting the silicon oxynitride layer with N<sub>2</sub>O plasma. Shibata states:

Next, the upper surface of P-SiN film 2 is formed by using the same apparatus subsequently to the formation of P-SiN film 2, and *oxide film 4 is formed by plasma treatment with a gas having oxidizing power such as nitrous oxide (Figure 1 (b.))* At this time, nitrogen atoms and nitrogen molecules on the upper surface of P-SiN film 2 and nitrogen atoms in P-SiN film 2 are removed by oxygen atoms in the nitrous oxide, oxygen atoms are introduced instead and oxide film 4 is formed. Next, a chemically amplified resist is coated on oxide film 4 and patterned to form positive chemically amplified resist film 5 (Figure 1 (c.))

Ex. 1011, ¶ 0015 (emphasis added).

211. Shibata also states:

In addition, it can be inferred that *the same result can be obtained regardless of whether P-SiON film is used instead of P-SiN film or a gas having oxidizing power is used instead of nitrous oxide.*

Ex. 1011, ¶ 0017 (emphasis added).

212. These descriptions indicate use of an N<sub>2</sub>O plasma.

213. Shibata discloses all elements of claim 5. Thus, Shibata anticipates claim 5.

**X. CLAIM 7 IS OBVIOUS OVER SHIBATA, LEE, CHEUNG AND JOESTEN**

214. Shibata, Lee, Cheung and Joesten demonstrate that claim 7 is obvious.

**A. Motivation to Combine Teachings of References**

215. As described above (§ VIII.I), a worker of skill would have reason to consider the teachings of Shibata with those of Lee, Joesten and Cheung.

216. First, Shibata, Lee, Joesten, and Cheung each are directed to the same field of endeavor – antireflection coatings made of silicon oxynitride.

217. Shibata, Joesten, and Cheung are directed to solutions to footing problems that arise from such antireflection coatings, and they describe the same solution – N<sub>2</sub>O plasma treatment to the surface of the silicon oxynitride layer.

218. A worker of skill would be motivated to investigate reflectivity of such surface treatments to confirm they do not impair performance of the silicon

oxynitride antireflection coating because the purpose of the antireflection coating is to cancel reflections from the substrate back to the photoresist.

219. Based on review of Shibata, Lee, Joesten, and Cheung, a person of skill would recognize that Shibata's structure can be tuned to achieve reflectivity less than 10%.

220. Lee demonstrates that silicon oxynitride antireflection layers with no coating can achieve reflectivity less than 10% at wavelengths less than 248 nm, even when used with metal substrates. Ex. 1018, FIG. 2b.

221. Shibata discloses oxide films having thicknesses of 35Å and 40 Å.

222. Shibata also explains that, when oxide films have a thickness less than 100Å, they have no effect on reflectivity of the antireflection coating. Ex. 1011, ¶ 0018.

223. Cheung also teaches that an oxide films having a thicknesses below 100Å do not noticeably affect reflectivity of antireflection films. Ex. 1012, Col. 13:10-14.

224. Cheung and Joesten both illustrate antireflection films having silicon oxynitride layer thicknesses that correspond to those of Shibata having reflectivities less than 10% at wavelengths less than 248 nm. Ex. 1012, FIGS. 6, 7; Ex. 1017, FIGS. 10. *See also*, § VIII.I (p. 64 above).

225. These teachings, in aggregate, demonstrate to a worker of skill not only that reflectivity properties of Shibata's antireflection coating are predictable and well understood, but also that his antireflection coating can achieve reflectivity of less than 10% at wavelengths less than 248 nm.

**B. Analysis of Challenged Claim**

226. Claim 7 of the '231 patent depends from claim 1 and recites:

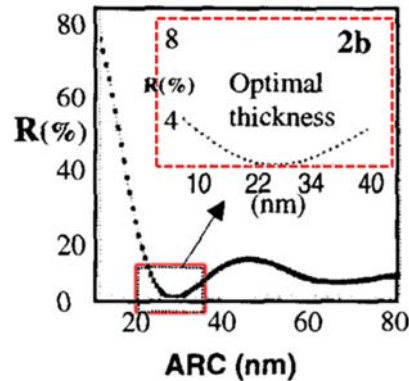
The method of claim 1, wherein the silicon oxynitride antireflection coating has a reflectivity of about 10% or less at a wavelength below about 248 nm.

Shibata, Lee, Joesten, and Cheung teach this subject matter.

227. Shibata discloses all elements of claim 1 as explained above.

228. Shibata does not explicitly state the reflectivity value of his antireflection coating, but clearly states the purpose of preventing reflection through the use of an antireflection coating is to improve accuracy of patterning. Ex. 1011, ¶ 0015.

229. Lee discloses that silicon oxynitride antireflection films achieve reflectivity less than 10% at wavelengths below 248 nm across a wide range of film thicknesses.



Lee (Ex. 1018), FIG. 2b (annotated)

230. Shibata does teach that when the thickness of an oxide film is less than  $100\text{\AA}$ , it does not influence the reflectivity of the base film:

In addition, since the thickness of oxide film 4 can be suppressed to 100 angstroms or less, there is no influence on the reflectance of the lower P-SiN film 4 as an anti-reflection film.

Shibata, ¶ 0017.

231. Cheung and Joesten disclose that reflectance of a dual-layer silicon oxynitride / oxide antireflection coating achieves reflectivity of 10% or less at wavelengths below about 248 nm.

232. Cheung describes that an anti-reflection coating that includes a silicon oxynitride layer with a thickness of  $300\text{\AA}$  has reflectivity less than 10% at a wavelength below about 248 nm.



233. Cheung provides reflectivity simulations of the silicon oxynitride ARC in Figures 6 and 7. These simulations estimate reflectivity of the ARC over thicknesses of the oxide layer that vary between 50 Å and 1000 Å. Cheung states:

A silicon oxynitride ( $\text{SiO}_x\text{N}_y$ ) ARC (or DARC) was used in these simulations because the use of such an ARC is preferred in the present invention. The simulated DARC was tuned for deep UV, and exhibited a refractive index of 2.15 and absorptive index of 0.53, again at a wavelength of 248 nm. The DARC's thickness was selected by simulating various DARC thicknesses between 50 Å and 1000 Å. This was done for a DARC layer applied over both tungsten silicide and polysilicon. As expected, the minimum reflectivity at the photoresist/DARC interface occurred at a DARC thickness of about 300 Å.

FIG. 6 shows this relationship for a structure having a capping layer/hardmask and DARC deposited over a tungsten silicide substrate. FIG. 7 shows this relationship for a similar structure deposited over a polysilicon substrate. *In both simulations, the capping layer's (hardmask's) thickness was varied from 50 Å to 1000 Å, while holding the DARC thickness constant at 300 Å.*

Ex. 1012, Col. 17:29-51 (emphasis added).

234. Cheung's simulations are shown below. As indicated, FIGS. 6 and 7 both show that reflectivities of the antireflection coatings are below 10% (*red*) for all simulated oxide (capping layer) thicknesses, even those at 50 Å:

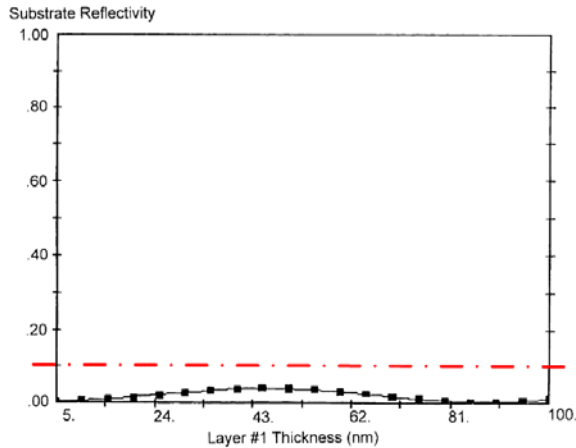


FIG. 6

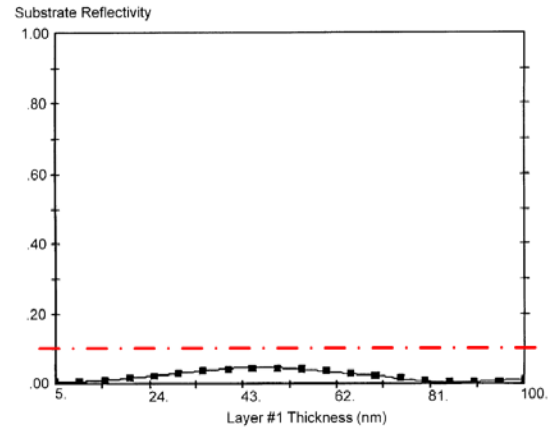


FIG. 7

**Cheung (Ex. 1012), FIGS. 6, 7 (annotated)**

235. Joesten also describes a variety of silicon oxynitride antireflection coatings with reflectivity less than 10% at a wavelength below about 248 nm:

The use of a nitrous oxide plasma treatment reduces the foot by more than a factor of three. The combination of a surface treatment with the reflection maximum of 550 Å completely eliminates all traces of footing for APEX-E 2408 and UV6.

Ex. 1017, p. 1.

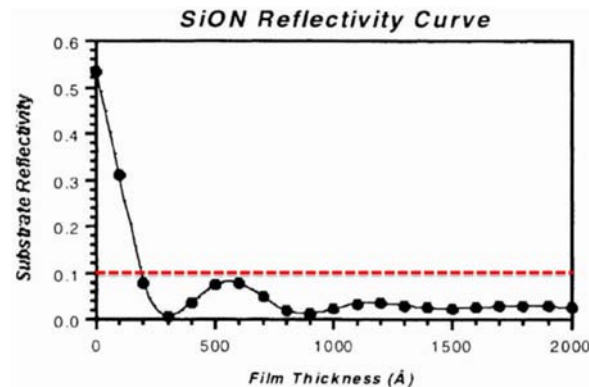
At the 1,500Å film thickness, a local minimum of 16% reflectivity, a 2X improvement in footing results over the 300Å film, *which has a reflectivity minimum of 3.0%.*

Ex. 1017, p. 7 (emphasis added).

236. Joesten also altered reflectivity of films to examine effects on footing. Joesten's films include films with reflectivity below 10%. Joesten states:

The footing results for UV6, as seen in Figure 13, show a non-linear behavior with the phase on the reflectivity curve. As *reflectivity increases from 1.0% to 5.0%* the footing appears to worsen, moving from a descending midpoint (267Å) to a minimum (300Å) on the reflectivity curve.

Ex. 1017, p. 8.



**Joesten (Ex. 1017), FIG 10 (annotated)**

237. Cheung's simulations and Joesten's simulations both are performed using radiation sources using 248 nm wavelengths. Ex. 1012, Col. 17:29-51; Ex. 1017, § 2 (KrF lasers).

238. The prior art teaches all elements of claim 7. Therefore, Shibata, Cheung and Joesten render claim 7 obvious.

#### **XI. CLAIMS 1-3 AND 5 ARE ANTICIPATED BY FOOTE '007.**

239. As stated above, it is my opinion that claims 1-5 are anticipated by Foote '007, Ex. 1013. In this portion of my declaration, I explain the bases for my opinion.

**A. Foote ‘007 Anticipates Claim 1**

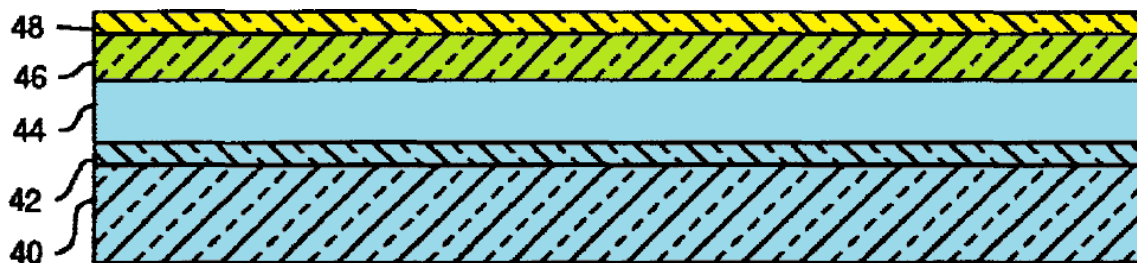
**1. Foote ‘007 discloses element [1.0]**

240. The preamble of claim 1, labeled element [1.0], states:

A method of forming a silicon oxynitride antireflection coating over a metal layer, comprising:

Foote ‘007 discloses this subject matter.

241. Foote ‘007 discloses a silicon oxynitride antireflection coating that is formed over a metal layer. These elements are shown in Foote ‘007, FIG. 5b, where the antireflection coating is formed from a silicon oxynitride layer 46 (*green*) and an oxide layer 48 (*yellow*). The silicon oxynitride antireflection coating is formed over a metal layer 44 (*blue*).



**Foote ‘007 (Ex. 1013), FIG. 5b (annotated)**

These layers are described in greater detail in my analysis of elements [1.1]-[1.4], below.

242. Foote ‘007 explains that the integrated circuit includes silicon oxynitride antireflection coating over a metal layer. Foote ‘007 states:

An anti-reflective coating is formed between a material layer which is to be patterned on a semiconductor structure using photolithography, and an overlying photoresist layer. The anti-reflective coating suppresses reflections from the material layer surface into the photoresist layer that could degrade the patterning. The anti-reflective coating includes *an anti-reflective layer of* silicon oxime, *silicon oxynitride*, or silicon nitride, and a barrier layer which is grown on the anti-reflective layer using a nitrous oxide plasma discharge to *convert a surface portion of the anti-reflective layer into silicon dioxide*.

Ex. 1013, *Abstract*. The metal layer is described at Ex. 1013, Col. 6:25-36.

243. Thus, Foote '007 discloses the subject matter of element [1.0].

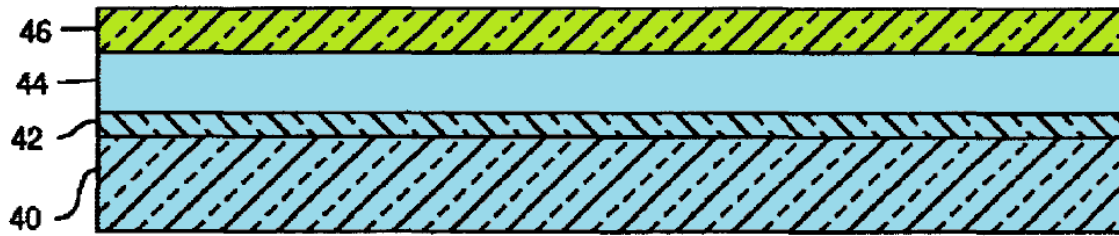
## 2. Foote '007 discloses element [1.1]

244. The next element of claim 1, which is labeled element [1.1], states:

providing a semiconductor substrate comprising the metal layer over at least part of the semiconductor substrate;

Foote '007 discloses this subject matter.

245. Foote '007 discloses providing a semiconductor substrate 40 (*blue*) comprising a metal layer 44 (*blue*) over at least part of the semiconductor substrate. These features are shown both in FIG. 5b above and in FIG. 5a below:



Footnote '007 (Ex. 1013), FIG. 5a (annotated)

246. Footnote '007 explains that the substrate 40 is made of silicon and the polysilicon layer 44 may include metals. Footnote '007 states:

FIG. 5 a illustrates a semiconductor structure at an intermediate step in the overall fabrication process, including a *silicon substrate 40*, a gate oxide layer 42 formed on the substrate 40, a polysilicon material layer 44 formed on the gate oxide layer 42, and an anti-reflective layer 46 formed on the polysilicon layer 44.

In the illustrated example, the polysilicon layer 44 is to be patterned to form a conductive gate for a field-effect transistor using photolithography. However, the present invention is not so limited, and can be applied to patterning any suitable semiconductor, *metal*, or other material layer.

Ex. 1013, Col. 6:25-36 (emphases added).

247. Footnote '007 further states:

A silicon oxime ARC in accordance with the present invention can be deposited on conductive and nonconductive layers comprising materials conventionally employed in the semiconductor industry. *Such materials may comprise polysilicon, aluminum and alloys thereof such as aluminum-silicon alloys, refractory metals, such as tungsten, refractory*

*metal alloys, such as titanium-tungsten, refractory metal compounds, and dielectric materials.* The conductive layer may also comprise a plurality of conductive layers as conventionally employed in the manufacture of semiconductor devices. For example, the conductive layer may comprise a barrier layer for enhanced adhesion to the substrate. Such barrier layers may comprise titanium, titanium nitride or titanium-titanium nitride. A layer of conductive material, such as one of the aforementioned conductive materials, e.g., aluminum or tungsten, is formed on the barrier layer.

Ex. 1013, Col. 12:30-46 (emphasis added).

248. Thus, Foote '007 discloses the subject matter of element [1.1].

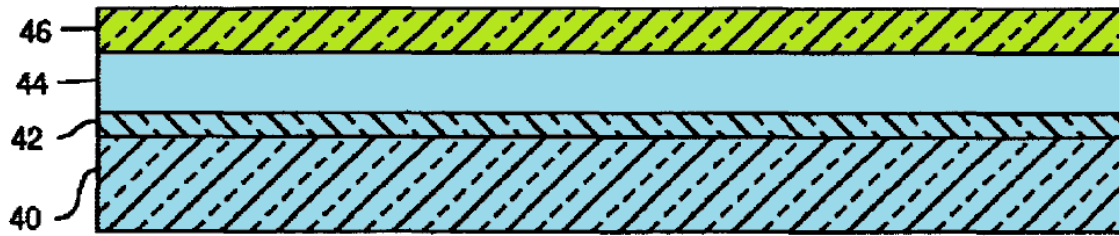
### **3. Foote '007 discloses element [1.2]**

249. The next element of claim 1, which is labeled element [1.2], states:

depositing a silicon oxynitride layer on the metal layer having a thickness from about 100 Å to about 1500 Å; and

Foote '007 discloses this subject matter.

250. Foote '007 discloses depositing a silicon oxynitride layer 46 (**green**) on the metal layer 44 (**blue**) having a thickness from about 100 Å to about 1500 Å. The silicon oxynitride layer directly contacts the metal layer 44. These features are shown both in FIG. 5b above and in FIG. 5a below:



Footnote '007 (Ex. 1013), FIG. 5a (annotated)

251. Footnote '007 discloses that the anti-reflection layer includes silicon oxynitride.

Footnote '007 states:

The anti-reflective coating suppresses reflections from the material layer surface into the photoresist layer that could degrade the patterning. The anti-reflective coating includes an anti-reflective layer of silicon oxime, *silicon oxynitride*, or silicon nitride, and a barrier layer which is grown on the anti-reflective layer using a nitrous oxide plasma discharge to convert a surface portion of the anti-reflective layer into silicon dioxide.

Ex. 1013, Abstract (emphasis added).

The present invention overcomes the drawbacks of the prior art by providing a process by which a thin silicon dioxide barrier layer can be formed on a silicon oxime, *silicon oxynitride*, or silicon nitride anti-reflective layer.

Ex. 1013, Col. 4:48-52 (emphasis added).

252. Footnote '007 discloses that the silicon oxynitride layer has a thickness from about 200 angstroms to about 400 angstroms. The preferred thickness is 300 angstroms. Footnote '007 states:



The anti-reflective layer 46 is preferably formed of silicon oxime (SiNO:H), *silicon oxynitride (SiON:H)*, or silicon nitride (Si<sub>3</sub>N<sub>4</sub>:H). ...

In a preferred embodiment of the present invention, the anti-reflective layer 46 is formed of silicon oxime in a Plasma Enhanced Chemical Vapor Deposition (PECVD) reactor to a thickness t of *approximately 200 to 400, preferably 300 angstroms*.

Ex. 1013, Col. 6:37-48 (emphases added). These ranges fall within the range defined in element [1.2], namely about 100 to about 1500 angstroms.

253. Foote '007 discloses that the silicon oxynitride layer is formed on a polysilicon layer 44 which may be metal. Foote '007 states:

FIG. 5 a illustrates a semiconductor structure at an intermediate step in the overall fabrication process, including a silicon substrate 40, a gate oxide layer 42 formed on the substrate 40, a polysilicon material layer 44 formed on the gate oxide layer 42, and *an anti-reflective layer 46 formed on the polysilicon layer 44*.

In the illustrated example, the polysilicon layer 44 is to be patterned to form a conductive gate for a field-effect transistor using photolithography. However, the present invention is not so limited, and can be applied to patterning any suitable semiconductor, *metal*, or other material layer.

Ex. 1013, Col. 6:25-36 (emphases added).

254. Thus, Foote '007 discloses the subject matter of element [1.2].

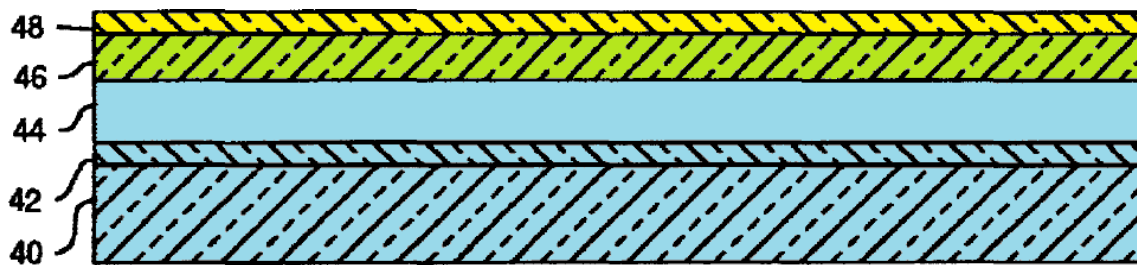
4. **Foote ‘007 discloses element [1.3]**

255. The next element of claim 1, which is labeled element [1.3], states:

forming an oxide layer having a thickness from about 5 Å to about 50 Å over the silicon oxynitride layer to provide the silicon oxynitride antireflection coating,

Foote ‘007 discloses this subject matter.

256. Foote ‘007 discloses forming an oxide layer 48 (**yellow**) having a thickness from about 5 Å to about 50 Å over the silicon oxynitride layer to provide the silicon oxynitride antireflection coating. The oxide layer 48 is shown in FIG. 5b below:



**Foote ‘007 (Ex. 1013), FIG. 5b (annotated)**

257. Foote ‘007 describes the barrier layer 48 as a silicon dioxide layer that is formed on the anti-reflective layer 46. In the art, silicon dioxide commonly is described simply as an “oxide.” Foote ‘007 states:

In FIG. 5 b, a *silicon dioxide barrier layer 48 is grown on the anti-reflective layer 46* using a nitrous oxide (N<sub>2</sub>O) plasma discharge to convert a surface portion of the anti-reflective layer into silicon dioxide.

This step is performed in-situ in the same PECVD reactor that was used to form the anti-reflective layer 46, thereby maximizing process throughput.

Ex. 1013, Col. 6:55-7:7 (emphasis added).

258. Foote '007 also describes that the oxide layer 48 has a thickness of 10 to 40 angstroms and, preferably, 15 to 25 angstroms. Foote '007 states:

The plasma growth process is continued for approximately 20 seconds which enables the silicon dioxide barrier layer 48 to be grown to a thickness *on the order of 10 to 40 (more preferably 15 to 25) angstroms*.

Ex. 1013, Col. 6:55-7:7 (emphasis added). These ranges fall within the range defined in element [1.3], namely about 5 to about 50 angstroms.

259. Thus, Foote '007 discloses the subject matter of element [1.3].

## **5. Foote '007 discloses element [1.4]**

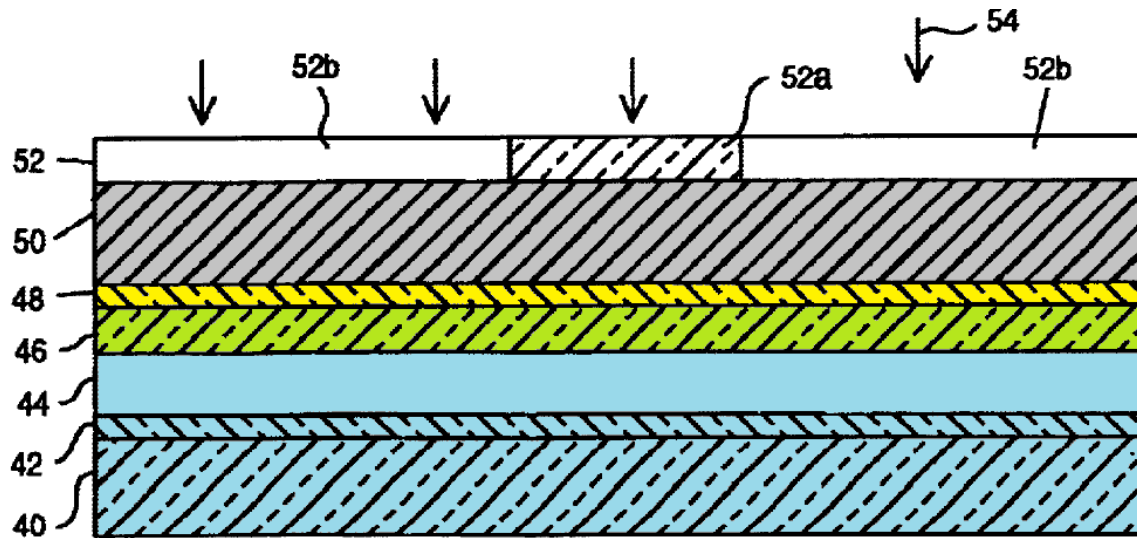
260. The final element of claim 1, which is labeled element [1.4], states:

wherein the oxide layer forms a barrier to migration of nitrogen atoms from the silicon oxynitride layer.

Foote '007 discloses this subject matter.

261. Foote '007 discloses that the oxide layer 48 (**yellow**) forms a barrier to migration of nitrogen atoms from the silicon oxynitride layer 46 (**green**).

262. Foote '007 discloses that the barrier layer 48 prevents interaction between the anti-reflective layer 46 and the photoresist layer 50. The relationship between the anti-reflective layer 46, the barrier layer 48, and the photoresist layer 50 are shown in FIG. 5c:



Ex. 1013, FIG. 5c (annotated)

263. Foote '007 states:

The anti-reflective coating includes an anti-reflective layer of silicon oxime, silicon oxynitride, or silicon nitride, and a barrier layer which is grown on the anti-reflective layer using a nitrous oxide plasma discharge to convert a surface portion of the anti-reflective layer into silicon dioxide. *The barrier layer prevents interaction between the anti-reflective layer and the photoresist layer that could create footing.*

Ex. 1013, Abstract (emphasis added)

264. Foote '007 further explains that the barrier layer 48 separates the amines in the anti-reflective layer from the photoresist layer:

It is known that this interaction, and thereby the footing, can be inhibited by forming a silicon dioxide barrier layer on the surface of the silicon oxime layer before forming the photoresist thereon. The barrier layer acts as a seal or cap *which separates the amines in the silicon oxime layer from the photoresist layer 14.*

Ex. 1013, Col. 3:1-6 (emphasis added). Although this statement refers to silicon oxime, which Foote '007 describes as one of three candidate materials for the anti-reflection layer 46, a worker would understand that the barrier layer also would separate amines in a silicon oxynitride anti-reflective layer (also a silicon nitride anti-reflective layer) from a photoresist layer.

265. Foote '007 confirms this teaching elsewhere in his disclosure where he states:

The anti-reflective coating includes an anti-reflective layer of silicon oxime ( $\text{SiNO:H}$ ), silicon oxynitride ( $\text{SiON:H}$ ), or silicon nitride ( $\text{Si}_3\text{N}_4\text{:H}$ ), and a barrier layer which is grown on the anti-reflective layer using a nitrous oxide plasma discharge to convert a surface portion of the anti-reflective layer into silicon dioxide.

*The barrier layer prevents interaction between the anti-reflective layer and the photoresist layer that could create footing.* The anti-reflective layer is deposited on the material layer using Plasma Enhanced Chemical Vapor Deposition (PECVD) in a reactor. The barrier layer is grown on the anti-reflective layer in-situ in the same reactor, thereby maximizing throughput.

Ex. 1013, Col. 4:66-5:11 (emphasis added).

266. Thus, Foote '007 discloses the subject matter of element [1.4].

267. As described above, Foote '007 discloses all elements of claim 1.

Accordingly, I conclude that Foote '007 anticipates claim 1 of the '231 patent.

**B. Foote '007 Anticipates Claim 2**

268. Claim 2 of the '231 patent depends from claim 1 and recites:

The method of claim 1, wherein the metal layer comprises at least one of aluminum, copper, gold, nickel, palladium, platinum, silver, tantalum, titanium, tungsten, zinc, aluminum-copper alloys, aluminum alloys, copper alloys, titanium alloys, tungsten alloys, titanium-tungsten alloys, gold alloys, nickel alloys, palladium alloys, platinum alloys, silver alloys, tantalum alloys, zinc alloys, and metal silicides.

Foote '007 discloses this subject matter.

269. Foote '007 discloses all elements of claim 1 as explained above.

270. Foote '007 discloses that the polysilicon layer 44 (*blue*) could alternatively be at least one of aluminum, titanium, tungsten, aluminum alloys, and titanium-tungsten alloys. Foote '007 states:

Photolithography is a semiconductor fabrication process that is widely used for patterning material layers on a semiconductor wafer or structure.

The material layers can be non-metal (e.g. silicon, polysilicon), *metal (e.g. aluminum)*, etc.

Ex. 1013, Col. 1:22-27 (emphasis added).

271. Foote '007 also states:

A silicon oxime ARC in accordance with the present invention can be deposited on conductive and nonconductive layers comprising materials conventionally employed in the semiconductor industry. Such materials may comprise polysilicon, *aluminum and alloys thereof such as aluminum-silicon alloys*, refractory metals, such as *tungsten*, refractory metal alloys, such as titanium-tungsten, refractory metal compounds, and dielectric materials. The conductive layer may also comprise a plurality of conductive layers as conventionally employed in the manufacture of semiconductor devices. For example, the conductive layer may comprise a barrier layer for enhanced adhesion to the substrate. Such barrier layers may comprise *titanium, titanium nitride* or *titanium-titanium nitride*. A layer of conductive material, such as one of the aforementioned conductive materials, e.g., aluminum or tungsten, is formed on the barrier layer.

Ex. 1013, 12: 30-46 (emphases added). Aluminum, titanium, tungsten, aluminum alloys, and titanium-tungsten alloys are included in the list of materials recited in claim 2.

272. Foote '007 discloses all elements of claim 2. Thus, Foote '007 anticipates claim 2.

**C. Foote ‘007 Anticipates Claim 3**

273. Claim 3 of the ‘231 patent depends from claim 1 and recites:

The method of claim 1, wherein the metal layer comprises at least one of aluminum, copper, aluminum-copper alloys, aluminum alloys and copper alloys.

Foote ‘007 discloses this subject matter.

274. Foote ‘007 discloses all elements of claim 1 as explained above.

275. Foote ‘007 discloses that the polysilicon layer 44 (*blue*) could alternatively be at least one of aluminum, and aluminum alloys. Foote ‘007 states:

Photolithography is a semiconductor fabrication process that is widely used for patterning material layers on a semiconductor wafer or structure. The material layers can be non-metal (e.g. silicon, polysilicon), *metal (e.g. aluminum), etc.*

Ex. 1013, Col. 1:22-27 (emphasis added).

276. Foote ‘007 also states:

A silicon oxime ARC in accordance with the present invention can be deposited on conductive and nonconductive layers comprising materials conventionally employed in the semiconductor industry. Such materials may comprise polysilicon, *aluminum and alloys thereof such as aluminum-silicon alloys*, refractory metals, such as tungsten, refractory metal alloys, such as titanium-tungsten, refractory metal compounds, and



dielectric materials. The conductive layer may also comprise a plurality of conductive layers as conventionally employed in the manufacture of semiconductor devices. For example, the conductive layer may comprise a barrier layer for enhanced adhesion to the substrate. Such barrier layers may comprise titanium, titanium nitride or titanium-titanium nitride. A layer of conductive material, such as one of the aforementioned conductive materials, e.g., aluminum or tungsten, is formed on the barrier layer.

Ex. 1013, Col. 12:30-46 (emphasis added). Aluminum and aluminum alloys are included in the list of materials recited in claim 3.

277. Foote '007 discloses all elements of claim 3. Thus, Foote '007 anticipates claim 3.

**D. Foote '007 Anticipates Claim 5**

278. Claim 5 of the '231 patent depends from claim 1 and recites:

The method of claim 1, wherein the oxide layer is formed by contacting the silicon oxynitride layer with N<sub>2</sub>O plasma.

Foote '007 discloses this subject matter.

279. Foote '007 discloses all elements of claim 1 as explained above.

280. Foote '007 discloses that the oxide layer 4 (**yellow**) is formed by contacting the silicon oxynitride layer with N<sub>2</sub>O plasma. Foote '007 states:

The anti-reflective coating includes an anti-reflective layer of silicon oxime, silicon oxynitride, or silicon nitride, and a barrier layer which is grown on the anti-reflective layer *using a nitrous oxide plasma* discharge to convert a surface portion of the anti-reflective layer into silicon dioxide.

Ex. 1013, Abstract (emphasis added). *See also*, Col. 4:66-5:4, 5:12-21, 6:55-7:7, 8:37-9:31 (disclosing nitrous oxide plasma).

281. Foote '007 discloses all elements of claim 5. Thus, Foote '007 anticipates claim 5.

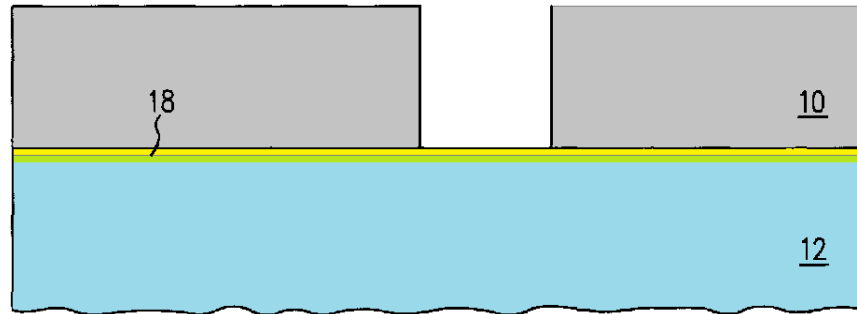
## **XII. CLAIMS 1-5 ARE OBVIOUS OVER KONJUH AND OGAWA**

### **A. Motivation to Combine Teachings of References**

282. As described above (§ VIII.I, p. 64), a worker of skill would have reason to consider the teachings of Ogawa with those of Konjuh.

283. Konjuh cites Ogawa expressly as providing a discussion of deep UV antireflection layers. *Id.*, at 1:28-40. Moreover, Konjuh identifies a problem with such antireflection layers – footing – and provides a solution to such a problem.

284. In following Konjuh's teachings, a person of skill would recognize that Konjuh's ARL finds application with substrates that contain metal, such as the tungsten silicide and aluminum silicon substrates described by Ogawa. Such applications result in a structure as shown below:



**Konjuh (Ex. 1015), FIG. 1 (annotated)**

285. A worker of skill would recognize that the structure shown above includes the substrate 12 (*blue*) and ARL 18 (*green*) that Konjuh identifies as prior art. The substrate 12 would be formed either of tungsten silicide or aluminum silicon as taught by Ogawa. The ARL 18 is formed on the substrate 12, is made of silicon oxynitride and has an initial thickness of approximately 300Å as taught by Konjuh.

286. As Konjuh teaches, an oxide layer (*yellow*) is created on the surface of the ARL 18 by nitrous oxide or oxygen plasma treatment. The plasma treatment creates silicon dioxide from a surface portion of the silicon oxynitride ARL 18 (*green*) to a thickness of 50Å

287. A photoresist 10 (*gray*) would be formed on the oxide layer. The oxide layer acts as a barrier to prevent amines (nitrogen) from the silicon oxynitride ARL 18 (*green*) from interacting with the photoresist 10.

**B. Konjuh and Ogawa Render Claim 1 Obvious**

**1. Konjuh and Ogawa teach element [1.0]**

288. The preamble of claim 1, labeled element [1.0], states:

A method of forming a silicon oxynitride antireflection coating over a metal layer, comprising:

Konjuh and Ogawa teach this subject matter.

289. The prior art discloses a method of forming a silicon oxynitride antireflection coating over a metal layer.

290. As shown in ¶ 284, Konjuh and Ogawa teach a structure that includes a silicon oxynitride antireflection coating 18 (*green*) formed on a substrate 12 (*blue*).

The substrate 12 is made either of tungsten silicide (W-Si) or aluminum silicon (Al-Si). These layers are described in greater detail in my analysis of elements [1.1]-[1.4], below.

291. Thus, Konjuh and Ogawa teach the subject matter of element [1.0].

**2. Konjuh and Ogawa teach element [1.1]**

292. The next element of claim 1, which is labeled element [1.1], states:

providing a semiconductor substrate comprising the metal layer over at least part of the semiconductor substrate;

Konjuh and Ogawa teach this subject matter.

293. As shown in ¶ 284, Konjuh and Ogawa teach a structure that includes a substrate 12 (**blue**) formed of either tungsten silicide (W-Si) or aluminum silicon (Al-Si). Tungsten silicide and aluminum silicon both are metals.

294. Ogawa states:

This new ARL, whose material is a type of hydro silicon oxynitride film ( $\text{SiO}_x\text{N}_y\text{H}$ ), *can be applied to tungsten silicide (W-Si) and even to aluminum silicon (Al-Si) substrates* by controlling deposition conditions in plasma enhanced chemical vapor deposition systems. Using this  $\text{SiO}_x\text{N}_y\text{H}$  film with 30nm and 25nm thicknesses on W-Si and Al-Si substrates respectively, critical dimension (CD) variations for both substrates are drastically reduced to within  $0.02\mu\text{m}$  for  $0.30\mu\text{m}$  imaging.

Ex. 1016, p. 1 (emphasis added).

295. Thus, Konjuh and Ogawa teach the subject matter of element [1.1].

### **3. Konjuh and Ogawa teach element [1.2]**

296. The next element of claim 1, which is labeled element [1.2], states:

depositing a silicon oxynitride layer on the metal layer having a thickness from about  $100 \text{ \AA}$  to about  $1500 \text{ \AA}$ ; and

Konjuh and Ogawa teach this subject matter.

297. As shown in ¶ 284, Konjuh and Ogawa teach a structure that includes a silicon oxynitride antireflection layer 18 (**green**) formed on a metal substrate 12 (**blue**).

298. As explained (§ VIII.G, p. 57), the silicon oxynitride antireflection layer 18 initially possesses a thickness of 300 angstroms. After surface treatment, the silicon oxynitride antireflection layer 18 possesses a thickness of ~250 angstroms.

299. Konjuh, for example, states:

*[I]norganic ARLs are generally thinner (e.g., 300Å)* and are formed by chemical vapor deposition. An advantage of the inorganic ARLs is that they generally do not need to be removed after the photolithographic process has been completed. Also, the inorganic layers tend to be less expensive than the organic layers.

One problem with inorganic ARLs *such as silicon oxynitride* is that amines (NH<sub>2</sub> groups) form on the surface of the layer.

Ex. 1015, Col. 1:34-43 (emphases added).

300. Ogawa states:

Using this *SiO<sub>x</sub>Ny:H film with 30nm and 25nm thicknesses on W-Si and Al-Si substrates* respectively, critical dimension (CD) variations for both substrates are drastically reduced to within 0.02µm for 0.30µm imaging.

Ex. 1016, p. 1 (emphasis added). These thicknesses correspond to 300Å for W-Si and 250Å for Al-Si, respectively.

301. Thus, Konjuh and Ogawa teach the subject matter of element [1.2].

#### 4. **Konjuh and Ogawa teach element [1.3]**

302. The next element of claim 1, which is labeled element [1.3], states:

forming an oxide layer having a thickness from about 5 Å to about 50 Å over the silicon oxynitride layer to provide the silicon oxynitride antireflection coating,

Konjuh and Ogawa teach this subject matter.

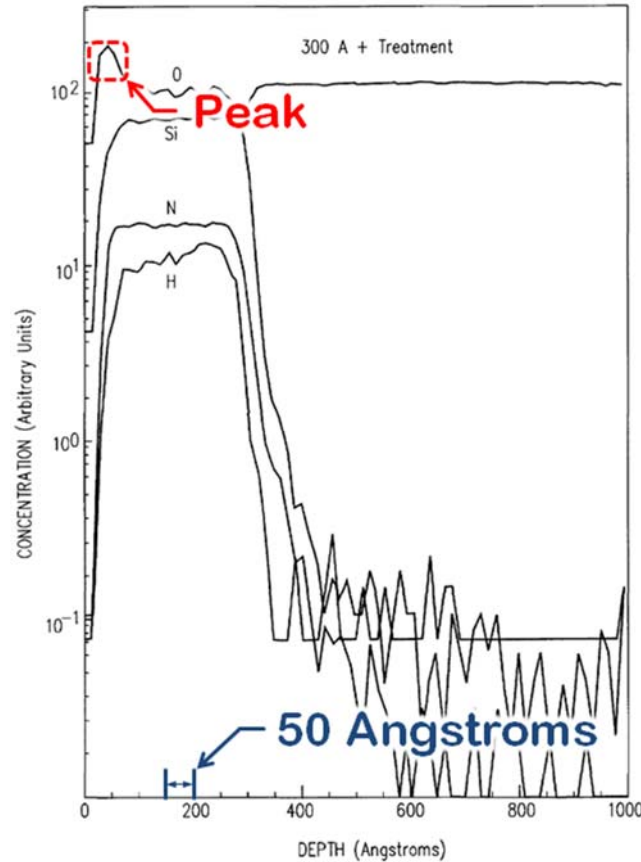
303. As shown in ¶ 284, Konjuh and Ogawa teach a structure that includes an oxide layer (**yellow**) formed on the silicon oxynitride layer 18 (**green**). The oxide layer (**yellow**) has a thickness of approximately 50 angstroms.

304. Konjuh states:

In one embodiment, the surface layer is formed on an ARL of silicon oxynitride (SiON) by introducing N<sub>2</sub>O into the chamber of chemical vapor deposition unit in the presence of radio frequency power. ...

*The inventors believe the foregoing process forms a layer of SiO<sub>2</sub> at the surface of the antireflective layer. ...* [I]n FIG. 3 the ARL had been treated with the process of this invention. The primary difference is the peak in the oxygen concentration which appears at the surface in FIG. 3. This peak is believed to represent a SiO<sub>2</sub> layer.

Ex. 1015, Col. 2:48-67 (emphasis added). As explained (§ VIII.G, p. 57), the peak of oxygen concentration has a width of approximately 50Å:



**Konjuh, FIG. 3 (annotated)**

305. Thus, Konjuh and Ogawa teach the subject matter of element [1.3].

### **5. Konjuh and Ogawa teach element [1.4]**

306. The final element of claim 1, which is labeled element [1.4], states:

wherein the oxide layer forms a barrier to migration of nitrogen atoms from the silicon oxynitride layer.

Konjuh and Ogawa teach this subject matter.



307. The prior art teaches that the oxide layer (**yellow**) prevents amines from the silicon oxynitride layer from interacting with the photoresist 10 (**gray**).

308. Konjuh states:

This invention involves the formation of a surface layer on an antireflective layer to counteract the effect of amines (NH<sub>2</sub>) on an overlying photoresist layer. The amines, which are basic, neutralize the acids that are formed when the photoresist layer is exposed to radiation and thereby prevent full development of the photoresist layer. ... ***The surface layer of this invention provides a barrier which prevents the amines from migrating into the photoresist layer.***

Ex. 1015, Col. 2:35-47 (emphasis added).

309. Thus, Konjuh and Ogawa teach the subject matter of element [1.4].

310. As described above, Konjuh and Ogawa teach all elements of claim 1. Accordingly, I conclude that Konjuh and Ogawa render claim 1 of the '231 patent obvious.

### **C. Konjuh and Ogawa Render Claim 2 Obvious**

311. Claim 2 of the '231 patent depends from claim 1 and recites:

The method of claim 1, wherein the metal layer comprises at least one of aluminum, copper, gold, nickel, palladium, platinum, silver, tantalum, titanium, tungsten, zinc, aluminum-copper alloys, aluminum alloys, copper alloys, titanium alloys, tungsten alloys, titanium-tungsten alloys,

gold alloys, nickel alloys, palladium alloys, platinum alloys, silver alloys, tantalum alloys, zinc alloys, and metal silicides.

Konjuh and Ogawa teach this subject matter.

312. Konjuh and Ogawa teach all elements of claim 1 as explained above.

313. Konjuh and Ogawa teach that the substrate 12 (*blue*) may be either tungsten silicide (W-Si) or aluminum silicon (Al-Si). Tungsten silicide is a metal silicide under the claims. Aluminum silicon is an aluminum alloy under the claims.

314. Ogawa states:

This new ARL, whose material is a type of hydro silicon oxynitride film ( $\text{SiO}_x\text{N}_y\text{:H}$ ), can be applied to *tungsten silicide (W-Si)* and even to *aluminum silicon (Al-Si) substrates* by controlling deposition conditions in plasma enhanced chemical vapor deposition systems. Using this  $\text{SiO}_x\text{N}_y\text{:H}$  film with 30nm and 25nm thicknesses on W-Si and Al-Si substrates respectively, critical dimension (CD) variations for both substrates are drastically reduced to within 0.02 $\mu\text{m}$  for 0.30 $\mu\text{m}$  imaging.

Ex. 1016, p. 1 (emphases added).

315. Konjuh and Ogawa teach all elements of claim 2. Thus, Konjuh and Ogawa render claim 2 obvious.

#### **D. Konjuh and Ogawa Render Claim 3 Obvious**

316. Claim 3 of the '231 patent depends from claim 1 and recites:

The method of claim 1, wherein the metal layer comprises at least one of aluminum, copper, aluminum-copper alloys, aluminum alloys and copper alloys.

Konjuh and Ogawa teach this subject matter.

317. Konjuh and Ogawa teach all elements of claim 1 as explained above.

318. The prior art teaches that the substrate 12 (*blue*) may be aluminum silicon (Al-Si). Aluminum silicon is an aluminum alloy under the claims.

319. Ogawa states:

This new ARL, whose material is a type of hydro silicon oxynitride film ( $\text{SiO}_x\text{N}_y\text{H}$ ), can be applied to tungsten silicide (W-Si) and even to *aluminum silicon (Al-Si) substrates* by controlling deposition conditions in plasma enhanced chemical vapor deposition systems. Using this  $\text{SiO}_x\text{N}_y\text{H}$  film with 30nm and 25nm thicknesses on W-Si and Al-Si substrates respectively, critical dimension (CD) variations for both substrates are drastically reduced to within  $0.02\mu\text{m}$  for  $0.30\mu\text{m}$  imaging.

Ex. 1016, p. 1 (emphasis added).

320. Konjuh and Ogawa teach all elements of claim 3. Thus, Konjuh and Ogawa render claim 3 obvious.

**E. Konjuh and Ogawa Render Claim 4 Obvious**

321. Claim 4 of the '231 patent depends from claim 1 and recites:

The method of claim 1, wherein the oxide layer is formed by contacting the silicon oxynitride layer with oxygen plasma.

Konjuh and Ogawa teach this subject matter.

322. Konjuh and Ogawa teach all elements of claim 1 as explained above.

323. Konjuh states:

For example, in some embodiments other oxygen-containing gases such as *pure oxygen* can be substituted for the N<sub>2</sub>O.

Ex. 1015, Col. 4:8-10 (emphasis added).

324. Konjuh and Ogawa teach all elements of claim 4. Thus, Konjuh and Ogawa render claim 4 obvious.

#### **F. Konjuh and Ogawa Render Claim 5 Obvious**

325. Claim 5 of the '231 patent depends from claim 1 and recites:

The method of claim 1, wherein the oxide layer is formed by contacting the silicon oxynitride layer with N<sub>2</sub>O plasma.

Konjuh and Ogawa teach this subject matter.

326. Konjuh and Ogawa teach all elements of claim 1 as explained above.

327. Konjuh states:

In one embodiment, the surface layer is formed on an ARL of silicon oxynitride (SiON) by introducing *N<sub>2</sub>O into the chamber of chemical*

*vapor deposition unit in the presence of radio frequency power.* The  $N_2O$  is introduced at a rate of from 0.2 sccm to 8 sccm per square centimeter of wafer surface, preferably about 4 sccm/cm<sup>2</sup>. The radio frequency power is applied at a rate of from 0.6 W to 6 W per square centimeter of wafer surface, preferably about 3 W/cm<sup>2</sup>. The radio frequency power is typically applied for from 1 to 20 seconds.

Ex. 1015, Col. 2:48-57 (emphasis added).

328. Konjuh further states:

For example, in some embodiments other oxygen-containing gases such as pure oxygen can be substituted for the  $N_2O$ .

Ex. 1015, Col. 4:8-10 (emphasis added).

329. Konjuh and Ogawa teach all elements of claim 5. Thus, Konjuh and Ogawa render claim 5 obvious.

### **XIII. CLAIM 7 IS OBVIOUS OVER KONJUH, OGAWA, JOESTEN AND CHEUNG.**

#### **A. Motivation to Combine Teachings of References**

330. As described above (§ VIII.I, p. 64), a worker of skill would have reason to consider the teachings of Konjuh and Ogawa with those of Lee, Joesten and Cheung.

331. First, Konjuh, Ogawa, Lee, Joesten, and Cheung each are directed to the same field of endeavor – antireflection coatings made of silicon oxynitride.

332. Konjuh, Joesten, and Cheung are directed to solutions to footing problems that arise from such antireflection coatings, and they describe the same solution – N<sub>2</sub>O plasma treatment to the surface of the silicon oxynitride layer.

333. A worker of skill would be motivated to investigate reflectivity of such surface treatments to confirm they do not impair performance of the silicon oxynitride antireflection coating because the purpose of the antireflection coating is to cancel reflections from the substrate back to the photoresist.

334. Based on review of Konjuh, Ogawa, Lee, Joesten, and Cheung, a person of skill would recognize that Konjuh's structure can be tuned to achieve reflectivity less than 10%.

335. Lee demonstrates that silicon oxynitride antireflection layers with no coating can achieve reflectivity less than 10% at wavelengths less than 248 nm, even when used with metal substrates. Ex. 1018, FIG. 2b.

336. Cheung teaches that oxide films that have thicknesses below 100Å do not noticeably affect reflectivity of antireflection films. Ex. 1012, ¶ 0017. *See also*, Shibata, Ex. 1011, ¶ 0018.

337. Both Ogawa and Joesten provide teachings to tune layer parameters to cancel reflection components. Exs. 1016, § 2.1, 1017, § 3.3.

338. Cheung and Joesten both illustrate antireflection films having silicon oxynitride layer thicknesses that correspond to those of Konjuh having reflectivities less than 10% at wavelengths less than 248 nm. Ex. 1012, FIGS. 6, 7; Ex. 1017, FIGS. 10. *See also*, § VIII.I (p. 64 above).

339. These teachings, in aggregate, demonstrate to a worker of skill not only that reflectivity properties of Konjuh's antireflection coating are predictable and well understood, but also that his antireflection coating can achieve reflectivity of less than 10% at wavelengths less than 248 nm.

**B. Analysis of Challenged Claim**

340. Claim 7 of the '231 patent depends from claim 1 and recites:

The method of claim 1, wherein the silicon oxynitride antireflection coating has a reflectivity of about 10% or less at a wavelength below about 248 nm.

Konjuh, Ogawa, Lee, Joesten, and Cheung teach this subject matter.

341. Konjuh and Ogawa teach all elements of claim 1 as explained above.

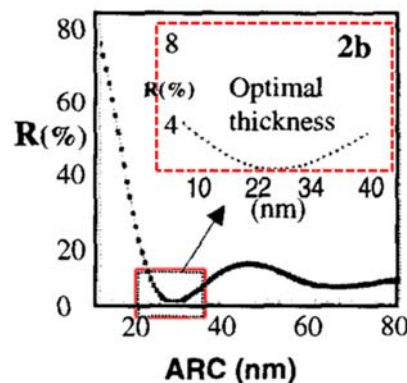
342. Neither Konjuh nor Ogawa explicitly state the reflectivity value of their antireflection coatings.

343. Ogawa, however, teaches that parameters of the antireflection coating may be optimized for individual use:

This method gives one direction for optimizing an ARL for some target substrate. Using this method, for any given substrates and ARL thicknesses, the optimal optical conditions as an ARL for a target substrate can be determined. Moreover, even if exposure wavelengths are changed, the optimization method does not change. For this case, the values of refractive indices of the substrates, photoresist, and various films need only be determined and the calculations once again performed with these new parameters.

Ex. 1016, p. 2.

344. Lee discloses that silicon oxynitride antireflection films achieve reflectivity less than 10% at wavelengths below 248 nm across a wide range of film thicknesses.



Lee (Ex. 1018), FIG. 2b (annotated)

345. Cheung and Joesten disclose that reflectance of a dual-layer silicon oxynitride / oxide antireflection coating achieves reflectivity of 10% or less at wavelengths below about 248 nm.



346. Cheung describes that an anti-reflection coating that includes a silicon oxynitride layer with a thickness of 300Å has reflectivity less than 10% at a wavelength below about 248 nm.

347. Cheung provides reflectivity simulations of the silicon oxynitride ARC in Figures 6 and 7. These simulations estimate reflectivity of the ARC over thicknesses of the oxide layer that vary between 50 Å and 1000 Å. Cheung states:

A silicon oxynitride ( $\text{SiO}_x\text{N}_y$ ) ARC (or DARC) was used in these simulations because the use of such an ARC is preferred in the present invention. The simulated DARC was tuned for deep UV, and exhibited a refractive index of 2.15 and absorptive index of 0.53, again at a wavelength of 248 nm. The DARC's thickness was selected by simulating various DARC thicknesses between 50 Å and 1000 Å. This was done for a DARC layer applied over both tungsten silicide and polysilicon. As expected, the minimum reflectivity at the photoresist/DARC interface occurred at a DARC thickness of about 300 Å.

FIG. 6 shows this relationship for a structure having a capping layer/hardmask and DARC deposited over a tungsten silicide substrate. FIG. 7 shows this relationship for a similar structure deposited over a polysilicon substrate. *In both simulations, the capping layer's (hardmask's) thickness was varied from 50 Å to 1000 Å, while holding the DARC thickness constant at 300 Å.*

Ex. 1012, Col. 17:29-51 (emphasis added).

348. Cheung's simulations are shown below. As indicated, FIGS. 6 and 7 both show that reflectivities of the antireflection coatings are below 10% (*red*) for all simulated oxide (capping layer) thicknesses, even those at 50 Å:

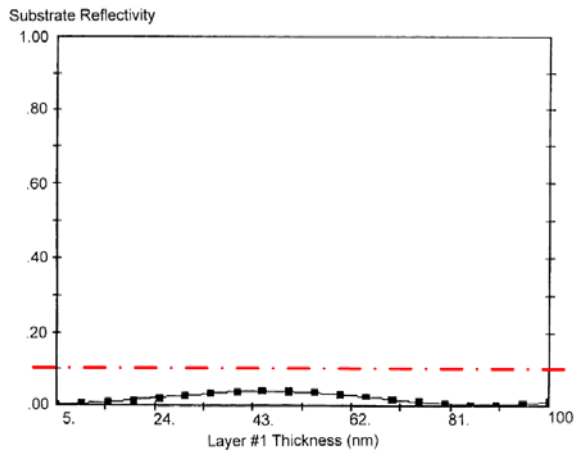


FIG. 6

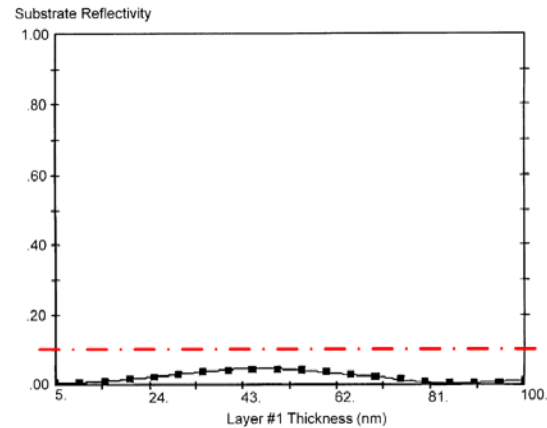


FIG. 7

**Cheung (Ex. 1012), FIGS. 6, 7 (annotated)**

349. Joesten also describes a variety of silicon oxynitride antireflection coatings with reflectivity less than 10% at a wavelength below about 248 nm:

The use of a nitrous oxide plasma treatment reduces the foot by more than a factor of three. The combination of a surface treatment with the reflection maximum of 550 Å completely eliminates all traces of footing for APEX-E 2408 and UV6.

Ex. 1017, p. 1.

At the 1,500Å film thickness, a local minimum of 16% reflectivity, a 2X improvement in footing results over the 300Å film, *which has a reflectivity minimum of 3.0%.*

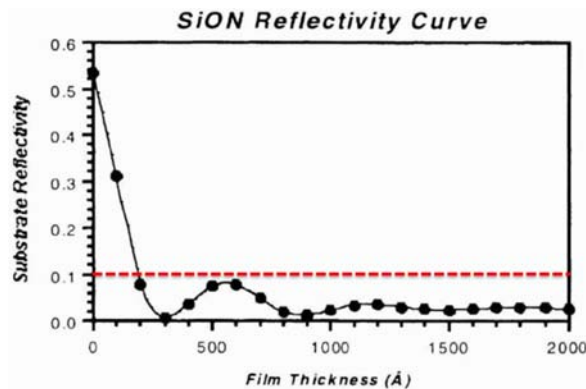
Ex. 1017, p. 7 (emphasis added).

350. Joesten also altered reflectivity of films to examine effects on footing.

Joesten's films include films with reflectivity below 10%. Joesten states:

The footing results for UV6, as seen in Figure 13, show a non-linear behavior with the phase on the reflectivity curve. As **reflectivity increases from 1.0% to 5.0%** the footing appears to worsen, moving from a descending midpoint (267Å) to a minimum (300Å) on the reflectivity curve.

Ex. 1017, p. 8 (emphasis added).



**Joesten (Ex. 1017), FIG. 10 (annotated)**

351. Cheung's simulations and Joesten's simulations both are performed using radiation sources using 248 nm wavelengths. Ex. 1012, Col. 17:29-51; Ex. 1017, § 2 (KrF lasers).

352. The prior art teaches all elements of claim 7. Therefore, Konjuh, Ogawa, Joesten and Cheung render claim 7 obvious.

**XIV. CONCLUSION**

353. For the reasons stated above, it is my opinion that claims 1-5 and 7 of the '231 patent are invalid over prior art.

**XV. DECLARATION IN LIEU OF OATH**

354. In signing this declaration, I realize that this declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office.

355. I am aware that willfully false statements and the like made by me in connection with this declaration are punishable by fine or imprisonment, or both (18 U.S.C. § 1001) and may jeopardize the validity of the Petition. All statements herein made by me of my own knowledge are true and all statements made on information and belief are believed to be true. I declare under penalty of perjury that the foregoing is true and correct.

Respectfully submitted,



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Dean Neikirk, Ph.D.

Date: September 21, 2017