UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

GLOBAL FOUNDRIES U.S., INC., GLOBALFOUNDRIES DRESDEN
MODULE ONE LLC & CO. KG, GLOBALFOUNDRIES DRESDEN MODULE
TWO LLC & CO. KG, and THE GILLETTE COMPANY,

Petitioners

v.

ZOND, LLC
Patent Owner

Case No. IPR2014-01100[1]

Patent 7,604,716 B2

DECLARATION OF LARRY D. HARTSOUGH, PH.D.

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[1] Case IPR 2014-00973 has been joined with the instant proceeding.

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I, Larry D. Hartsough, do hereby declare:

1. I am making this declaration at the request of patent owner Zond, LLC, in connection with the *Inter Partes* Reviews (IPRs) of U.S. Patent No. 7,604,716 (the "'716 patent"), set forth in the above caption.

2. I am being compensated for my work in this matter at the rate of $300 per hour. I have no interest in the '716 patent and my compensation in no way depends on the outcome of this proceeding.

3. In forming the opinions set forth in this declaration I reviewed a number of materials, including the '716 patent, the file history of the '716 patent, the Petitions for *Inter Partes* Review and the cited references discussed below, the Patent Trial and Appeal Board's (PTAB's) Institution Decisions in these IPR proceedings, the transcript of the deposition of Dr. Uwe Kortshagen concerning the '716 patent, and the additional materials discussed herein.

I. EDUCATION AND PROFESSIONAL BACKGROUND

4. My formal education is as follows. I received a Bachelors of Science degree in 1965, Master of Science degree in 1967, and Ph.D. in 1971, all in Materials Science/Engineering from the University of California, Berkeley.

5. I have worked in the semiconductor industry for approximately 30 years. My experience includes thin film deposition, vacuum system design, and plasma processing of materials. I made significant contributions to the development of magnetron sputtering hardware and processes for the metallization of silicon integrated circuits. Since the late 1980s, I have also been instrumental in the development of standards for semiconductor fabrication equipment published by the Semiconductor Equipment and Materials International ("SEMI") trade organization.

6. From 1971-1974, I was a research metallurgist in the thin film development lab of Optical Coating Laboratory, Inc. In 1975 and 1976, I developed and demonstrated thin film applications and hardware for an in-line system at Airco Temescal. During my tenure (1977-1981) at Perkin Elmer, Plasma Products Division, I served in a number of capacities from Senior Staff Scientist, to Manager of the Advanced Development activity, to Manager of the Applications Laboratory. In 1981, I co-founded a semiconductor equipment company, Gryphon Products, and was VP of Engineering during development of the product. From 1984-1988, I was the Advanced Development Manager for Gryphon, developing new hardware and process capabilities. During 1988-1990, I was Project Manager at General Signal Thinfilm on a project to develop and prototype an advanced cluster tool for making thin films. From 1991-2002, I was Manager of PVD

(physical vapor deposition) Source Engineering for Varian Associates, Thin Film Systems, and then for Novellus Systems, after they purchased TFS. Since then, I have been consulting full time doing business as UA Associates, where my consulting work includes product development projects, film failure analysis, project management, technical presentations and litigation support.

7. Throughout my career, I have developed and/or demonstrated processes and equipment for making thin films, including Al, Ti-W, Ta, and Cu metallization of silicon wafers, RF sputtering and etching, and both RF and DC magnetron reactive sputtering, for example SiO_2, Al_2O_3, ITO (Indium-Tin Oxide), TiN, and TaN. I have been in charge of the development of two sputter deposition systems from conception to prototype and release to manufacturing. I have also specialized in the development and improvement of magnetically enhanced sputter cathodes. I have experience with related technology areas, such as wafer heating, power supply evaluation, wafer cooling, ion beam sources, wafer handling by electrostatics, process pressure control, in-situ wafer/process monitoring, cryogenic pumping, getter pumping, sputter target development, and physical, electrical and optical properties of thin films.

8. I am a member of a number of professional organizations including the American Vacuum Society, Sigma Xi (the Scientific Research Society), and as a

referee for the Journal of Vacuum Science & Technology. I have been a leader in the development of SEMI Standards for cluster tools and 300mm equipment, including holding various co-chair positions on various standards task forces. I have previously served as a member of the US Department of Commerce's Semiconductor Technical Advisory Committee.

9. I have co-authored many papers, reports, and presentations relating to semiconductor processing, equipment, and materials, including the following:

a. P. S. McLeod and L. D. Hartsough, "High-Rate Sputtering of Aluminum for Metalization of Integrated Circuits", J. Vac. Sci. Technol., 14 263 (1977).

b. D. R. Denison and L. D. Hartsough, "Copper Distribution in Sputtered Al/Cu Films", J. Vac. Sci. Technol., 17 1326 (1980).

c. D. R. Denison and L. D. Hartsough, "Step Coverage in Multiple Pass Sputter Deposition" J. Vac. Sci. Technol., A3 686 (1985).

d. G. C. D'Couto, G. Tkach, K. A. Ashtiani, L. Hartsough, E. Kim, R. Mulpuri, D. B. Lee, K. Levy, and M. Fissel; S. Choi, S.-M. Choi, H.-D. Lee, and H. –K. Kang, "*In situ* physical vapor deposition of ionized Ti and TiN thin films using hollow cathode magnetron plasma source" J. Vac. Sci. Technol. B 19(1) 244 (2001).

10. My areas of expertise include sputter deposition hardware and processes,

thin film deposition system design and thin film properties. I am a named inventor on twelve United States patents covering apparatus, methods or processes in the fields of thin film deposition and etching. A copy of my CV is attached as Attachment A.

II. SUMMARY

11. My opinions in this matter are set forth in detail below. Briefly, it is my opinion that:

a. none of apparatus recited claims 1-11 and 33 of the ‘716 patent are anticipated by *Wang*;

b. the apparatus recited in claims 12 and 13 would not have been obvious to a person of ordinary skill in the art at the time of the invention in view of the combined teachings of *Wang* and *Lantsman*;

c. the methods recited in claims 14-18 and 21, and 25 and the apparatus recited in claims 26-32 would not have been obvious to a person of ordinary skill in the art at the time of the invention in view of the combined teachings of *Wang* and *Kudryavtsev*;

d. the methods recited in claims 19 and 20 would not have been obvious to a person of ordinary skill in the art at the time of the invention in view of the combined teachings of *Wang*, *Kudryavtsev,* and *Lantsman*; and

e. the methods recited in claims 22-24 would not have been obvious to a person of ordinary skill in the art at the time of the invention in view of the combined teachings of *Wang*, *Kudryavtsev,* and *Mozgrin.*

12. *Wang* discusses a magnetron sputter reactor in which DC power pulses are applied to a plasma in order to sputter material from a target. While *Wang* describes controlling aspects of these power pulses, *Wang* does not teach controlling voltage amplitude or pulse width when generating a high-density plasma to perform the sputtering. Nor does Wang explain any of the electrodynamics of the high-density plasma. As I explain below, control of a pulse's power level (as in *Wang*) is very different from controlling the voltage amplitude and rise time of a pulse and even *Wang* acknowledges this distinction.[1] Any voltage pulses disclosed by *Wang* are merely a consequence of the system attempting to deliver the desired power level, i.e., the voltage (and current) are

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[1] *Ex. 1104* at 5:52-54 ("Where chamber impedance is changing, the power pulse width is preferably specified rather than the current or voltage pulse widths.").

driven by the power supply of *Wang* based upon the desired power level but are determined by the plasma impedance.

13. *Kudryavtsev* describes a flash tube, which is designed to apply a high voltage greater than the breakdown voltage across an inert gas resulting in a brilliant flash of light for a short duration. Flash tubes apply a voltage greater than the breakdown voltage, which may initiate the flash by an arc between the cathode and the anode. *Kudryavtsev* describes a voltage pulse that causes an "explosion" in electron density that appears to cause an arcing condition as shown in his measured voltage and current waveforms. A person of ordinary skill in the art would therefore not refer to *Kudryavtsev* at all when designing a plasma generator, where arcing is an undesirable characteristic.[2]

14. In my opinion, it would not have been obvious to combine the teachings of *Wang* and *Kudryavtsev*. As I explain further below, there are significant differences between the experimental apparatus of *Kudryavtsev* and the magnetron sputter reactor described by *Wang.* Consequently, a person of ordinary skill in the art would not have expected that applying the teachings of *Kudryavtsev* in a *Wang*-type system would have yielded predictable results or would have performed in an expected way. Behaviors of charged particles (such as electrons and ions) in

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[2] *Ex. 1101* at 3:48-52.

magnetic fields (as in systems such as those discussed by *Wang*) are vastly different from their behaviors in the absence of magnetic fields (as in systems reported by *Kudryavtsev)*.

15. My conclusions regarding *Wang* and *Kudryavtsev* are not changed when one further considers the teachings of *Mozgrin*. While *Mozgrin* purports to have considered certain dependencies reported by *Kudryavtsev*, *Mozgrin* determined that for systems employing a magnetic field, a supply unit "providing square voltage and current pulses with rise times (leading edge) of 5 – 60 μs and durations as much as 1.5 ms" was needed.[3] *Wang*, on the other hand, was concerned with systems that used magnetic filed but considered it important that pulses have "significant" rise times and pulse widths preferably less than 200 μs and no more than 1 ms.[4] Given these important distinctions in the nature of the supply unit, the teachings of *Mozgrin* would be of little value to a person of ordinary skill in the art when considering the system of *Wang*. Significant experimentation would still be required in order to adapt any teachings of *Mozgrin* to the new regime of *Wang*.

16. It is also my opinion it would not have been obvious to combine the teachings of *Wang* and *Lantsman*. *Lantsman* differs substantially from *Wang*.

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[3] IPR2014-00808 *Ex. 1303* at p. 401, rt. col. ¶ 1.

[4] *Ex. 1104* at 5:26-27, 43-48; 8:41-42.

Whereas *Wang* describes the application of "narrow pulses of negative DC power supplied from a pulsed DC power supply,"[5] *Lantsman* employs two separate power supplies: "[a] secondary power supply [that] pre-ignites the plasma by driving the cathode to a process initiation voltage[, and] a primary power supply [that thereafter] electrically drives the cathode to generate plasma current and deposition on a wafer."[6] *Lantsman* does not disclose a pulsed power supply, any type of electrical pulse, or a strongly-ionized plasma. Consequently, a skilled artisan would not have been motivated to modify *Wang's* pulsed power magnetron sputtering system with a system that employs separate, continuous DC power supplies, such as that discussed by *Lantsman*.

17. My opinions in this regard do not change when one considers the additional teachings of *Kudryavtsev*. As explained in detail below, because *Kudryavtsev* suggests forming an arc, a person of ordinary skill in the art would not have applied any of its teachings to a magnetron sputter reactor for which reducing arcing (as in *Wang*) was a consideration. Accordingly, it would not have been obvious to combine the teachings of *Wang, Lantsman,* and *Kudryavtsev*.

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[5] *Id.* at 5:18-22.

[6] *Ex. 1105,* Abstract.

III. LEGAL STANDARDS

18. In this section I describe my understanding of certain legal standards. I have been informed of these legal standards by Zond’s attorneys. I am not an attorney and I am relying only on instructions from Zond’s attorneys for these legal standards.

A. Level of Ordinary Skill in the Art.

19. I understand that a person of ordinary skill in the art provides a reference point from which the prior art and claimed invention should be viewed. This reference point prevents one from using his or her own insight or hindsight in deciding whether a claim is obvious.

20. In my opinion, given the disclosure of the ‘716 patent and the disclosure of the prior art references considered here, I consider a person of ordinary skill in the art at the time of filing of the ‘716 patent to be someone who holds at least a bachelor of science degree in physics, material science, or electrical/computer engineering with at least two years of work experience or equivalent in the field of development of plasma-based processing equipment. I met or exceeded the requirements for one of ordinary skill in the art at the time of the invention and continue to meet and/or exceed those requirements.

B. Claim Interpretation.

21. I understand that the Board has construed the term "strongly ionized plasma" as "a plasma with a relatively high peak density of ions" and has construed the term "weakly ionized plasma" as "a plasma with a relatively low peak density of ions." In rendering the opinions set forth herein I have applied these constructions.

22. I further understand that the Board has construed the term "weakly-ionized plasma substantially eliminating the probability of developing an electrical breakdown condition in the chamber" as "weakly-ionized plasma that substantially eliminates the probability of developing an electrical breakdown condition when an electrical pulse is applied across the plasma thereby to generate a strongly-ionized plasma." In rendering the opinions set forth herein I have applied this construction.

23. I also understand that a means plus function claim limitation must be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof. To that end, I understand the Board has adopted the following constructions of means plus function terms in the claims of the '716 patent.

Term	Construction
"means for ionizing a feed gas in a chamber to form a weakly-ionized plasma that substantially eliminates the probability of developing an electrical breakdown condition in the chamber"	a power supply electrically connected to a cathode, an anode, and/or an electrode
"means for supplying an electrical pulse across the weakly-ionized plasma to transform the weakly-ionized plasma to a strongly-ionized plasma without developing an electrical breakdown condition in the chamber"	a pulsed power supply electrically connected to a cathode, an anode, and/or an electrode

In rendering the opinions set forth herein I have applied the above constructions, with the exception of the Board's construction for "means for ionizing a feed gas . . . ." In my opinion, the Board's construction of this term is flawed inasmuch as it fails to account for the important cathode-anode arrangement that is described by Dr. Chistyakov. According to the '716 patent, "[t]he anode 216 is positioned so as to form a gap 220 between the anode 216 and the cathode 204 that is sufficient to allow current to flow through a region 222 between the anode 216 and the cathode 204."[7] "The gap 220 and the total volume of the region 222 are parameters in the

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[7] *Ex. 1101* at 4:30-33.

ionization process . . . ."[8] Because the gap (and the volume resulting therefrom) between the anode and cathode is specifically called out as being a parameter in the ionization process, in my opinion a person of ordinary skill in the art would consider the gap to be a part of the structure of the recited "means for ionization." Therefore, in rendering the opinions set forth herein I have construed the "means for ionizing a feed gas in a chamber to form a weakly-ionized plasma that substantially eliminates the probability of developing an electrical breakdown condition in the chamber" as "a power supply electrically connected to a cathode separated from an anode, and/or an electrode, by a gap there between."

C. Legal Standards for Anticipation.

24. I understand that a claim is anticipated if (i) each and every element and limitation of the claim at issue is found either expressly or inherently in a single prior art reference, and (ii) the elements and limitations are arranged in the prior art reference in the same way as recited in the claims at issue.

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[8] *Id.* at 4:36-38.

D. Legal Standards for Obviousness.

25. I understand that even if a patent is not anticipated, it may still be invalid if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person of ordinary skill in the pertinent art.

26. I understand that obviousness must be analyzed from the perspective of a person of ordinary skill in the relevant art at the time the invention was made. In analyzing obviousness, I understand that it is important to understand the scope of the claims, the level of skill in the relevant art, the scope and content of the prior art, the differences between the prior art and the claims, and any secondary considerations of non-obviousness. I have not been asked to study or analyze any secondary considerations of non-obviousness. As discussed further below, the prior art references describe systems that are so different from what is claimed that these do not form a basis for an obviousness determination of the claimed subject matter.

27. I also understand that a party seeking to invalidate a patent as obvious must demonstrate that a person of ordinary skill in the art would have been motivated to combine the teachings of the prior art references to achieve the claimed invention, that the person of ordinary skill in the art would have had a reasonable expectation of success in doing so, and that such determinations are evaluated as of the time the invention was made. I understand that this temporal requirement prevents the

forbidden use of hindsight. I also understand that rejections for obviousness cannot be sustained by mere conclusory statements and that Petitioners must show some *reason* why a person of ordinary skill in the art would have thought to combine *particular* available elements of knowledge, as evidenced by the prior art, to reach the claimed invention. I also understand that the motivation to combine inquiry focuses heavily on the scope and content of the prior art and the level of ordinary skill in the pertinent art.

28. In arriving at the opinions set forth herein, I have considered questions of obviousness from the perspective of a person of ordinary skill in the relevant art at the time the invention was made and have given consideration to (1) the scope and content of the prior art; (2) the differences between the prior art and the asserted claims; and (3) the level of ordinary skill in the pertinent art. I have been informed and understand that the obviousness analysis requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

IV. BACKGROUND TOPICS

29. The ‘716 patent relates to “[m]ethods and apparatus for generating a

strongly-ionized plasma."[9] I understand that IPR2014-01099 was instituted to consider the novelty of claims 1-11 and 33 of the '716 patent over Wang, et al., U.S. Patent 6,413,382 (Ex. 1104) ("*Wang*"). I also understand that IPR2014-01100 was instituted to consider the obviousness of claims 12 and 13 in view of the combined teachings of *Wang* and Lantsman, U.S. Patent 6,190,512 (Ex. 1105) ("*Lantsman*"). I further understand that IPR2014-00807 was instituted to consider the obviousness of claims 14-18 and 25-32 in view of the combined teachings of *Wang* and Kudryavtsev, et al, *Ionization relaxation in a plasma produced by a pulsed inert-gas discharge*, Sov. Phys. Tech. Phys. 28(1), January 1983 (IPR2014-00807 Ex. 1205) ("*Kudryavtsev*"). I also understand that IPR2014-00808 was instituted to consider the obviousness of claims 19 and 20 in view of the combined teachings of *Wang, Kudryavtsev*, and *Lantsman*; of claim 21 in view of the combined teachings of *Wang* and *Kudryavtsev*; and of claims 22-24 in view of the combined teachings of *Wang, Kudryavtsev*, and Mozgrin et al., *High-Current Low-Pressure Quasi- Stationary Discharge in a Magnetic Field: Experimental Research*, Plasma Physics Reports, Vol. 21, No. 5, 1995 (Ex. 1103) ("*Mozgrin*"). In this section I provide some background information useful to understanding these cited references and the subject matter claimed in the '716 patent.

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[9] *Ex. 1101* at Abstract.

A. Voltage, current, impedance and power.

30. As is commonly known, when a voltage “V” is applied across an impedance “I,” an electric field is generated that forces a current I to flow through the impedance. For purely resistive impedance, the relation between the voltage and the resultant current is given by: V = I * R.

31. A common analogy is that voltage is like a pressure that causes charged particles like electrons and ions to flow (i.e., current), and the amount of current depends on the magnitude of the pressure (voltage) and the amount of resistance or impedance that inhibits the flow. The ‘716 patent and the cited references considered here involve the flow of current through an assembly having a pair of electrodes with a plasma in the region between them. The effective impedance of such an assembly varies greatly with the density of charged particles in the region between the electrodes. Although such an impedance is more complex than the simple resistive impendence of the above equation, the general relation is similar: a voltage between the electrode assembly forces a current to flow through the plasma, such that the amount of current is determined by the amplitude of the voltage and the impedance of the plasma. Thus, the current through the electrode assembly increases with the electrode voltage and, for a given electrode voltage, the current will increase with a drop in the impedance of the plasma.

32. The impedance varies with the charge density of the plasma: With a high density of charged particle the impedance is relatively small, and with a low density of charged particles the impedance is relatively large. Simply, the more ions and electrons to carry the charge, the less resistance. However, the charges and fields react with each other in a very complicated manner.

33. In response to the electric field in the region between the electrodes (i.e., the voltage across the electrodes), all charged particles in the region (the electrons and positive ions) feel a force that propels them to flow. This flow is an electric current "I." The amount of current depends upon the number of charged particles. When there are no charged particles (i.e., no plasma), there is no current flow in response to the electric field. In this condition, the impendence of the assembly is extremely high, like that of an open circuit. But when there is a dense plasma between the electrodes (with many charged particles), a substantial current will flow in response to the electric field. In this condition, the impendence of the electrode assembly is very low. Thus, in general, the impedance of an electrode assembly varies greatly with the charge density of the plasma: The impedance is effectively infinite (an open circuit) when there is no plasma, and is very low when the charge density of the plasma is very high.

34. It is also well known that electric power (P) is the product of voltage (V) and

current (I): P = V * I. Thus, for a given voltage across an electrode assembly, the amount of power will depend on the amount of corresponding current flowing through the electrode assembly. If there is no current flow (such as when there is no plasma between the electrodes), the power is zero, even if the voltage across the electrodes is very large. Similarly, at very low electrode voltages, the power can still be quite high if the current is large.

35. The claims of the ‘716 patent refer to a strongly-ionized plasma that is created by application of an electric field across a gap between a cathode and an anode. In some cases, the electric field is said to have rise times chosen to increase ionization rates of the plasma. Also, the electric filed may be applied at a constant power or a constant voltage. I consider these and other aspects of the claims of the ‘716 patent below, but first, to provide context for understanding aspects of the ‘716 patent, I consider some basic principles of control systems (such as used in power supplies) for controlling various parameters.

B. Control systems.

36. The ‘716 patent describes a magnetically enhanced plasma processing apparatus that includes a power supply that controls the amplitude and pulse width

of an electrical pulse.[10] The pulse produces an electric field in the plasma processing apparatus, and the rise time of the electric field is chosen to increase an ionization rate of excited atoms in a weakly-ionized plasma to generate a strongly-ionized plasma.[11] This power supply is an example of a control system. A simplified block diagram of a common feedback control system is shown the figure below from a text by Eronini.[12]

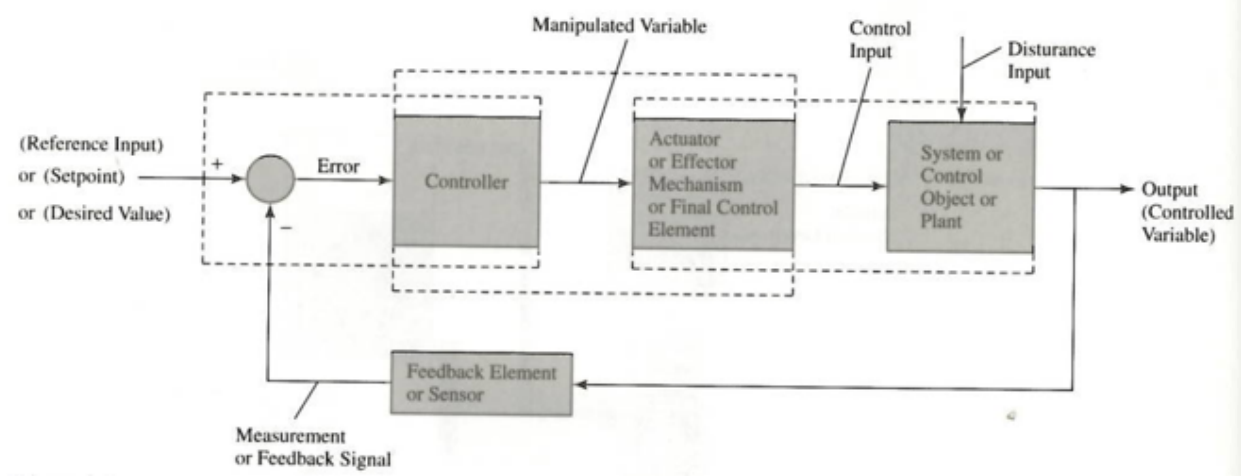

Figure 1: Control system simplified block diagram

37. The "reference input" signal represents a "desired value" or "set-point" of the controller. The control system directly controls the "controlled variable." In

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[10] See, e.g., *id.* at 11:59 – 12:6.

[11] *Id*. at 8:42-47; 11:59 – 12:6; and 22:29-32.

[12] *Ex. 2005* at p. 12, Fig. 1.6.

response to the difference between the set-point and a feedback signal (which represents the condition of the controlled variable), the control system directs the controlled variable in an attempt to reduce the difference to zero, thereby causing the controlled variable to equal the set point value.

38. For example, the set-point for filling a water tank may be 1,000 gallons, or full. The desired value, set-point or desired level is the value "full" or "1000 gallons." An open loop control system (a control system without any feedback elements) might just fill the tank for a pre-calibrated time that result in the tank being full. The control system might be set to fill the tank once per day based on historical water usage. However, if water usage is not consistent, the tank may run empty before it is filled, or may overflow because there was less water usage than normal. On the other hand, a closed loop system such as that shown above uses feedback control. For example, it measures the water level, and only adds the needed amount. It might have a switch or sensor that detects when the tank is full, and turns off the flow of water. The set point is the desired value. In such a system, all of the components could be left on in order to fill the tank if its level dropped to low. "Here the comparison of the tank level signal with the desired value of the tank level (entered into the system as a set-point setting) and the turning of the

pump on or off are all performed by appropriate hardware in the controller."[13] Further, a closed loop system could be left on to fill the tank if the level dropped too low. "In feedback control, a measurement of the output of the system is used to modify its input in such a way that the output stays near the desired value."[14]

C. Set point (Controlled Parameter).

39. As shown in the above figure from *Eronini*, the parameter that is directed to a desired value is called the "controlled variable." The diagram also shows that while controlling the "controlled variable," the control system may "manipulate" another parameter called the "manipulated variable."[15] In this parlance, "[t]he *controlled output* [ ] is the process quantity being controlled" and "[t]he *manipulated variable* [ ] is the control signal which the control elements process."[16] With this understanding, I now consider the difference between controlling the amplitude of a voltage and controlling the power.

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[13] *Id*. at p. 12.

[14] *Id.* (internal citations omitted).

[15] *Id*. at p. 12, Fig. 1.6; see also *Ex. 2006* at p. 13, Fig. 1-21.

[16] *Id*. at p. 13 (emphasis in original).

D. Power Control vs. Voltage Control.

40. To demonstrate the difference between the control of voltage and the control of power, I will refer to the generic block diagram of a feedback control system from *Eronini*, labeled Figure 1 above. In a system for controlling voltage, the set point is a specified voltage and the controlled variable is voltage. Thus, in such a system, as shown in the above diagram, a feedback signal representative of the measured voltage is fed back and compared to the desired voltage level or set point. Based on the difference between the measured voltage and the desired voltage or set point, the control system drives or restrains the voltage in an attempt to move the actual voltage to match the desired voltage.

41. In a system for controlling power, the set point is a specified power value and the controlled variable is power. In such a system, the voltage and/or current can be driven by the control system to whatever levels are needed to achieve the target power level. Thus, in the example of a system for controlling the power of a plasma electrode assembly, if there is no plasma between the electrodes (and therefore little or no current) a controller attempting to achieve a target power level will drive the voltage extremely high in an attempt to achieve the target power P; i.e., $P = V * I$, and because I is very low (or zero) in this situation, V will be very high.

42. Thus, in a control system for controlling power to a desired set point, voltage will vary as the controller attempts to achieve the desired power level (i.e., a desired product of voltage and current). However, the amplitude of the voltage is not controlled and instead the voltage and/or the current vary as needed to achieve the desired power.

43. In addition to power, voltage and/or current levels, one may also need to consider the “rise time” of a controlled parameter. A “rise time” is the time required for the value of the controlled parameter to be driven from one level to another level.

44. The rise time of a voltage is a different parameter that the rise time of power. For example, consider a scenario in which a voltage source outputs a constant voltage. If that source is connected across an impedance that gradually drops, the current will increase as the impedance drops. Since power is the product of voltage (here a constant) and current, the power will rise as the current increases. Thus, in this situation, power rises at rate determined by the rate at which the impedance decreases. But there is no rise in voltage because the source maintains a static, constant voltage at its output in this example. This demonstrates that a rise time in voltage is a different parameter than rise time in power.

45. This example can also be used to demonstrate the difference between a

controlled change in the output of a voltage source, and a reaction to a change in impedance. If the impedance drops so fast that the voltage source cannot maintain the voltage at its target level, the voltage output by the source can drop due to limitations of the voltage source. This drop in voltage is not a controlled drop, caused by the power supply in response to a programmed change in the voltage set point: It is a transient drop caused by a change in the impedance load that exceeds the capacity of the voltage source.

E. Plasmas.

46. Plasma is a distinct state of matter characterized by a significant number of electrically charged particles.[17] In an ordinary gas, each atom or molecule contains an equal number of positive and negative charges, so that each is electrically "neutral." When those atoms or molecules are subjected to heat or other energy, they begin to lose electrons and are left with a positive charge. This process is called ionization. When enough gas atoms or molecules have been ionized such that the ions, together with the free electrons, significantly affect the electrical characteristics of the substance it is said to be plasma. Although made up of

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[17] *Ex. 1101* at 1:6-8.

charged particles the plasma remains electrically neutral overall.[18]

47. Common examples of the use of plasmas include applications in neon signs and fluorescent lights. Plasmas are also used in a number of industrial processes, including the manufacture of semiconductor devices. To that end, consider an object (hereinafter referred to as a "target") in or near a plasma. If the target (or an object in its vicinity) is made electrically negative compared to the plasma, positively charged ions in the plasma will be accelerated towards the target. At the surface of the target, a number of different interactions can occur (see Figure 2, below).

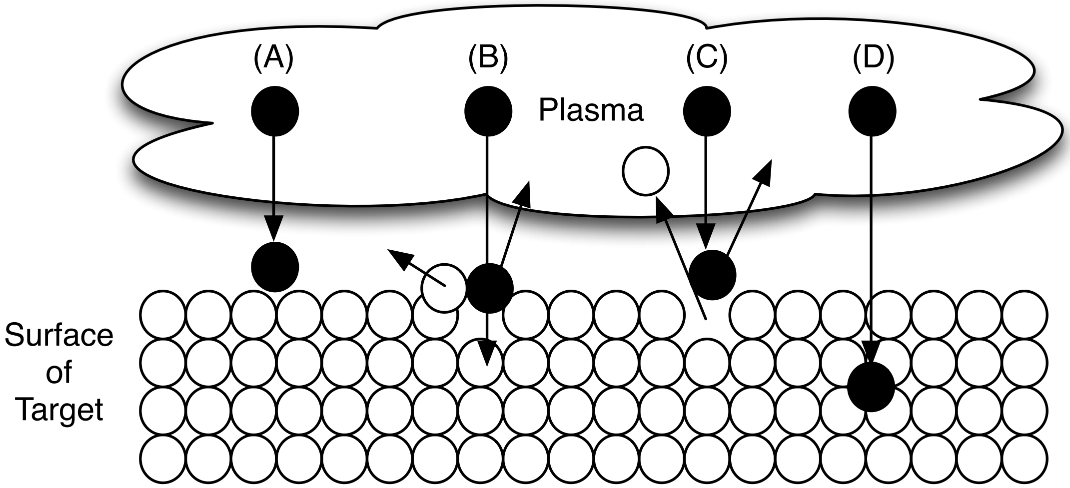

Figure 2: Interactions at a target's surface

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[18] *Id*. at 1:8.

48. In Figure 2, an arriving ion is “adsorbed” onto the surface of the target at (A). Adsorption is an adhesion of ions (or other particles) to a surface and is typically a low energy process, which is dominant around a few tens of eV, or less. At (B), the incoming ion transfers some of its momentum to one of the target’s surface atoms and causes it to move. This is called displacement. If the energy of the incoming ion is sufficiently high, say on the order of 100 eV or more, surface atoms of the target may be removed in a process referred to as sputtering (shown in (C)). If the ion energy is even greater, say above 1 keV, then it may be implanted into the target (at (D)). These various processes form the bases of a number of plasma-assisted semiconductor manufacturing techniques.

F. Plasma ignition.

49. To ignite a plasma, a gas is introduced in a space between two electrodes, for example in a tube or other container, and an electric field is applied between the electrodes. A simplified example of such an arrangement is shown in Figure 3.

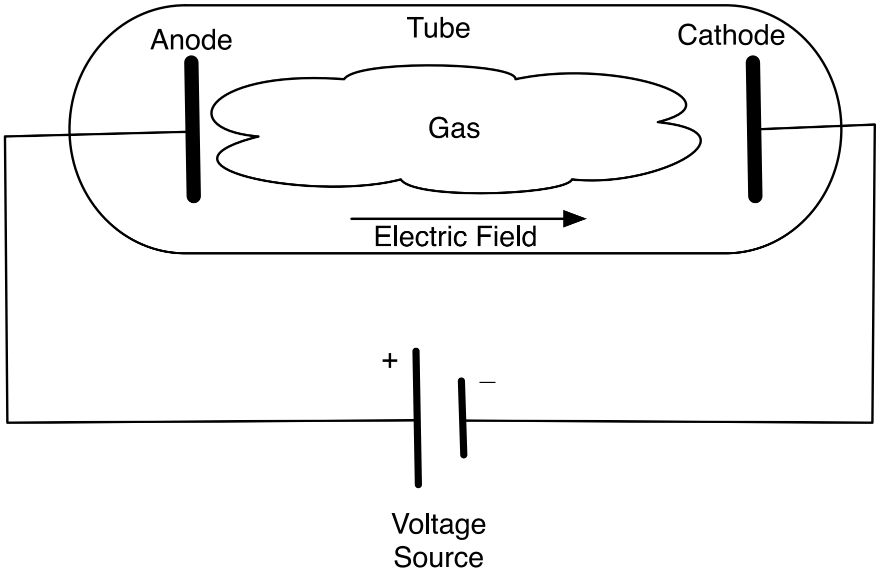

Figure 3: Simplified plasma system

Even at room temperature, the gas will contain a small number of ions and free electrons. These ions and electrons are accelerated towards the electrically negative electrode (the "cathode") and the electrically positive electrode (the "anode"), respectively. As electrons collide with gas atoms, they produce new ions.

50. When the ions are in close proximity to the cathode (e.g., on the order of a few Angstroms), electrons can tunnel from the cathode, and the ions are neutralized. When an ion is neutralized, some amount of energy (corresponding to the ionization energy of the ion) is released. If this energy is transferred to a surface electron at the cathode (via an Auger process) and it is greater than the electron work function, new electrons (so-called "secondary electrons") are emitted into the gas from the cathode. These secondary electrons are accelerated

towards the anode, and when they collide with gas atoms they generate new ions and free electrons. By the addition and acceleration of new electrons, the process of ionization proceeds; and, if the applied power is sufficiently high, a plasma is created.

G. High-Density Plasmas.

51. The ‘716 patent is particularly concerned with high-density plasmas, for example, plasmas having a density greater than 10^{12} cm^{-3}.[19] Magnetron reactors develop high-density plasmas using a magnetic field configured parallel to a target surface. The magnetic field constrains the secondary electrons ejected by the bombarding ions to the vicinity of the target surface. The ions are also subject to the same forces and tend to concentrate in the same region, maintaining the quasi-electrical neutrality of the plasma.[20] The trapping of electrons and ions creates a dense plasma.

52. Conventional magnetron systems of the kind just described suffer from undesirable, non-uniform erosion or wear of the target that results in poor target

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[19] See, e.g., *id.* at 21:45-47.

[20] *Id.* at 3:13-28.

utilization.[21] To address these problems, researchers tried increasing the applied power and later pulsing the applied power. However, increasing the applied power increased “the probability of generating an electrical breakdown condition leading to an undesirable electrical discharge (an electrical arc) in the chamber . . . .”[22] Even the pulsed approach, in which the power is delivered over many pulses in an attempt to keep the average power relatively low, is accompanied by risks. For example, “very large power pulses can still result in undesirable electrical discharges regardless of their duration.”[23] An abrupt large increase in applied voltage can cause localized instabilities in electric fields to be large enough to initiate an arc on the cathode, even if a low-density discharge is already present.

53. This latter point deserves further explanation. There are large changes in plasma impedance between the stages that occur during a pulsed DC magnetron discharge. The more charged particles within a plasma, the more electrically conducting it becomes. During ignition, the impedance may be in the hundreds of ohms, dropping to the tens of ohms in the low-density mode. In the transition from a low-density to a high-density plasma, the impedance drops to a few ohms,

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[21] *Id*. at 3:29-31.

[22] *Id*. at 3:38-41.

[23] *Id*. at 3:50-52.

accompanied by up to two orders of magnitude increase in current. Depending on power supply design and control settings, the density of the plasma may increase quite unevenly, also leading to the possibility of plasma breakdown or arcs, if the transitions are uncontrolled. Thus, pulsed DC magnetron systems prior to the '716 patent were prone to arcing, for example upon igniting the plasma and when working with high-power pulses.[24] Such arcing can result in the release of undesirable particles in the chamber that can contaminate the sample, which is especially undesirable in semiconductor processing.[25]

54. Prior to the '716 patent, power supplies for DC magnetron sputtering included those that set power for the duration of a deposition step. In power control mode, the output is controlled until the product of discharge voltage and current equals the set power. In pulsed power mode, as described by *Wang*, the total energy delivered during a pulse is controlled.[26] However, such pulsed power systems are prone to arcing upon igniting the plasma, especially when working with high-power pulses.[27] Such arcing can result in the release of undesirable

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[24] *Id.* at 3:48-52; *Ex. 1104* at 7:3-6, 46-48.

[25] *Ex. 1101* at 3:48-50; *Ex. 1104* at 7:3-8.

[26] *Ex. 1104* at 6:16-24.

[27] *Id.* at 7:3-6, 46-48.

particles in the chamber that can contaminate the sample, which is especially undesirable in semiconductor processing.[28]

55. To overcome some of the deficiencies of the prior art, Dr. Chistyakov invented a plasma processing apparatus and corresponding method in which:

> An ionization source generates a weakly-ionized plasma proximate to the cathode. A power supply produces an electric field in the gap between the anode and the cathode. The electric field generates excited atoms in the weakly-ionized plasma and generates secondary electrons from the cathode. The secondary electrons ionize the excited atoms, thereby creating a strongly-ionized plasma.[29]

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> Forming the weakly-ionized or pre-ionized plasma [ ] substantially eliminates the probability of establishing a breakdown condition in the chamber when high-power pulses are applied between the cathode [ ] and the anode [ ]. The probability of establishing a breakdown condition is substantially eliminated because the weakly-ionized plasma [ ] has a low-level of ionization that provides electrical conductivity through the plasma. This conductivity

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[28] *Id*.

[29] *Ex. 1101* at Abstract.

> substantially prevents the setup of a breakdown condition, even when high power is applied to the plasma.[30]

56. As illustrated in Fig. 2A of the '716 patent, Dr. Chistyakov's plasma processing apparatus includes a cathode 204.[31] An anode 216 is positioned "so as to form a gap 220 between the anode 216 and the cathode 204 that is sufficient to allow current to flow through a region 222 between the anode 216 and the cathode 204. . . . The gap 220 and the total volume of the region 222 are parameters in the ionization process . . . ."[32]

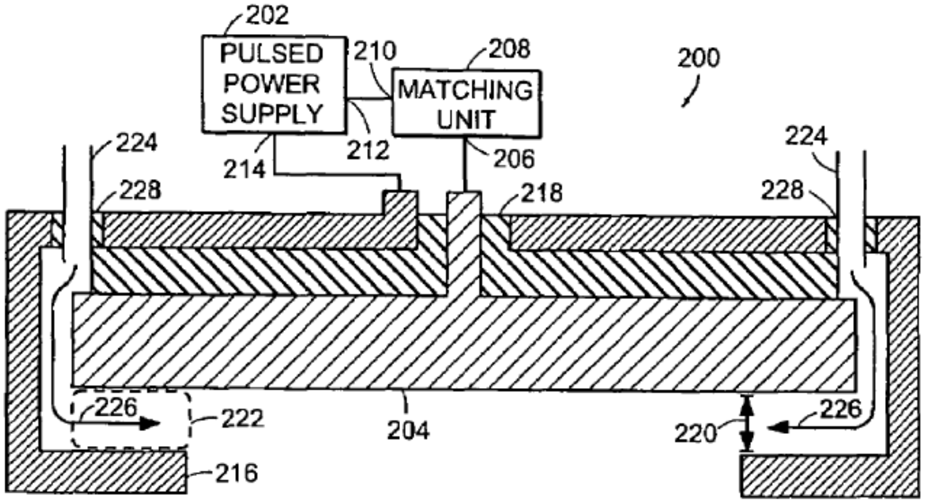

FIG. 2A

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[30] *Id*. at 4:16-25.

[31] *Id*. at 3:63-64.

[32] *Id*. at 4:30-39.

57. “[O]nce the weakly-ionized plasma 232 is formed, the pulsed power supply 202 generates high-power pulses between the cathode 204 and the anode 216 (FIG. 2C).”[33]

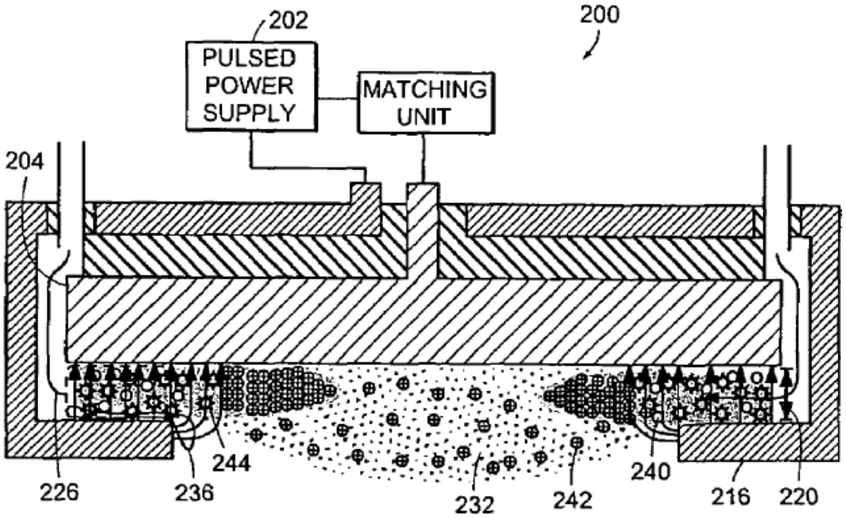

FIG. 2C

“The high-power pulses generate a strong electric field 236 between the cathode 204 and the anode 216. . . . [and] generate a highly-ionized or a strongly-ionized plasma 238 from the weakly-ionized plasma 232 . . . .”[34] The strongly-ionized plasma is also referred to as a high-density plasma.[35]

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[33] *Id*. at 6:51-53.

[34] *Id*. at 7:3-18.

[35] *Id*. at 7:18-19.

V. SCOPE AND CONTENT OF THE PRIOR ART.

A. Wang.

58. *Wang* discusses "[a] pulsed magnetron sputter reactor [with] a high plasma density."[36] In this reactor, "narrow pulses of negative DC power" are used to sputter material from a target.[37] In one example, *Wang* indicates that the pulses are applied to both ignite the plasma and maintain it,[38] while in another example *Wang* describes maintaining the plasma using a background power level with the pulses applying a much greater peak power to increase the density of the plasma.[39] In both examples it is the power applied to a cathode target that is driven to a prescribed level, not voltage.[40]

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[36] *Ex. 1104* at 3:16-22.

[37] *Id*. at 4:33-34.

[38] *Id*. at 5:29-30.

[39] *Id*. at 7:13-30.

[40] *Id*. at 5:18-20; 7:13-30; and see 5:52-54 ("Where chamber impedance is changing, the power pulse width is preferably specified rather than the current or

59. As is known in the art, power (P) is the product of voltage (V) and current (I): P = V * I. Therefore, when *Wang* specifies a power supply output (e.g., as illustrated in Wang's Figs. 4 and 6), this is understood to be a combination (a product) of voltage and current. Stated differently, *Wang* does not teach controlling the amplitude of a voltage pulse (or a resulting electric field) when generating a high-density plasma, but rather teaches controlling the power applied to the cathode.

60. This is not merely a difference in semantics. *Wang* acknowledges there is a substantive difference between controlling power and controlling voltage, and chooses to control power parameters rather than those of current or voltage:

> Where chamber impedance is changing, the power pulse width is preferably specified rather than the current or voltage pulse widths.[41]

Thus, unlike the '716 patent, in which the rise time of the electric field is chosen to increase an ionization rate of excited atoms in a weakly-ionized plasma to generate a strongly-ionized plasma,[42] *Wang* discloses a very different approach to achieving

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voltage pulse widths.").

[41] *Ex. 1104* at 5:52-54.

[42] See, e.g., *Ex. 1101* at 8:40-47; 22:29-32.

a high density plasma. In particular, *Wang* does not control voltage (or the resulting electric field) rise time for any purpose, and certainly not for the purpose of achieving an increase in ionization rate.

61. *Wang's* elections in this regard have consequences because when it comes to manipulating plasma density, configuring a power supply to generate electrode power pulses can yield substantially different results than configuring a power supply to generate voltage pulses with amplitude and rise times: Constant power pulses have a voltage and current that can vary significantly as the system attempts to control the power to a target power level. Since such power supplies are designed to control the product of voltage and current to a target level, they can drive the voltage extremely high when the current is near zero (e.g., before plasma ignition or when the plasma density is low) as they attempt to maintain the target power level.[43] As a result, power pulses will tend to produce an arc during the ignition of the plasma, as observed by *Wang*:

> Plasma ignition, particularly in plasma sputter reactors, has a tendency to generate particles during the initial arcing, which may dislodge large particles from the target or chamber.[44]

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[43] *Ex. 1104* at 5:32-33.

[44] *Id.* at 7:3-6.

62. More specifically, before gas is ionized, there are no charged particles, hence there is no current flow. Once the gas ionizes, there is a small amount of current. In order to keep the target power level, the voltage must be very high when the current is very low. Recall that power is voltage times current. There is effectively no controlled generation of the voltage pulses with amplitudes and rise times when the power supply is generating power pulses with amplitudes and rise times to target power levels. There is only control over the power, which causes the supply to output a very high voltage when there is little current, and to drop as the current increases. Referring to *Wang's* Fig. 4, the case that arcs when a power pulse ignites a plasma, *Wang* describes the changes in voltage and current needed to control the power to a target power level. This is due to the large change in impedance in the plasma as the plasma density or ionization level changes.

> "Also, in this embodiment, each pulse 82 needs to ignite the plasma and maintain it. The effective chamber impedance dramatically changes between these two phases. A typical pulsed power supply will output relatively high voltage and almost no current in the ignition phase and a lower voltage and substantial current in the maintenance phase."[45]

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[45] *Id*. at 5:28-34.

63. **Arcing in Wang**: The *Wang* patent teaches that, "plasma ignition … has a tendency to generate particles during the initial arcing."[46] This statement suggests that *Wang* expects arcing to occur on plasma ignition. This arcing is very problematic, because of the problems it causes, such as particle generation. Also, arcing can damage the chamber and power equipment.[47] Because *Wang* expects arcing when his power pulses are used to ignite a plasma, the patent proposes only igniting the plasma once and applying a fixed background power so that the plasma is maintained in between power pulses. This is shown in Fig. 6.

> Accordingly, it is advantageous to use a target power waveform illustrated in FIG. 6 in which the target is maintained at a background power level P_B between pulses 96 rising to a peak level P_P corresponding to that contemplated in FIG. 4. The background level P_B is chosen to exceed the minimum power necessary to support a plasma in the chamber at the operational pressure. Preferably, the peak power P_P is at least 10 times the background power P_B, more preferably at least 100 times, and most preferably 1000 times to achieve the greatest effect of the invention. A background power P_B of 1 kW will typically be sufficient to support a plasma with the torpedo magnetron and a 200 mm wafer although with little if any actual sputter

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[46] *Id*. at 7:3-5.

[47] *Id*. at 7:1-12.

> deposition. As a result, once the plasma has been ignited at the beginning of sputtering prior to the illustrated waveform, no more plasma ignition occurs. Instead, the application of the high peak power P_P instead quickly causes the already existing plasma to spread and increases the density of the plasma.[48]

64. *Wang* does not solve the problem of arcing during plasma initiation. Instead, *Wang* proposes reducing the amount of arcing by keeping the plasma maintained so as not to require re-ignition with each pulse. That is, *Wang* views arcing as a problem that can be improved, but not eliminated, by having the plasma maintained with a background fixed power. Note that even this does not stop the plasma from arcing, but merely reduces the arcing.[49]

65. *Wang's* use of pre-ionization did not eliminate arcing for his power pulses, it only reduced the likelihood of same. Arcing is still possible when a pulse is applied across a pre-existing plasma, particularly when there is a large, abrupt increase in the electric field as would occur upon the sudden application of a power pulse, such as in the transition from *Wang's* P_B to P_P. *Wang* still uses power-controlled pulses, P_P, in Fig. 6 that are applied across an existing plasma. Such pulses would cause an abrupt increase in the electric field, just like the pulses in Fig. 4 that *Wang*

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[48] *Id*. at 7:13-31.

[49] *Id*. at 7:47-55.

admits yielded arcs upon plasma ignition. *Wang* does not discuss the risk of arcing in connection with the application of power pulses, P_P, or how to avoid it. Thus, *Wang* does not teach or suggest that arcing could be avoided. In contrast, the ‘716 patent demonstrates that arcing can be avoided, even on plasma ignition, with proper control of electric field amplitude and rise time.

66. **Variances between Wang’s Target Power Levels and Actual Power:** *Wang* states that the actual power waveforms differ from the set points, which are illustrated as perfect square waves:

> Once again, the actual waveforms will differ from the idealized illustrated ones. In particular, a long fall time for the pulses will present a inter-pulse power that is much lower than the peak power, but may not ever settle to a substantial DC level. However, the minimum power in the inter-pulse period will not fall below a selected DC level. The initial plasma ignition needs be performed only once and at much lower power levels so that particulates produced by arcing are much reduced. Further, the chamber impedance changes relatively little between the two power levels P_B, P_P since a plasma always exist in the chamber. Therefore, the design of the pulsed DC power supply is

> simplified since it does not need to adjust to vastly different chamber impedances while handling large amounts of power.[50]

67. The difference that the *Wang* patent describes between the actual power waveform and the target square wave is not the result of control or configuration. It is due to the inability of the supply to deliver the target square power pulse. This is very different from the technique described in the '716 patent for configuring the power supply to generate a pulse with a controlled rising edge or slope and magnitude. *Wang* surmises that the rise time of his power pulse is significant (i.e., longer than instantaneous), but does not teach or suggest configuring the power supply to control the rise time, or the advantage of doing so.

> According to the invention, the target 14 is powered by narrow pulses of negative DC power supplied from a pulsed DC power supply 80, as illustrated in FIG. 1. The pulse form is generically represented in the timing diagram of FIG. 4 and includes a periodic sequence of power pulses 82 having a pulse width τ_W and a pulse repetition period τ_P, which is the inverse of the pulse repetition frequency f_P,. The illustrated pulse form is idealized. Its exact shape depends on the design of the pulsed DC power supply 80, and significant rise times and fall times are expected. A long fall time may produce a long tail, but the power levels in the tail will be significantly lower than the peak.

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[50] *Id*. at 7:40-55.

> Also, in this embodiment, each pulse 82 needs to ignite the plasma and maintain it. The effective chamber impedance dramatically changes between these two phases. A typical pulsed power supply will output relatively high voltage and almost no current in the ignition phase and a lower voltage and substantial current in the maintenance phase. As mentioned by Kouznetsov et al., ignition may require over 50 μs.[51]

68. Commercial prior art power supplies that control power have no control over the rise time of the power pulse. *Wang* describes conventional power supplies, without any special or inventive features. There is only control over the power, the duty cycle and the pulse width. The voltage and current vary greatly with the impedance of the plasma, the product of the first two determining power.[52]

69. Wang's system varies the level of metal ionization by adjusting the peak pulse power and pulse width:

> The level of metal ionization can be controlled by varying the peak pulse power. In the case that pulsed power supply is limited by the total pulse energy, the peak pulse power can be controlled by varying the peak pulse width. In a multi-step

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[51] *Id*. at 5:18 -36

[52] *Id*. at 5:29-32.

> sputtering process, the pulse width is changed between the steps.[53]

70. As discussed above, the *Wang* patent discloses a very different approach to achieving a high-density plasma than that described in the ‘716 patent. *Wang* does not disclose a power supply configured to generate a pulse with rise time or amplitude for any purpose, and certainly not for the purpose of achieving an increase in the excitation rate of ground state atoms in the weakly-ionized plasma to generate a strongly-ionized plasma while avoiding arcing. Conversely, the ‘716 patent uses a power supply configured to generate a pulse, controlling amplitude and/or rise time, to rapidly increase the excitation rate of ground state atoms in the weakly-ionized plasma to generate a strongly-ionized plasma while avoiding arcing.

71. *Wang* further does not discuss any of the electrodynamics of the high-density plasma, but does describe some reactor characteristics, at least by reference. For example, although *Wang* does not specify what “low pressure” means in terms of operating conditions, *Wang* does refer to *Chiang*, which specifies pressures below 5 mTorr and preferably below 1 mTorr.[54] Likewise,

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[53] *Id*. at 3:29-34.

[54] See, e.g., *Ex. 2008* at Abstract; 6:60-62.

although *Wang* does not specify actual dimensions for the subject magnetron sputter reactor, readers are again referred to *Chiang* for such details: "Most parts of this reactor have already been described by Chiang et al."[55] *Chiang* discloses a source to substrate spacing of 14-29 cm, and extension of a floating shield to 6-10 cm from the target (source).[56] Thus, readers could reasonably conclude that *Wang's* anode would preferably be at least 10-14 cm from the cathode.

B. Kudryavtsev.

72. *Kudryavtsev* reports on "ionization relaxation" in a plasma when an external electric field is suddenly increased.[57] More particularly, *Kudryavtsev* is a study to determine how well or poorly a set of measured data fits into a simplified, analytically-solvable model for the initial stage of an inert gas pulsed discharge plasma in a flash tube. A flash tube is comprised of a sealed glass tube filled with an inert gas such as Argon with a cathode and an anode at either end to apply an electric field to the gas. Flash tubes are designed to apply a high voltage greater than the breakdown voltage across the inert gas, resulting in a simultaneous

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[55] *Ex. 1104* at 3:60-61.

[56] *Ex. 2008* at 14:37-50; 6:66 – 7:2.

[57] IPR2014-00807 *Ex. 1205* at p. 30, left col, ¶ 1.

excitation and ionization of the gas and finally in a brilliant flash of light for a short duration. Flash tubes apply a voltage greater than the breakdown voltage, which may initiate the flash by an arc between the cathode and the anode.

73. *Kudryavtsev* predicts that electron density can “increase explosively” if an electric field is applied long enough to a pre-ionized gas in the tube.[58] Using the specified mathematical model (which presumes a tubular shaped assembly of radius R and, apparently, no magnetic field) *Kudryavtsev* shows that the electron density initially grows very slowly for a period of time designated “τ_s” but then enters a “fast stage:” “[O]nce steady conditions have been reached during the fast stage, ionization builds up explosively when the external field is constant.”[59]

74. *Kudryavtsev’s* work is targeted for “pulsed gas lasers, gas breakdown, laser sparks, etc.”[60] The pressures or gas densities reported by *Kudryavtsev* are much higher than those used for sputtering.[61] Moreover, *Kudryavtsev’s* experimental

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[58] *Id*. at p. 32, rt. col. ¶ 1.

[59] *Id*. at p. 32, left col. ¶ 1; and see p. 32, rt. col. ¶ 1 (“We see by inspecting the form of the above solutions that n_e builds up explosively with time.”).

[60] *Id.* at p. 34, right col, ¶ 4.

[61] See, e.g., *Id.* at p. 32, FIG. 3 (reporting pressures of 11.4 Torr and 3.7 Torr); p. 33, FIG. 5 (11.4 Torr) and *cf. Ex. 2008* at Abstract, 6:60-62, which specifies

system involved a 2.5 cm diameter tube with two electrodes spaced 52 cm apart. This apparatus did not use magnets or magnetic fields.[62]

75. **Arcing in *Kudryavtsev*:** Figures 2a-2f are useful in determining what happens in *Kudryavtsev's* flash tube. However, I note that only a qualitative analysis is possible because there is no scaling provided on these figures. Such a qualitative analysis reveals that the flash is caused by breakdown, and very likely, arcing. Since the '716 patent requires generation of plasma without arcing, *Kudryavtsev* is not suitable as prior art. I describe this analysis below.

76. *Kudryavtsev's* flash tube instrument measured the following parameters, listed by their letters designations in Figs. 2a-2f:

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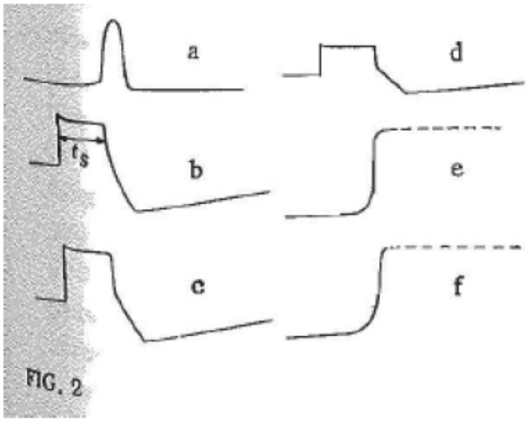
pressures preferably below 1 mTorr.

[62] *Ex. 1205*, p. 32, right col, ¶ 4.

Signals	**Parameter**
 FIG. 2	a) Current measured as flowing from cathode to ground; b) Voltage measured between cathode and anode; c) Voltage between electrodes, likely near the cathode; d) Voltage between electrodes, likely near anode; and e, f) Emission of light from the plasma which *Kudryavtsev* states is proportional to electron density.[63]

However, the source of the emission is the radiation emitted when excited atoms and ions return to the ground state, plasma heating due to the high current, and other high energy state relaxation.

77. *Kudryavtsev* uses "a specially designed electrical circuit"[64] to apply a "high-voltage pulse"[65] to a "pre-ionized" gas. *Kudryavtsev* does not say how "high" the

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[63] *Id*. at p. 31, signal waveforms described at p. 33, left col.

[64] *Id*. at p. 31, rt. col.

[65] *Id*. at p. 33, left col.

voltage was, but he does indicate that the desired voltage or setpoint was constant, even when the current exploded.[66] However, as shown in Fig. 2, the field is not constant and is, in fact, collapsing. This collapse is indicative of an arc, as described further below.

78. The following sequence of events describes the condition of the plasma in the flash tube over time according to the description given by *Kudryavtsev*[67] and an examination of Fig. 2:

> a. At t=0, there is a weak DC plasma with current in the low mA (a), constant voltage (b), constant electric fields (c,d) and very low emission of light (e,f).
>
> b. A high voltage is applied across the electrodes and the electric field across the tube simultaneously rises. The electric field along the tube is approximately the same and relatively unchanging.
>
> c. During the slow ionization phase (denoted by t_s), the current increases slightly and the voltage starts to sag slightly as does the field at (c). The impedance of the discharge is decreasing near the cathode.

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[66] *Id*. at p. 32, left col. ("external field is constant").

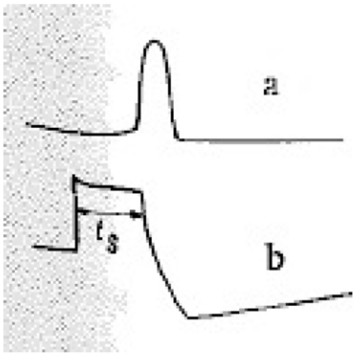
[67] *Id*. at p. 33.

The ionization of the plasma is increasing by less than 100 times.

d. At the beginning of the fast ionization phase, the current begins to rise very rapidly with a corresponding rapid drop in voltage (i.e., the plasma impedance is rapidly decreasing) and the field at (c) shortly thereafter undergoes a precipitous drop, while the field at (d) is still at its elevated value. The emission intensity begins to rise. As shown in Fig. 5, the region of highest ion density is close to the tube axis but the plasma is also expanding toward the tube walls. The model was calculated only for the first few microseconds of the explosive growth stage. This appears to be the end of the initial stage to which the model applies.

e. At the very peak of current, the field at (d) undergoes a precipitous drop, indicating that the highly conducting plasma has expanded to the entire tube length between electrodes and to the tube walls. At this point, there is an almost instantaneous increase in emission—the flash. This is indicative of the end of the fast ionization stage and the start of far more excited gas atoms relaxing to the ground state than are being ionized as emission happens on relaxation and not excitation, and fewer gas atoms in the ground state being excited; i.e., the population of the excited state is being rapidly depleted. The ions are releasing energy as they become neutralized. Further, the expansion of the high density plasma to the tube walls means that many more ions and electrons diffuse to the tube walls where they combine to form neutral gas atoms, which also decreases plasma density. In fact, the duration of the flash is not indicated, likely because it was so intense that the detectors were saturated by its intensity.

f. Also at this time, the voltage (b) drops precipitously. As shown, the measured voltage "remains almost constant" until the current rises, at which time the measured voltage drops substantially as shown:



79. *Kudryavtsev* observes that if the "high voltage" (and corresponding electric field) was maintained long enough, there was a "sudden rise in the current,

accompanied by a drop in voltage across the tube."[68] *Kudryavtsev* does not say that this steep drop in voltage was a controlled drop in the voltage set point, so this drop apparently was an uncontrolled drop in measured voltage that results from the "explosion" of electron density (and corresponding drop in plasma impedance), and supports the conclusion that *Kudryavtsev's* system was transitioning into an arc.

80. When a plasma collapses into an arc, it has an extremely low impedance that can act like a short circuit across the electrodes that pulls the electrode voltage down as shown in *Kudryavtsev's* voltage diagram. Note that *Kudryavtsev's* voltage does not merely drop slightly when the plasma density "explodes," it drops below the level that existed before the voltage pulse (the electric field) was applied, suggesting an arcing, "short-circuit-like" condition has occurred.

81. When a plasma enters an arcing condition, a region of the plasma becomes highly conductive. This causes a rapid surge in current and a corresponding drop in voltage, as shown in the annotated version of Fig. 2 from *Kudryavtsev* as representative of an arc:

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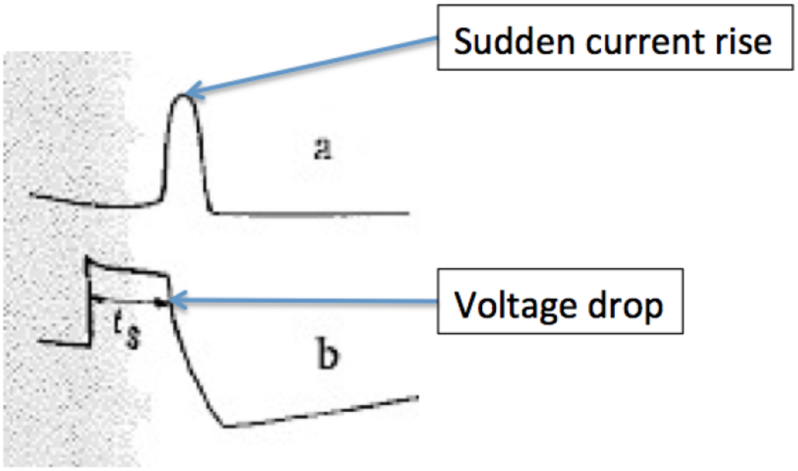
[68] *Id*. at p. 33, left col.



82. Further, *Kudryavtsev* states that "the ionization is highly nonuniform and a narrow plasma column forms on the axis."[69] This could be described as an arc, as the narrow plasma column extends from the cathode to the anode as in an arc.

83. Thus, based on the above, the plasma in the flash tube of *Kudryavtsev* entered an arcing condition, and any plasma that could possibly be considered "strongly-ionized" due to the "explosive increase" in electron density was formed with a concurrent arc in contravention of the claims of the '716 patent.

84. **Lack of Disclosure of Configured Rise Time or Amplitude:** The DC pulse in *Kudryavtsev* is not described in any detail, but *Kudryavtsev* writes the following: "The total voltage across the tube and the voltage between the probes

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[69] *Id*. at p. 34, rt. col. ¶ 2.

were recorded by a capacitive divider (C1 = 2 pF and C2 = 100 pF) capable of transmitting rectangular pulses with rise time ~ 10^{-7} s without appreciable distortion."[70] The very first paragraph of the article also notes that ionization was studied "when the electric field strength increases discontinuously."[71] Based on this description, one of ordinary skill in the art would understand the pulse to have a target voltage with a rectangular (i.e., "discontinuous") shape. There is no deliberate configuration of the voltage rise time or the voltage amplitude that increases an excitation rate. The voltage rise time is described as (1-2) 10^{-7} s (i.e., 0.1-0.2 microseconds), but there is no suggestion that rise time is controlled to a desired value or of a correlation between rise time and any effect. Indeed, that is not the purpose of the study, which involved applying a "discontinuous" electric field to a plasma to study "ionization relaxation" and what happens to the voltage and current as the system transitions into an arcing state.

85. Further, a person of ordinary skill in the art would not find it obvious to redesign the power supply used in the system of *Kudryavtsev* to configure it to generate a voltage pulse with amplitude or rise time to increase an excitation rate of ground state atoms in the weakly-ionized plasma and ionize the excited atoms in

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[70] *Id*. at p. 32.

[71] *Id*. at p. 30, left col. ¶ 1.

the weakly-ionized plasma without forming an arc discharge. Indeed, as described above, the experiments described in *Kudryavtsev* were designed with the opposite in mind, that is, to form an arc in order to generate the desired flash and to study the resulting effects.

C. Mozgrin.

86. *Mozgrin* relates to "high-power quasi-stationary low-pressure discharge in a magnetic field."[72] "Two noncontracted discharge regimes in crossed E and H fields were studied."[73] The study used two "[d]ischarge device configurations: (a) planar magnetron; (b) shaped-electrode configuration."[74] The planar magnetron included "a plane cathode 120mm in diameter and a ring-shaped anode 160 mm in diameter."[75] "The system with shaped electrodes involved two hollow axisymmetrical electrodes 120 mm in diameter separated by about 10mm, and

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[72] *Ex. 1103* at p. 400, Abstract.

[73] *Id*.

[74] *Id*. at p. 401, Figs. 1a and 1b.

[75] *Id*. at p. 400, rt. col. ¶ 5.

immersed in a cusp-shaped magnetic field produced by oppositely directed multilayer coils."[76]

D. Lantsman.

87. *Lantsman* relates to "a power supply circuit which reduces oscillations generated upon ignition of a plasma within a processing chamber."[77] In particular, *Lantsman's* circuit has two power supplies: "[a] secondary power supply pre-ignites the plasma by driving the cathode to a process initiation voltage. Thereafter, a primary power supply electrically drives the cathode to generate plasma current and deposition on a wafer."[78] Significantly, *Lantsman* does not disclose a pulsed power supply, any type of electrical pulse, or even a strongly-ionized plasma as recited in the claims of the '716 patent. *Lantsman* thus differs substantially from *Wang*. Whereas *Wang* is concerned with a "target 14 [ ] powered by narrow pulses of negative DC power supplied from a pulsed DC power supply,"[79] *Lantsman* relies on separate power supplies, one to ignite a plasma and the other to provide

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[76] *Id*. at p. 401, left col. ¶ 2.

[77] *Ex. 1105* at Abstract.

[78] *Id.*; see also 4:11 and 4:19 (describing two DC power supplies).

[79] *Ex. 1104* at 5:18-22.

power for an entire deposition period.[80] Systems that use a pulsed discharge supply unit, like those of *Wang*, would operate very differently if modified to use two DC power supplies as taught by *Lantsman*, requiring significant changes to semiconductor processing methods employing such apparatus. Petitioners failed to provide any objective evidence that a skilled artisan would have been motivated to modify *Wang* in such a fashion, and in my opinion there would be no such motivation. Indeed, inasmuch as *Lantsman* fails to even mention strongly-ionized plasma, there appears to be little, if any, reason for a person of ordinary skill in the art to have consulted *Lantsman* for any relevant teachings concerning systems in which an electrical pulse is applied across a weakly-ionized plasma to generate a strongly-ionized plasma, as recited in the '716 patent.

VI. CLAIM ANALYSIS VIS-À-VIS THE CITED REFERENCES

A. *Wang* Does Not Anticipate the Invention Claimed in the '716 Patent.

88. It is my opinion that *Wang* does not anticipate the invention recited in claim 1 of the '716 patent. As I discuss above, *Wang* teaches applying a power pulse to a cathode target.[81] In making this election, *Wang* accepts the consequence that

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[80] *Ex. 1105* at Fig. 6; 2:49-51; 4:33-37; 5:42-52.

[81] *Ex. 1104* at 5:18-20; 7:13-30; and see 5:52-54 ("Where chamber impedance is

voltage and current will vary significantly as the system attempts to control the power to a target power level. One of ordinary skill in the art would expect that the voltage would be very high and the current near zero before plasma ignition.[82] Then, as admitted by *Wang*, an arc would tend to result during ignition of the plasma:

> Plasma ignition, particularly in plasma sputter reactors, has a tendency to generate particles during the initial arcing, which may dislodge large particles from the target or chamber.[83]

Clearly, such conditions would not meet claim 1's requirement for "the electrical pulse having at least one of a magnitude and a rise-time that is sufficient to transform the weakly-ionized plasma to a strongly-ionized plasma without developing an electrical breakdown condition in the chamber."[84]

89. *Wang* further proposes igniting the plasma only once and applying a fixed background power so that the plasma is maintained in between power pulses:

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changing, the power pulse width is preferably specified rather than the current or voltage pulse widths.").

[82] *Ex. 1104* at 5:32-33.

[83] *Id.* at 7:3-6.

[84] *Ex. 1101* at 20:23-27; see also Exhibit B hereto.

> Accordingly, it is advantageous to use a target power waveform illustrated in FIG. 6 in which the target is maintained at a background power level P_B between pulses 96 rising to a peak level P_P corresponding to that contemplated in FIG. 4. The background level P_B is chosen to exceed the minimum power necessary to support a plasma in the chamber at the operational pressure. Preferably, the peak power P_P is at least 10 times the background power P_B, more preferably at least 100 times, and most preferably 1000 times to achieve the greatest effect of the invention. A background power P_B of 1 kW will typically be sufficient to support a plasma with the torpedo magnetron and a 200 mm wafer although with little if any actual sputter deposition. As a result, once the plasma has been ignited at the beginning of sputtering prior to the illustrated waveform, no more plasma ignition occurs. Instead, the application of the high peak power P_P instead quickly causes the already existing plasma to spread and increases the density of the plasma.[85]

However, this proposal does not solve the problem of arcing during plasma initiation. Instead, the proposed technique merely reduces the amount of arcing by keeping the plasma maintained so as not to require re-ignition with each pulse.[86]

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[85] *Ex. 1104* at 7:13-31.

[86] *Id*. at 7:47-55.

90. Arcing is also still possible when a pulse is applied across *Wang's* initial plasma, particularly when there is a large, abrupt increase in the electric field as would occur upon the sudden application of a power pulse such as in the transition from *Wang's* P_B to P_P. Even with respect to the Fig. 6 embodiment, *Wang* still teaches the application of power pulses, P_P, across the existing plasma. Such pulses would cause an abrupt increase in the electric field, just like the pulses in Fig. 4 that *Wang* admits yielded arcs upon plasma ignition. Even Petitioners' expert, Dr. Kortshagen, agreed that at best *Wang* describes "reducing" (not eliminating) the arcing.[87]

91. In contrast, claim 1 of the '716 patent recites "the electrical pulse having at least one of a magnitude and a rise-time that is sufficient to transform the weakly-ionized plasma to a strongly-ionized plasma ***without developing an electrical breakdown condition*** in the chamber."[88] Reducing, but not eliminating, arcing (as taught by Wang) is not the same as transforming a weakly-ionized plasma to a

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[87] *Ex. 2007* at 42:19-23 ("So Wang goes on to teach that arcing can be reduced by igniting the plasma only once and using the background power level, P sub B, to maintain the plasma between the high power pulses, P sub P.")

[88] *Ex. 1101* at 20:23-27 (emphasis added).

strongly-ionized plasma ***without developing an electrical breakdown condition*** because it still admits of some arcing.

92. These conclusions should not be surprising because, as discussed above, the *Wang* patent discloses a very different approach to achieving a high-density plasma than that described in the ‘716 patent. Rather than using a power supply configured to generate a pulse, controlling amplitude and/or rise time, to rapidly increase the excitation rate of ground state atoms in the weakly-ionized plasma to generate a strongly-ionized plasma while avoiding arcing, *Wang* teaches the application of a power pulse that actually differs from that shown in the diagrams of the reference.[89] That difference is not the result of control or configuration; rather, it is due to the inability of the power supply to deliver the target square power pulse. *Wang* surmises that the rise time of his power pulse is significant (i.e., longer than instantaneous), but does not teach or suggest configuring the power supply to control the rise time, or the advantage of doing so.[90] Accordingly, *Wang* does not anticipate claim 1.

93. A similar result is true for claim 33. Claim 33 recites “means for supplying an electrical pulse across the weakly-ionized plasma to transform the weakly-

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[89] *Ex. 1104* at 7:40-55.

[90] *Id*. at 5:18-36.

ionized plasma to a strongly-ionized plasma ***without developing an electrical breakdown condition*** in the chamber."[91] Thus, claim 33 includes the same requirements for eliminating the electrical breakdown condition as claim 1 and so claim 33 is patentable over *Wang* for the same reasons as claim 1.

B. *Wang* Does Not Teach a Power Supply Generating "a constant power," as recited in Dependent Claim 4.

94. Petitioners argue that, "Wang's pulsed DC power supply 80 (shown in Wang's Figs. 1 and 7) generates a peak level power, P_P, which is constant for the duration of the pulse τ_w, as shown in Fig. 6."[92] However, *Wang* indicates that Fig. 6 is idealized ("[o]nce again, the actual waveforms will differ from the idealized illustrated ones")[93] and that the actual shape of the power pulse is expected to have significant rise and fall times. In fact, it is most likely to be described as rounded (e.g., Gaussian, or the like), not having any constant power portion. Hence, the actual power pulse applied in *Wang* is not constant for the duration of the pulse τ_w. *Wang's* phrase "[o]nce again" refers to the discussion of Fig. 4, as that figure is the

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[91] *Ex. 1101* at 22:47-50 (emphasis added).

[92] Petition at p. 53.

[93] *Ex. 1104* at 7:40-41.

only other instance in the reference where waveform shape is discussed. With respect to Fig. 4, *Wang* states that, "[t]he illustrated pulsed form is idealized. Its exact shape depends on the design of the pulsed DC power supply 80, and significant rise times and fall times are expected."[94] *Wang* further describes the shape of the pulse widths: "[t]he illustrated rectangular pulse widths are idealized. Numerical values of pulse widths should be measured as the full width at half maximum."[95] Full width at half maximum is a term common to a person of ordinary skill in the art that signifies a rising then falling curve versus time in which the pulse width is defined as the 'full width' of the curve at half the peak of the curve. Accordingly, the pulse that is actually applied in Wang does not have constant power, as required by claim 4.

C. *Wang* Does Not Teach a Power Supply Generating "a constant voltage," as recited in Dependent Claim 5.

95. Petitioners argue that, "[o]ne of ordinary skill would have understood that Wang's voltage would be constant for at least a portion of the duration of the pulse

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[94] *Id*. at 5:23-27.

[95] *Id*. at 5:50-52.

τ_W so as to produce pulse P_P of constant power."[96] I disagree. As I explained above, power is the product of voltage and current. If, as Petitioners contend, power is constant during the pulse τ_W taught by *Wang*, then the product of voltage and current must be constant for that period. With *Wang's* admitted drop in plasma impedance during the pulse, current will rise and voltage will drop.

96. Moreover, claim 5 does not require a "constant voltage to produce a power pulse of constant power;" it instead requires that the "power supply generates a constant voltage."[97] Petitioners' statement that a constant voltage would produce a power pulse of constant power is wrong because the power in a plasma generator with a constant voltage would vary with the change in current that occurs with the change in the state of the plasma. Instead of controlling an electrical pulse in the particular way required by the claims, *Wang* controls a power pulse:

> the target 14 is powered by narrow pulses of negative DC power supplied from a pulsed DC power supply 80, as illustrated in FIG. 1. The pulse form is generically represented in the timing diagram of FIG. 4 and includes a periodic

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[96] Petition at p. 53.

[97] *Ex. 1101* at 20:38-39.

sequence of power pulses.[98]

97. A power supply for a sputtering system may either control the power pulse or the voltage pulse, but not both. In particular, power and voltage are related by the equation Power = Voltage x Current. The current in a sputtering system varies with the state of the plasma between the electrodes. In a system that controls the power, like *Wang's* system,[99] the amplitude and rise time of the voltage pulse is not controlled but instead, varies with the current. Accordingly, Wang's disclosure of controlling power and its mere mention of voltage pulses is not nearly sufficient to teach a power supply that generates a constant voltage, as required by claim 5.

D. *Wang* Does Not Teach a Power Supply "supplying power to the weakly-ionized plasma at a time that is between about fifty microseconds and five seconds after the ionization source generates the weakly-ionized plasma," as recited in Dependent Claim 6.

98. Petitioners argue that *Wang* anticipates claim 6,[100] but fail to actually describe anything in *Wang* that teaches supplying power to the weakly-ionized

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[98] *Ex. 1104* at 5:17-21.

[99] *Id*. at 5:52-54. ("the power pulse width is preferably specified rather than the voltage pulse width.")

[100] Petition at pp. 53-54.

plasma between about fifty microseconds and five seconds after it is generated, as required by the claim. In *Wang's* Fig. 6 embodiment, the only embodiment relied upon by Petitioners for this argument, the weakly-ionized plasma is generated some time before the curve depicted in the figure. *Wang* is silent as to the time between the generation of the weakly-ionized plasma (which is not shown in the figure) and the application first power pulse P_P. All of Petitioners' computations are with respect to the time between power pulses, however, since the weakly-ionized plasma is always maintained between pulses P_P, those timings are irrelevant inasmuch as the pulses do not satisfy the criterion that they be supplied within the specified time period "after the ionization source ***generates*** the weakly-ionized plasma." Hence, *Wang* cannot teach the limitations of claim 6.

E. *Wang* Does Not Teach the Power Supply Supplying "power to the weakly ionized plasma for a duration that is sufficient to generate a quasi-static electric field," as Recited in Dependent Claim 7.

99. Petitioners argue that *Wang's* electric field is quasi-static because the pulse width of the peak power P_P of 50 μs is greater than the collision time of 1.88 μs.[101] However, the '716 patent defines a quasi-static electric field as "an electric field that has characteristic time of electric field variation that is much greater than the

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[101] Petition at pp. 55-56.

collision time for electrons with neutral gas particles.[102] With this definition of "quasi-static electric field," it is clear that claim 7 requires the characteristic time of electric field variation to be much greater than the collision time. Petitioners' analysis did not make any comparison between the ***characteristic time of electric field variation*** and collision time, let alone demonstrate that the former is much greater than the latter in *Wang's* system. Rather, Petitioners compared a different quantity (i.e., the pulse width of a power pulse) with a collision time.[103] There is no indication in *Wang* that the voltage is constant during any part of the power pulse as even *Wang* recognizes that the idealized pulses shown in Figures 4 and 6 are not what are actually applied.[104] Accordingly, Petitioners' computations do not establish the proposition for which they are being advanced.

F. It Would Not Have Been Obvious To Combine the Teachings of *Wang* and *Lantsman* To Achieve the Invention Recited in Claims 12 and 13 of the '716 Patent.

100. Irrespective of any teachings *Lantsman* may or may not provide concerning the provision of a feed gas, *Lantsman* teaches the use of two power supplies: "[a]

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[102] *Ex. 1101* at 7:3-13.

[103] Petition at at pp. 55-56.

[104] See, e.g., *Ex. 1104* at 5:24-27; 7:41-45.

secondary power supply pre-ignites the plasma by driving the cathode to a process initiation voltage. Thereafter, a primary power supply electrically drives the cathode to generate plasma current and deposition on a wafer,"[105] and fails to discuss any pulsed power supply, electrical pulse, or strongly-ionized plasma. *Lantsman* thus differs substantially from *Wang* in important regards. Systems that use a pulsed discharge supply unit, like those of *Wang*, would operate very differently if modified to use two DC power supplies, one of which supplies power for an entire deposition period, as taught by *Lantsman*. Such modifications would be significant changes to semiconductor processing methods employing such apparatus and a person of ordinary skill in the art would need to undertake significant experimentation with such equipment to understand how the plasma was affected. Petitioners failed to provide any objective evidence that a skilled artisan would have been motivated to modify *Wang* in such a fashion, and in my opinion there would be no such motivation. Indeed, inasmuch as *Lantsman* fails to even mention strongly-ionized plasma, there appears to be little, if any, reason for a person of ordinary skill in the art to have consulted *Lantsman* for any relevant teachings concerning systems in which an electrical pulse is applied across a weakly-ionized plasma to generate a strongly-ionized plasma.

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[105] See, e.g., *Ex. 1105* at 4:11 and 4:19 (describing two DC power supplies).

G. It Would Not Have Been Obvious To Combine the Teachings of *Wang* and *Kudryavtsev* To Achieve the Invention Claimed in the '716 Patent.

101. It is my opinion that it would not have been obvious to combine the teachings of *Wang* and *Kudryavtsev* to achieve the invention recited the claims of the '716 patent. Given the marked differences between the experimental apparatus of *Kudryavtsev* and the magnetron sputter reactor described by *Wang,* a person of ordinary skill in the art would not have expected that applying the teachings of *Kudryavtsev* in a *Wang*-type system would have yielded predictable results or would have performed in an expected way.

102. *Kudryavtsev's* theoretical work is targeted for "pulsed gas lasers, gas breakdown, laser sparks, etc."[106] Moreover, *Kudryavtsev's* experimental system involved a 2.5 cm diameter tube between two electrodes spaced 52 cm apart. This apparatus did not use magnets or magnetic fields. *Wang*, on the other hand, discusses "[a] pulsed magnetron sputter reactor [with] a high plasma density."[107] Magnetron sputter reactors achieve their high plasma densities specifically through the use of magnetic fields, which trap secondary electrons near the target

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[106] *Ex. 1205*, p. 34, right col, ¶ 4.

[107] *Ex. 1104* at 3:16-22.

increasing the probability that these electrons will collide with gas atoms and create additional ions and free electrons. One of ordinary skill in the art would not be motivated to apply teachings related to the application of an electric field to a weakly ionized gas across a space of 52 cm unaffected by a magnetic field to a pulsed magnetron sputter reactor characterized by a "magnetic field near the face of the target [ ] which traps electrons from [a] plasma to increase the electron density."[108] There would be no predictable results to be achieved by such an experiment, for example because it was known at the time of the invention that "very large power pulses can still result in undesirable electrical discharges regardless of their duration," and such discharges (arcs) will corrupt the plasma process.[109] Moreover, the behaviors of charged particles (such as electrons and ions) in magnetic fields are vastly different from their behaviors in the absence of magnetic fields. The examples of instances cited by *Kudryavtsev* (pulsed gas lasers, gas breakdown and laser sparks) are not indicative of conditions within a magnetron sputter reactor (such as that described by *Wang*). Hence, one could not expect that models derived for such applications (and experiments designed to confirm such models) would be directly applicable to magnetron sputter reactors.

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[108] *Id.* at 4:24-26.

[109] *Ex. 1101* at 3:48-52.

103. An examination of the levels of operating parameters specified by *Wang* belies Petitioners' attempt to demonstrate that the combination of *Wang* and *Kudryavtsev* would be one that would be made by a person of ordinary skill in the art. For example, *Wang* describes the deposition process as "low pressure."[110] Although *Wang* does not specify exactly what this means, *Wang* does refer to *Chiang*, which specifies pressures below 5 mTorr and preferably below 1 mTorr.[111] Such working pressures are well below those reported by *Kudryavtsev*, for example in Figure 3 where results for pressures of 3.7 and 11.4 Torr are noted.[112] Thus, the references themselves contradict the proposed combination of teachings being advanced.

104. Petitioners also seem to ignore, or at least conveniently overlook, what the actual combination of the teachings of *Wang* and *Kudryavtsev* might suggest. *Wang* does not specify actual dimensions for the subject magnetron sputter reactor, but does refer readers to *Chiang* for such details: "Most parts of this reactor have already been described by Chiang et al."[113] *Chiang* discloses a throw (source to

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[110] *Ex. 1104* at 7:32-36.

[111] See, e.g., *Ex. 2008* at Abstract, 6:60-62.

[112] *Ex. 1205* at p. 32, FIG. 3.

[113] *Ex. 1104* at 3:60-61.

substrate) of 14-29 cm, and extension of a floating shield to 6-10 cm from the target (source).[114] Thus, Wang's anode would preferably be at least 10-14 cm from the cathode. *Kudryavtsev* reports, "the distance between the electrodes was L = 52 cm."[115] Thus, any combination of *Wang* and *Kudryavtsev,* to the extent such a combination would be made by a person of ordinary skill in the art, would suggest a system having a long gap. The '716 patent, in sharp contrast to both *Wang* and, especially, *Kudryavtsev* discloses a "gap 244 is between approximately 0.3 cm and 10 cm."[116] That is, the *Kudryavtsev* apparatus operates using a gap more than five times the length of the gap specified in the '716 patent[117] and, to the extent *Wang* relies on *Chiang*, *Wang* teaches a preference for longer gaps and not the magnetically enhanced plasma processing apparatus having a gap between approximately 0.3 cm and 10 cm taught by Dr. Chistyakov. While the dimensions of the gap are not recited in the claims of the '716 patent one must consider what the actual scope and content of the prior art is, and the conclusions the teachings of prior art references would lead to when considering the obviousness question as a

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[114] *Ex. 2008* at 14:37-50; 6:66 – 7:2.

[115] *Ex. 1205*, p. 32, right col, ¶ 4.

[116] *Ex. 1101* at 4:33-34.

[117] *Ex. 1205 at* p. 32, right col, ¶ 6.

whole. Here, it seems that any combination of the teachings of *Wang* and *Kudryavtsev*, to the extent such a combination could be made, would suggest to the person of ordinary skill in the art that any apparatus seeking to employ such teachings should, at a minimum, be characterized by an anode-cathode spacing significantly different from that advocated by Dr. Chistyakov and, therefore, that such teachings would not be applicable to an apparatus or method such as that described in the ‘716 patent.

H. The Combination of *Wang* and *Kudryavtsev* Does Not Suggest The Invention Recited in Independent Claims 14 and 26.

105. It is my opinion that the combination of *Wang* and *Kudryavtsev* does not suggest “supplying an electrical pulse across the weakly-ionized plasma that excites atoms in the weakly-ionized plasma, thereby generating a strongly-ionized plasma without developing an electrical breakdown condition in the chamber,” as recited in independent claim 14.

106. As discussed in detail above, *Wang* does <u>not</u> solve the problem of arcing during plasma initiation. Instead, the proposed techniques merely reduce the amount of arcing by keeping the plasma maintained so as not to require re-ignition

with each pulse.[118] Arcing is still possible when a pulse is applied across *Wang's* initial plasma, particularly when there is a large, abrupt increase in the electric field as would occur upon the sudden application of a power pulse such as in the transition from *Wang's* PB to PP. This is true even with respect to Wang's Fig. 6 embodiment, and Dr. Kortshagen's testimony is in agreement.[119]

107. The teachings of *Kudryavtsev* do not suggest any different result. As I demonstrated above, a qualitative analysis reveals that *Kudryavtsev's* flash tube experiments had results consistent with arcing. As shown in *Kudryavtsev's* Fig. 2, the field was not constant and was, in fact, collapsing—indicative of an arc. Moreover, the drop in voltage apparently was uncontrolled, resulting from the "explosion" of electron density (and corresponding drop in plasma impedance). This supports the conclusion that *Kudryavtsev's* system was transitioning into an arc. Consequently, any combination of *Wang* and *Kudryavtsev* would, at best, suggest techniques to reduce, but not eliminate, arcing.

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[118] *Id*. at 7:47-55.

[119] *Ex. 2007* at 42:19-23 ("So Wang goes on to teach that arcing can be reduced by igniting the plasma only once and using the background power level, P sub B, to maintain the plasma between the high power pulses, P sub P.")

108. In contrast, claim 14 of the ‘716 patent recites “generating a strongly-ionized plasma ***without developing an electrical breakdown condition in the chamber***.”[120] Reducing, but not eliminating, arcing is not the same as generating a strongly-ionized plasma ***without developing an electrical breakdown condition*** because it still admits of some arcing. Consequently, claim 14 is not obvious in view of the combined teachings of *Wang* and *Kudryavtsev*.

109. Claim 26, like claim 14, recites a power supply “generating an electric field . . . thereby forming a strongly-ionized plasma ***without developing an electrical breakdown condition in the chamber***.”[121] Inasmuch as this is the same requirement as specified in claim 14, claim 26 is not obvious in view of the combined teachings of *Wang* and *Kudryavtsev* for at least the reasons specified above.

110. Further, Claim 26 recites “a cathode that is positioned adjacent to the anode.”[122] There are differences between the arrangement of the anode and cathode taught by *Wang* and that required by the ‘716 patent. For example, *Wang* teaches an important feature placed intermediate the two electrodes, namely a floating

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[120] *Ex. 1101* at 21:47-50 (emphasis added).

[121] *Id.* at 22:13-15 (emphasis added).

[122] *Id*. at 22:4.

shield.[123] The floating shield performs the essential function of focusing the sputtered ions toward the wafer:

> A grounded shield 24 protects the chamber walls from sputter deposition and also acts as a grounded anode for the cathode of the negatively biased target 14. A floating shield 26 supported on a second dielectric isolator 28 becomes negatively charged in the presence of a high-density plasma and acts to focus sputtered metal ions towards the wafer 20.[124]

Further, although *Wang* incorporates *Fu* by reference,[125] there is no indication that this was intended to be specific to the anode-cathode arrangement. Instead, a person of ordinary skill in the art would recognize that *Wang* was referring to (and incorporating by reference) *Fu's* teachings regarding the modifications that would be required in order to adapt a SIP sputtering reactor for use in high aspect ratio deposition processes. *Wang* goes on to explain that those modifications include the use of high amounts of DC power applied to a target, and the use of magnets with unbalanced poles.[126] It is also worth noting that in the same sentence referencing

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[123] *Ex. 1104* at FIG. 1 (ref. 26); 4:1-5.

[124] *Id*. at 4:1-5.

[125] *Ex. 1104* at 1:42-51.

[126] *Id.* at 1:54 – 2:15.

Fu, *Wang* incorporates by reference teachings of *Chiang*, which (as I discussed above) did disclose a SIP reactor and a grounded shield interposed between cathode and anode. Therefore, one could expect that *Wang* intended such an anode-cathode arrangement.

111. Because Wang does not teach a cathode positioned adjacent to an anode, and *Kudryavtsev's* experimental system involved a 2.5 cm diameter tube with two electrodes spaced 52 cm apart,[127] no combination of Wang and *Kudryavtsev* would, in my opinion, suggest to a person of ordinary skill in the art an apparatus having a cathode positioned adjacent to an anode as required by claim 26.

I. The Combination of *Wang* and *Kudryavtsev* Does Not Suggest Supplying the Electric Pulse Comprises " applying a quasi-static electric field," as Recited in Dependent Claim 21.

112. It is my opinion that the combination of *Wang* and *Kudryavtsev* does not suggest that any electric field is "a quasi-static electric field," as recited in dependent claims 21.

113. As I discuss above, Petitioners' argument that *Wang's* electric field is quasi-static because the pulse width of the peak power P_P of 50 μs is greater than the

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[127] *Ex. 1205*, p. 32, right col, ¶ 4.

collision time of 1.88 μs is unconvincing because that analysis did not make any comparison between the ***characteristic time of electric field variation*** and collision time, let alone demonstrate that the former is much greater than the latter in *Wang's* system. Rather, Petitioners compared a different quantity (i.e., the pulse width of a power pulse) with a collision time. There is no indication in *Wang* that the voltage is constant during any part of the power pulse as even *Wang* recognizes that the idealized pulses shown in Figures 4 and 6 are not what are actually applied.[128] Accordingly, Petitioners' computations do not establish the proposition for which they are being advanced.

J. The Combination of *Wang* and *Kudryavtsev* Does Not Suggest That Either of "a rise time and magnitude of the electrical pulse" is "selected to increase an density of the weakly-ionized plasma," as Recited in Dependent Claim 16.

114. Petitioners argue, in essence, that because *Wang's* pulses have an associated rise time, *Wang* teaches the limitations of claim 16."[129] This conclusory allegation is unsupported by any teaching of *Wang*.

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[128] See, e.g., *Ex. 1104* at 5:24-27; 7:41-45.

[129] IPR2014-00807 Petition at p. 52.

115. With respect to the pulse described by *Wang*, "Its exact shape depends on the design of the pulsed DC power supply 80, and significant rise times and fall times are expected."[130] In contrast, claim 16 requires that a rise time or magnitude be ***selected.*** While Wang discloses a pulse having various characteristics, those characteristics vary with the design of the power supply and Petitioners did not explain how *Wang's* disclosure of a power pulse with such variable characteristics could suggest a *selection*, as required by claim 16.

K. The Combination of *Wang* and *Kudryavtsev* Does Not Suggest That Either of "a rise time and magnitude of the electrical pulse" is "selected to excite atoms in the weakly-ionized plasma to generate secondary electrons that increase an ionization rate of the weakly-ionized plasma," as Recited in Dependent Claim 17 or "increase an ionization rate of the excited atoms in the weakly-ionized plasma," as Required by Dependent Claim 30.

116. Petitioners argue, in essence, that because *Wang's* pulses have an associated rise time and amplitude, these parameters are necessarily are selected to increase the ionization rate of excited atoms in the weakly ionized plasma."[131] This conclusory allegation is unsupported by any teaching of *Wang*.

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[130] *Ex. 1104* at 5:23-26.

[131] IPR2014-00807 Petition at pp. 53, 54.

117. With respect to the pulse described by *Wang*, "Its exact shape depends on the design of the pulsed DC power supply 80, and significant rise times and fall times are expected."[132] In contrast, claims 17 and 30 each require that a rise time or magnitude be ***selected.*** While Wang discloses a pulse having various characteristics, those characteristics vary with the design of the power supply and Petitioners did not explain how *Wang's* disclosure of a power pulse with such variable characteristics could suggest a *selection*, as required by the claims.

L. The Combination of *Wang* and *Kudryavtsev* Does Not Suggest a Cathode that is Positioned Adjacent to the Anode "form[ing] a gap there between," as Recited in Claim 28.

118. It is my opinion that the combination of *Wang* and *Kudryavtsev* does not suggest a cathode that is positioned adjacent to the anode "form[ing] a gap there between," as recited in claim 28. As explained above, *Wang* and *Kudryavtsev* do not suggest a cathode that is positioned adjacent to the anode. Furthermore, claim 28 requires "a gap" between the cathode and the anode. Inasmuch as *Wang* and *Kudryavtsev* do not suggest a cathode that is positioned adjacent to the anode, these references cannot suggest a cathode that is positioned adjacent to the anode, wherein the anode and cathode form a gap there between.

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[132] *Ex. 1104* at 5:23-26.

M. The Combination of *Wang* and *Kudryavtsev* Does Not Suggest "a dimension of the gap between the anode and the cathode is chosen to increase an ionization rate of the excited atoms in the weakly-ionized plasma," as Required by Dependent Claim 29.

119. Claim 29 requires that the dimension of the gap between the anode and cathode be *chosen* to increase the ionization rate of excited atoms.[133] None of the cited references discusses the impact of the choosing of the spacing between the anode and cathode on such an ionization rate. At best, *Kudryavtsev* provides a model that describes ionization relaxation in terms of atomic densities in different states, electron densities, rate constants for collisional transitions, rate coefficients for ionization contributions through different processes, diffusion fluxes of electrons and excited atoms for a particular geometry, and other factors, but none of these parameters are specified in terms of the distance between the anode and cathode.[134] Moreover, the equations defining the model do not permit a solution for volume between the anode and cathode (or any related parameter), hence, one could not "choose" such a volume based on this model.

120. Petitioners speculate that one would adjust spacing between *Wang's* and

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[133] *Ex. 1101* at 22:25-28.

[134] *Ex. 1205* at pp. 30-31.

cathode until achieving the "explosive increase" in ionization,[135] but this is clearly not the case because, as I describe above, the "explosive increase" in ionization reported by *Kudryavtsev* was associated with arcing and Wang sought to reduce arcing. Moreover, because nothing in *Kudryavtsev's* model would suggest any dependency on the gap dimensions, such teachings say nothing about how one would go about *choosing* a dimension that would lead to the reported increase in the ionization rate of excited atoms and molecules. Indeed, while the '716 patent discloses the "gap 244 is between approximately 0.3 cm and 10 cm,"[136] *Kudryavtsev*, teaches using a gap more than five times that length,[137] and *Wang* (insofar as it relies on *Chiang*), teaches a preference for longer gaps and not the 0.3 cm and 10 cm taught by Dr. Chistyakov. If anything then, the combination of references relied upon by Petitioners suggests an apparatus having a long anode-cathode gap, but does not teach or suggest choosing that gap dimension so as to increase the ionization rate of excited atoms and molecules. Therefore, it is my opinion that the combination of *Wang* and *Kudryavtsev* does not suggest the subject matter required by dependent claim 29.

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[135] IPR2014-0807 Petition at p. 58.

[136] *Ex. 1101* at 4:33-34.

[137] *Ex. 1205*, p. 32, right col, ¶ 6,

N. It Would Not Have Been Obvious To Combine the Teachings of *Wang*, *Kudryavtsev,* and *Mozgrin* To Achieve the Invention Claimed in the '716 Patent.

121. It is my opinion that it would not have been obvious to combine the teachings of *Wang*, *Kudryavtsev,* and *Mozgrin* to achieve the invention recited the claims of the '716 patent. There are marked differences between the experimental apparatus of *Kudryavtsev* and the magnetron sputter reactor described by *Wang* and a person of ordinary skill in the art would not have expected that applying the teachings of *Kudryavtsev* in a *Wang*-type system would have yielded predictable results or would have performed in an expected way. *Kudryavtsev's* theoretical work is targeted for "pulsed gas lasers, gas breakdown, laser sparks, etc."[138] Moreover, *Kudryavtsev's* experimental system involved a 2.5 cm diameter tube between two electrodes spaced 52 cm apart. This apparatus did not use magnets or magnetic fields.[139] *Wang*, on the other hand, discusses "[a] pulsed magnetron sputter reactor [with] a high plasma density."[140]

122. Magnetron sputter reactors achieve their high plasma densities specifically through the use of magnetic fields, which trap secondary electrons near the target

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[138] IPR2014-00808 *Ex. 1305*, p. 34, right col, ¶ 4.

[139] *Id.*, p. 32, right col, ¶ 4.

[140] *Ex. 1104* at 3:16-22.

increasing the probability that these electrons will collide with gas atoms and create additional ions and free electrons. One of ordinary skill in the art would not be motivated to apply teachings related to the application of an electric field to a weakly ionized gas across a space of 52 cm unaffected by a magnetic field to a pulsed magnetron sputter reactor characterized by a "magnetic field near the face of the target [ ] which traps electrons from [a] plasma to increase the electron density."[141] There would be no predictable results to be achieved by such an experiment, for example because it was known at the time of the invention that "[v]ery large power pulses can still result in undesirable electrical discharges regardless of their duration"[142]

123. Moreover, the behaviors of charged particles (such as electrons and ions) in magnetic fields are vastly different from their behaviors in the absence of magnetic fields. The examples of instances cited by *Kudryavtsev* (pulsed gas lasers, gas breakdown and laser sparks) are not indicative of conditions within a magnetron sputter reactor (such as that described by *Wang*). Hence, one could not expect that models derived for such applications (and experiments designed to confirm such models) would be directly applicable to magnetron sputter reactors.

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[141] *Id.* at 4:24-26.

[142] *Ex. 1101* at 3:50-52.

124. Furthermore, operating parameters specified by *Wang* belie Petitioners' attempt to imply that the combination of *Wang* and *Kudryavtsev* would be one that would be made by a person of ordinary skill in the art. For example, *Wang* describes the deposition process as "low pressure."[143] Although *Wang* does not specify exactly what this means, *Wang* does refer to *Chiang*, which specifies pressures below 5 mTorr and preferably below 1 mTorr.[144] Such working pressures are well below those reported by *Kudryavtsev*, for example in Figure 3 where results for pressures of 3.7 and 11.4 Torr are noted.[145] Thus, the references themselves contradict the proposed combination of teachings being advanced.

125. Petitioners also seem to ignore, or at least conveniently overlook, what the actual combination of the teachings of *Wang* and *Kudryavtsev* might suggest. *Wang* does not specify actual dimensions for the subject magnetron sputter reactor, but does refer readers to *Chiang* for such details: "Most parts of this reactor have already been described by Chiang et al."[146] *Chiang* discloses a throw (source to substrate) of 14-29 cm, and extension of a floating shield to 6-10 cm from the

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[143] *Ex. 1104* at 7:32-36.

[144] See, e.g., *Ex. 2008* at Abstract, 6:60-62.

[145] *Ex. 1305* at p. 32, FIG. 3.

[146] *Ex. 1104* at 3:60-61.

target (source).[147] Thus, Wang's anode would preferably be at least 10-14 cm from the cathode. *Kudryavtsev* reports, "the distance between the electrodes was L = 52 cm."[148] Thus, any combination of *Wang* and *Kudryavtsev,* to the extent such a combination would be made by a person of ordinary skill in the art, would suggest a system having a long throw. The '716 patent, in sharp contrast to both *Wang* and, especially, *Kudryavtsev* discloses a "gap 244 is between approximately 0.3 cm and 10 cm."[149] That is, the *Kudryavtsev* apparatus operates using a gap more than five times the length of the gap specified in the '716 patent[150] and, to the extent *Wang* relies on *Chiang*, *Wang* teaches a preference for longer gaps and not the magnetically enhanced plasma processing apparatus having a gap between approximately 0.3 cm and 10 cm taught by Dr. Chistyakov. While the dimensions of the gap are not recited in the claims of the '716 patent one must consider what the actual scope and content of the prior art is, and the conclusions the teachings of prior art references would lead to when considering the obviousness question as a whole. Here, it seems that any combination of the teachings of *Wang* and

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[147] *Ex. 2008* at 14:37-50; 6:66 – 7:2.

[148] *Ex. 1305*, p. 32, right col, ¶ 4.

[149] *Ex. 1101* at 4:33-34.

[150] *Ex. 1305 at* p. 32, right col, ¶ 6.

Kudryavtsev, to the extent such a combination could be made, would suggest to the person of ordinary skill in the art that any apparatus seeking to employ such teachings should, at a minimum, be characterized by an anode-cathode spacing significantly different from that advocated by Dr. Chistyakov and, therefore, that such teachings would not be applicable to an apparatus or method such as that described in the '716 patent.

126. My conclusions regarding *Wang* and *Kudryavtsev* are not changed when one further considers the teachings of *Mozgrin* cited by Petitioners. *Mozgrin* relates to "high-power quasi-stationary low-pressure discharge in a magnetic field,"[151] and although *Mozgrin* shows a space between a cathode and an anode, there is no teaching in *Mozgrin* as to its importance. In Dr. Chistyakov's '716 patent the dimensions and volume of the gap are important parameters in the ionization process, as I pointed out above. The fact that *Mozgrin* shows a gap adds no teaching to aid in combining *Wang* and *Kudryavtsev*. Further, while it is true that *Mozgrin* took into account certain dependencies reported by *Kudryavtsev* in designing a pulsed supply unit,[152] this does not imply that one or ordinary skill in the art would have combined the teachings of *Wang* and *Kudryavtsev*. *Mozgrin*

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[151] IPR2014-00808 *Ex. 1303* at p. 400, Abstract.

[152] *Id.* at p. 401, rt. col.

determined that for systems employing a magnetic field, a supply unit "providing square voltage and current pulses with rise times (leading edge) of 5 – 60 μs and durations as much as 1.5 ms" was needed.[153] *Wang*, on the other hand was concerned with regimes in which pulses had "significant" rise times and pulse widths were preferably kept to less than 200 μs and no more than 1 ms.[154] Given these important distinctions in the nature of the supply unit, the teachings of *Mozgrin* would be of little value to a person of ordinary skill in the art when considering the system of *Wang*. Significant experimentation would still be required in order to adapt any teachings of *Mozgrin* to the regime of *Wang*.

VII. DECLARATION

127. I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true, and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both,

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[153] *Id.*

[154] *Ex. 1104* at 5: 26-27, 43-48; 8:41-42.

under Section 1101 of Title 18 of the United States Code.

Date: January 12, 2015

Larry D Hartsough

Larry D. Hartsough, Ph.D.

Appendix A

Larry D. Hartsough, Ph.D.
dba U A Associates
3007 Benvenue Ave.
Berkeley, CA 94705

Ph: 510-548-5027 Cell: 510-847-7033 email: ldhphd1971@yahoo.com

Updated: December 2014

Technical Expertise

- Semiconductor Manufacturing Equipment
- Physical metallurgy
- Thin film metallurgy
- Planar and hollow-cathode magnetron sputter source design
- SEMI Standards Development and Compliance
- Vacuum system design & practice
- Cluster tool design and interfaces
- PVD Thin film process and process control
- Electrostatic chuck technology
- Magnetic modeling

Education

B.S., M.S., and Ph.D. in Materials Science/Engineering from the University of California, Berkeley

Professional Summary

Thirty years of R&D and Engineering in the semiconductor capital equipment industry in the areas of thin film deposition, vacuum system design and plasma processing of materials. Pioneer in the development of magnetron sputtering hardware and processes for the metallization of silicon integrated circuits. Instrumental in the development of cluster tool and 300mm interface standards for semiconductor fabrication equipment.

Professional Experience

1990- Present	*Consultant in private practice.* dba **UA Associates** Product development projects; litigation support; film failure analysis; project management; technical presentations.
1997- 2002	*Manager, PVD Source Engineering* **Novellus Systems, Inc.** Sputter hardware, target and process development. Thin film and component failure analysis.
1991- 1997	*Manager, PVD Source Technology* **Varian Associates, Thin Film Systems Division** Development and improvement of advanced deposition sources and hardware.

1988-1990 *Project Manager*

General Signal Thinfilm Co.

Design, engineer and build an advanced cluster tool.

1984-1988 *Manager, Advanced Development*

Gryphon Products, Inc.

Develop enhancements for semiconductor fabrication equipment to enable advanced processes.

1981-1984 *VP Engineering & Founding Partner*

Gryphon Products/Exeltek, Inc.

Cofounder and partner in startup company. Led engineering, prototyping and initial testing of magnetron sputtering system with automated wafer handling.

1977-1981 *Manager, Advanced Development; Manager, Applications Lab; Senior Staff Scientist*

Perkin-Elmer Corp., Plasma Products Division

Development, characterization, demonstration and maintenance of

Sputter deposition equipment.

1975-1977 *Research Engineer*

Airco Temescal

Characterization, process development and demonstration of a high

throughput in-line magnetron sputter deposition system.

1971-1975 *Research Metallurgist*

Optical Coating Laboratory, Inc.

Deposition processes and optical properties of thin films

Litigation Support Experience

- Confidential technical consultant
- Trade secrets analysis, discovery, declarations, deposition
- Analyze patent portfolio for relative value of lapsed patent
- Prepare expert reports and declarations
- Testify as expert witness before arbitration panel
- Literature searches
- Deposition testimony before opponents counsel

Professional Associations and Activities

- Member, American Vacuum Society since 1977
- Member, Sigma Xi, The Scientific Research Society, since 1971
- Referee for Journal of Vacuum Science & Technology
- Leader in development of SEMI Standards for cluster tools and 300mm equipment:
  - Co-Chair, first MESA task force on Utilities (electrical interconnect and EPO)(1989)
  - Co-Chair, SEMI Standards E6 task force to revise Facilities Interface Specifications Format
  - Co-Chair, SEMI Standards E15 task force to rewrite Load Port Interface Standard
  - Technical Architect, SEMI Standards North America Physical Interfaces Committee
  - North America Co-Chair, SEMI Standards Global Physical Interfaces and Carriers (PIC) Committee
  - Recipient, 1997 North America Regional Standards Merit Award
  - Co-Chair, SEMI Standards North America Factory Integration Division (2003-2005)
  - Member-at-Large, SEMI Standards North America Regional Standards Committee (2005-2009)

  - Member, SEMI International Standards Committee Audit & Review Sub-Committee (2008-); Chair (2011-)
  - Technical Editor, SEMI Standards North America Physical Interfaces Committee (2005-)
  - Member, SEMI International Standards Committee Regulations Sub-Committee (2011-)
  - Leader, PIC Standards Maintenance TF (2011-)
  - Recipient, 2012 North America Regional Standards Honor Award
  - Recipient, 2013 Karel Urbanek Memorial Award
- Member of ASTM subcommittee F01.17 on Sputter Metallization (1997-2002)
- Local Arrangements Chair – 1978 International Conference on Metallurgical Coatings
- Member of US Department of Commerce Semiconductor Technical Advisory Committee, 1980-84 (in re: Export Administration Act of 1979).

U. S. Patents (as inventor or co-inventor)

Patent Number	Date Issued	Title
6,500,321	Dec 31, 2002	Control of erosion profile and process characteristics in magnetron sputtering by geometrical shaping of the sputtering target..
6,497,796	Dec 24, 2002	Apparatus and method for controlling plasma uniformity across a substrate
6,444,105	Sept 3, 2002	Physical Vapor Deposition Reactor Including Magnet to Control Flow of Ions
6,193,854	Feb 27, 2001	Apparatus and Method for Controlling Erosion Profile in Hollow Cathode Magnetron Sputter Source
6,179,973	Jan 30, 2001	Apparatus and Method for Controlling Plasma Uniformity Across a Substrate
5,985,115	Nov 16, 1999	Internally Cooled Target Assembly for Magnetron Sputtering
5,503,676	Apr 2, 1996	Apparatus and Method for Magnetron In-Situ Cleaning of Plasma Reaction Chamber
5,417,833	May 23, 1995	Sputtering Apparatus Having a Rotating Magnet Array and Fixed Electromagnets
4,420,385	Dec. 13, 1983	Apparatus and Process for Sputter Deposition of Reacted Thin Films
4,260,649	Apr. 7, 1981	Laser Induced Dissociative Chemical Gas Phase Processing of Workpieces
4,204,936	May 27,	Method and Apparatus for Attaching A Target to

	1980	the Cathode of a Sputtering System
4,125,446	Nov. 14, 1978	Controlled Reflectance of Sputtered Aluminum Layers

Publications

G. C. D’Couto, G. Tkach, K. A. Ashtiani, L. Hartsough, E. Kim, R. Mulpuri, D. B. Lee, K. Levy, and M. Fissel; S. Choi, S.-M. Choi, H.-D. Lee, and H. –K. Kang, “*In situ* physical vapor deposition of ionized Ti and TiN thin films using hollow cathode magnetron plasma source” J. Vac. Sci. Technol. B 19(1) 244 (2001).

Larry D. Hartsough, “Electrostatic Wafer Holding”, Solid State Technology, January 1993, p. 87.

D. R. Denison, L. D. Hartsough and S. Minners, “Characterization of an Aluminum Silicon Planarization Process in a Production Sputtering System", Microelectronic Manufacturing and Testing, November 1987, p. 6.

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D. R. Denison and L. D. Hartsough, "Copper Distribution in Sputtered Al/Cu Films", J. Vac. Sci. Technol., 17 1326 (1980).

J. I. Steinfeld, T. G. Anderson, C. Reiser, D. R. Denison, L. D. Hartsough and J. R. Hollahan, "Surface Etching By laser-Generated Free Radicals", J. Electrochem. Soc., 127 (2) 514 (1980).

L. D. Hartsough, A. Koch, J. Moulder, and T. Sigmon, "Quantitative Analysis of Ti-W Films", J. Vac. Sci. Technol., 17 392 (1980).

A. Joshi, L. D. Hartsough and D. R. Denison, "Segregation Effects in Thin Films", Thin Solid Films, 64 409 (1979).

L. D. Hartsough, "Resistivity of Bias-Sputtered Ti-W Films", Thin Solid Films, 64 (1) 17 (1979).

L. D. Hartsough and D. R. Denison, "Aluminum and Aluminum Alloy Sputter Deposition for VLSI", Solid State Technology, December 1979, p. 66.

L.D. Hartsough, "Sputtered Oxides for Optical Coatings", presentation at Electro-Optics/Laser 77.

L. D. Hartsough and P. S. McLeod, "High-Rate Sputtering of Enhanced Aluminum Mirrors", J. Vac. Sci. Technol., 14 123 (1977).

P. S. McLeod and L. D. Hartsough, "High-Rate Sputtering of Aluminum for Metalization of Integrated Circuits", J. Vac. Sci. Technol., 14 263 (1977).

L. D. Hartsough, "Stability of A15 Phases", J. Phys. Chem. Solids 35 1691 (1974).

L. D. Hartsough and R. H. Hammond, "The Synthesis of Low Temperature Phases by the Co-Condensation of the Elements: A New Superconducting Compound, V_3Al", Solid State Commun. 9 885 (1971).

L. D. Hartsough, V. F. Zackay and E. R. Parker, "High Field Characteristics of $Nb_3(Al,Ge)$", Appl. Phys. Letts. 13 68 (1968).

Exhibit B: Summary of Comparison of Claims 1-11 and 33 to Wang.

Claim from ‘716 Patent	**Deficiency in *Wang***
Claim 1	
1. An apparatus for generating a strongly-ionized plasma, the apparatus comprising: a. an ionization source that generates a weakly-ionized plasma from a feed gas contained in a chamber, the weakly-ionized plasma substantially eliminating the probability of developing an electrical breakdown condition in the chamber; and b. a power supply that supplies power to the weakly-ionized plasma though an electrical pulse that is applied across the weakly-ionized plasma, the electrical pulse having at least one of a magnitude and a rise-time that is ***sufficient to transform the weakly-ionized plasma to a strongly-ionized plasma without developing an electrical breakdown condition in the chamber***.	*Wang* does not teach “transform[ing] the weakly-ionized plasma to a strongly-ionized plasma without developing an electrical breakdown condition in the chamber In *Wang’s* Fig. 4 embodiment, arcing takes place when a power pulse ignites a plasma. *Ex. 1004* at 7:3-6. In *Wang’s* Fig. 6 embodiment, arcing upon ignition is not eliminated, it is merely reduced. *Id*. at 7:47-55. Moreover, *Wang’s* use of pre-ionization does not eliminate arcing for his power pulses, it only reduced the likelihood of same. Electrical breakdown conditions such as arcing are still possible when a pulse is applied across a pre-existing plasma, particularly when there is a

Claim from ‘716 Patent	Deficiency in *Wang*
	large, abrupt increase in the electric field as would occur upon the sudden application of a power pulse, such as in the transition from P_B to P_P shown in *Wang’s* Fig. 6.
Claim 4	
The apparatus of claim 1 wherein the power supply generates a constant power.	*Wang* indicates that Fig. 6 is idealized (“[o]nce again, the actual waveforms will differ from the idealized illustrated ones”) and that the actual shape of the power pulse is expected to have significant rise and fall times. *Ex. 1004* at 7:40-41. Hence, the actual power pulse applied in *Wang* is not constant for the duration of the pulse τ_w. *Wang* further describes the shape of the pulse widths: “[t]he illustrated rectangular pulse widths are idealized. Numerical values of pulse widths should be measured as the full width at half maximum.”[156] Full width at half

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[156] *Id*. at 5:50-52.

Claim from '716 Patent	**Deficiency in *Wang***
	maximum is a term common to a person of ordinary skill in the art that signifies a rising then falling curve versus time in which the pulse width is defined as the 'full width' of the curve at half the peak of the curve. Accordingly, the pulse that is actually applied in Wang does not have constant power, as required by claim 4.
Claim 5	
5. The apparatus of claim 1 wherein the power supply generates a constant voltage.	If, as Petitioners contend, power is constant during the pulse τ_w taught by *Wang*, then the product of voltage and current must be constant for that period. With *Wang's* admitted drop in plasma impedance during the pulse, current will rise and voltage will drop. Consequently, Wang cannot teach the limitations of claim 5.
Claim 6	
6. The apparatus of claim 1 wherein the power supply supplies power to the weakly ionized plasma at a time that is	In connection with Fig. 6, the weakly-ionized plasma is generated some time ***before*** the curve depicted in the figure.

Claim from '716 Patent	**Deficiency in *Wang***
between about fifty microsecond and five second after the ionization source generates the weakly-ionized plasma.	*Wang* **says nothing** about the time between the generation of the weakly-ionized plasma (which is not shown in the figure) and the application first power pulse P_P. Hence, *Wang* cannot anticipate claim 6
Claim 7	
7. The apparatus of claim 1 wherein the power supply supplies power to the weakly ionized plasma for a duration that is sufficient to generate a quasi-static electric field across the weakly-ionized plasma.	The quasi-static electric field is "an electric field that has characteristic time of electric field variation that is much greater than the collision time for electrons with neutral gas particles. *Ex. 1001* at 7:3-13. Thus, claim 7 requires the characteristic time of electric field variation to be much greater than the collision time. Petitioners' analysis did not compare the ***characteristic time of electric field variation*** and collision time, and did not demonstrate that the former is much greater than the latter in *Wang's* system. There is no indication in *Wang* that the

Claim from '716 Patent	**Deficiency in *Wang***
	voltage is constant during any part of the power pulse as even *Wang* recognizes that the idealized pulses shown in Figures 4 and 6 are not what are actually applied. *Ex. 1004* at 5:24-27; 7:41-45 Accordingly, Petitioners' computations do not establish the proposition for which they are being advanced and claim 7 is not anticipated by *Wang*.
Claim 33	
An apparatus for generating a strongly-ionized plasma, the apparatus comprising: a. means for ionizing a feed gas in a chamber to form a weakly-ionized plasma that substantially eliminates the probability of developing an electrical breakdown condition in the chamber; and b. means for supplying an electrical pulse across the weakly-ionized plasma ***to transform the weakly-ionized plasma to a strongly-ionized plasma without developing an electrical breakdown condition in the***	*Wang* does not teach "transform[ing] the weakly-ionized plasma to a strongly-ionized plasma without developing an electrical breakdown condition in the chamber In *Wang's* Fig. 4 embodiment, arcing takes place when a power pulse ignites a plasma. *Ex. 1004* at 7:3-6. In *Wang's* Fig. 6 embodiment, arcing upon ignition is not eliminated, it is merely reduced. *Id*. at 7:47-55.

Claim from '716 Patent	Deficiency in *Wang*
***chamber*.**	Moreover, *Wang's* use of pre-ionization does not eliminate arcing for his power pulses, it only reduced the likelihood of same. Electrical breakdown conditions such as arcing are still possible when a pulse is applied across a pre-existing plasma, particularly when there is a large, abrupt increase in the electric field as would occur upon the sudden application of a power pulse, such as in the transition from P_B to P_P shown in *Wang's* Fig. 6.