

BEFORE THE PATENT TRIAL AND APPEAL BOARD

THE BOEING COMPANY
Petitioner,

v.

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
Patent Owner.

Case IPR2024-00761
Patent 7,487,684

**DECLARATION OF VIJAY GUPTA, PH.D.
IN SUPPORT OF PATENT OWNER'S RESPONSE**

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I. INTRODUCTION

I, Vijay Gupta, Ph.D. declare as follows:

1. I have been asked to testify as an expert consultant on behalf of The Regents of the University of California, the Patent Owner in this Inter Partes Review proceeding (“IPR”) before the Patent Trial and Appeal Board (“Board” or “PTAB”) of the United States Patent and Trademark Office (“PTO”) regarding U.S. Patent No. 7,487,684 (“the ’684 Patent” or “the Challenged Patent”) (Ex-1001)¹. I am being compensated for the time I spend on this matter, in addition to expenses. I am a co-inventor of the ’684 Patent and am the founder of Laser Spallation Technologies (LST, Inc.), which has an exclusive licensee of the ’684 patent.

2. This Declaration summarizes the opinions I have formed to date. I reserve the right to modify my opinions, if necessary, based on further review and analysis of information that I receive subsequent to the filing of this Declaration, including in response to any positions taken by The Boeing Company (“Petitioner” or “Boeing”) or its experts that I have not been provided yet.

3. I am the named inventor along with Dr. Vassili Kireev on the the’684 Patent, which I understand is the subject of this IPR.

¹ In this Declaration, I reference documents by exhibit numbers that, as I understand, are attached to Exhibits in this IPR.

4. I understand that Boeing has challenged the validity of Claims 1-24 (“Challenged Claims”) of the ‘684 patent on 7 grounds, summarized in Table 1 below.

Ground	Claims Challenged	35 U.S.C. § ⁵	Reference(s)/Basis
1	1–22	102(b)	Wang
2	4, 6, 9, 15, 17, 20, 23, 24	103(a)	Wang
3	1–24	103(a)	Wang, Gupta-1992
4	1–8, 10–19, 21, 22	102(b)	Gupta-1992
5	9, 20	103(a)	Gupta-1992, Gupta-1993
6	4, 6, 10, 15, 17, 23, 24	103(a)	Gupta-1992
7	1–24	103(a)	Wang-2002, Gupta-1992

5.

6. I understand that Boeing has used a number of documents, listed in the third column of the table above, to argue that claims 1-24 of the ‘684 patent are invalid. As explained herein, I disagree with this assessment. The ‘684 patent claims are not invalid.

7. Relying on testimony by Dr. Junlan Wang, Boeing argues that the Wang-Dissertation (Ex-1005) anticipates claims 1-22 of the ‘684 patent (Ground 1), claims 4, 6, 9, 15, 17, 20, 23-24 are obvious in view of the Wang-Dissertation (Ex-1005) alone (Ground 2), claims 1-24 are obvious in view of the Wang-Dissertation (Ex-1005) Gupta-1992 (Ex-1011) (Ground 3), claims 1-8, 10-19, and 21-22 are anticipated by the Gupta-1992 reference (Ex-1011) (Ground 4), claims 9 and 20

are obvious in view of Gupta-1992 (Ex-1011) and Gupta-1993 (Ex-1013) (Ground 5); claims 4, 6, 10, 15, 17, 23-24 are obvious in view of Gupta-1992 (Ex-1011) (Ground 6), and claims 1-24 are obvious in view of Wang-2002 (Ex-1016) and Gupta-1992 (Ex-1011) (Ground 7). I disagree with each of Boeing's stated Grounds 1-7, and I specifically explain and address these Grounds below.

II. MATERIALS CONSIDERED

8. In preparing this Declaration, I have reviewed the '684 Patent, its file history, Exs. 1001-1005, 1007-1021, 1027-1032, and 1034, and the deposition testimony of Dr. Wang, as well as all of the materials and references cited in this Declaration.

9. Additionally, in arriving at my opinions contained in this declaration, I have relied upon my professional experience and judgment, as well as my education, training, and experience regarding laser spallation technology, and knowledge regarding technologies related to the '684 Patent.

III. QUALIFICATIONS

10. I am currently a Full Tenured Distinguished Professor of Mechanical and Aerospace Engineering at the University of California Los Angeles ("UCLA"). I also hold appointments as Distinguished Professor in the Materials Science and Engineering Department and Biomedical Engineering Department at UCLA. I have a Ph.D. in Mechanical Engineering and an M.S. in Structural Engineering,

both from the Massachusetts Institute of Technology (“MIT”). After finishing my Ph.D. in 1990, I joined the faculty at Dartmouth College as an Assistant Professor and was promoted to the rank of Full Professor, with tenure, at UCLA in 1995, directly from the Assistant Professor rank, without undergoing the usual Associate Professor step. At age 31, I became the youngest Full Professor with tenure in the United States, only 5 years after receiving my Ph.D. degree and 10 years after my undergraduate degree.

11. In April 2018, I was given the status of “Distinguished Professor” by the Regents of the University of California, which is the highest rank bestowed on a Full Professor in the University of California System.

12. My research has covered a wide range of areas, including interface science and engineering, composite materials, aircraft structures, applied mechanics, fracture mechanics, mechanical engineering design, manufacturing, and biomechanics—both experimentally as well as through mechanistic computer modeling. I am widely acknowledged as the leading experimentalist in the field of solid mechanics, notably in the areas of mechanical characterization of joints and interfaces, high energy material physics involving shockwaves, phase transformations in amorphous glasses using laser-generated shockwaves, and mechanical behavior and reliability of aerospace structures made using composite materials, where I have made sustained and pioneering contributions. My research

has been widely disseminated in these areas, with over 150 papers published in leading technical journals, conference proceedings and books. I have also given over 200 principal keynote lectures in governmental agencies, companies, and national and international conferences and symposia in nearly all industrial countries. I also hold four United States Patents, with several others pending, with one widely used in the semiconductor industry.

13. Attached as **Ex-X** is a true and correct copy of my curriculum vitae. That attachment accurately sets forth some of my training and experience in the fields of mechanical engineering design, applied mechanics, dynamics (stability), and materials science.

IV. LEGAL FRAMEWORK

14. I am a technical expert and do not offer legal opinions. However, I have been informed about certain legal principles regarding patentability and related matters under United States patent law, which I have applied in performing my analysis and arriving at my technical opinions in this matter.

A. Anticipation

15. I have been informed and understand that a patent claim is invalid as “anticipated” if each and every feature of the claim is found in a single prior art reference. I also understand that anticipation requires the presence in a single prior art a description of all elements of the claim arranged as required in the claim. I

have been informed that for a reference to be considered as anticipating, it must disclose the relevant technology in a manner such that a POSA (person of ordinary skill in the art) would be able to carry out or utilize the technology that the reference describes without having to undertake undue experimentation.

B. Obviousness

16. I have been informed and understand that a patent claim is not patentable if the claimed invention would have been obvious to someone of ordinary skill in the art at the time the patent application was filed. This means that even if all of the requirements of the claim cannot be found in a single prior art reference so as to anticipate the claim, the claim might still not be patentable if the subject matter in the claim would have been obvious. I also have been informed that a claim would have been obvious when the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to someone of ordinary skill in the art.

17. I have been informed and understand that to prove that a prior art reference or a combination of prior art references renders a patent obvious, it is necessary to: (1) identify the particular references that either alone, or in combination, render the patent obvious; (2) specifically identify which elements of the patent claim appear in each of the asserted references; and (3) explain how the

prior art references could have been combined in order to create the inventions defined in the particular claim at issue.

18. I have been informed and understand that, in order to establish that a claimed invention would have been obvious based on a combination of prior art documents, a clear articulation of the reason(s) why the claimed invention would have been obvious, or why a certain prior art document would have been modified, must be provided.

19. I also have been informed and understand that it is improper to combine references where the references teach away from their combination. I have been informed that a prior art reference may be said to teach away when a person of ordinary skill in the art, upon reading the prior art reference, would have been led in a direction divergent from the path that was taken by the inventors.

20. I have been informed and understand that a final determination of obviousness should also consider secondary considerations, if any, such as commercial success of products covered by the patent. I understand that to date secondary considerations have not been raised in these proceedings.

C. Person of Skill in the Art

21. I have been informed and understand that for a patent claim to have been obvious, the claim must be obvious to a person of ordinary skill in the art at the time of the alleged invention. I have been informed that the factors to consider in

determining the level of ordinary skill in the art include (1) the educational level and experience of people working in the field at the time the invention was made, (2) the types of problems faced in the art and the solutions found to those problems, and (3) the sophistication of the technology in the field.

22. It is my understanding that for purposes of this proceeding, the Petitioner is of the opinion that a person of ordinary skill in the art at the time of the alleged invention (“POSITA”), which for purposes of this proceeding is on or around March 5, 2004, would have had an M.S. in Mechanical Engineering or a related field, and at least five years of experience using laser systems to characterize and test mechanical behavior in materials. More education may supplement practical experience or vice versa. In my opinion, in addition to these qualifications, a POSITA developing new laser-based methodologies for mechanical behavior of materials would also have had education or training in wave mechanics and shock physics.

23. Based on my education, training, and professional experience in the field of the claimed invention, I exceed the level and abilities of a POSA at the time of the claimed invention. Although my qualifications may exceed those of one skilled in the art, my analysis and opinions regarding the patent at issue have been rendered from the perspective of one skilled in the art at the time of the invention.

D. Claim Construction

24. In my analysis I have interpreted the claims in accordance with their plain and ordinary meaning in view of the specification and prosecution history.

25. It is my understanding that the term “the glass element is configured to propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating” recited in claim 1, and similarly recited in claim 13 (“propagating and modifying a stress wave through the glass element to the coating/substrate interface to generate a tensile force between the Substrate and the coating”) means changing the profile of the laser generated compressive wave and propagating the wave profile as modified to the free surface of the coating, which upon reflection from the free surface as a tension wave generates a tensile stress at the coating/substrate interface. This meaning is consistent with the plain and ordinary meaning of the claim language as would be understood by a POSITA in view of the claim language as a whole, the patent specification and figures and the prosecution history. *See, e.g.*, Ex-1001, 8:52-67, 9:32-49, Figs. 5A, 5B, 6, and 8A-8B; Ex-1002, 37-43, 62, 79-80, 91-93.

V. OVERVIEW OF THE ‘684 LASER SPALLATION TECHNOLOGY

26. Measurement and control of the tensile strength of an interface or a joint between two different materials is key to developing reliable components in a variety of industries such as aircraft engines, paint, microelectronics, aerospace

structures, and civil construction. Notable among these is a laser spallation experiment that uses a laser-generated stress wave to pry off an interface.

27. I first began work on this technique as part of my Ph.D. dissertation at MIT between 1985 and 1989 under Professor Ali S Argon, and a commercial version of this tool, with additional features, such as the design of waterglass constraining layer and design of world's fastest optical interferometer to record fringes from free surface of films, was developed in 1992 during my tenure at Dartmouth College. The latter allowed a more direct quantification of the interface tensile stress in the MIT version of the laser spallation experiment.

28. Contrary to the statements made by Dr. Wang in her declaration, no **quantification** of the laser spallation experiment was performed prior to my MIT work in 1978 by J. L. Vossen (*Adhesion Measurement of Thin films, Thick Films and Bulk Coatings*, edited by K.L. Mittal, pp. 122-133, STP-640, ASTM, Philadelphia) — who merely showed that laser pulse can blow off the films but did not quantify the actual magnitude of the interface tensile stress. Without quantification, Vossen's experiments were unable to provide any practical use to the industry and the research community. As such, research related to the laser spallation experiment remained limited to that singular Vossen paper up until my work at MIT. Thus, the development of an optical interferometer and design of the

constraining waterglass layer were major advances that allowed the first practical use of the laser spallation experiment in the industry.

29. These major developments by myself in the field of adhesion science and technology were recognized by the U.S. Patent and Trademark Office, which granted U.S. Patent No. 5,438,402 (“the ’402 Patent”) (Ex.-1034). The application for the ’402 Patent was filed in 1993, as shown on the cover page.

30. With the afore-described modifications in the ’402 Patent related to waterglass and optical interferometry, the laser spallation technique has been used by virtually all major semiconductor companies in the world for characterization of adhesion in devices and packages. It has been transferred to or used for product development in Intel Corporation, Texas Instruments, Hitachi, Freescale Semiconductor, On Semiconductor, and Dow Corning Corporation. Even today, every chip that is designed and manufactured at Intel Corporation uses the laser spallation technology that I transferred to Intel Corporation back in 1999.

31. In the late 1990s, the aerospace industry had the need to test composite joints which required higher stress wave amplitudes of the interrogating stress pulse in the laser spallation tool. At the same time, the microelectronics industry was manufacturing high density nanoscale chips and packages and needed to test the adhesion properties in such nanoscale structures.

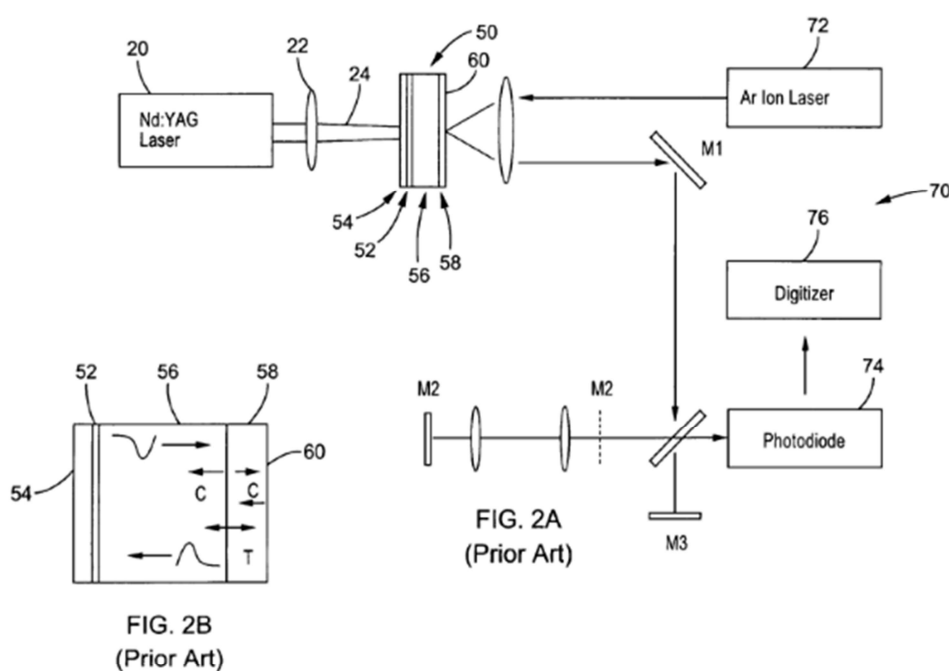
32. Recognizing these long-felt needs in the industry, I, along with Vassili Kireev, worked to develop a method and apparatus that modified the stress wave profiles described in the '402 patent by using a glass element that resulted in sharper stress wave profiles and much higher interface stress amplitudes required to test nanoscale structures and composite joints, especially those between thicker composite sections.

33. My collaborative work with Vassilli Kireev on these subjects over several years eventually led to the invention disclosed in U.S. Patent No. 7,487,684 (“the '684 Patent”) directed to an apparatus and method for propagating a modified stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating after its reflection from the free surface of the coating (or “film,” the term used by Dr. Wang in her Declaration (Ex-1003)).

34. Sometime after my move to UCLA in 1995 and prior to the year 2000, I met Professor Nancy Sottos from the University of Illinois Urbana Champagne (UIUC) at an American Society of Mechanical Engineers meeting where she said she has been reading many of my publications and was interested in my laser spallation technique and would like to pursue interface adhesion research in her own lab by using the laser spallation technique. From 2004 to 2006, I collaborated with Texas Instruments on characterizing solder joints in their packages using the laser spallation technique and published articles with their lead scientist Dr. Cheryl

Hartfield. Professor Sottos' group then followed my work with Texas Instruments, with Dr. Cheryl Hartfield, from 2005 onwards, as indicated by her joint publication with Texas Instruments in 2008 [*“Adhesion strength measurement of polymer dielectric interfaces using laser spallation technique,”* S. S. V. Kandula, Cheryl D. Hartfield, Philippe H. Geubelle, Nancy R. Sottos, Thin solid Films, V. 516 (21), 2008, pp. 7627-7635].

35. Figures 2A and 2B below, taken from '684 patent, presents a schematic of a laser spallation technique.



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36.

37. Fig. 1 shows a substrate with a coating deposited on its front surface. The aim of the experiment is to measure the tensile strength of the coating/substrate interface. As part of the experimental strategy, a thin laser-

absorbing layer, typically a metal such as aluminum or gold of less than 1 micrometers (μm) in thickness is deposited on the backside of the substrate. This metal layer is constrained from the top by a constraining transparent disc through which a laser beam can pass freely to reach the now sandwiched layer of metal. A single pulse from an Nd: YAG laser is fired through the transparent confining layer onto the metal laser absorbing film, which expands or undergoes melting or even vaporization upon absorption of the laser pulse. This constrained expansion launches a mechanical compressive stress wave in the substrate that travels towards the interface and is reflected as a tension wave from the free surface of the coating and during its return journey loads the interface in tension. Ex.-1001, 2:16-34, 7:6-40. If the peak tensile stress is greater than the tensile strength of the interface, the interface fails separating the coating from the interface. When the compression wave is reflecting from the free surface of the coating, it induces surface displacements at the free surface that are recorded by a trained optical interferometer on the film's surface. The optical interferometer responds by generating optical fringes at the photodiode, with each full fringe corresponding to a surface displacement equal to half the wavelength of the interferometer laser (not the main YAG laser). Since fringes are recorded as a function of time, this allows for measuring the transient surface displacements and velocities of the free surface of the film. Ex.-1001, 6:26-7:5, 7:41-49, Figs. 1, 2A-2B, 5A-5B, 6, 8A and 8B.

Finally, for a given thickness and mechanical properties of the film, this velocity information is converted into the interface stress that lies below the free surface of the coating by using a wave mechanics based simulation. Ex.-1001, 8:42-51.

What makes this interferometric measurement challenging is that the free surface of the film moves only during the time when the stress wave is bouncing back from the film's surface, which in turn, is broadly equal to the stress wave length of 16 ns to 20 ns. Additionally, this motion occurs only once and therefore fringes must be recorded precisely in the single shot mode by coordinating it with the firing of the main laser pulse and that too with a resolution that is at least much faster than the rise-time of the stress wave, which is controlled by the laser heating pulse, and is typically less than 2 to 3 ns. Ex.-1001, 6:43-7:5, FIGS. 5A-5B, 6, 8A and 8B.

38. Fig. 3A in the '684 patent (reproduced below as Fig. 2), displays several such stress waves. As the laser pulse energy is increased, the amplitude of the generated stress wave increases and all waves have a rise-time that is essentially linear and all these rise-times are parallel to each other.

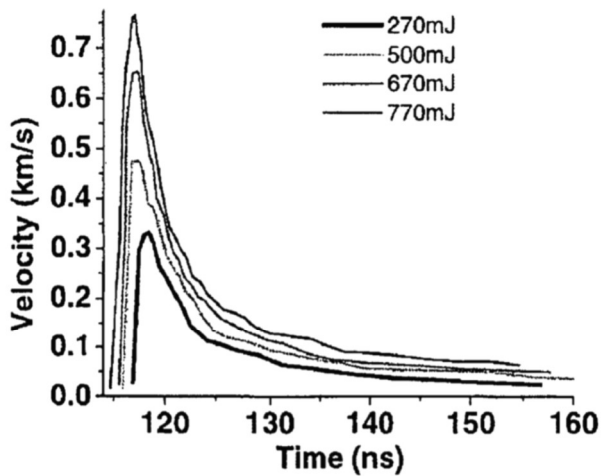


FIG. 3
(Prior Art)

39. The '684 patent teaches a technique to modify a laser-generated *compressive* stress wave profile that has a sharper rise-time and a gradual post-peak stress decay, compared to the stress wave profiles utilized in the '402 patent and shown in Fig. 2 above (hereinafter referred to as the "402 wave"), into a "modified stress wave profile" that has essentially a reversed profile with a gradual rise-time to the peak compressive stress and a sharper post-peak decay, including a sharp drop from the peak compressive stress, or "rarefaction shock." EX-1001, EX-1001, 3:5-14, 8:42-52, 9:17-58, Figs. 5A-5B and 6.

40. As described in the '684 patent, this modification to the '402 wave profile is done by passing it through "a glass element" in the '684 patent. The glass

element, by virtue of its material non-linearity, results in the formation of a rarefaction shock as higher stress amplitudes propagate with lower speeds than the lower stress amplitudes of the tail of the compression wave. After such a modification is performed by the glass element, the modified stress wave is transmitted into the backside of a substrate with a coating (or film) attached on its front surface. EX-1001, 3:5-14, 8:42-52, 9:30-58, Figs. 5A-5B and 6 .

41. One aim of the '684 patent is to measure the tensile strength of the coating/substrate interface. As described in the '684 patent, the **modified compression** wave after propagating through the substrate arrives at the substrate/coating interface. The glass element is therefore configured to **modify and propagate** the stress wave **to** the substrate/coating interface. There is **no tension** attached to this glass modified stress wave during its onward journey towards the coating interface. Once the modified compression stress wave **reaches** the substrate/coating interface, it enters the test coating with its **gradual ramp** profile, stressing the interface into **compression** first. This compression builds up at the interface, while the front end of the wave travels through the interface and arrives at the free surface of the coating, where it is instantly converted into a tensile wave of exactly the same amplitude that struck the free surface of the coating in compression. This portion of the stress wave, bearing now tensile amplitude, travels back towards the interface. This tension is however

immediately cancelled by the much larger compression amplitude that keeps rising at the interface due to the **shallow ramp** profile of the parent compression wave that is still transiting through the interface towards the free surface of the coating. EX-1001, 3:5-14, 8:42-52, 9:17-58,10:34-45; Figs. 5A-5B and 6.

42. As described in the '684 patent, due to the gradual ramp structure of the compression wave, **no tensile stress** can be generated at the interface when the gradual ramp portion of the compression wave is passing through the interface inside the coating and is reflected back from the free surface of the coating. This is because the much larger compressive stress from the original compression pulse is still sitting at the interface when a much smaller tension arrives at the interface. Consequently, the **net stress** at the interface is always in compression or close to zero stress but never in tension. When the net interface stress is in compression, there is **no failure** of the interface, as coating failure or interface separation requires generation of a **net tensile stress** at the interface that exceeds its tensile strength. EX-1001, 3:5-14, 8:42-52, 9:30-10:45, Figs. 5A-5B and 6.

43. As described in the '684 patent, as the initial compression wave continues to the move towards the free surface of the coating, the destructive interference between the tension from the reflected waves and initial compression wave continues till there comes a time when the entire ramp portion of the initial compression wave has left the interface. Since the largest compression in the

glass-modified wave is towards the rear end of the wave, when the latter reflects from the free surface of the coating, it instantly generates a very large tension at the interface. It is important to note that this tension is created **after** its reflection from the free surface of the coating. If this net tension exceeds the tensile strength of the interface, the film physically separates from the interface. EX-1001, 3:5-14, 8:42-52, 9:30-10:45, Figs. 5A-5B, 6, 8A-8B.

44. As described in the '684 patent, all tension waves that return from the free surface of the coating and strike the interface upon their return, undergo a transmission into the substrate towards the laser-impingement point and some portion of it is reflected back into the coating and travels towards the free surface where they are again inverted into a compression wave and upon their return journey strikes the interface in compression. This process then continues during the entire time when the original **modified compression wave** at the interface has completely passed through the interface and the above multiple reflection processes have been completed exhausted. EX-1001, 3:5-14, 8:42-52, 9:30-10:45, Figs. 5A-5B and 6.

45. As described in the '684 patent, the stress history at the interface, which essentially is the stress an observer will feel as a function of time if sitting at the interface, will start **initially** with a **compressive stress** indicating the arrival of the compression wave and then **later** a **tensile stress** will build after reflection of the

compression wave. If the peak of the tensile stress exceeds the strength of the interface, it would lead to the separation of the test coating. EX-1001, 10:10-45, Figs. 8A-8B.

46. It is noteworthy that the above-described wave reflections and transmissions from the interface and from the free surface of the coating would be the same for both the waves described in the '402 patent and the glass-modified waves described in the '684 patent, when either arrives at the interface, except that for a given thickness of the coating, the '684 waves, with their sharper post-peak stress drops, will generate a much greater tensile stress at the interface compared to that generated by the regular '402 wave. This is shown in Figs. 8A and 8B of the '684 patent, reproduced in the figure below, where the modified stress wave marked as 132 in Fig. 8A of the '684 patent results in a much higher interfacial tensile stress at the interface, shown in Fig. 8bB of the '684 patent as profile 136, compared to the one generated and shown as profile 134 (Fig. 8B of the '684 patent) by the regular '402 wave profile 130 (Fig. 8A of the '684 patent).

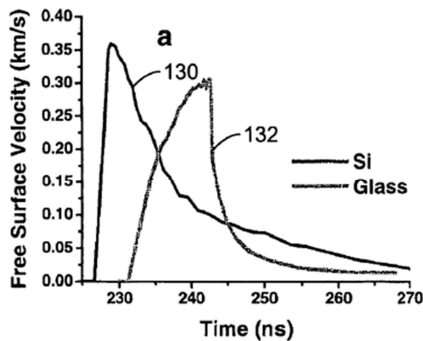


FIG. 8A

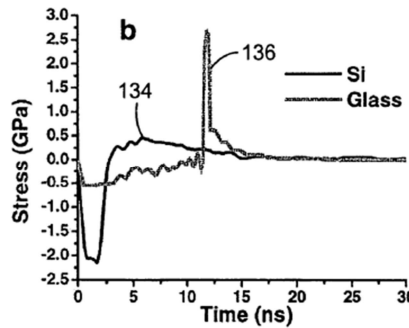


FIG. 8B

47. Note however that, as shown above, **both** waves result in a **pre-compression** prior to the generation of the respective tensile stresses at the interface, consistent with the arrival and transmission of the **initial compression wave** through the interface.

48. The '684 patent teaches a compressive stress wave **with the modified profile** to **arrive to** the interface and to generate tensile stress at the interface **after reflection from the free surface of the coating** (*see, e.g., claim 1*) and the tensile stress so generated after reflection from the free surface of the coating is increased until it exceeds the tensile strength of the interface **to separate the coating** or the film at the interface (*see, e.g., claim 13*).

VI. THE CHALLENGED CLAIMS OF THE '684 PATENT ARE NOT ANTICIPATED BY THE WANG DISSERTATION

49. As explained below, the Wang Dissertation (Ex-1005) fails to disclose all the limitations of the challenged claims of the '684 patent and, therefore, fails to anticipate these claims.

50. An analysis of Dr. Wang's Dissertation conclusively shows that what Dr. Wang refers to as a **decompression shock** (Ex.-1003, ¶¶ 77, 78) is actually the unloading caused by the unmodified direct tension wave² that, by Dr. Wang's own admission (Ex-2009 152:17-153:1), is generated in her experiments from the reflection of a second compression wave from the free surface of the constraining waterglass layer and enters the substrate behind the main compression wave. This direct tension wave travels faster than the peak compression wave, as also acknowledged by Dr. Wang in both her deposition testimony (Ex-2011, 91:9-14, 20-92:9; 94:5-20) and her statements in her Ph.D. dissertation (EX-2011, ¶64), and it completely neutralizes any decompression shock of the initial compression wave, even if one were to assume such a decompression shock were formed in the first place. In fact, a decompression shock is never formed, regardless of the presence of the tension wave, as demonstrated below through my analysis of Dr. Wang's Dissertation data.

² Also referred herein as tension-wave-1.

51. In Wang, the direct tension wave directly generates the tensile stress at the interface on its onward journey towards the free surface of the coating. Being already in tension, there is no need for this wave to reflect from the free surface of the coating to cause the tensile stress at the interface. In fact, if that were to happen, the stress wave would be **reflected into a compression wave and result in generating a large compression at the interface which will not result in the separation of the film at the interface.**

A. The Wang Dissertation (Ex-1005) Fails to Teach a Modified Wave

52. As described below in more detail the Wang Dissertation (Ex-1005) fails to anticipate any of the challenged claims because in the Wang-Dissertation: (1) there is no modified wave as required by the challenged claims of the '684 patent (indeed, in the Wang dissertation, there is no wave with a rarefaction shock or decompression shock profile); and (2) the tension described in Wang is not generated by a reflection from the free surface of the coating, but rather directly by a direct tension wave (generated at a free surface of the confining medium from the initial compression wave being reflected from the laser side) when it first strikes the interface during its onward journey towards the free surface of the coating.

53. One should keep in mind that there are two compression waves that are generated in the laser spallation experiment at the laser impingement point: Compression wave-1 goes into the substrate in the forward axial direction of the

laser, and compression wave-2 of exactly the same magnitude as compression wave-1 goes into the constraining medium in the opposite direction. In her dissertation (Ex-1005), Dr. Wang characterizes this compression wave-2 as being of “comparable magnitude.” Ex-1006, p. 66.

54. The compression wave-2 that goes toward the constraining medium is reflected from the free surface of the constraining medium as a tension wave of the same amplitude and then starts its journey towards the substrate where the compression wave-1 has already propagated into the substrate. All experimental data reported in Dr. Wang’s dissertation (Ex-1005) (except for data shown in Fig. 3.19 on page 74) and the publication based on her Dissertation (Ex-1016), show that this tension wave is transmitted into the fused silica substrate, behind the initial compression wave, with a time delay. On page 66 of the Wang dissertation, Dr. Wang acknowledges the origin and presence of this tension wave in the fused silica substrate. Ex-1005, p. 66. In this Declaration, I refer to this tension wave as the **direct tension wave** and the compression wave-1 also as the **initial compression wave**. Dr. Wang further explains that the initial delay between these two waves depends upon the thickness of the constraining medium and should be equal to the round trip travel time within the constraining layer of the compression wave generated inside the constraining layer. In the Wang Dissertation, the delay between these two waves varies from test to test as the thickness and properties of

the constraining waterglass layer are not well controlled as per Dr. Wang's own admission. This time delay is reported to be anywhere between 13 ns and 30 ns in the tests reported in Dr. Wang's Dissertation. Ex-1005, 74 and 77.

55. In contrast to what is described in the Wang Dissertation, as taught in the '684 Patent, the direct tension wave does not enter the substrate because a laser fluence is taught to be used that vaporizes the laser absorbing layer instantly. This results in a physical gap between the constraining layer and the substrate and, therefore, prevents the transmission of the tension wave into the substrate. In fact, as taught by the '684 patent, the constraining layer is blasted off by the trapped tension wave inside the constraining layer to totally remove it at the laser impingement point. This can be clearly seen in the '684 wave profiles or equivalently in the velocity profiles, reproduced below from the '684 patent, which bears only compression and no markings of any tension (or velocity reversal) whatsoever. Contrary to the waves described in the Wang Dissertation, the modified '684 wave is a pure compression wave with a well-developed rarefaction shock and generates the tensile stress at the interface only **after** reflecting from the free surface of the coating. Ex.-1001, 2:31-33.

56. As further explained below, Dr. Wang incorrectly interpreted all of her experimental fringe records in her dissertation (Ex-1005).

57. Fig. 3.15c from the Wang Dissertation is reproduced below with annotations.³

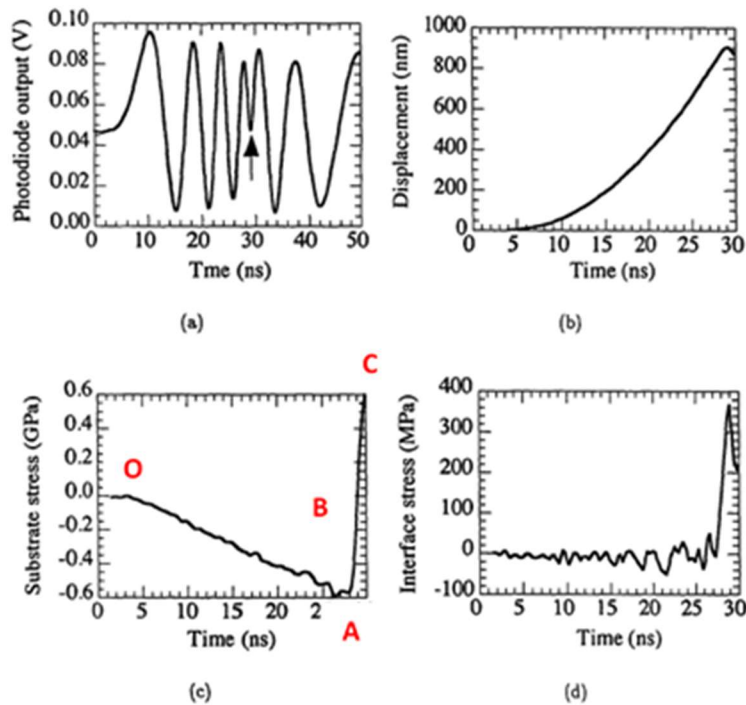


Figure 3.15: Typical data profile for a 1.0 μm thick aluminum film deposited on a 3000 μm thick fused silica substrate (laser fluence of 0.140 J/mm²): (a) interferometric fringe pattern, arrow points to turning point; (b) displacement profile; (c) substrate stress profile; (d) interface stress profile.

58. In her deposition, Dr. Wang testified that the portion of the stress wave in the substrate shown in Fig. 3.15c, from its peak compressive stress **A** to zero stress **B** is the “decompression shock” which she equates to the “rarefaction shock” of the ‘684 modified wave. See Ex-2009, 48-51. I have annotated the original Fig. 3.15c in the Dissertation with markings A, B, C, and O for easier explanation. The portion of the substrate stress from zero stress **B** to peak tensile stress **C** she

³ The exact same figure appears in the Wang-2002 publication (Ex-1016).

attributes to the arrival of the tension wave. This is wrong and not supported by Dr. Wang's own discussion throughout her Dissertation (Ex-1005). Portions AB and BC are part of the same continuous curve. Additionally, it would be a remarkable and not plausible coincidence that each figure in her Dissertation (for example in Fig. 3.15, Fig. 3.16, Fig. 3.17, Fig. 3.18, Fig. 3.20, Fig. 3.21, and Fig. 3.22, some reproduced below where several wave profiles in fused silica substrate are shown) would all indicate the arrival of the tension wave at precisely the same moment when the compression rarefaction shock ends at point B. This cannot be true because, as Dr. Wang admits, the initial delay between the tension wave and the compression wave is controlled by the thickness and properties of the waterglass layer which, in turn, are not very well controlled or characterized and hence would vary from test to test. Ex-1005, 65. The thickness of the waterglass layers in the test data shown in Fig. 5 varies significantly, from a fraction of a micrometer, 0.25 μm , to as high as 30 μm .

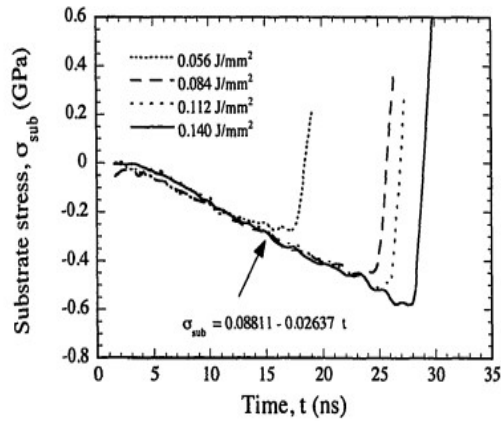
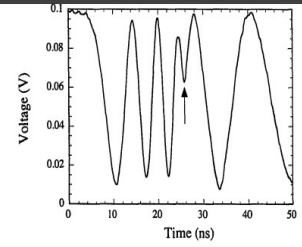
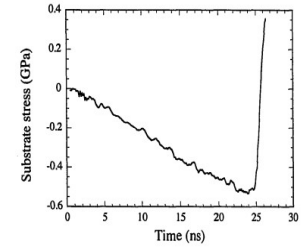


Figure 3.16: Effect of laser fluence for a 1.1 μm thick aluminum film deposited on a 3000 μm thick fused silica substrate with 0.4 μm thick absorbing layer.

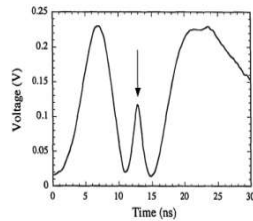


(a)

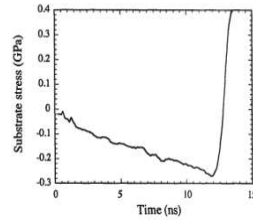


(b)

Figure 3.17: Interferometric signal obtained for a 1.8 μm thick aluminum film deposited on a 3000 μm thick fused-silica substrate with 30 μm thick waterglass (0.140 J/mm²): (a) photodiode output; (b) substrate stress. Arrow points to the position where fringes suddenly changed direction.



(a)



(b)

Figure 3.18: Interferometric signal obtained for a 1.8 μm thick aluminum film deposited on a 3000 μm thick fused-silica substrate with 8 μm thick waterglass (0.140 J/mm²): (a) photodiode output; (b) substrate stress. Arrow points to the position where fringes suddenly changed direction.

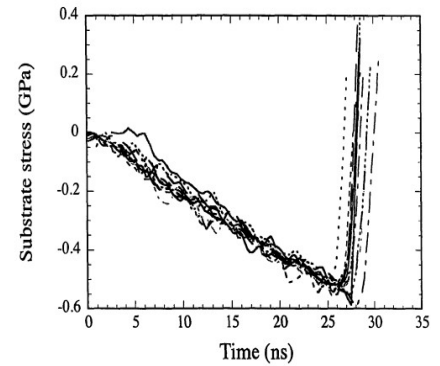
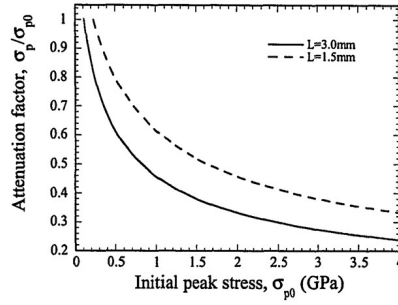


Figure 3.22: Substrate stress profile for a 1.8 μm thick aluminum film deposited on a 3000 μm thick fused silica substrate.

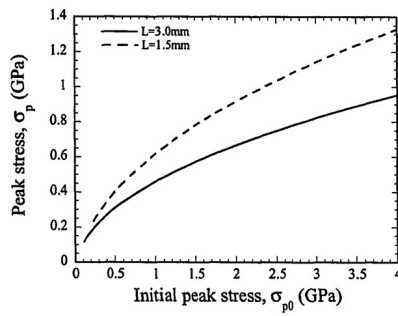
59. What Dr. Wang calls a decompression shock is a stress drop caused by the direct tension wave. This was confirmed by Dr. Wang, who testified that this direct tension wave was also generated in her experiments from the reflection of the second compression wave of “comparable magnitude” from the surface of the

confining waterglass layer, which entered the fused silica substrate behind the initial compression wave. Ex-1005, 65. That is, portions AB and BC are none other than part of the sharp rise-time of the direct tension wave. And, which unlike the compression wave, the tension wave does not undergo any elongation because it is well known in the shock physics literature that the non-linearity in the stress-strain behavior is only exhibited by the fused silica material only under compression. This fact was also confirmed by Dr. Wang in her deposition. *See* Ex-2009, 76:17-22; 88.

60. As described in the Wang Dissertation, while the initial compression wave undergoes a major reduction in its shock amplitude, almost 50% over its propagation distance from the laser absorbing layer to the coating interface as shown in Fig. 2.15(b) in the Wang-Dissertation, reproduced below, the tension wave of comparable magnitude when it was first generated alongside the initial compression wave remains essentially of the same strength (amplitude) except for undergoing a minor loss due to geometrical dispersion, as confirmed by Dr. Wang. Ex-1005, p. 37.



(a)



(b)

Figure 2.15: Shock attenuation in fused silica: (a) attenuation factor as a function of initial peak stress and substrate thickness; (b) remaining peak stress as a function of initial peak stress and substrate thickness.

61. That is, the amplitude of the tension wave would be almost twice the compression wave amplitude near the film interface for a 1.5mm propagation distance. The exact difference in the amplitudes of these two waves will however depend upon their amplitude when they are first generated near the laser absorbing layer, as per Fig. 2.15 (b) in Wang's dissertation, reproduced above. Additionally it will also depend upon their propagation distance to the coating interface or the thickness of the substrate as illustrated in the inset above. These are only theoretical predictions and how these amplitudes actually attenuate in Dr. Wang's

experiments would depend upon the specific composition (including impurities) of the fused silica material used by Dr. Wang in her experiments. .

62. Dr. Wang acknowledged both in her Dissertation and in her deposition that the initial delay between these two waves depends upon the thickness of the constraining medium and should be equal to the round trip travel time of compression wave-2 within the constraining layer. In Fig. 3.15c of Dr. Wang's Dissertation (reproduced above), this delay is about 27.5 ns. Even though this direct tension wave lags behind the main compression wave by 27.5 ns, this tension wave, in Dr. Wang's own words, "*propagates faster than the peak compressive stress, and faster than the low stress tail of the main pulse...*" and "*eventually overtakes the compressive pulse.*" Ex.-1005, p. 65.

63. In fused silica materials the decompression shock is generated because of the stress-strain non-linearity material properties. This non-linearity is however exhibited by fused silica **only under compressive stress** and **not in tension**. Dr. Wang agreed that the non-linear stress strain relationship in equation 2.53 on page 27 of her Dissertation was directly taken from the Barker and Hollenbeck's work and it was valid only under compression. Ex.2009, 86:2-8. Dr. Wang also testified that she was not aware of any corresponding data in tension. Id., 86:9-11. That is, Dr. Wang acknowledged, the tension wave from the experiments depicted in her Dissertation is **not modified**.

64. Dr. Wang confirmed that if she were to use the same non-linear stress-strain relationship, as measured by Barker and Hollenback, under compression to also be applicable in tension then her expectation would be that higher tensile stress amplitudes will move faster than the lower stress amplitudes. Ex-2009, 88. This is the opposite to what is exhibited by fused silica under compression. Because of the lack of any such data, one can safely assume that the tension wave will **not** form any pre-peak stress ramp and essentially propagate unaltered into the substrate. Dr. Wang confirms this understanding throughout her Dissertation, *e.g.*, when she indicates that the tension wave travels faster than the compression wave and overtakes the peak compressive stress and the low stress tail of the compression wave. Ex-1005, 65. This provides further proof that the tension wave does not undergo any wave elongation effect similar to its compression counterpart. Therefore in the experiments described in the Wang Dissertation, all amplitudes of the tension wave travel with the same velocity equal to the velocity of the zero-stress point of the initial compression wave, shown in the annotated Fig. 3.15c, reproduced above. That is, the compressive stress amplitude-dependent wave speed which is predicated by the non-linear stress-strain relationship of Barker and Hollenback would not be applicable to the tension wave amplitudes. The amplitude-*independent* stress wave velocity measured by Dr. Wang in her thesis is given as 5940 m/s in Table 2 of her thesis. Therefore this is also the

velocity of the point O where the amplitude is zero in the compression wave.

Therefore, the tension wave will never be able to overrun or reach point O of the compression wave as the front of the tension wave will remain separated from point O by precisely the initial delay time. For the data shown in Fig. 3.15c, this appears to be 27.5 ns.

65. Fig. 3.21 and Fig. 3.20 of the Wang Dissertation, reproduced above, shows that very near the film interface, the tension wave has reached points on the compression wave ramp corresponding to 13 ns and 22 ns, respectively. The tension wave starts unloading and canceling the compressive stress from these locations of the ramp as already discussed above. The wave speed in waterglass layers is unknown, but in these two samples for which the data is given in Fig. 3.20 and Fig. 3.21, they were prepared with the exact same chemistry. Therefore, Fig. 3.21 data with a 0.25 micrometers thick waterglass layer with a tension wave round trip time of 13 ns would predict a tension wave roundtrip time of about 21.5 ns for a 0.40 micrometer thick waterglass layer for the Fig. 3.20 sample with identical acoustic properties. The latter matches with the recorded delay of 22 ns in Fig. 3.20. This is further proof that the “unloading” observed in Dr. Wang’s substrate wave profile in her Dissertation is caused by the direct tension wave.

66. The precise location along the ramp of the initial compression wave where the tension wave will start unloading the compression wave will depend

upon (1) the thickness of the constraining layer which controls the initial delay between the direct tension wave and the zero stress point O of the initial compression wave and (2) the total distance it travels prior to arriving at the film interface. In Dr. Wang's Dissertation, it is described that the thickness of the constraining (i.e., confining⁴) layer varies from test to test. Ex.1005, pp. 69-75. Thus, the delay shown in her data is anywhere between 13 ns and 30 ns.

67. The only thing that remains to be explained is the slope of the unloading curve AC in Fig. 3.15c of the Dissertation and why in every figure in Dr. Wang's Dissertation which displays the substrate stress, the unloading curves are parallel to each other (*see* Fig. 3.16 of the Wang Dissertation). As discussed above, AC relates to the rise-time of the tension wave when it is first generated at the laser-impingement point in the constraining layer. Consistent with statements she made in her Dissertation; Dr. Wang agreed in her deposition that the rise-time of the two stress waves generated inside the constraining medium and the fused silica at the laser absorbing film is controlled by the rise-time of the laser pulse. Ex-2009, 30-31. This is also well known in the literature on laser-generated stress waves and a POSITA would readily understand this. This is further shown in Fig. 3A of the '684 patent. As the laser pulse energy is increased, the amplitude of the stress

⁴ Herein, the terms "confining layer" of "confining material", or "constricting layer" or "constricting material" are used interchangeably.

wave increases and the rise-time of the generated stress waves follow exactly the same slope because the rise-time of the laser pulse which in turn is controlled by the laser hardware (optical components) remains the same when more energy is pumped inside the laser pulse.

68. In her deposition, Dr. Wang was shown Fig. 3.14c from her Dissertation, which shows the stress wave in the silicon substrate, a material that does not modify the stress wave. That is, this wave in Si substrate will retain the character of the initial stress pulse that is generated immediately after impingement of the laser pulse. The slope of the rise-time of this wave is about $1.8 \text{ GPa}/3 \text{ ns} = 0.6$ in units of GPa/ns. This matches exactly with the slope of the line AC of $1.2 \text{ GPa}/2 \text{ ns} = 0.6 \text{ GPa/ns}$ in Fig. 3.15c. A POSITA would understand that as the laser fluence is increased, as per Dr. Wang's experiments in her Dissertation, all higher amplitude stress waves would have rise-time slopes that would be parallel to each other (see Fig. 3A in '684 patent). Indeed, each and every data point shown in the Wang Dissertation, including Fig. 3.16c, Fig. 3.19c, Fig. 3.17, Fig. 3.18, Fig. 3.19, Fig. 3.20 and Fig. 3.21 has the stress unloading with exactly the same or a very similar slope. This would be expected as the laser pulse rise time is fixed, except that the total energy in the pulse is changed from shot to shot.

69. As explained above, when the direct tension wave and the initial compression wave are generated at the laser impingement point, they are of same

amplitude. This is also confirmed by Dr. Wang in her Dissertation. Ex-1005, p. 66 (Describing that the compression wave-2 is of “comparable magnitude” as the compression wave-1). As further explained in Chapter 2 of the Wang Dissertation, this compression wave is expected to develop a decompression profile soon after it is generated, and, as per Fig. 2.12 on page 32 of her Dissertation reproduced below, this depends upon the amplitude of the initial stress wave.

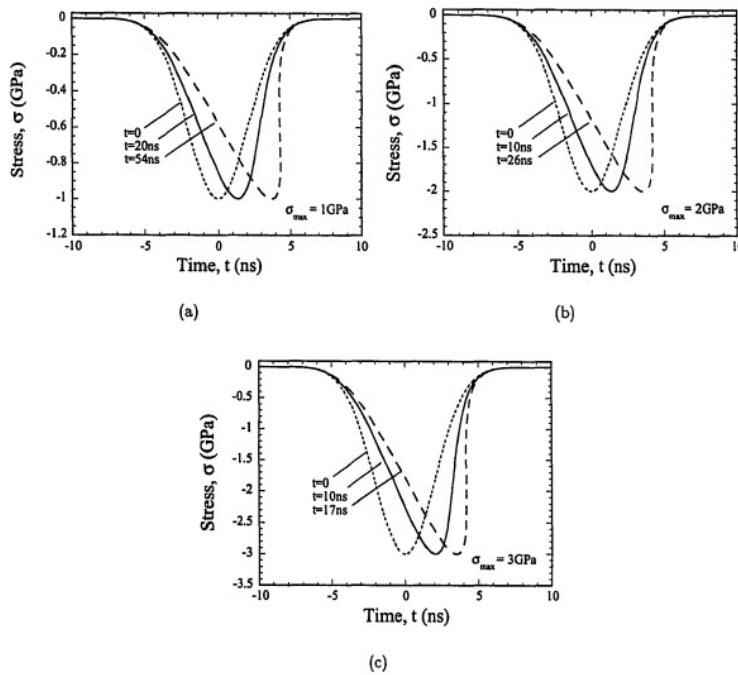


Figure 2.12: Evolution of the Gaussian stress pulse in fused silica with time: (a) 1.0 GPa peak stress; (b) 2.0 GPa peak stress; (c) 3.0 GPa peak stress.

70. For a 1 GPa, 2 GPa, and 3 GPa, peak amplitude waves, it takes 54ns, 26ns, and 17ns, respectively, to form the decompression shocks. As described in Wang’s Dissertation, this is only a **theoretical possibility**. Ex.-1005, Chapter 2.

But as explained later in the her Dissertation, its presence is nowhere documented in any of the data in the Dissertation.

71. Notwithstanding the above, even if one were to assume that the decompression shock would be generated, it would undergo a dramatic reduction in its amplitude as it travels towards the substrate/coating interface. As per Fig. 2.15 (b) in Wang's Dissertation, the shock wave amplitude in compression is more than halved over a propagation distance of 3 mm. In fact, with regards to Fig. 3.15c, the tension wave amplitude at the point A of the ramp has to be much higher than the compressive stress value of -0.6 GPa when it was first generated near the laser absorbing layer. Although the exact value is not known due to the geometrical dispersion effects, it is at least 1.2 GPa based on the shock attenuation effect based on the theoretical predictions in Fig. 6. The profile of this tension wave remains preserved and does not undergo formation of the decompression shock as the stress is tensile.

72. Data in Dr. Wang's Dissertation thus confirms that the tension wave will cancel the ramp compression value first and bring it down to zero and then continue to build the peak tension stress following its rise-time. The rate at which this unloading of compression stress occurs is precisely controlled by the rise-time of the direct tension wave.

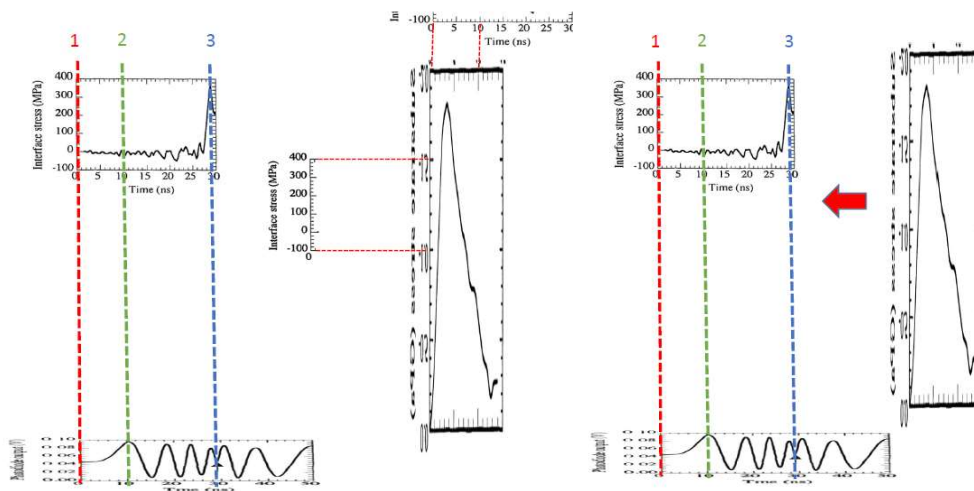
73. Another way to describe Fig. 3.15c in the Wang Dissertation is that it results from a simple superposition of the direct tension wave with the ramped portion of the initial compression wave at point A of the ramp.

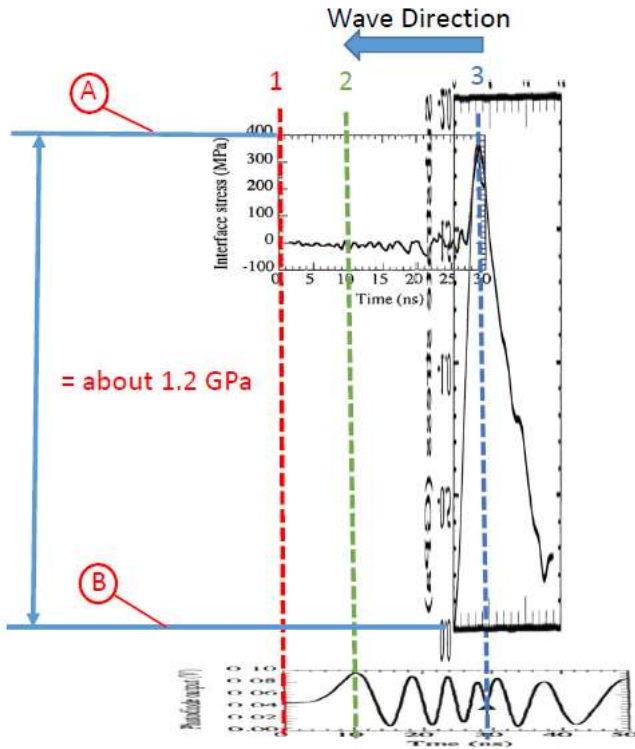
74. Specifically with regards to Fig. 3.15c, the tension wave with 1.2 GPa stress amplitude would first cancel the compression stress attendant at point A of the ramp to zero and then increase it to 0.6 GPa. Dr. Wang did not convert the fringe record she recorded using the optical interferometer shown in Fig. 3.15a beyond 30 ns, even though she recorded them to 50 ns. Beyond 30 ns, the tension can still rise but at least the stress will remain tensile and then slowly drop to zero, as acknowledged by Dr. Wang in her deposition. Ex-2009, 56-57.

75. The net effect of this superposition is that the tension wave would completely neutralize and remove the decompression shock from the original compression wave (assuming it was even present, which it was not) that could be developed soon after the initial compression wave was launched inside the fused silica substrate. The resulting wave has **no decompression shock** and the sharp unloading Dr. Wang sees and describes in the experiments in her Dissertation has **nothing to do with the rarefaction shock in the pure compression wave** taught in the '684 patent.

76. To further demonstrate that what Dr. Wang calls a decompression shock is a mere superposition of tension wave and the front ramp portion of the

compression wave, I constructed a composite illustration shown below, by using the data and figures from Dr. Wang's thesis. I started with Fig. 3.15d which shows the interface stress history calculated by Dr. Wang. It shows no compressive stress and a build-up of a tensile stress that starts at 27 ns which peaks at 29ns. The stress then falls from 29ns till 30 ns. Dr. Wang did not resolve the fringes beyond 30ns to 50 ns and therefore the tension stress is not seen to fall further beyond 30 ns in Fig. 3.15c. All the wiggles prior to the point where the tension starts to build up (27ns mark) is essentially noise in the photodiode signal and well-known in the art and a POSA would be familiar with it. Next, I drew a horizontal axis, spaced from the origin (zero stress) in Fig. 3.15d at a distance of 800 MPa by using the same scale in the y-axis of Fig. 3.15d. I have marked this line as "B". I also marked the 400 MPa point by a line "A". So the total separation between the line A and line B is 1200 MPa or 1.2 GPa.





77. As discussed above, the profile of the tension wave is very similar to the stress wave profile in silicon, which Dr. Wang records in Fig. 3.14. I then took the substrate stress profile in Fig. 3.14c and flipped it about the x-axis by 180 degrees. I then stretched this figure only along its y-axis such that the amplitude of the wave fit exactly between the line A and line B, which, as per my construction, equals 1.2 GPa. I then scaled the x-axis of this figure such that the time scale in Fig. 3.15d will match with the time scale in Fig. 3.14c.

78. Next, I took the fringe record in Fig. 3.15a and placed it at the bottom of the composite figure by using a vertical red line to align the origin in Fig. 3.15a with the origin of the fringe record (Fig. 3.15a). I then stretched the time axis of

the fringe record to match the time-scale used in Fig. 3.15d. I note that the fringe record is recorded for 50 ns which is greater than the duration of 30 ns up to which Dr. Wang reduced the fringe data in Fig. 3.15c. Therefore the fringe record goes beyond the 30 ns mark.

79. Consistent with my discussion above, the tension wave intersects the initial compression wave at point A of the ramp in Fig. 3.15c. As evident from Fig. 3.15c, this occurs between 27ns and 28 ns. As Dr. Wang testified in her deposition and also discussed in her thesis, this tension wave moves faster than the peak-amplitude of the compression wave, which would be to the right of point A in Fig. 3.15c. Technically, as discussed above, this point does not exist as the tension wave cancels it. Both waves are moving to the left towards the interface at this point.

80. The exact location where the substrate stress in Fig. 3.15c is calculated is not known, but Dr. Wang testified it would be quite close to the film interface. Since the tension wave is moving faster than the compression wave, when the tension wave arrives at the interface it would have moved a bit closer to the point O in Fig. 3.15c to the left. I took the flipped and stretched wave, which I consider similar to the tension wave of amplitude 1.2 GPa, and placed it's zero on line B at a location that would overlap the tension calculated at the interface in Fig. 3.15d by Dr. Wang. As one can see, there is conceptually a perfect match between the

tension wave profile, including its post-peak decay profile, when the zero point of the tension wave is aligned with the 25ns mark, with respect to Fig. 3.15c. As discussed above, this would conceptually make sense as the tension wave would move closer to point O as it arrives at the interface.

81. This discussion further confirms that the tension at the film interface is generated by the direct tension wave when it **first** strikes the interface during its onward journey towards the free surface of the film and it has nothing to do with the compression wave-1 whose rear end has been taken out completely by the direct tension wave. Therefore, the Wang-Dissertation (and Wang-2002 reference) do not teach to a POSA key limitations of independent claims 1 and 13, which require the wave to be modified first by a glass element to generate tensile stress at the film interface .

82. This analysis is also consistent with Dr. Wang's deposition testimony that the fringe record beyond 30 ns, which she did not resolve, would relate to tensile stress. However, she did not resolve it because it would have yielded lower stress amplitudes. As discussed above, these lower tensile stress amplitudes would belong to the tail of the tension wave and their low values would be consistent with the very low fringe frequency data recorded by Dr. Wang in Fig. 3.15a.

83. In conclusion,, what Dr. Wang refers to as a decompression shock in her Declaration and the Wang-Dissertation (Ex.1005), as well as in Wang-2002

reference (Ex.1016)s is nothing more than an unloading caused by the direct tension wave.

84. During her deposition, Dr. Wang attempted to explain the drop in stress from A to B in 2 ns in Fig. 3.15c as essentially a vertical drop in stress in zero time, claiming that it is due to an instrumentation recording limitation. But later she contradicted that earlier testimony and confirmed that her instrumentation had a least count of 200 picoseconds or 0.2 ns, meaning that her instrumentation could have easily recorded events that occur faster than 2ns. Her testimony is consistent with her ability to record optical fringes, which are essentially digital recordings, with minimum inter-point separation of 0.2 ns. That is, had the stress from peak compression in Fig. 3.15c dropped like a rarefaction shock as described in the '684 Patent, Dr. Wang easily would have been able to capture that as she clearly was able to record fringes with much smaller time resolution than 2 ns.

When confronted in her deposition about the statements she made regarding the tension wave on page 66 of her Dissertation, **Dr. Wang agreed that what she had been calling a decompression shock could also be explained from the tension wave unloading.** Ex-2009 152:17-153:1.

B. The Wang Dissertation Fails to Teach a Reflected Tension Wave

85. So then, one now needs to determine what is the source of the tensile stress at the interface that Dr. Wang observed in all her experiments in her

Dissertation, as it is clear that it does not come from the reflection from the rarefaction shock attached to the initial compressive wave. I shall next explain the source of this tensile stress observed by Dr. Wang. Indeed, the data in Dr. Wang's Dissertation provides the answer. On page 66 of her Dissertation Dr. Wang explains that the tension wave outruns the slower moving compression wave. The direct tension creates a tension at the interface at the very instant it strikes it for the very first time as it moves towards the free surface of the coating. This is consistent with the interface stress calculated by Dr. Wang in Fig. 3.15d (in her Dissertation). The tensile stress created by the front shallow ramp of the initial compression wave will result in zero stress as when the front portion of the ramp strikes the film's free surface and returns as a tensile wave there is already a higher compressive stress from the initial compressive stress sitting at the interface and it instantly is reduced to zero. In fact, the net interface stress during this time should be compressive and less than zero. The tension spike comes precisely when the **direct tension wave** strikes the interface on its journey towards the free surface of the coating, which happens when the front ramp portion up to point A has already transmitted through the film. . None of the interfacial failures described in Dr. Wang's Dissertation are related to the glass-modified compression stress wave as described in the '684 Patent, with a rarefaction shock.

86. Below I provide additional observations from Dr. Wang's Dissertation that also confirm that the failures Dr. Wang observed in her Dissertation are from the interfacial tension generated by the direct tension wave..

87. While the formation of a decompression shock in the initial compression wave is predicted by the theory discussed in Chapter 2 in Dr. Wang's Dissertation, Dr. Wang's Dissertation was not able to reproduce in actual experimental data for this shock, let alone generating it through modification by a glass element and propagate this modified wave to the coating/substrate interface to remove a film.

88. In Fig. 3.19 on wave has an amplitude of about 1.2 GPa, which clearly exceeds the 1 GPa page 74 of Dr. Wang's Dissertation (reproduced below), there is no influence of the tension wave. Here however, the substrate stress never went into tension. Here, the compression threshold at for which the results of her theoretical analysis shown in Fig. 2.12a would predict the formation of the decompression shock. Fig. 3.19 clearly shows there is no sharp decay in the post-peak stress in the recorded wave. Notably, this is the **only data** in the entire Wang Dissertation where there is no influence of the direct tension wave.

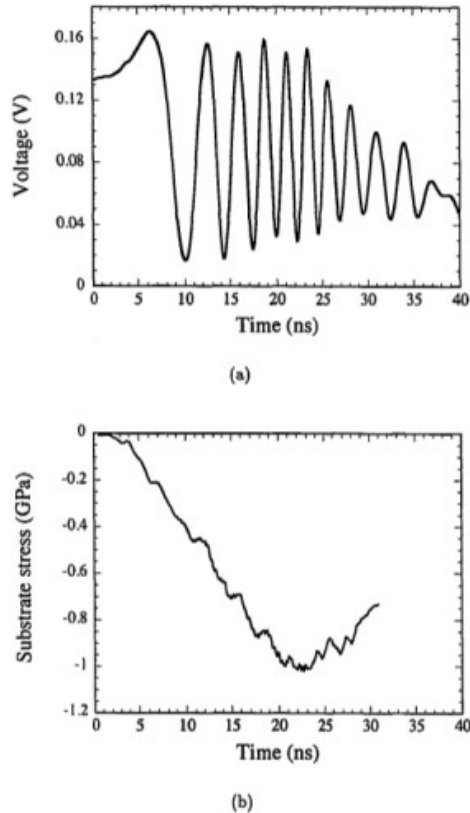


Figure 3.19: Interferometric signal obtained for a $0.5\ \mu\text{m}$ thick aluminum film deposited on a $1500\ \mu\text{m}$ thick fused-silica substrate with $2\ \mu\text{m}$ thick waterglass ($0.112\ \text{J}/\text{mm}^2$): (a) photodiode output; (b) substrate stress.

89. Dr. Wang could not explain Fig. 3.19 in her deposition as to why there is no decompression shock seen. Ex-2009, 153-156. In her deposition, she referred to a statement in her Dissertation that she read. *Id.* But that portion of the Dissertation does not explain why there is no post-peak shock formation in the compression stress wave shown in Fig. 3.19c. Rather, it merely explains why the failure stress corresponding to the fringe record was low. I reproduced that portion of the Dissertation below:

of 2.57 μm . Significant film damage was also observed. In the first 20 ns, the fringe spacing becomes tighter and tighter, indicating acceleration in surface velocity. Without any direction change after 20 ns, the fringe spacing becomes larger indicating a deceleration in surface velocity. The leading ramp ($t < 20$ ns in figure) in the substrate stress profile is consistent with the discussion of the initial effect of nonlinear elasticity for fused silica substrate (see Section 2.4). Because there is no sudden change of velocity (turning point), and no actual shock, there is a slow long fall time of the apparent substrate stress. Although the maximum substrate stress is high, 1.1 GPa, the resulting interface stress is quite low (~ 20 MPa for a half micron thick test film). A possible explanation for the discrepancy between extensive damage observation and low interface stress is that the fringe data is not reflecting the actual movement of the interface. After the test film delaminated from the substrate, the film keeps moving forward, which results in the large number of fringes and no turning point. Because the interface stress is proportional to the slope of the tail-end of the substrate stress wave, the fringe data associated with extensive film failure are not reliable for extracting the interface strength. The actual interface stress could be much higher than the measured value. The estimated substrate stress, however, is accurate until delaminating.

Ex-1005, 70.

90. In fact, the last statement in the quoted text undermines Dr. Wang's testimony in her deposition, as it clearly states that—*"The estimated substrate stress, however, is accurate until delaminating."* This means that the post-peak stress profile in the substrate, prior to it getting cut off, is indeed correct and it shows no formation of the decompression shock.

91. Decompression shock in fused silica is never seen in any of Dr. Wang's experimental work, including in all publications stemming from her Dissertation (including Ex-1016) and her Dissertation itself.

92. The discrepancy between the theoretical predictions in Chapter 2 and actual measurements in Chapter 3 of Dr. Wang's Dissertation could be due to one of several reasons. Dr. Wang confirmed in her deposition that for her own fused silica samples she **did not measure** the non-linear stress-strain curves, but she directly used the data from Barker and Hollenbeck's work. It is well-known that the fused silica properties are very sensitive to the level of impurities during manufacturing. Therefore it is possible that the compression stress-strain relationship for her own samples do not follow what was observed in the Barker and Hollenbeck's samples.

93. Additionally, Dr. Wang failed to account for the substantial attenuation effect which is described with reference to in Fig. 2.15 of Dr. Wang's Dissertation. In fact, Dr. Wang acknowledges this in her Dissertation: "If the waterglass is too thin, no shock is detected either because no shock is developed at all or because the shock is so weak that it is attenuated before reaching the film interface. Little or no damage occurs on the film." Ex.-1005, pp. 69-70.

94. Based on the theory presented in Chapter 2 in the Wang Dissertation, laser generated stress waves with decompression shock profiles in fused silica lose

almost 50% to 90% of their stress amplitudes by travelling merely 1.5 mm to 3mm of distance in the fused silica substrate. Dr. Wang herself acknowledges this fact with reference to Fig. 2.12 of her Dissertation. In fused silica, as the wave amplitude decreases it can no longer cause the volumetric compression of the fused quartz structure that results in the formation of the decompression shock. Meaning that as the wave amplitude decreases, the profile of the stress wave will revert back to an ordinary wave with no rarefaction shock. However to observe this, one would have to remove the influence of the tension wave in Dr. Wang's data. There is one place in her entire Dissertation where Dr. Wang presents data where the influence of a tension wave does not exist — Fig. 3.19 . Here, **no modified wave is shown.**

95. The inability of the decompression shock to be formed in fused silica at lower stresses is also confirmed by Dr. Wang's own measurements of the wave velocity in her fused silica samples reported in Table 2.1 of her Dissertation, reproduced below. The velocity is measured by sending acoustic pulses of small amplitudes that do not deform the fused silica structure and consequently the velocity she reports of 5940 m/s is the elastic wave velocity. It takes a certain minimum stress to maintain the shock profile in fused silica material.

Table 2.1: Material properties.

Material	Glass [31]	Aluminum [31]	Fused silica*	Silicon [31]
ρ (g/cm ³)	2.5	2.71	2.2	2.3
C (J/kg · K)	750	896	670	729
k (J/ms · K)	1.4	204	1.4	138
λ (GPa)	23.3	58.5	15.9	62.0
μ (GPa)	29.6	26.0	30.8	41.0
c (m/s)	5378	6385	5940**	7910
α (K ⁻¹)	5.0×10^{-6}	8.4×10^{-6}	5.5×10^{-6}	7.6×10^{-6}

* from manufacturer

** measured in the Laboratory for Incoherent Ultrasound at UIUC

Ex.-1005, p. 14.

96. Figure 2.15 in the Wang Dissertation demonstrates how quickly the peak pressure or amplitude of the stress wave decreases as it travels through the fused silica substrate. At pressure levels of those discussed in the '684 patent, Figure 2.15 shows that a mere 1.5mm (Wang considers 1.5mm, 3mm and 6 mm thick substrates in her Dissertation) of travel of the wave in fused silica will result in the pulse amplitude reduction by almost 70% to 80% even **before** the stress wave has reached the test interface. When the stress drops by almost 70% to 80% of its initial value, the wave's ability to maintain its profile in fused silica is lost. The wave profile turns back into a regular wave.

97. Evidence of reduction in the interface stress is provided in the Wang Dissertation itself. Table 3.4 from her Dissertation is reproduced further below. This table shows that as the thickness of the substrate, which is fused silica, is increased from 1500 μm (1.5mm) to 6000 μm (6mm), the maximum substrate stress drops from -1.2 GPa to only -0.3 GPa in the substrate (almost 6 times). This then

results in a dramatic decrease in the maximum stress at the aluminum/fused silica interface from 370 MPa to a mere 50 MPa. (a 7.5 times reduction). These stress levels were generated using the maximum laser fluence of 0.140 J/mm^2 . Here, the shock profile cannot be maintained at such low stress amplitudes in fused silica and hence could be another reason that Dr. Wang was unable to record them.

98. Accordingly, the decompression wave in Dr. Wang's experiments described in her Dissertation never arrives at the interface and has nothing to do with the interface failures she sees in her fused silica/aluminum samples.

99. There is simply no evidence of any formation of any rarefaction shock in the compression wave anywhere in the data presented in Dr. Wang's Dissertation.

C. In the Wang Dissertation, Tension Generated at the Interface is From the Direct Tension Wave

100. Further proof that the film failures in the Wang's Dissertation are from the direct tension wave is supported by the Al/fused silica interface strength data in Tables 3.4 and 3.7 of the Dissertation, reproduced below.

Table 3.4: Effect of substrate thickness on $\sigma_{\text{sub}}^{\text{max}}$ and $\sigma_{\text{int}}^{\text{max}}$ on fused silica samples with a 1.1 μm thick aluminum film at maximum YAG power (0.140 J/mm²).

Substrate thickness	1500 μm	3000 μm	6000 μm
$\sigma_{\text{sub}}^{\text{max}}$	-1.2	-0.5	-0.3
$\sigma_{\text{int}}^{\text{max}}$	370	350	50

Table 3.7: Interface strength of a 0.5 μm thick aluminum film deposited on a 1500 μm thick fused-silica substrate.

Test No.	Laser fluence (J/mm ²)	Substrate stress (GPa)	Interface stress (MPa)
1	0.140	-1.1	583
2		-1.1	502
3		-1.2	420
4		-1.1	547
5		-1.1	435
Range	0.140	-(1.1 ~ 1.2)	420 ~ 583
Average	0.140	-1.12 $\pm$ 0.045	497 $\pm$ 70

Ex.-1005, pp. 69, 80.

101. Data in these tables can only be explained if the failure is caused by the direct tension wave and is not due to the reflection of the compression wave with rarefaction shock from the free surface of the film.

102. In Table 3.4 of the Wang Dissertation, the maximum compressive stress is 1.2 GPa. Assuming this wave has an initial ramp to the peak stress, and a sharp post-peak fall profile, as per Table 3.4 of the Wang Dissertation, the wave generates a **maximum** tensile stress of 370 MPa at the interface between a 1.1 μm thick Al coating and fused silica substrate. Dr. Wang acknowledges in her Dissertation that as the Al film thickness is reduced while keeping the substrate thickness the same, the interface stress at the thinner film will be less than a thicker film when subjected to exact same substrate thickness. Wang concludes this on page 80 of her Dissertation (emphasis added):

103. Tables 3.6, 3.7 and 3.8 indicate that for different film thicknesses and different substrate thicknesses, the interface strength of aluminum /fused silica is approximately the same, 481 ± 28 MPa for 1.8 μm film on 3000 μm substrate, 497 ± 70 MPa for 0.5 μm film on 1500 μm substrate and 492 ± 55 MPa for 1.8 μm film on 1500 μm substrate. For the same film thickness on different substrate thickness, the maximum substrate and interface stress are the same, but lower laser fluence is required for the thinner substrate. This result is probably due to the reduced stress wave attenuation in the thinner substrates. For different film thicknesses on the same substrate thickness, thicker films require less laser fluence, and consequently lower substrate stress to fail. This result is consistent with the predictions from Eqs. (2.46) and (2.47), higher stress is generated in thicker films.

Ex.-1005, p. 80.

104. Now examine the data in Table 3.7 of the Wang Dissertation. The maximum substrate stress is exactly the same as in Table 3.4 of the Wang Dissertation, between 1.1 GPa and 1.2 GPa, generated at the **same** maximum laser power of 0.140 J/mm². The Al film in all the tests reported in Table 3.7 of the Wang Dissertation is for a 0.5 μm thick substrate, which is substantially less than the 1.1 μm thick film in Table 3.7 of the Wang Dissertation. Assume a fixed substrate thickness of 1500 μm and compare the data for this substrate thickness in Tables 3.4 and 3.7 of the Wang Dissertation. This gives the conditions cited in

Wang's Dissertation on page 80, which I repeat- "For different film thicknesses on the same substrate thickness, thicker films require less laser fluence, and consequently lower substrate stress to fail. This result is consistent with the predictions from Eqs. (2.46) and (2.47), higher stress is generated in thicker films."

105. The **maximum** interface stress in Table 3.4 of the Wang Dissertation for a 1500 μm thick substrate is 370 GPa. For the same substrate thickness and same maximum substrate stress as per Wang's Dissertation above, the maximum interface stress generated by this exact same substrate wave, travelling the exact same substrate thickness, should generate **lower** interface stress at the **thinner** 0.5 μm thick film. This is also consistent with basic wave mechanics laws. As already explained, the tension at the interface is built upon reflection from the free surface of the film. Compared to a larger film thickness, a smaller film thickness gives less room for the incoming compression wave to totally reflect back from its free surface into a tension wave, prior to reaching back at the interface and loading it in tension. In fact, if the film thickness is very small, no tension will be created at the interface as when the front end of the wave has returned in tension there is still a large compression from the incoming compression wave sitting at the interface. Remarkably, the first 5 entries for interface stress in Table 3.7 of the Wang Dissertation are 583 MPa, 502 MPa, 420MPa, 547MPa, and 435 MPa and all

correspond to 0.140 J/mm^2 and a substrate stress between 1.1 and 1.2 GPa. Each and every one of these values is **greater** than the 370 MPa reported in Fig. 3.4 for an Al film that is almost **twice** the thickness of film tested in Table 3.7. What is remarkable is that most of these Table 3.7 values are generated even at a **lower** level of substrate stress of 1.1 GPa. This **conclusively proves**, and **Dr. Wang herself acknowledges** in her Dissertation, that the failures she is observing in her experiments are due to the tension wave generated from compression wave-2 when it reflects from the free surface of the constraining medium and enters the substrate as a direct tension wave. As already discussed above, this is fully consistent with the lack of pre-compression in the interface stress history in Fig. 3.15d of the Wang's Dissertation .

D. Dr. Wang Misinterprets the Fringe Signals in Her Dissertation

106. On pages 62-63 of her Dissertation, Dr. Wang attempts to provide a rationale for reducing the optically recorded fringes and why she relates it to the decompression shock.

107. In silicon samples, the spacing between successive fringes grows with time; in fused silica the fringes become more tightly spaced. Possibly most telling is the occurrence of a turning point (marked by an arrow in Fig. 3.15a), where the material velocity changes direction in the middle of a fringe.

108. Ex.-1005, pp. 62-63.

109. Dr. Wang misinterprets this change in the direction of the free surface velocity and relates it to decompression shock. As explained above, the decompression shock is never developed in the experiments described in the Wang Dissertation; and even if such a shock were to develop, it would be neutralized and cut off by the direct tension wave, before it ever were to reach the film interface, as already explained above. When the ramp compression portion of the wave (note that at this stage when it reaches the interface, it is a simple un-modified wave, without any decompression shock) reaches the interface, it would **pull in the free surface** of thin film gradually as compression builds up rather slowly along a ramp. That is, the free surface of the film will move inwards towards the interface. The optical interferometer will record the intensity change of the light wave at the photodiode corresponding to the above motion. As soon as the tension wave arrives, which as discussed above, has a rather short rise-time of 2 ns or so, it instantly will push the surface of the film outward away from the interface, thus **reversing** the direction of the surface movement. Dr. Wang incorrectly characterizes this as related to decompression shock. Ex.-1003, ¶77, 78, 86. There is in fact no decompression shock formed in her experiments. I again note that Dr. Wang records fringes up to 50 ns (*see* Fig. 3.15a in her Dissertation), but only resolves the interface stress and the substrate stress to only 30 ns. In fact, the last 20 ns of fringe data, the fringes are of much lower frequency and related to the tail

of the direct tension wave and possibly later to the arrival of a regular compression stress pulse with **no** rarefaction profile. Dr. Wang does not resolve those fringes in her Dissertation or Declaration. Indeed, Dr. Wang acknowledged the presence of these extra fringes in her deposition but claimed that the stress would be much lower and was of no interest to her. Ex-2009, 55-57.

110. Dr. Wang is essentially resolving partial fringes and the initial portion of the fringe where the reversal occurs, if it were to be resolved, the stress would in fact keep increasing in tension in some of her tests but in others the tension will get terminated as soon as the film separates from the interface (film will fail when the tension exceeds the interfacial strength). This explains why in some of her tests, the tension does not increase to the same level as the compressive stress corresponding to point A from where the unloading from the tension wave starts. At least 15ns of these fringes could correspond to the tension stress of the tension wave coming back to zero, which essentially would correspond to the post-peak length of the tension wave, followed by the *unmodified* compression wave. Or it could be the net stress due to the superposition of the rest of the tension wave and the continued ramp portion of the unmodified compression wave.

111. Regardless, one thing that is scientifically certain is that none of these unresolved fringes correspond to the decompression shock or rarefaction of the compression wave, as fringe frequency is the lowest in that region.

112. It is instructive to compare the fringe patterns one would expect to see if those were generated with a stress wave with a rarefaction shock profile as taught in the '684 Patent. Fig. 3a from the '684 patent, reproduced below, shows the fringe pattern recorded from a soda lime glass element surface with the corresponding velocity (equivalently stress) profile with rarefaction shock feature. Note that the shock develops around 215 ns (Fig 3b). Compare the fringe activity in Fig. 3(a) between 210 ns and 215 ns. Figure 3(a) is again reproduced at greater magnification to clarify the structure of the fringe pattern below.

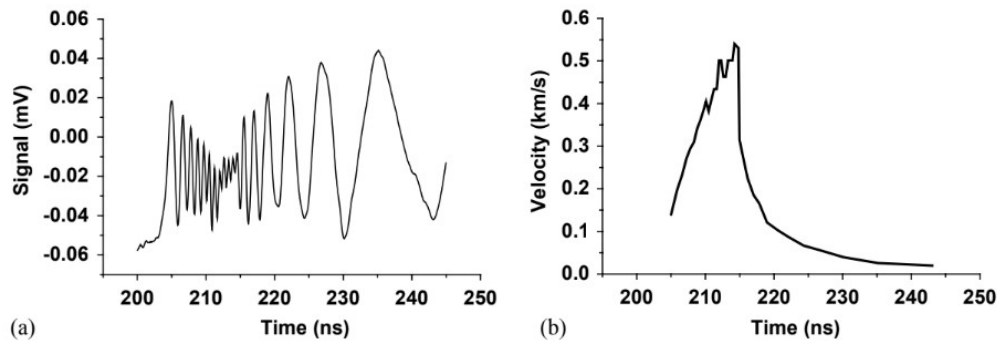
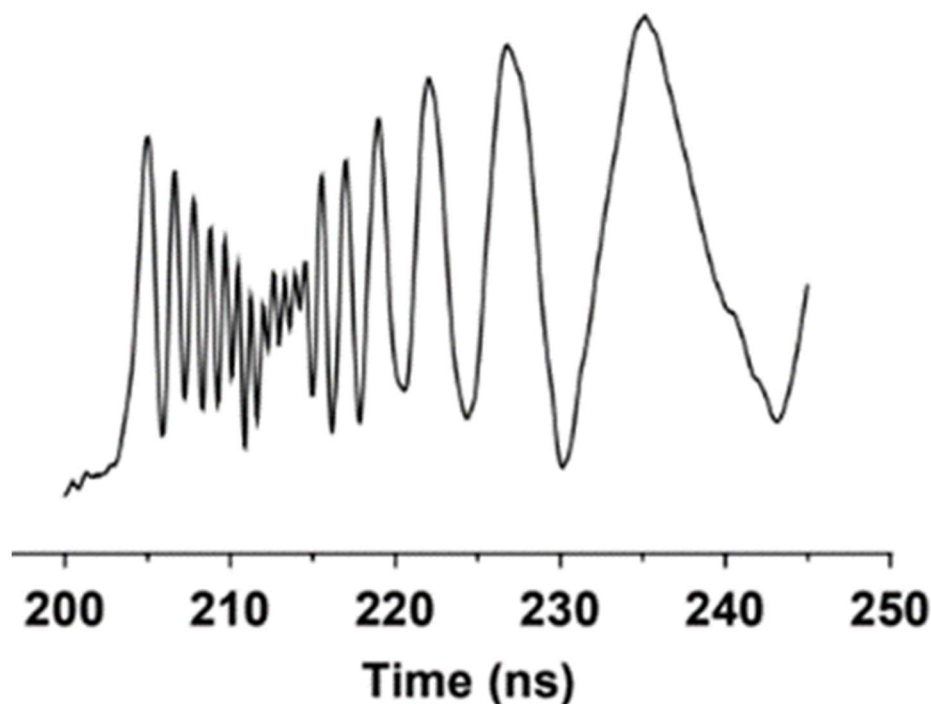


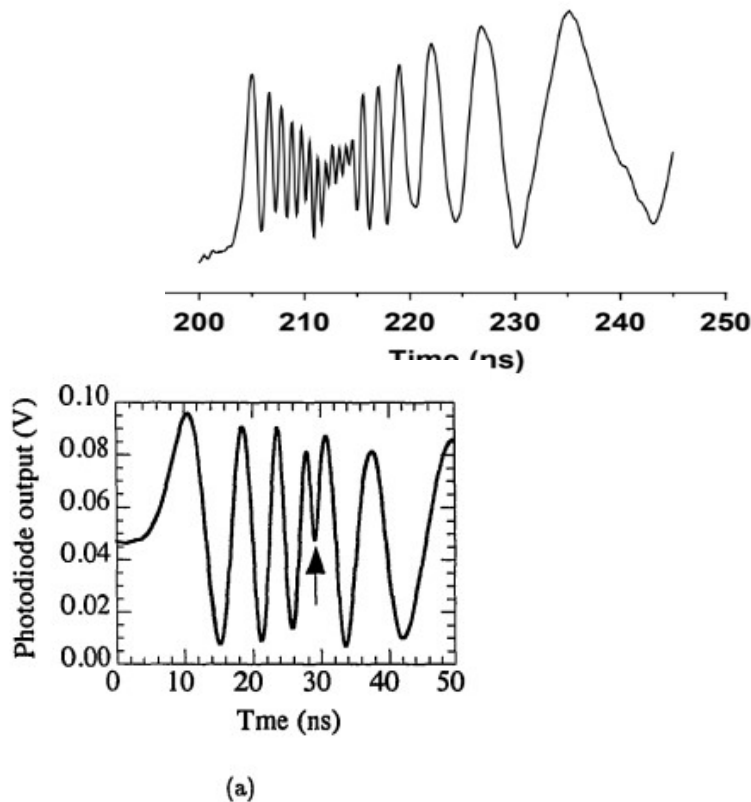
Fig. 3. (a) Interferometer signal observed from the free surface of a soda lime glass. (b) The stress wave profile derived from (a) using the standard interferometric procedures.



113. There are almost 7 to 8 fringes in a short span of just 5 ns as shown above. That is, a rapid deceleration and rapid acceleration of the free surface that is indeed the hallmark of a shockwave arrival signature. Now contrast this fringe record with the fringe record in Dr. Wang's Dissertation. The maximum fringes she records are shown in Fig. 3.15a.

114. I have put the fringe record from the Wang Dissertation and the one from the '684 patent, side by side, for ease of comparison below. The difference in fringe count is dramatic. There is only one fringe in Dr. Wang's record and Dr. Wang erroneously attempts to relate it to the shock formation. This is wrong. The reversal in the fringe record has absolutely nothing to do with the arrival of the

rarefaction shock wave, and is further proof that no modified stress wave as taught in the '684 patent arrives to the film interface in the experiments disclosed in the Wang Dissertation.



115. It is of note that on page 65 of her Dissertation, Dr. Wang recognizes this and even acknowledges that the fringe reversal is caused by the tension wave.

116. In Fig. 3.15(a), the shock is followed by a regime in which the velocity has changed sign indicating that the tensile pulse has overtaken the compression pulse.

Ex.-1005, p. 66.

117. Referring to Dr. Wang's analysis regarding Fig. 3.15(c) of her Dissertation, which is a theoretically calculated stress wave profile in the substrate that is NOT at the interface, but at a point that (as discussed in Appendix B of her Dissertation) would indicate as the wave which will be consistent with the experimentally measured free surface velocity of the film at minus infinity. That is, the profile of the substrate stress is at a point where the tension wave crosses the back end of the compression wave.

118. Further proof that the tension wave is what causes fringe reversal and not the compression shock wave is given in Figure 3.19 of the Wang Dissertation, reproduced below. Missing from the fused silica substrate profile (Fig. 3.19 b) is the tension leg of the stress which was present in all other stress profiles. The constraining material must have been blasted out before the tension wave could enter the fused silica substrate.

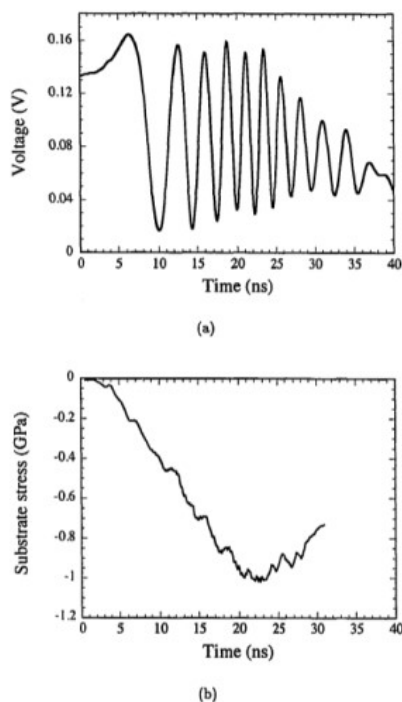


Figure 3.19: Interferometric signal obtained for a $0.5\ \mu\text{m}$ thick aluminum film deposited on a $1500\ \mu\text{m}$ thick fused-silica substrate with $2\ \mu\text{m}$ thick waterglass ($0.112\ \text{J}/\text{mm}^2$): (a) photodiode output; (b) substrate stress.

119. It appears at least in this test, that Dr. Wang accidentally separated the confining layer prematurely and hence the tension wave could not enter the fused silica substrate. Therefore it never outran the compression wave as it never entered the substrate. Note for this case, there is **no** fringe reversal event in Fig. 3.19a, proving conclusively that the fringe reversal in the Wang Dissertation is seeing is related to the tension wave and has nothing to do with the decompression shock. What is even more telling is that the compression wave profile that is generated inside her samples **did not** form a decompression shock profile.

E. In the Wang Dissertation, No Modified Stress Wave Reaches the Interface

120. Page 10 (last paragraph) of the Board’s Institution Decision (Paper 8) states (emphasis added):

121. Wang further discloses that the structure used in Wang results in “[a]n initial fall time of a few nanoseconds” for a shock wave propagated through the layers of the structure being “reduced to near zero” **by the time “the pulse arrives at the test film.”** *Id.* at 65. This “decompression shock” is recognized by Wang as “especially beneficial for tensile thin film tests, where the optimal compressive pulse ought to have a rapid fall time.” *Id.* at 65–66, 81.

122. Neither page 65, nor any other portion of the Wang Dissertation disclose a shock wave or any modified wave *reaching the interface*. Page 65 of the Wang Dissertation is reproduced in relevant part below expressly acknowledges this:

123. As expected from the shock analysis, the initial Gaussian stress pulse evolves into a shock long before it reaches the test film. The rising part of the initial compression pulse thus evolves into a linear ramp, a classic acceleration wave. This ramp is precisely what is seen in Fig. 3.15c. The slope of that ramp (in units of stress per time/thickness) is a material parameter and is the same as that reported by Barker and Hollenbeck [51]. The falling part of the stress pulse evolves in a very different manner. The tail of the initial pulse propagates more quickly than does the peak. It overtakes the peak in a time which may be calculated

using the material properties apparent in the slope of the ramp. A discontinuity in stress (and therefore also in material velocity) develops when the tail overtakes the peak. That sufficient time has occurred in the present case for a decompression shock to develop is evident. After traveling through the substrate, the rising front edge of the pulse has stretched from about 4.1ns to 20 ns or 30 ns. The falling tail-end of the pulse has compressed by the same amount. *An initial fall time of a few nanoseconds has therefore been reduced to nearly zero and occurs long before the pulse arrives at the test film.*

Ex.-1005, p65 (emphasis added).

124. In the Wang Dissertation: (1) there is no evidence of the formation of any decompression shock in any of the test data therein; (2) what Dr. Wang describes as a decompression shock is essentially unloading due to the arrival of the tension wave; (3) even if the Wang Dissertation did disclose a decompression or rarefaction shock, it would have been truncated or neutralized or completely removed by the tension wave when it overcomes the rear end of the compression wave; (4) the initial compression wave, even if hypothetically formed with a decompression shock, will undergo a significant drop in its energy and amplitude such that it's profile would be converted back into an unmodified compression wave, with no shock profile by the time it were to reach the interface; (5) the tension generated at the film interface is from the direct tension wave when it first

strikes the interface on its way towards the free surface of the coating; and (6) the tension at the interface is therefore not developed upon the reflection of the initial compressive wave with a rarefaction shock profile.

F. The Wang Dissertation's Arrangement of Using Fused Silica as a Glass Element as Taught by the '684 Patent Will Reduce Stress at the Coating Interface, A Principal of Operation *Opposite* To That Of the '684 Patent

125. Dr. Wang speculates in her Dissertation on potential "Future Work," stating :

126. By inserting an extra layer of the desired substrate material between the fused silica and the thin film, the current technique can be used to test a variety of substrates and films, especially those of interest to the microelectronics industry, such as polyimide, copper (Cu), aluminum (aluminum) and polysilicon on single-crystal silicon substrates.

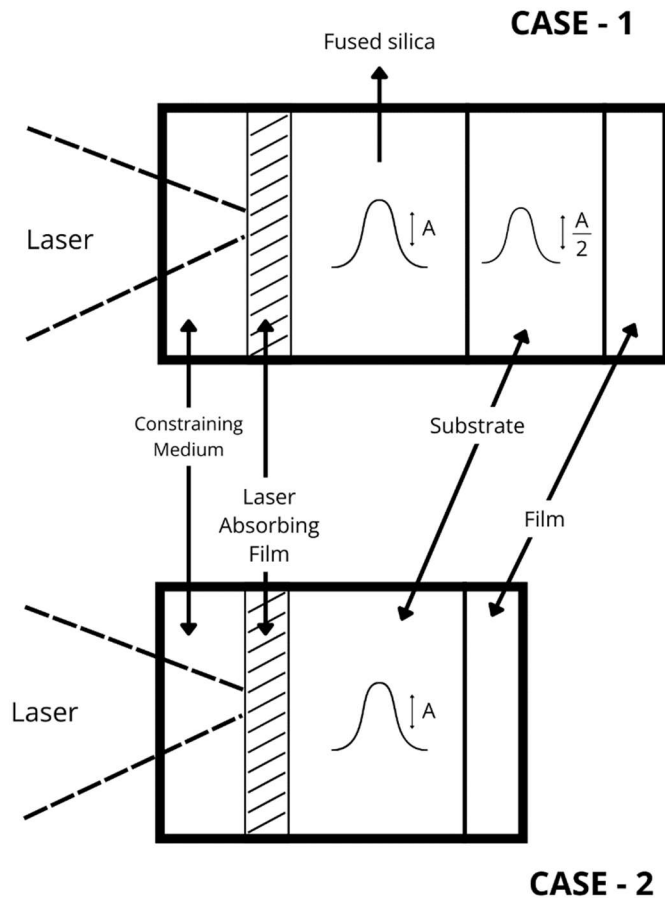
127. Ex.-1005, p. 124.

128. This isolated statement at the end of her Dissertation does not disclose, nor would it have led one skilled in the art to, the invention of the '684 patent for several reasons.

129. First and foremost, as discussed later in this declaration, the Gupta-1992 reference (Ex.-1011), which Dr. Wang has stated replicates the exact same arrangement as her statement in the "Future Work" section of her thesis (Ex.1005, 124), confirmed that the compression wave was **not** modified with the rarefaction

shock when it passed through the fused quartz plate to arrive at the substrate/fused quartz interface. My findings in 1992 were fully consistent with Dr. Wang's dissertation results much later, which also lacked the formation of decompression shock.

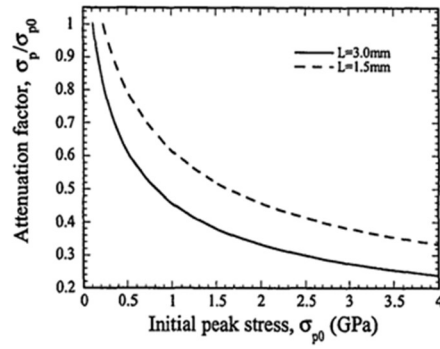
130. Furthermore, a POSITA would conclude based on Wang's Dissertation that the tensile stress will actually decrease at the coating/substrate interface by the insertion of the additional substrate material between the fused silica and thin film. Consider a first case where a desired substrate is inserted between the fused silica and thin film as per the Wang Dissertation statement of "Future Work" (Case 1 below). Now consider a second case, where the same substrate and thin film combination are shown without the fused silica and whose strength will be determined by using traditional technology, e.g., as described in the '402 patent (Case 2 below). To keep the stress generation conditions the same, I use a laser absorbing film and a constraining medium of the exact same materials and thicknesses in both the cases. Let us also use the exact same laser heating spot size and laser energy. With this, the stress wave generation conditions would be exactly the same at the laser impingement point in both cases. In this hypothetical, the purpose may be to generate tensile stress at the substrate/film interface and separate it using a modified stress wave profile (Case 1, with the alleged fused silica glass element) and known waveform (Case 2).



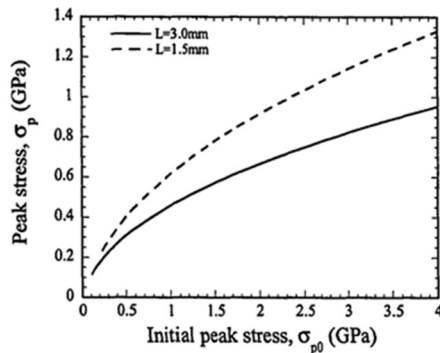
131. Here, let “A” be the amplitude of the stress wave that is generated at the laser impingement point in both cases as the laser generation conditions are identical. In Case 1, the amplitude A will undergo a significant attenuation due to both the geometrical and shock attenuation effects, confirmed by Dr. Wang in her Dissertation, and already discussed above. A POSITA would consider fused silica thicknesses to be in the 1.5mm to 6 mm range, as directed in Wang’s Dissertation for which there is experimental wave dispersion data in her Dissertation. Consider

the maximum substrate stress level in the range of 1.1 GPa to 1.2 GPa, as at these stress levels Dr. Wang saw film failures (Table 3.7) in the 0.5 μm thick films.

132. I have reproduced Fig. 2.15a from Wang's Dissertation again below, which shows that for these combination of stress amplitude and propagation distances, just the shockwave attenuation would drop the stress amplitude A to between $0.45A$ to $0.6A$ for fused silica thickness of 1.5 mm to 3 mm and the 6 mm thickness is off the figure but an extrapolation would suggest a value less than $0.1A$. One needs to further reduce these values due to the geometrical dispersion effects, also acknowledged by Dr. Wang in Fig. 2.9, page 25, of her Dissertation. That is another 14% reduction in stress amplitude for a 3mm travel distance in the substrate. When considered these wave dissipation effects together, this would yield a stress amplitude between $0.38A$ to $0.51A$ when it arrives at the glass element (fused silica)/substrate interface in Case 1. This is the stress wave amplitude that would arrive at the fused silica/substrate interface and then proceed towards the test interface between the film and the substrate that is located further down the substrate and would undergo further geometrical dispersion.



(a)



(b)

Figure 2.15: Shock attenuation in fused silica: (a) attenuation factor as a function of initial peak stress and substrate thickness; (b) remaining peak stress as a function of initial peak stress and substrate thickness.

133. In Case 2, the stress is generated directly in the substrate as it is in direct contact with the laser impingement point and therefore the stress wave amplitude will be A. In Case 2, the stress wave profile will **not** be the one with the rarefaction shock but with the unmodified wave.

134. When the stress wave amplitude with the rarefaction shock reduces to 0.38A to 0.51A, the shock profile may also cease to exist as suggested by the wave velocity measurements in fused silica performed by Dr. Wang and presented in Table 2.1 on page 14 of her dissertation. Dr. Wang's Dissertation appears to imply

that the fused silica structure requires a minimum stress to develop a shock. That is, the material structure cannot be compressed at low stress wave amplitudes to generate the decompression shock profile.

135. This conclusion of disappearance of the shock profile is fully supported by the observations of the lack of pre-compression stress in the interface stress history (Fig. 3.15d) in Dr. Wang's Dissertation. As already discussed in my declaration, Dr. Wang's own data in her dissertation, and acknowledged by Dr. Wang in her declaration, the failure is caused directly by the tension wave that was generated by the reflection of the compression wave generated in the constraining medium from its free surface.

136. Even if we assume that the shock profile is maintained when the stress wave enters the substrate in Case 1, its amplitude is even lower than 38% to 51% of the stress wave amplitude that will be generated directly in the substrate in Case 2. The modified stress wave profile with only 38% to 51% amplitude cannot generate an interface stress larger than an unmodified stress wave with an amplitude A in Case 2.

137. When significant attenuation effects are considered in fused silica, as discussed in Chapter 2 of the Wang Dissertation, the proposed "Future Work" of Wang, would result in *decreased, not increased, stress at the interface*.

138. It also should be understood that fused silica is **not** considered as an example of the glass element in the '684 patent. Instead, "quartz" is one of the glass elements described in the '684 patent, which is totally different than the fused silica material. Fused silica is amorphous, whereas quartz is crystalline and as such has very different elastic constants and dissipative properties.

139. The '684 patent contemplates, as materials for the "glass element," **only** those where the attenuation of the shock wave is geometrical and does not undergo the attenuation of the type discussed in Fig. 2.15 in Wang's Dissertation for fused silica. *See, e.g.*, Ex.1001, Fig.6. That attenuation is displayed by the specific material structure of fused silica. That is, it is not a property displayed by any of the materials suitable as the "glass elements" disclosed in the specification of the '684 patent.

140. This is experimentally demonstrated in Fig. 6 of the '684 patent, reproduced below as Fig. 17, where the velocity profiles for few exemplary glass elements were measured **after** the waves propagated 2 mm to 3 mm beyond the laser impinging point.

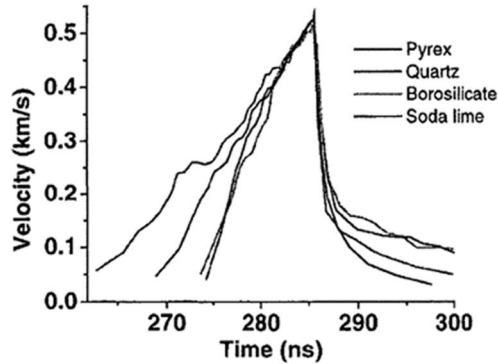


FIG. 6

141. With reference to Case 1 discussed above, this means that the glass element of the '684 patent will keep the stress arriving at the glass element/substrate interface to nearly the same amplitude as A (except for the small geometrical attenuation) in Case 1. With the modified profiles shown in Fig. 6 of the '684 patent, Case 1 will generate a much higher tensile stress at the interface **after reflecting from the free surface of the coating** compared with that with a regular wave, without the modified profile, in Case 2.

142. Indeed, this is demonstrated in Fig. 8A and Fig. 8B of the '684 patent (reproduced again below) where the unmodified wave 130 results in a low stress 134 at the interface while the modified wave even with a somewhat lower amplitude, 132, results in a much higher interface tensile stress, 136.

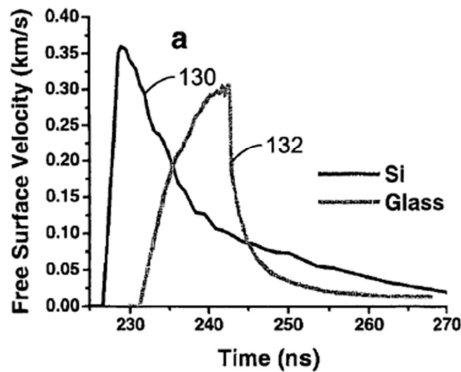


FIG. 8A

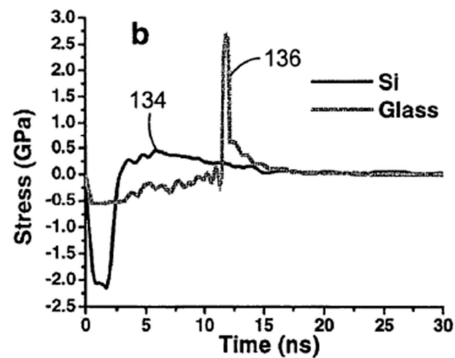


FIG. 8B

143. Moreover, substantial experimentation would be required to make sure that the wave with the rarefaction shock can maintain its shock profile when it enters the substrate material and eventually reaching the film interface, with its shock profile intact. Every substrate material is different and that would require substantial experimentation of the type performed by Dr. Wang for fused silica by the POSITA, with unpredictable results, as every material structure is different.

VII. THE CHALLENGED CLAIMS OF THE '684 PATENT ARE NOT ANTICIPATED BY THE WANG DISSERTATION (GROUND 1)

144. Claim 1 of the '684 Patent Recites:

[1.pre]⁵ An apparatus for generating a tensile stress between a Substrate and a coating, comprising:

⁵ Using claim element numbers proposed by Petitioner.

[1.a] a Substrate having a thickness, said thickness defined by a first side and a second side in a first axis;

[1.b] a coating applied to the first side of the substrate such that the coating and substrate are axially spaced along the first axis in intimate facing contact with each other such to form a coating/substrate interface; and

[1.c] a glass element disposed on the second side of the substrate and axially spaced along the first axis;

[1.d] wherein the glass element is configured to propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating.

145. In my opinion, and in view of my discussion thus far, the Wang Dissertation fails to disclose at least claim 1 elements [1.c] and [1.d]. I explain below.

146. First, the Wang Dissertation fails to disclose [1.c] “a glass element disposed on the second side of the substrate and axially spaced along the first axis” as recite in claim 1. In her Declaration (Ex-1003), Dr. Wang opines that “fused silica is a glass consisting of almost pure silica (silicon dioxide, SiO₂). It was known by the 1970s that fused silica is a nonlinear elastic material having the property of propagating stress waves into rarefaction shock waves.” Ex-1003, ¶102. Here, Dr. Wang relies on p. 26 of her Dissertation and Barker and

Hollenbeck (Ex-1021). Fused silica is not a glass element of the '684 patent for several reasons already discussed in my declaration. First, neither Dr. Wang nor I were able to observe the formation of decompression shock when the unmodified stress wave transmitted through the fused silica substrate. The laser generated stress wave remained unmodified after its transmission through fused silica, as evidenced by Fig. 3.19 in Wang-dissertation and Fig. Fig. 11 in the Gupta-1992 reference (Ex.1011), discussed in the next section. What Dr. Wang refers to in her entire thesis work as a decompression shock is merely an unloading in the unmodified wave caused by the direct tension wave. Theoretically, as discussed in Chapter 2 of Dr. Wang's Dissertation, the decompression shock is formed in fused silica soon after the unmodified wave enters the fused silica substrate. As the Wang-Dissertation also explains, a dramatic reduction in its amplitude then occurs soon after its formation and as Fig. 2.12 in her dissertation shows, the wave can lose almost 80% to 90% of its amplitude at wave amplitudes (1 GPa and higher) that are of interest to the laser spallation technique. This occurs when the wave has propagated only 1mm to 6mm into fused silica which are the practical range of glass element thickness used in the '684 patent or a POSITA would try to recreate the arrangement suggested by Dr. Wang in her "Future Work" section of her dissertation. At such lower stresses, the stress wave would lose its shock character or profile, as demonstrated by both Fig. 3.19 in the Wang dissertation and Fig. 11

in the Gupta-1992 reference. This was also confirmed by Dr. Wang in her Dissertation discussing Fig. 3.19. Such a large reduction in stress will make it impossible to separate the film from the interface, with or without the rarefaction shock profile. This becomes even more untenable, especially when the modified wave has to transit into a new substrate and propagate through its entire thickness before arriving at the film interface.

147. Second, the Wang Dissertation fails to disclose [1.d] “wherein the glass element is configured to propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating,”

148. **First**, as already discussed, fused silica is not a glass element as it does not modify the compression wave to result in a rarefaction shock, nor does it propagate this modified wave to the test interface. Instead, what Dr. Wang erroneously claims as decompression shock is merely an unloading caused at the rear end of the compression wave. Evidence in both Gupta-1992 reference (Ex.-1011) and Wang-Dissertation makes it clear that the pure compression wave does not have the rarefaction shock profile when it arrives at the film interface. Even if it were to be present at the rear end of the compression wave, the direct tension wave totally neutralizes it or removes it prior to that shock portion ever reaching the interface. This can be conclusively stated based on my detailed analysis above

of Dr. Wang's thesis data, which demonstrates that the tension wave profile matches the tensile stress history at the interface (*see* ¶76 (and accompanying figure(s))); and higher tensile stress reported at the aluminum/fused silica interface that is greater than the maximum possible tension that could be generated by the direct compression wave because of its amplitude (analysis of the data in Tables 3.4 and 3.7) and the significant attenuation effects that results in loss of shock profile.

149. **Second**, the ramp portion of the compression wave does not cause any tension as when the front portion of this ramp when it reflects into a tensile stress from the free surface of the film. There is a much larger compression wave amplitude from the initial compression wave still sitting at the interface that not only would neutralize this small tension, but it would result in a net compressive stress at the interface. As already shown in the figure in ¶76, the building-up and peaking of the tension at the interface shown in Fig. 3.15d of the Wang thesis matches generally with the expected profile of the tension wave, including its rise-time and post-peak stress decay. The fringe record in Fig. 3.15a beyond the 30ns mark till 50 ns would correspond to the decaying portion of the tension wave, which is further proof that even this unmodified compression wave has not yet arrived at the interface and the entire experiment of Dr. Wang was over. Evidence in both the Wang-Dissertation and Gupta-1992 reference (Ex.-1011) clearly shows

the rear end of the compression wave does not have the rarefaction shock profile so even if it were to ever arrive at the interface it would be created by the reflection of the unmodified wave which would not qualify as tension generated as per the claim requirement.

150. **Third,** The tension wave is not modified when it passes through fused silica as the non-linear stress-strain relationship that results in the prediction of the formation of decompression shock is only shown to be valid under compression. This can be confirmed by reviewing the Barker and Hollenback's reference from where Dr. Wang has directly taken the stress-strain relationship shown on page 28 of her thesis. Dr. Wang also confirmed this in her deposition. By making statements throughout her Dissertation that the tension wave speed is greater than the compression wave, Dr. Wang inherently acknowledged that the tension wave propagates without undergoing any modification by the fused silica material. She also confirmed in her deposition that equation 92.47, taken from Barker and Hollenback's work, was valid only under compression. Perhaps most telling is the hard evidence present in Dr. Wang's own Dissertation in all of her stress wave profiles in the fused silica substrate (except Fig. 3.19) where all unloading of the stress from the ramp of the initial compression wave occurs along a sharp rise-time, all with same slopes, which clearly are due to the arrival of the direct tension wave. The rise-time of the tension wave is clearly sharp even after it has

propagated the entire thickness of the substrate and no way displays the long ramp profile that was formed under compression.

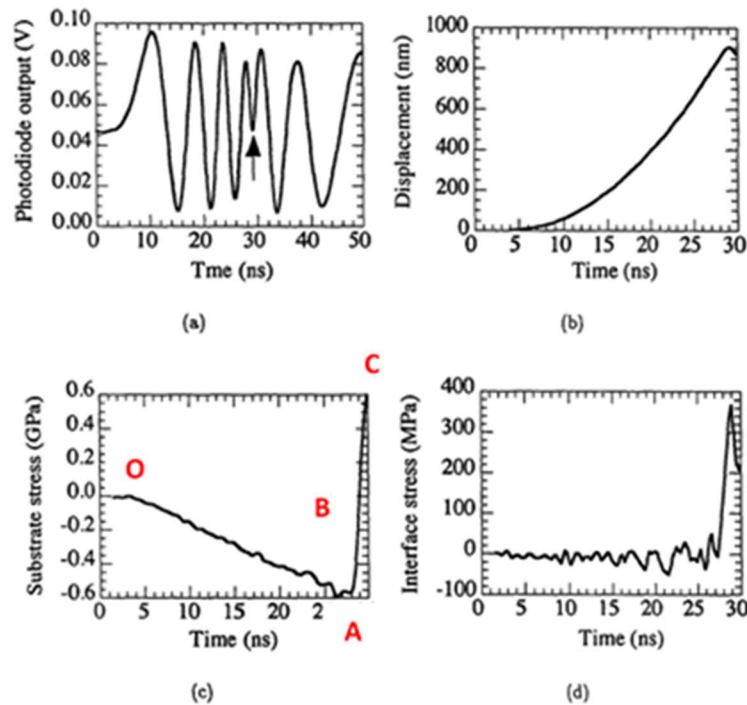


Figure 3.15: Typical data profile for a 1.0 μm thick aluminum film deposited on a 3000 μm thick fused silica substrate (laser fluence of 0.140 J/mm²): (a) interferometric fringe pattern, arrow points to turning point; (b) displacement profile; (c) substrate stress profile; (d) interface stress profile.

151. With reference to annotated Fig 3.15 of the Wang Dissertation above, Dr. Wang agreed that at least the portion of this unloading, from point B to point C, belongs to the direct tension wave, means that even she agrees that the tension wave has not modified in its character as clearly the portion of tension wave from point B to point C is rather sharp and does not display the ramp that would be expected if it were to be modified by the glass element. Furthermore, the fringe record beyond 30ns, which she did not resolve but testified that it would belong to

the tension wave of significant lower stress would further prove that the tension wave does not form the rarefaction shock as if it did one would see an extremely high fringe frequency which is absent. Therefore Dr. Wang and I are in agreement on this issue and this is also supported by hard evidence in her dissertation that the tension wave is ***not modified*** by the glass element and its original sharp rise-time and post-peak decay profile largely remain intact from its generation point at the laser absorbing film to all the way to the film interface.

152. Since the Wang Dissertation Fails to disclose each and every element of claim 1, in my opinion the Wang Dissertation fails to anticipate claim 1 of the '684 Patent.

153. Claim 13 of the '684 Patent recites:

[13.pre] A method for separating a coating from a substrate, the substrate having a first side and a second side transversely disposed in a first axis, the coating applied to the first side of the substrate such that the coating and substrate are axially spaced along the first axis in intimate facing contact to form a coating/substrate interface, the method comprising:

[13.a] positioning a glass element along the first axis on the second side of the substrate;

[13.b] directing a laser pulse in the first axis at the glass element;

[13.c] propagating and modifying a stress wave through the glass element to the coating/substrate interface to generate a tensile force between the Substrate and the coating; and

[13.d] separating the coating from the Substrate as a result of the stress wave-generated tensile force.

154. In my opinion, for reasons explained above, the Wang Dissertation fails to teach elements [13a]-13[d].

155. As discussed with respect to claim 1 analysis, fused silica is not a glass element, which is a requirement of this limitation. Fused silica behaves as a regular substrate in the context of this claim.

156. This limitation also requires that the laser pulse be directed at the glass element which in turn is absent in the Wang-Dissertation.

157. Limitations of this claim element are not met because of several reasons already discussed with respect to my analysis for claim 1. First, the compression stress wave is not modified. *See* my claim 1 analysis why this is so. Second, the tensile force in Dr. Wang's dissertation was generated by the direct tension wave and had nothing to do with the modified compression wave which did not even exist, let alone create a tensile force at the film interface. It can be concluded without doubt that the tension is created by the direct tension wave for all of the

reasons I have already discussed as to why claim 1 is not anticipated by the Wang-Dissertation.

158. With respect to element [13d], as described in the Wang Dissertation and above, all film separations in the Wang Dissertation are caused by the direct tension wave . The tension wave is not modified by the glass element for the various reasons I have discussed in my claim 1 analysis. A compression wave with rarefaction shock profile is required by this claim element to generate the tensile force for film separation upon reflection from the free surface of the coating. The ramp portion of the compression wave cannot generate any tension at the interface. The fringe record does not support any late arrivals of any decompression shock as the fringe frequency is very low as per Dr. Wang's own admission in her deposition. Fig. 3.19 makes clear that a rarefaction shock profile is never generated inside the fused silica material in Dr. Wang's dissertation. The tension at the film interface is built by the direct tension wave and not even by the unmodified compression wave let alone by the modified compression wave which does not exist anywhere in the Wang-Dissertation.

159. Since the Wang Dissertation fails to disclose each and every element of claim 1, in my opinion the Wang Dissertation fails to anticipate claim 13 of the '684 Patent.

160. Claim 2 depend from claim 1 and therefore it inherits all limitations of claim 1 which as I already analyzed are not met by the Wang-Dissertation. Claim 2 has the additional requirement that the “tensile stress is so configured” to separate the coating from the coating/substrate interface. By depending upon claim 1, this claim requires that the tension be generated by the modified compression wave with the rarefaction shock profile be upon reflection from the free surface of the coating. As already discussed, the tension is generated by the direct tension wave and not even by the unmodified compression wave let along the modified wave. Therefore all film separations discussed in the Wang-Dissertations fall outside the scope of this claim limitation.

161. Claim 3 recites: “An apparatus as recited in claim 1, wherein the glass is configured to propagate the stress wave as a result of impingement by a Nd-Yag laser beam directed in the first axis.” As explained above, the Wang dissertation fails to teach each and every element of claim 1, from which claim 3 depends. Thus, for this reason alone, the Wang dissertation cannot anticipate claim 3. Furthermore, the Wang dissertation fails to teach this specific limitation of the configured glass to propagate the stress wave as a result of impingement by a Nd-Yag in an arrangement that has a glass element and none of the experimental procedures and methods disclosed in the Wang dissertation, including the one in

Future Work section does not show the presence of a glass element configured to propagate and modify the stress wave to the coating interface.

162. Claim 4 recites: “An apparatus as recited in claim 1, wherein the stress wave has a length ranging from approximately 5 nanoseconds to approximately 1 microsecond.” As explained above, Wang-Dissertation fails to teach each and every element of claim 1, from which claim 4 depends. Thus, for this reason alone, Wang-Dissertation cannot anticipate claim 4. Furthermore, Wang-Dissertation fails to teach the specific limitations of this claim as the length of the wave this claims refers to is the glass modified wave which, as already discussed, is not disclosed anywhere in the Wang dissertation.

163. Claim 5 of the '684 Patent recites: “An apparatus as recited in claim 4, wherein the stress wave comprises a rarefaction shock formation.” In my opinion the Wang Dissertation fails to anticipate claim 5. Specifically, through claim 4, claim 5 inherits all of the limitations of claim 1, which I have already discussed are not met by the Wang-Dissertation. There is no rarefaction shock formation shown anywhere in the Wang-Dissertation; what Dr. Wang calls decompression shock is an unloading cause by the direct tension wave. Therefore any length of the stress wave that is disclosed in the Wang-Dissertation that falls in the range required by claim 4 is not met as that claim 4 wave must have the rarefaction shock profile which the Wang-Dissertation waves do not have.

164. Claim 6 recites: “An apparatus as recited in claim 1, wherein the coating has a thickness less than approximately 0.5 μm .” As explained above, Wang-Dissertation fails to teach each and every element of claim 1, from which claim 6 depends. Thus, for this reason alone, Wang-Dissertation cannot anticipate claim 6.

165. Claim 7 recites: “An apparatus as recited in claim 1, wherein the glass element is bonded to the second side of the substrate.” As explained above, Wang-Dissertation fails to teach each and every element of claim 1, from which claim 7 depends. Thus, for this reason alone, Wang-Dissertation cannot anticipate claim 7. Furthermore, Wang-Dissertation fails to teach the limitations of this claim as fused silica does not qualify as the glass element in the experimental apparatus disclosed in the Wang-Dissertation. Additionally, the reference fails to disclose the additional element of “wherein the glass element is bonded to the second side of the substrate” because the “Future Work” section of the Dissertation describes adding an additional fused silica element “between the fused silica and the thin film”, which is analogous to the “first side” of the substrate, not the “second side.”

166. Claim 8 requires that the glass element be made from Pyrex, quartz, borosilicate, or soda lime materials. Through its dependency on claim 1 it requires that these glass elements be able to modify a compression wave into a wave with rarefaction shock profile. The fused silica in the Wang-Dissertation does not modify the stress wave. It is just an ordinary substrate. Dr. Wang in her

declaration suggests that the structure of the fused silica is similar to that found in soda lime, borosilicate, quartz and pyrex. This is wrong as the material composition, level of crystallinity, impurities, and most important porosity and hence density and elastic moduli of these materials vary. Because of these variations, the acoustic properties of these materials are different and they behave differently when probed by the same incoming elastic stress wave. Just because Dr. Wang finds traces of SiO₂ in these materials she jumps to the conclusion that her fused silica belongs to the glass elements disclosed in claim 8 b. When multiple atomic species are present the interatomic arrangement and bond formations are dependent upon their volume fraction and even small impurities less than 1% can dramatically alter the mechanical response of solids. If we were to apply the same logic to Dr. Wang's thesis then both her silicon samples and fused silica samples should show some similarity in their shock response as after all there is almost 50% of Si by weight in fused silica. This is obviously not true as implied by the rather different response by these materials to the laser generated stress waves that was recorded by Dr. Wang in her dissertation experiments.

167. Claim 9 discloses the range of thicknesses for the glass element that via its dependency on claim 1 would result in the generation of the compression wave with rarefaction shock profile and then eventually resulting in the generation of the tensile force at the interface. The fact that the Wang-dissertation does not disclose

the formation of rarefaction shock, as required by claim 1, the thicknesses she uses in her experiments for the fused silica substrates fall outside the scope of those disclosed in claim 9.

168. Claim 10 recites: “An apparatus as recited in claim 1, wherein the substrate comprises silicon.” As explained above, Wang-Dissertation fails to teach each and every element of claim 1, from which claim 10 depends. Thus, for this reason alone, Wang-Dissertation cannot anticipate claim 10. Furthermore, the Wang dissertation fails to teach this specific limitation because Si was not tested in the arrangement that was discussed in the Future Work section of the Wang-Dissertation. Even if for whatever reasons it is considered tested as part of that arrangement the Wang-Dissertation would still not meet this limitation because it requires that silicon be a part of an apparatus where a glass modified wave enters its thickness from the side opposite to where the test coating interface is located. That would be the side attached to the fused silica disc. Since fused silica is not a glass element it cannot propagate and modify a wave into the Si substrate. For all these reasons the Wang-Dissertation does not anticipate this claim element.

169. Claim 11 recites: “An apparatus as recited in claim 1, further comprising a constraining element disposed adjacent to the glass element.” As explained above, Wang-Dissertation fails to teach each and every element of claim 1, from which claim 11 depends. Thus, for this reason alone, Wang-Dissertation cannot

anticipate claim 11. Furthermore, the Wang dissertation fails to teach this specific claim limitation as the constraining layer is required to be covering the glass element. In both the arrangements-the one tested and the one proposed in the future work section of the dissertation-no glass element is disclosed which will modify a compression stress wave into a wave with rarefaction shock profile. Evidence that such a wave modification did not occur has been discussed earlier in this Declaration. Additionally, in the “future work” section, the additional fused silica element is disposed between the substrate and the film interface, not the adjacent to the constraining layer.

170. Claim 12 recites: “An apparatus as recited in claim 11, further comprising an energy absorbing layer disposed between the constraining layer and the glass element.” As explained above, Wang-Dissertation fails to teach each and every element of independent claim 1 and dependent claim 11, from which claim 12 depends. Thus, for this reason alone, the Wang dissertation cannot anticipate claim 12. Furthermore, Wang-Dissertation fails to teach the specific limitation as it requires the energy absorbing layer to be disposed between the constraining layer and the glass element. In both the experimental arrangements disclosed in the Wang dissertation-one used for testing and the other proposed for future work-no glass element is used as it does not modify the compression stress wave into a one with rarefaction shock profile to ultimately result in the generation of tensile force

at the interface.. Evidence that such a wave modification did not occur has been provided earlier in this declaration. Additionally, for similar reasons why the Wang Dissertation does not anticipate claim 11, the reference cannot anticipate claim 12 because the “future work” section describes positioning the additional fused silica element between the substrate and the thin film.

171. Claim 14 recites: “A method as recited in claim 13, wherein directing a laser pulse in the first axis comprises directing a Nd-Yag laser beam in the first axis.” As explained above, the Wang dissertation fails to teach each and every element of claim 13, from which claim 14 depends. Thus, for this reason alone, the Wang dissertation cannot anticipate claim 14. Furthermore, the Wang dissertation fails to teach this specific limitation as the laser pulse must be directed in an arrangement that having a glass element and none of the experimental procedures and methods disclosed in the Wang dissertation, including the one in Future Work section does not show the presence of a glass element that would propagate and modify the stress wave to the coating interface and lead to the generation of a tensile force upon reflection of the modified wave from the free surface of the coating, and eventually leading to its removal when the generated tension exceeds the interface strength.

172. Claim 15 recites: “A method as recited in claim 13, wherein propagating a stress wave comprises propagating a stress wave having a length ranging from

approximately 5 nanoseconds to approximately 1 microsecond.” As explained above, the Wang dissertation fails to teach each and every element of claim 13, from which claim 15 depends. Thus, for this reason alone, the Wang dissertation cannot anticipate claim 15. Furthermore, the Wang dissertation specifically fails to teach this claim limitation as there is no wave disclosed in the Wang-Dissertation that is modified by the glass element to form a rarefaction shock profile. Therefore, any length of the stress wave that is disclosed in the Wang-dissertation that falls in the range required by claim 15 is not met as that claim 14 wave must have the rarefaction shock profile which the Wang-Dissertation wave does not.

173. Claim 16 recites: “A method as recited in claim 15, wherein the stress wave comprises a rarefaction shock formation.” As explained above, the Wang dissertation fails to teach each and every element of independent claim 13 and dependent claim 15, from which claim 16 depends. Thus, for this reason alone, the Wang dissertation cannot anticipate claim 16. Furthermore, the Wang dissertation fails to teach the limitations of this claim as all the figures showing substrate stress do not shows the formation of a rarefaction shock profile.

174. Claim 17 recites: “A method as recited in claim 15, wherein the stress wave is configured to separate a coating having a thickness less than approximately 0.5 μm .” As explained above, the Wang thesis fails to teach each and every element of independent claim 13 and dependent claim 15, from which

claim 17 depends. Thus, for this reason alone, the Wang thesis cannot anticipate claim 17. Furthermore, the Wang dissertation fails to teach this specific claim limitation as film separation must be performed by a glass modified wave which is not present in the Wang-Dissertation. reference.

175. Claim 18 recites: “A method as recited in claim 15, wherein positioning a glass element along the first axis comprises bonding the glass element to the second side of the substrate.” As explained above, the Wang dissertation fails to teach each and every element of independent claim 13 and dependent claim 15, from which claim 18 depends. Thus, for this reason alone, the Wang dissertation cannot anticipate claim 18. Furthermore, Wang-Dissertation fails to teach this limitation as fused quartz is bonded to the substrate in the Fig. 2(b) of the Gupta-1992 reference. As already discussed, fused silica is not a glass element as used in this reference. Therefore this claim is not anticipated by the Wang dissertation.

176. My arguments for why claim 19 is not anticipated by the Wang-Dissertation would mirror those provided for claim 8 as like claim 8 which depends upon claim 1, claim 19 depends upon claim 13, which has the same requirements as claim 1 regarding the functionality of the glass element.

177. For claim 20, my arguments as to why it is not met by the Wang-Dissertation, would mirror those provided for claim 9, as it would inherit limitations from claim 13 regarding its functional properties which are totally

missing in the Wang-Dissertation. Therefore the thicknesses for the fused silica substrate that were investigated by Dr. Wang in her dissertation are outside the scope of those disclosed in claim 20.

178. Claim 21 recites: “ A method as recited in claim 13, further comprising positioning a constraining element adjacent to a free side of the glass element.” As explained above, the Wang dissertation fails to teach each and every element of independent claim 13, from which claim 21 depends. Thus, for this reason alone, the Wang dissertation cannot anticipate claim 21. Furthermore, Wang-Dissertation fails to teach this specific claim element as the constraining layer is required to be covering the glass element, which does not exist in the Wang dissertation. In both the experimental arrangements disclosed in this reference, neither the substrate nor fused silica are glass elements as they do not modify the compression stress wave. Additionally, in the “future work” section, the additional fused silica element is disposed between the substrate and the film interface, not the adjacent to the constraining layer.

179. Claim 22 recites: " A method as recited in claim 21, further comprising: coating an energy absorbing layer on the free side of the glass element between the constraining layer and the glass element; wherein directing a laser pulse in the first axis comprises directing the laser pulse the energy absorbing layer coated on the glass element." As explained above, the Wang dissertation fails to teach each and

every element of independent claim 13 and dependent claim 21, from which claim 22 depends. Thus, for this reason alone, the Wang dissertation cannot anticipate claim 22. Furthermore, the Wang dissertation fails to teach the specific limitation of this claim as it requires the energy absorbing layer to be disposed between the constraining layer and the glass element. In both the arrangements disclosed in this reference, neither the substrate nor the fused silica are glass elements as they do not modify the compression stress wave. Additionally, for similar reasons why the Wang Dissertation does not anticipate claim 11, the reference cannot anticipate claim 12 because the “future work” section describes positioning the additional fused silica element between the substrate and the thin film.

180. Moreover, I understand that since the Wang Dissertation fails to anticipate the independent claims 1 and 13, all dependent claims are also not anticipated.

VIII. THE CHALLENGED CLAIMS OF THE '684 PATENT ARE NOT ANTICIPATED BY GUPTA 1992 (GROUND 4)

181. As explained below, it is my opinion that Gupta 1992 fails to anticipate claims 1-8, 10-19, and 21-22 of the '684 Patent.

182. As explained above, fused silica fails to form a rarefaction shock. This is fully consistent with the experimental observations I made in my own research dealing with fused silica, wherein my findings were published in the Gupta-1992

reference. Indeed, as admitted by Dr. Wang, the arrangement depicted in Gupta 1992 is coextensive with the “Future Work” described in the Wang Dissertation.

183. Petitioner relies on Fig. 2 (b) of Gupta 1992 (reproduced below) and argues that the fused silica in this arrangement acts as the glass element of the ‘684 patent. This is erroneous. As discussed below, in Gupta 1992, I measured the stress wave profiles at a point just prior to, and after it propagates through to the Pitch-55 substrate. As shown in the Gupta-1992 reference and discussed below, the stress wave profile I measured in Gupta 1992 resembles close to what Dr. Wang herself recorded in Fig. 3.19 of her Dissertation , without any decompression or rarefaction shock. In fact, I discussed this issue and particularly this figure with the USPTO examiner during my phone interview prior to him granting the ‘684 claims.

184. Dr. Wang in her deposition agreed that Fig. 2 (b) of Gupta 1992 depicts essentially the same arrangement as the statement made in her future research section of her Dissertation. She also claimed in her declaration that this is one of the references she read and was fully aware of during her doctoral Dissertation research and as such this Gupta-1992 paper is referenced in her Dissertation. Ex-2009, 184-186.

185. The “Future Work” proposed by Wang in her Dissertation is in fact shown in Fig. 2 (b) of this Gupta 1992 reference. Fused silica and fused quartz are

essentially the same material. Both are amorphous solids. Quartz (without the word fused) on the other hand is a totally different material with pure crystalline phase. Fig. 2b of Gupta 1992 is reproduced below.

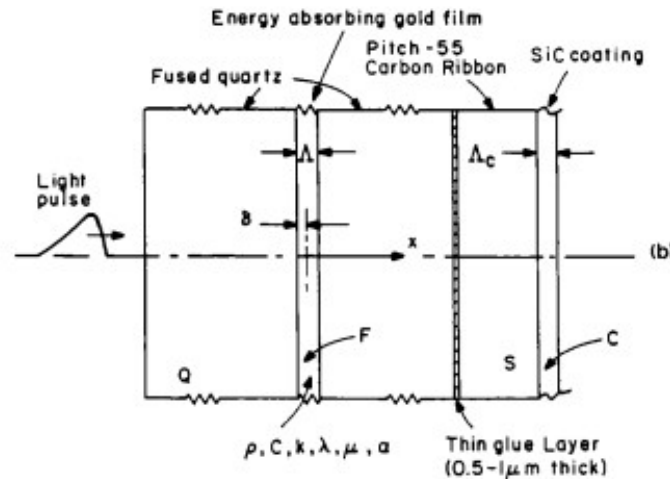


FIG. 2. (a) Configuration of the laser spallation probe with a homogeneous substrate. (b) Configuration for testing the Pitch-55 Ribbon/SiC system.

186. Here, the constraining medium is fused quartz, which is similar to the waterglass material used in Wang's Dissertation and prior art Gupta works. Gold is used as the laser absorbing film in Gupta 1992 which already shown in several publications is no different than the aluminum film that is used as the laser absorbing film in my subsequent works and also in the Wang-Dissertation. The rise-time and shape of the generated stress wave does not change except that the dependence of the stress wave amplitude on the laser energy is slightly different but that can be easily compensated by adjusting the laser pulse energy. The Pitch-55 carbon ribbon substrate in Gupta 1992 is inserted between the SiC coating and the fused quartz (fused silica), as referenced by Dr. Wang in her "Future Work"

section of her Dissertation. That is, the Gupta 1992 arrangement is identical to arrangement proposed by Dr. Wang in her Dissertation.

187. In the Gupta-1992 reference, the stress wave profile that is generated inside the fused quartz (fused silica) element in Fig. 2 (a) was measured independently using an arrangement where the carbon ribbon substrate and SiC coating were removed. This measurement configuration is shown in Fig. 8 of the

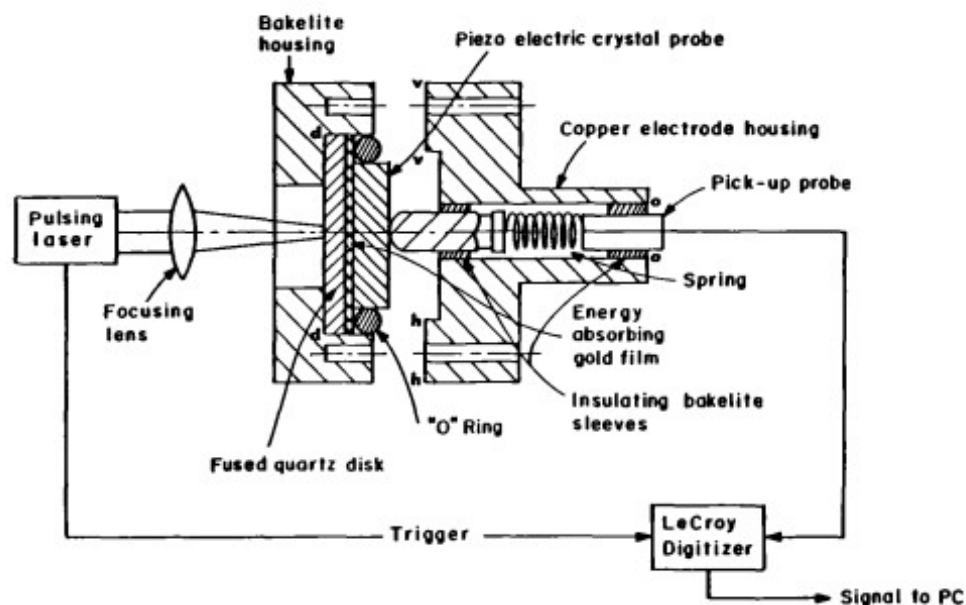


FIG. 8. A schematic view of the micro-electronics device with the X-cut piezo-electric crystal used to characterize the laser pulses.

Gupta-1992 reference shown below:

188. Here, the fused quartz is replaced by another X-cut fused quartz crystal that has identical elastic constants as the fused silica or fused quartz. This is evident in Table 2 from the Gupta 1992 reference, reproduced below, which shows identical properties for fused quartz and piezo-electric quartz (compare values in

columns 3 and 6 of the table). They are identical, meaning that the fused quartz, fused silica, and piezo-electric quartz are identical materials as far as wave propagation is concerned. Furthermore, Dr. Wang has taken the position in her sworn declaration that fused silica and quartz are the same material.

TABLE 2. *Relevant physical constants for fused quartz, gold, and piezo-electric quartz crystal, silicon crystal, and carbon, entering the computer simulation*

	Silicon	Fused quartz	Gold film	Carbon film	Piezo-electric quartz
ρ (g/cm ³)	2.3	1.8	19.3	2.2	1.8
C (J/Kg K)	729.0	1130.0	130.0	1800.0	1130.0
k (J/ms K)	138.0	1.7	316.0	3.2	1.7
λ (GPa)	62.0	84.3	145.8	7.5	84.3
μ (GPa)	41.0	21.1	27.8	11.2	21.1
c (m/s)	7910.0	8380.0	3230.0	3690.0	8380.0
γ	1.21	5.8×10^{-2}	0.36	4.3×10^{-2}	0.58
f [(coulombs/m ²)/MPa]	—	—	—	—	21.5×10^{-7}
α (K ⁻¹)	7.6×10^{-6}	4×10^{-7}	14.1×10^{-6}	3.8×10^{-6}	4×10^{-6}
ϵ (absorptivity)	—	—	(0.18)	(0.23)	—

189. Piezo quartz has the property that it generates a short circuit current that is identical to the stress wave profile. In Fig. 8 of the Gupta-1992 reference, laser impinges onto the gold film which is sandwiched between the two fused quartz plates. The compression wave travels in the fused quartz reaches the free surface where its profile is recorded by an electronic circuit that measures the current signal. As discussed in the Gupta-1992 reference, this short circuit signal is identical to the stress wave profile. Figure 11 in the Gupta-1992 reference, reproduced below, shows a number of short circuit current profiles generated with increasing levels of laser energies (fluence).

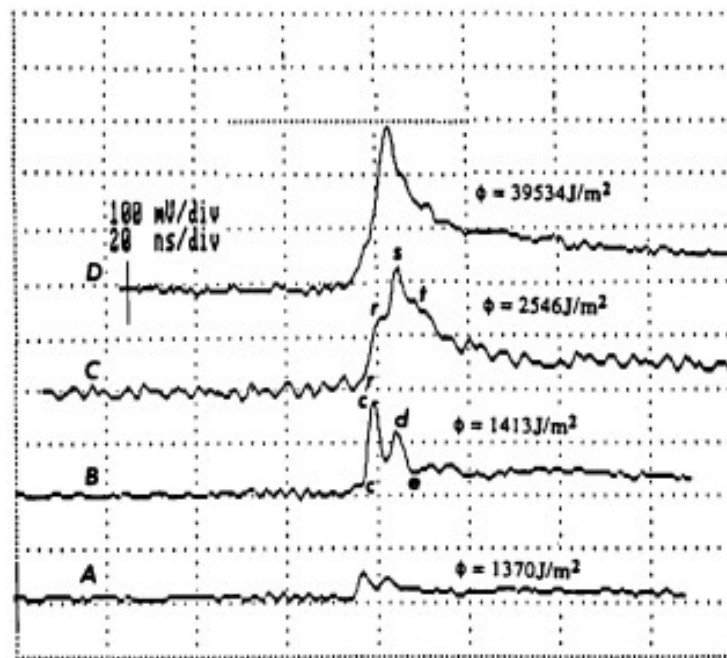


FIG. 11. Effect of the laser fluence on the structure of the stress pulse with gold as the laser energy absorbing film.

190. None of the stress wave profiles shown in this figure have the rarefaction shock profile described in the '684 patent. That is, in Gupta 1992, by the time the stress wave has arrived at the surface, after travelling 2 mm to 3 mm thickness of the fused quartz plate, the wave has either lost its rarefaction shock profile or it was never formed. With respect to Fig. 2 (b) of Gupta 1992, these wave profiles are measured just prior to entering the pitch-55 carbon substrate. Furthermore, Figure 15 of the Gupta-1992 reference, reproduced below, shows the experimentally measured stress wave profile in fused silica or fused quartz that

was used in Fig. 2b of Gupta 1992 to calculate the tensile stress at the pitch-55 Carbon ribbon and SiC coating interface.

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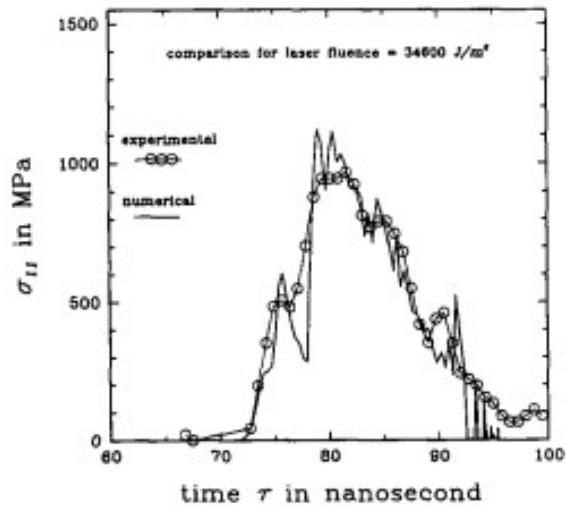


FIG. 15. Comparison of the simulated and measured profiles of the input stress pulse for a fluence of 34,600 J/m² for gold as the laser energy absorbing film.

191. The stress wave profile in fused silica does not show any rarefaction shock profile when it reaches the coating interface. In her deposition when Dr. Wang was shown these profiles, she agreed that none of these wave profiles show the formation of decompression shock even though there is no tension wave effect. This is exactly the same observations as she made in Fig. 3.19 of her Dissertation where no decompression shock was observed when there was no influence of the direct tension wave. Ex-2009, 106; Ex-2009 188:22-189:2 .

192. I also conducted the above experiments by using a thick x-cut fused quartz substrate. As discussed in the Gupta-1992 reference, with such a geometry

one can also record the profile of the stress wave that is immediately generated at the laser absorbing layer and then when it reaches the free surface after traversing the entire thickness of the substrate. The current signal is proportional to the polarization vector and as explained in the Gupta-1992 reference the amplitude of the reflected wave is twice of input wave but its profile is identical. Figure 10 from this reference shows both the current signals, corresponding two the two wave profiles, at the laser generation point and after the wave has travelled 2mm thickness of the substrate, do not show any rarefaction shock development. This is yet another proof that fused quartz cannot support the formation of rarefaction shock profiles. One should also note that in all the observations in the Gupta-1992 reference there is no direct tension wave that is generated in the substrate.

193. Claim 1 of the '684 Patent Recites:

194. [1.pre]⁶ An apparatus for generating a tensile stress between a Substrate and a coating, comprising:

195. [1.a] a Substrate having a thickness, said thickness defined by a first side and a second side in a first axis;

196. [1.b] a coating applied to the first side of the substrate such that the coating and substrate are axially spaced along the first axis in intimate facing contact with each other such to form a coating/substrate interface; and

⁶ Using claim element numbers proposed by Petitioner.

197. [1.c] a glass element disposed on the second side of the substrate and axially spaced along the first axis;

198. [1.d] wherein the glass element is configured to propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating.

199. In my opinion, Gupta 1992 fails to disclose claim 1 elements [1.c] and [1.d]. I explain below.

200. First, Gupta 1992 fails to disclose [1.c] “a glass element disposed on the second side of the substrate and axially spaced along the first axis” as recite in claim 1. In her Declaration (Ex-1003), Dr. Wang opines that this limitation is met because there is a fused quartz disc in the experimental setup shown in Fig. 2 (b) of the Gupta-1992 reference. I disagree with Dr. Wang. This claim element requires the fused quartz to be a glass element which as per this limitation has the functional requirement that it modifies a compressive stress wave into a compression wave with a rarefaction profile and guides such a profile to arrive at the film interface. As discussed above, there is clear experimental evidence that the fused silica in fig. 2 (b) did not modify the stress wave. In fact the Gupta-1992 reference also shows that such a wave profile was never generated at the laser-absorbing film. Unfortunately Dr. Wang is basing her entire analysis for the Gupta-1992 reference by assuming that fused silica in her work generates a

decompression shock profile. As already discussed, that was a false claim. In fact, Gupta-1992 reference shows several examples of compression wave profiles in fused silica without the influence of any direct tension wave and none of them show the formation of any decompression shock. Interestingly, there is only one profile in the Wang-Dissertation without the influence of direct tension wave, Fig. 3.19, and it conforms to the observations I made in the Gupta-1992 reference.

201. Second, Gupta 1992 fails to disclose [1.d] “wherein the glass element is configured to propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating” as recited in claim 1 of the ’684 Patent. There is clear experimental evidence presented in the Gupta-1992 reference that shows that as the laser-generated compressive stress wave passes through the fused silica substrate there is no modification of the stress wave. Figure 10 in that reference shows that the unmodified stress wave that enters the fused silica substrate remains unmodified during its entire transit through its thickness before emerging at its free surface. Such a wave would fall under the Gupta ’402 patent and therefore the USPTO examiner after thoroughly reviewing this reference during my interview granted the ’684 claims. No tension wave is transmitted in any of the Gupta-1992 experiments and therefore all interface failures are caused by the reflection of the unmodified wave from the free surface of the coating.

202. Since Gupta-1992 fails to disclose each and every element of claim 1, in my opinion the Wang Dissertation fails to anticipate claim 1 of the '684 Patent.

203. Claim 13 of the '684 Patent recites:

204. [13.pre] A method for separating a coating from a substrate, the substrate having a first side and a second side transversely disposed in a first axis, the coating applied to the first side of the substrate such that the coating and substrate are axially spaced along the first axis in intimate facing contact to form a coating/substrate interface, the method comprising:

205. [13.a] positioning a glass element along the first axis on the second side of the substrate;

206. [13.b] directing a laser pulse in the first axis at the glass element;

207. [13.c] propagating and modifying a stress wave through the glass element to the coating/substrate interface to generate a tensile force between the Substrate and the coating; and

208. [13.d] separating the coating from the Substrate as a result of the stress wave-generated tensile force.

209. In my opinion, and as explained above, Gupta 1992 fails to teach elements [13a]-13[d].

210. As explained above in my analysis with respect to claim 1, fused quartz or fused silica does not qualify as a glass element in light of the direct experimental

observations of compression stress wave profiles made at various locations in Fig. 2b of the Gupta-1992 reference. All the measured profiles do not show the formation of rarefaction shock after the unmodified wave passes through the fused silica substrate prior to the wave entering the substrate to arrive at the coating/substrate interface. Figure 15 in the Gupta-1992 reference shows the input stress wave profile that enters the Pitch-55 Carbon Ribbon substrate after passing through the fused silica substrate in the Fig. 2 (b) arrangement. The wave profile, confirmed by both theory and experiments, do not show the formation of any shock profile. In fact Dr. Wang in her deposition agreed that she did not see the formation of rarefaction shock in any of the stress waves shown in Fig. 15 or Fig. 11 in the Gupta-1992 reference.

211. For the same reason discussed above the claim element [13b] is not met by the Gupta-1992 reference as fused quartz does not qualify as glass element.[Dr. Gupta, please insert a paragraph explaining why element [13b] is not met.

212. Claim element [13c] is not anticipated by the Gupta-1992 reference because as already discussed the fused quartz does not propagate and modify the stress wave to the substrate/coating interface. What arrives at the coating/substrate interface is an unmodified compression wave after travelling through the substrate. The wave then reflects into a tension wave from the free surface of the coating and

generates a tensile force between the substrate and coating, exactly the same way as the prior art '402 technology.

213. Coating separation must occur at the interface as a result of the tensile force generated by the modified wave upon reflection from the free surface of the coating. Consistent with the USPTO examiner's decision, this process in the Gupta-1992 reference was caused by prior art '402 technology using the '402 wave.

214. Since the Gupta-1992 reference fails to disclose each and every element of claim 1, in my opinion the Wang Dissertation fails to anticipate claim 13 of the '684 Patent.

215. Claim 2 recites: "An apparatus as recited in claim 1, wherein the tensile stress is configured to separate the coating from the substrate at the coating/substrate interface." As explained above, Gupta 1992 fails to teach each and every element of claim 1, from which claim 2 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 2. Furthermore, Gupta 1992 fails to teach this limitation because the tensile stress required to separate the coating from the interface must be configured by a glass modified compression wave which as already discussed is not disclosed in the Gupta-1992 reference.

216. Claim 3 recites: "An apparatus as recited in claim 1, wherein the glass is configured to propagate the stress wave as a result of impingement by a Nd-Yag

laser beam directed in the first axis.” As explained above, Gupta 1992 fails to teach each and every element of claim 1, from which claim 3 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 3. Furthermore, Gupta 1992 fails to teach the specific limitations of this claim as “glass” referred to in this claim does not disclosed in the Gupta-1992 reference. This is because there are specific functional requirements for the “glass” to satisfy such as modifying a prior art compression wave into a wave, *e.g.*, with sharper post-peak profile. No shock is generated. Indeed, the Gupta-1992 reference is silent on such a disclosure.

217. Claim 4 recites: “An apparatus as recited in claim 1, wherein the stress wave has a length ranging from approximately 5 nanoseconds to approximately 1 microsecond.” As explained above, Gupta 1992 fails to teach each and every element of claim 1, from which claim 4 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 4. Furthermore, Gupta 1992 fails to teach the specific limitations of this claim as the length of the wave this claims refers to is the glass modified wave which as already discussed is not disclosed anywhere in the Gupta-1992 reference.

218. Claim 5 recites: “ An apparatus as recited in claim 4, wherein the stress wave comprises a rarefaction shock formation.” As explained above, Gupta 1992 fails to teach each and every element of independent claim 1 and dependent claim 4, from which claim 5 depends. Thus, for this reason alone, Gupta 1992 cannot

anticipate claim 5. Furthermore, Gupta 1992 fails to teach the specific limitations of this claim as it does not disclose the formation of rarefaction shock when the laser-generated stress wave propagates through the fused silica substrate. Figs. 10, 11, and 15 from this reference clearly show the absence of any rarefaction shock modification. The stress wave remains unmodified. Dr. Wang focused only on the arrangement shown in Fig. 2 (b) of the Gupta-1992 reference without appreciating that there are functional requirements for the fused quartz to modify the stress wave when it exits it prior to entering the substrate and that the modified wave should travel all the way to the interface to generate a tensile force after reflection from the free surface of the coating. Dr. Wang completely missed this aspect of the claim limitation.

219. Claim 6 recites: “An apparatus as recited in claim 1, wherein the coating has a thickness less than approximately 0.5 μm .” As explained above, Gupta 1992 fails to teach each and every element of claim 1, from which claim 6 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 6. Furthermore, Gupta 1992 fails to teach this limitation because it requires the coatings with the claimed thicknesses to be separated from the interface by the glass modified wave. It is not merely sufficient to point out the coating thicknesses that are tested by the setup and stress waves used in the Gupta-1992 reference as that reference uses the

technique which was covered under prior art '402 patent. The USPTO examiner agreed with this characterization.

220. Claim 7 recites: “An apparatus as recited in claim 1, wherein the glass element is bonded to the second side of the substrate.” As explained above, Gupta 1992 fails to teach each and every element of claim 1, from which claim 7 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 7. Furthermore, Gupta 1992 fails to teach this element as neither the substrate nor the fused quartz qualify as the glass substrate in the experimental apparatus disclosed in the Gupta-1992 reference.

221. Claim 8 recites: “An apparatus as recited in claim 1, wherein the glass element comprises one of the following: Pyrex, soda lime, quartz, or borosilicate.” As explained above, Gupta 1992 fails to teach each and every element of claim 1, from which claim 8 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 8. Claim 8 requires that the glass element be made from Pyrex, quartz, borosilicate, or soda lime materials. Gupta 1992 does not disclose the use of these, or equivalent materials. Through its dependency on claim 1 it requires that these glass elements be able to modify a compression wave into a wave with rarefaction shock profile. The fused quartz in the Gupta-1992 reference does not modify the stress wave. It is just an ordinary substrate. Dr. Wang in her declaration simply points to the presence of fused quartz in Fig. 2 (b) of this

reference. While analyzing this reference for claim 8, she is driven by her erroneous conclusion from her own dissertation that fused silica is a glass element because it modifies the stress wave to result in a profile with the rarefaction shock. By analyzing the data in the Wang-thesis, I have already shown that those claims are false as what she calls a rarefaction shock is an unloading caused by the tension wave.

222. Claim 10 recites: “An apparatus as recited in claim 1, wherein the substrate comprises silicon.” As explained above, Gupta 1992 fails to teach each and every element of claim 1, from which claim 10 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 10. Furthermore, Gupta 1992 fails to teach this specific limitation because Si was not tested in the arrangement shown in Fig. 2 (b). Even if for whatever reasons it is considered tested as part of that arrangement the Gupta-1992 reference would still not meet this limitation because it requires that silicon be a part of an apparatus where a glass modified wave enters its thickness from the side opposite to where the test coating interface is located. That would be the side attached to the fused quartz disc. Since fused quartz is not a glass element it cannot propagate and modify a wave into the Si substrate. For all these reasons the Gupta-1992 reference does not anticipate this claim element.

223. Claim 11 recites: “An apparatus as recited in claim 1, further comprising a constraining element disposed adjacent to the glass element.” As explained

above, Gupta 1992 fails to teach each and every element of claim 1, from which claim 11 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 11. Furthermore, Gupta 1992 fails to teach this specific element as the constraining layer is required to be adjacent to the glass element. In both the arrangements shown in Fig. 2 of this reference, neither the substrate nor the fused quartz are glass elements as they do not modify the compression stress wave. Evidence that such a wave modification did not occur is provided in Fig. 10, 11, and 15 of the Gupta-1992 reference.

224. Claim 12 recites: “An apparatus as recited in claim 11, further comprising an energy absorbing layer disposed between the constraining layer and the glass element.” As explained above, Gupta 1992 fails to teach each and every element of independent claim 1 and dependent claim 11, from which claim 12 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 12. Furthermore, Gupta 1992 fails to teach the specific limitation as it requires the energy absorbing layer to be disposed between the constraining layer and the glass element. In both the arrangements shown in Fig. 2 of this reference, neither the substrate nor the fused quartz are glass elements as they do not modify the compression stress wave. Evidence that such a wave modification did not occur is provided in Fig. 10, 11, and 15 of the Gupta-1992 reference.

225. Claim 14 recites: “A method as recited in claim 13, wherein directing a laser pulse in the first axis comprises directing a Nd-Yag laser beam in the first axis.” As explained above, Gupta 1992 fails to teach each and every element of claim 13, from which claim 14 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 14. Furthermore, Gupta 1992 fails to teach this specific limitation as the laser pulse must be directed in an arrangement that having a glass element and none of the experimental procedures and methods disclosed in the Gupta-1992 reference, including those displayed in its Fig. 2, show the presence of a glass element that would propagate and modify the stress wave to the coating interface and lead to the generation of a tensile force upon reflection of the modified wave from the free surface of the coating, and eventually leading to its removal when the generated tension exceeds the interface strength.

226. Claim 15 recites: “A method as recited in claim 13, wherein propagating a stress wave comprises propagating a stress wave having a length ranging from approximately 5 nanoseconds to approximately 1 microsecond.” As explained above, Gupta 1992 fails to teach each and every element of claim 13, from which claim 15 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 15. Furthermore, Gupta 1992 specifically fails to teach this claim limitation as there is no wave disclosed in the Gupta-1992 reference that is modified by the glass element. Therefore, any length of the stress wave that is disclosed in the

Gupta-1992 reference that falls in the range required by claim 15 is not met as that claim 14 wave must have a shock profile which the Gupta-1992 waves do not have. While analyzing this reference, Dr. Wang is driven by her erroneous conclusion from her own dissertation that fused quartz is a glass element because it modifies the stress wave to result in a profile with the rarefaction shock. By analyzing the data in the Wang-thesis, I have already shown that those claims are false as what she calls a shock is an unloading caused by the tension wave.

227. Claim 16 recites: “A method as recited in claim 15, wherein the stress wave comprises a rarefaction shock formation.” As explained above, Gupta 1992 fails to teach each and every element of independent claim 13 and dependent claim 15, from which claim 16 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 16. Furthermore, Gupta 1992 fails to teach the limitations of this claim as Figs. 10, 11, and 15 of the Gupta-1992 reference do not show the formation of a wave with rarefaction shock.

228. Claim 17 recites: “A method as recited in claim 15, wherein the stress wave is configured to separate a coating having a thickness less than approximately 0.5 μm .” As explained above, Gupta 1992 fails to teach each and every element of independent claim 13 and dependent claim 15, from which claim 17 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 17. Furthermore, Gupta 1992 fails to teach this specific claim limitation as film

separation must be performed by a glass modified wave which is not present in the Gupta-1992 reference.

229. Claim 18 recites: “A method as recited in claim 15, wherein positioning a glass element along the first axis comprises bonding the glass element to the second side of the substrate.” As explained above, Gupta 1992 fails to teach each and every element of independent claim 13 and dependent claim 15, from which claim 18 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 18. Furthermore, Gupta 1992 fails to teach this limitation as fused quartz is bonded to the substrate in the Fig. 2(b) of the Gupta-1992 reference. As already discussed, fused quartz is not a glass element as used in this reference. Therefore this claim is not anticipated by the Gupta-1992 reference.

230. Claim 19 recites: “A method as recited in claim 13, wherein the glass element comprises one of the following: Pyrex, soda lime, quartz, or borosilicate.” As explained above, Gupta 1992 fails to teach each and every element of independent claim 13, from which claim 19 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 19. Claim 19 requires that the glass element be made from Pyrex, quartz, borosilicate, or soda lime materials. Gupta 1992 does not disclose the use of these, or equivalent materials. Through its dependency on claim 1 it requires that these glass elements be able to modify a compression wave into a wave with rarefaction shock profile. The fused quartz in the Gupta-1992

reference does not modify the stress wave. It is just an ordinary substrate. Dr. Wang in her declaration simply points to the presence of fused quartz in Fig. 2 (b) of this reference. While analyzing this reference for claim 19, she is driven by her erroneous conclusion from her own dissertation that fused silica is a glass element because it modifies the stress wave to result in a profile with the rarefaction shock. By analyzing the data in the Wang-Dissertation, I have already shown that those claims are false as what she calls a rarefaction shock is an unloading caused by the tension wave.

231. Claim 21 recites: “ A method as recited in claim 13, further comprising positioning a constraining element adjacent to a free side of the glass element.” As explained above, Gupta 1992 fails to teach each and every element of independent claim 13, from which claim 21 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 21. Furthermore, Gupta 1992 fails to teach this specific element as the constraining layer is required to be covering the glass element. In both the arrangements shown in Fig. 2 of this reference, neither the substrate nor the fused quartz are glass elements as they do not modify the compression stress wave. Evidence that such a wave modification did not occur is provided in Fig. 10, 11, and 15 of the Gupta-1992 reference. .

232. Claim 22 recites: “ A method as recited in claim 21, further comprising:

233. coating an energy absorbing layer on the free side of the glass element between the constraining layer and the glass element;

234. wherein directing a laser pulse in the first axis comprises directing the laser pulse the energy absorbing layer coated on the glass element.” As explained above, Gupta 1992 fails to teach each and every element of independent claim 13 and dependent claim 21, from which claim 22 depends. Thus, for this reason alone, Gupta 1992 cannot anticipate claim 22. Furthermore, Gupta 1992 fails to teach the specific limitation as it requires the energy absorbing layer to be disposed between the constraining layer and the glass element. In both the arrangements shown in Fig. 2 of this reference, neither the substrate nor the fused quartz are glass elements as they do not modify the compression stress wave. Evidence that such a wave modification did not occur is provided in Fig. 10, 11, and 15 of the Gupta-1992 reference.

235. Further, I understand that since the Wang Dissertation fails to anticipate the independent claims 1 and 13, the remaining challenged dependent claims are also not anticipated for at least that reason.

IX. CLAIMS 4, 6, 9, 15, 17, 20, AND 23-24 OF THE '684 PATENT ARE NOT RENDERED OBVIOUS BY THE WANG DISSERTATION (GROUND 2)

236. As explained below, it is my opinion that the Wang Dissertation (Ex-1005) fails to render obvious claims 4, 6, 9, 15, 17, 20, and 23-24 of the '684 Patent.

237. Claim 4 of the '684 patent recites: "An apparatus as recited in claim 1, wherein the stress wave has a length ranging from approximately 5 nanoseconds to approximately 1 microsecond." As explained above, the Wang dissertation fails to anticipate independent claim 1. Thus, for this reason alone the Wang dissertation cannot render claim 4 obvious.

238. Petitioner has failed to show that the reference describes an overlapping range (in fact none exists because the Wang Dissertation fails to disclose a modified wave). Furthermore, a POSITA has no basis to even imagine the profile of this wave for which he or she would be trying to optimize its length through routine experimentation. If the POSITA does not even know what the wave profile looks like then the question of playing with numerous experimental parameters to modify its length would appear a totally random exercise. I do not know how this person would arrive at the invention disclosed in this dependent claim but if history is any guide it took me more than 25 years after the laser-generated stress profiles to be changed by inventing a thin waterglass layer to significantly reduce the size

of the laser pulse. For Dr. Wang to claim that such a reduction in the pulse length can be achieved by a POSITA even without knowing the profile of the wave is pure speculation and not credible.

239. Claim 6 of the '684 patent recites: An apparatus as recited in claim 1, wherein the coating has a thickness less than approximately $0.5\text{ }\mu\text{m}$.” As explained above, the Wang dissertation fails to anticipate independent claim 1. Thus, for this reason alone the Wang dissertation cannot render claim 6 obvious. Furthermore, without knowing the profile of the glass modified wave, which clearly is not present in the Wang-Dissertation, it is unclear as to how a POSITA would randomly reduce the thickness of the film with predictable results. In fact, In Dr. Wang’s own thesis, there are several tests where the failure is in the substrate. In some instances, a thicker film could not be separated but a thinner film could. Ability to separate a film depends upon numerous interdependent parameters. Interface tension is controlled not only by the thickness of the film but by its elastic constant that depends upon its atomic structure, the intrinsic tensile strength of the interface, the dispersion characteristics of the wave that is formed by the laser pulse, the rise time of the laser pulse, the energy of the laser pulse and the thickness and properties of the constraining waterglass layers. I wish it was so easy to test the interface strength of thinner films via routine experimentation because

then I would have done so by using the '402 technology and there would not be any need to invent the '684 technology.

240. Claim 9 of the '684 patent recites: "An apparatus as recited in claim 1, wherein the glass element has a thickness ranging from approximately 0.1 mm to approximately 5 mm." As explained above, the Wang dissertation fails to anticipate independent claim 13. Thus, for this reason alone the Wang dissertation cannot render claim 9 obvious. It is not clear how a POSITA would be guided in performing this routine experimentation if the profile of the wave is not even taught by the Wang dissertation. In fact, even if such a profile was known to the POSITA then these claims require that a POSITA know for each of the glass element type how the stress wave profile is not only maintained but it does not deteriorate in its amplitude significantly prior to reaching the coating interface. That is, a POSITA would have to do all of the theoretical analysis performed in chapter 2 of Wang dissertation and perform associated experiments detailed in chapter 3 for each of the glass element with the hope that the experimental data does not yield the negative surprise that Dr. Wang encounter where she failed to observe the decompression shock profile in the fused silica substrate. This is a non-trivial exercise, with unpredictable results.

241. Claim 15 of the '684 patent recites: "A method as recited in claim 13, wherein propagating a stress wave comprises propagating a stress wave having a

length ranging from approximately 5 nanoseconds to approximately 1 microsecond.” As explained above, the Wang dissertation fails to anticipate independent claim 13. Thus, for this reason alone the Wang dissertation cannot render claim 15 obvious. Furthermore, a POSITA has no basis to even imagine the profile of this wave for which he or she would be trying to optimize its length through routine experimentation!. If the POSITA does not even know what the wave profile looks like then the question of playing with numerous experimental parameters to modify its length would appear a totally random exercise. I do not know how this person would arrive at the invention disclosed in this dependent claim but if history is any guide it took me more than 25 years after the laser-generated stress profiles to be changed by inventing a thin waterglass layer to significantly reduce the size of the laser pulse. For Dr. Wang to claim that such a reduction in the pulse length can be achieved by a POSITA even without knowing the profile of the wave is pure speculation and not credible.

242. Claim 17 of the '684 patent recites: “A method as recited in claim 15, wherein the stress wave is configured to separate a coating having a thickness less than approximately 0.5 μm .” As explained above, the Wang dissertation fails to anticipate independent claim 13 and dependent claim 15. Thus, for this reason alone the Wang dissertation cannot render claim 17 obvious. Furthermore, without knowing the profile of the glass modified wave, which clearly is not present in the

Wang-Dissertation, it is unclear as to how a POSITA would randomly reduce the thickness of the film with predictable results. In fact, In Dr. Wang's own thesis, there are several tests where the failure is in the substrate. In some instances, a thicker film could not be separated but a thinner film could. Ability to separate a film depends upon numerous interdependent parameters. Interface tension is controlled not only by the thickness of the film but by its elastic constant that depends upon its atomic structure, the intrinsic tensile strength of the interface, the dispersion characteristics of the wave that is formed by the laser pulse, the rise time of the laser pulse, the energy of the laser pulse and the thickness and properties of the constraining waterglass layers. I wish it was so easy to test the interface strength of thinner films via routine experimentation because then I would have done so by using the '402 technology and there would not be any need to invent the '684 technology.

243. Claim 20 of the '684 patent recites: "A method as recited in claim 19, wherein the glass element has a thickness ranging from approximately 0.1 mm to approximately 5 mm." As explained above, the Wang dissertation fails to anticipate independent claim 13 and dependent claim 19. Thus, for this reason alone the Wang dissertation cannot render claim 20 obvious.

244. It is not clear how a POSITA would be guided in performing this routine experimentation if the profile of the wave is not even taught by the Wang

dissertation. In fact, even if such a profile was known to the POSITA then these claims require that a POSITA know for each of the glass element type how the stress wave profile is not only maintained but it does not deteriorate in its amplitude significantly prior to reaching the coating interface. That is, a POSITA would have to do all of the theoretical analysis performed in chapter 2 of Wang dissertation and perform associated experiments detailed in chapter 3 for each of the glass element with the hope that the experimental data does not yield the negative surprise that Dr. Wang encounter where she failed to observe the decompression shock profile in the fused silica substrate. This is a non-trivial exercise, with unpredictable results.

245. Claim 23 of the '684 patent recites: "A method as recited in claim 13, wherein the stress generated by the stress wave at the coating/substrate interface exceeds approximately 1.0 GPa." As explained above, the Wang dissertation fails to anticipate independent claim 13. Thus, for this reason alone the Wang dissertation cannot render claim 23 obvious. A POSITA after reading the Wang-Dissertation arguably would focus on enhancing the amplitude of the direct tension wave that causes all of the failures seen in that reference. The enhancement of the interface stress amplitude is not merely dependent upon the laser fluence as all of the parameters that I discussed above with respect to the length of the stress wave, and thickness of the film that can be tested, also govern the amplitude of the stress

wave. Additionally, if one were to simply increase the laser energy, there comes a point when the efficiency to the stress wave energy conversion decreases as the vaporized plume of laser absorbing material is ionized by the still incoming laser pulse and therefore its entire energy is not deposited into the laser absorbing layer. These are fairly sophisticated laser-material interaction effects governed by material's ionized states and as such not amenable to routine experimentation with predictable results for the generation of stress wave amplitude.

246. Claim 24 of the '684 patent recites: "A method as recited in claim 23, wherein the stress generated by the stress wave at the coating/substrate interface exceeds approximately 2.0 GPa." As explained above, the Wang dissertation fails to anticipate independent claim 13 or dependent claim 23. Thus, for this reason alone the Wang dissertation cannot render claim 24 obvious. A POSITA after reading the Wang-Dissertation would probably focus on enhancing the amplitude of the direct tension wave that causes all of the failures seen in that reference. The enhancement of the interface stress amplitude is not merely dependent upon the laser fluence as all of the parameters that I discussed above with respect to the length of the stress wave, and thickness of the film that can be tested, also govern the amplitude of the stress wave. Additionally, if one were to simply increase the laser energy, there comes a point when the efficiency to the stress wave energy conversion decreases as the vaporized plume of laser absorbing material is ionized

by the still incoming laser pulse and therefore its entire energy is not deposited into the laser absorbing layer. These are fairly sophisticated laser-material interaction effects governed by material's ionized states and as such not amenable to routine experimentation with predictable results for the generation of stress wave amplitude.

X. CLAIMS 1-24 OF THE '684 PATENT ARE NOT RENDERED OBVIOUS BY THE WANG DISSERTATION IN VIEW OF GUPTA 1992 (GROUND 3)

247. The Gupta-1992 reference is cumulative of the Wang-Dissertation. The Gupta-1992 reference discloses each and every disclosure that would be relevant to challenging the '684 patent claims that are present in the Wang dissertation.

Except for the direct tension wave, which is irrelevant to the technology disclosed on the '684 patent, every other disclosure is contained in the Gupta-1992 reference. In fact, Dr. Wang by her own admission confirms that the experimental apparatus shown in Fig. 2 (b) of the Gupta-1992 reference is the same she describes through words in the "Future Work" section of her thesis. Gupta-1992 does not cure any of the deficiencies in the Wang Dissertation discussed above.

248. Gupta-1992 reference already shows how, much stronger interfaces than those shown in Wang-Dissertation, can be separated from the interface by using laser-generated stress waves. Like the Wang-Dissertation it shows a regular compression wave with no sharp post-peak decay. There is no disclosure in the

Wang-Dissertation of the decompression shock in fused silica that is any different than what was already known from Barker and Hollenback's work. That is, a POSITA would still have the same knowledge from Barker and Hollenback's work from the 1970 which existed at the time of the Gupta-1992 reference.

249. Notwithstanding the above, I have carried out an analysis assuming that a POSITA would have the knowledge disclosed in both the Gupta 1992 and Wang-Dissertation.

250. As explained below, it is my opinion that the alleged combination of the Wang Dissertation (Ex-1005) and Gupta 1992 fail to render obvious claims 1-24 of the '684 Patent.

251. First, it would not have been obvious to combine the teachings of the Wang Dissertation with those of Gupta 1992.

252. A primary motivation of the Wang Dissertation is disclosed as being to measure the tensile strength of thin film interface. Ex-1005, generally. Throughout her Dissertation, failures were not shown to be at the interface but rather inside the substrate. It is noteworthy that the thinnest film she tested in her Dissertation was 0.3 micrometers thick. The highest level of interface tension she created in all of her works was less than 0.6 GPa (Table 3.4 and Table 3.7).

253. A POSITA reviewing the Gupta-1992 reference would readily conclude that interfacial tension exceeding 1 GPa could be routinely achieved prior to Wang's Dissertation.

254. Dr. Wang fails to articulate why she did not start her Dissertation research with the Gupta 1992 Fig. 2 (b) arrangement she puts in her future work section. After all, through several of my publications long before the start of Dr. Wang's Ph.D. research, I had already shown that laser-generated stress waves can be used to measure the tensile strengths of thin film interfaces; and both experimental observations and theories related to the development of decompression shocks in fused silica were already well known as early as 1970 from the work in the Barker and Hollenbeck's group at the Sandia National Lab-something both Dr. Wang and I have acknowledged in our publications.

255. In her deposition, Dr. Wang was asked if she had tried the arrangement she proposed in her "Future Work" section and she said she did and that work was published in 2006, years after the '684 patent was filed. Ex-2009, 160

256. Additionally, as explained above, both the Wang Dissertation and Gupta 1992 fail to disclose certain elements of the challenged claims. Specifically for example:

257. Claim 1 of the '684 Patent Recites:

[1.pre]⁷ An apparatus for generating a tensile stress between a Substrate and a coating, comprising:

[1.a] a Substrate having a thickness, said thickness defined by a first side and a second side in a first axis;

[1.b] a coating applied to the first side of the substrate such that the coating and substrate are axially spaced along the first axis in intimate facing contact with each other such to form a coating/substrate interface; and

[1.c] a glass element disposed on the second side of the substrate and axially spaced along the first axis;

[1.d] wherein the glass element is configured to propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating.

258. In my opinion, the alleged combination of the Wang Dissertation and Gupta 1992 fails to disclose claim 1 elements [1.c] and [1.d]. I explain below.

259. Claim element [1.c] requires the glass element to be disposed on the second side of the substrate and axially spaced along the first axis. Fused silica is not a glass element of the '684 patent because of several reasons already discussed in my declaration. First and foremost, neither Dr. Wang nor I were able to observe the formation of decompression shock when the unmodified stress wave

⁷ Using claim element numbers proposed by Petitioner.

transmitted through the fused silica substrate. The laser generated stress wave remained unmodified after its transmission through fused silica, as evidence by Fig. 3.19 in the Wang dissertation and Figs. 10, 11, and 15 in the Gupta-1992 reference. What Dr. Wang calls in her entire thesis work a decompression shock is merely an unloading in the unmodified wave caused by the direct tension wave. Theoretically, as discussed in chapter 2 of Dr. Wang's thesis, the decompression shock is formed in fused silica soon after the unmodified wave enters the fused silica substrate. As the Wang dissertation also explains, a dramatic reduction in its amplitude then occurs soon after its formation and as Fig. 2.12 in her dissertation shows, the wave can lose almost 80% to 90% of its amplitude at wave amplitudes (1 GPa and higher) that are of interest to the laser spallation technique. This occurs when the wave has propagated only 1 mm to 6 mm distance into the fused silica substrate which are the practical ranges of glass element thickness used in the '684 patent or a POSITA would try to recreate the arrangement suggested by Dr. Wang in her "Future Work" section of her dissertation. At such lower stresses, the stress wave would lose its shock character or profile, as demonstrated by both Fig. 3.19 in the Wang dissertation and Fig. 15 in the Gupta-1992 reference. Such a large reduction in stress will make it impossible to separate the film from the interface, with or without the rarefaction shock profile. This will become even more untenable especially when the modified wave has to transit into a new

substrate and propagate through its entire thickness before arriving at the film interface.

260. Second, the alleged combination of the Wang Dissertation and Gupta 1992 fails to disclose [1.d] “wherein the glass element is configured to propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating” as recited in claim 1 of the ’684 Patent. (1) As already discussed fused silica is not a glass element in the Wang-Dissertation as it does not modify the compression wave to result in a rarefaction shock. Instead, what Dr. Wang erroneously claims as decompression shock is merely an unloading caused at the rear end of the compression wave. Evidence in both Gupta-1992 reference and Wang-Dissertation makes it clear that the pure compression wave does not have the rarefaction shock profile when it arrives at the film interface. Even if it were to be present at the rear end of the compression wave, the direct tension wave totally neutralizes it or removes it prior to that shock portion ever reaching the interface. This can be conclusively stated based on my detailed analysis of Dr. Wang’s thesis data, which included proving the tension wave profile matches with the tensile stress history at the interface (*see* composite illustration shown in paragraph 74); higher tensile stress reported at the aluminum/fused silica interface that are greater than the maximum possible tension that could be generated by the direct compression wave because of its amplitude

(analysis of the data in Tables 3.4 and 3.7) and the significant attenuation effects that results in loss of shock profile. (2) The ramp portion of the compression wave does not cause any tension as when the front portion of this ramp when reflects into a tensile stress from the free surface of the film, there is a much larger compression wave amplitude from the initial compression wave still sitting at the interface that not only would neutralize this small tension but it would result in a net compressive stress at the interface. As already shown in the composite illustration shown, the building-up and peaking of the tension at the interface shown in Fig. 3.15d of the Wang thesis matches generally with the expected profile of the tension wave, including its rise-time and post-peak stress decay. The fringe record in Fig. 3.15a beyond the 30ns mark till 50 ns would correspond to the decaying portion of the tension wave, which is further proof that even this unmodified compression wave has not yet arrived at the interface and the entire experiment of Dr. Wang was over. Evidence in both the Wang-Dissertation and Gupta-1992 reference clearly shows the rear end of the compression wave does not have the rarefaction shock profile so even if it were to ever arrive at the interface it would be created by the reflection of the unmodified wave which would not qualify as tension generated as per the claim requirement. (3) The tension wave is not modified when it passes through fused silica as the non-linear stress-strain relationship that results in the prediction of the formation of decompression shock

is only shown to be valid under compression. This can be confirmed by reviewing the Barker and Hollenbeck's reference from where Dr. Wang has directly taken the stress-strain relationship shown on page 27 of her thesis. Dr. Wang also confirmed this in her deposition. By making statements throughout her thesis that the tension wave speed is greater than the compression wave, Dr. Wang is inherently acknowledging that the tension wave propagates without undergoing any modification by the fused silica material. She also confirmed in her deposition that equation 92.47), taken from Barker and Hollenbeck's work, was valid only under compression. Perhaps most telling is the hard evidence present in Dr. Wang's own dissertation in all of her stress wave profiles in the fused silica substrate (except Fig. 3.19) where all unloading of the stress from the ramp of the initial compression wave occurs along a sharp rise-time, all with same slopes, which clearly are due to the arrival of the direct tension wave. The risetime of the tension wave is clearly sharp even after it has propagated the entire thickness of the substrate and no way displays the long ramp profile that was formed under compression. Dr. Wang agreed that at least the portion of this unloading, from point B to point C (Fig. 4), belongs to the direct tension wave, means that even she agrees that the tension wave has not modified in its character as clearly the portion of tension wave from point B to point C is rather sharp and does not display the ramp that would be expected if it were to be modified by the glass element.

Furthermore, the fringe record beyond 30ns, which she did not resolve but testified that it would belong to the tension wave of significant lower stress would further prove that the tension wave does not form the rarefaction shock as if it did one would see an extremely high fringe frequency which is absent. Therefore Dr. Wang and I are in agreement on this issue and this is also supported by hard evidence in her dissertation that the tension wave is ***not modified*** by the glass element and its original sharp rise-time and post-peak decay profile largely remain intact from its generation point at the laser absorbing film to all the way to the film interface.

261. In conclusion, none of these references, taken together, and even combining the knowledge and experience of a POSITA can cure the major deficiency in these references which is the lack of the teaching of a pure compression stress wave with a rarefaction shock profile. Thus, as already explained, this combination will not disclose the glass modified stress wave limitation and generating the tensile stress upon reflection from the coating's free surface as required by independent claim 1 of the '684 patent and separating the coating by generating a tensile stress of sufficient amplitude in the same manner as required by claim 13.

262. Since the alleged combination of the Wang Dissertation and Gupta 1992 fails to disclose each and every element of claim 1, in my opinion the combination fails to render obvious claim 1 of the '684 Patent.

263. I noticed that while performing her invalidity analysis, Dr. Wang uses analysis that is technically infeasible. For example, for dependent claims dealing with film thickness, pulse length, pulse amplitude, level of interface stress, etc., Dr. Wang points to specific data in her thesis totally forgetting that all her data was acquired by not the arrangement she has proposed in the future work section of her thesis but rather by using the prior art '402 patent arrangement. There is absolutely no reason to believe that all those experimental observations would be replicated by the '684 apparatus. In fact, as already discussed at length in my declaration, they will not. There are numerous parameters such as laser fluence, thickness of the film, laser pulse profile, laser energy, area of laser impingement, constraining layer thickness and its elastic properties, thickness and elastic constants of the substrate material, thickness, type, absorptivity of the laser absorbing layer, to just name a few. These parameters collectively, and through their interdependency that is driven by multi-scale physical phenomenon that span mechanics, materials, wave dynamics, and high energy materials physics, ultimately govern the generation and propagation of the stress wave that ultimately decides if the film will spall or not. It is anything but routine experimentation. This is the reason that

it took me several years after the issue of the '402 patent to come up with the '684 invention. Dr. Wang has failed to recognize this aspect of laser spallation experiment and used results obtained from the prior art arrangement as a basis to perform her analysis of the dependent claims without appreciating that the dependent claims also inherit the limitations of the independent claims 1 and 13, which she had planned in the future.

264. Claim 13 of the '684 Patent recites:

[13.pre] A method for separating a coating from a substrate, the substrate having a first side and a second side transversely disposed in a first axis, the coating applied to the first side of the substrate such that the coating and substrate are axially spaced along the first axis in intimate facing contact to form a coating/substrate interface, the method comprising:

[13.a] positioning a glass element along the first axis on the second side of the substrate;

[13.b] directing a laser pulse in the first axis at the glass element;

[13.c] propagating and modifying a stress wave through the glass element to the coating/substrate interface to generate a tensile force between the Substrate and the coating; and

[13.d] separating the coating from the Substrate as a result of the stress wave-generated tensile force.

265. In my opinion, and as explained above, the alleged combination of the Wang Dissertation and Gupta 1992 fails to teach elements [13a]-13[d].

266. As discussed with respect to claim 1 analysis, fused silica is not a glass element, which is a requirement of this limitation. Fused silica behaves as a regular substrate in the context of this claim.

267. This limitation also requires that the laser pulse be directed at the glass element which in turn is absent in the Wang-Dissertation.

268. Limitations of this claim element are not met because of several reasons already discussed with respect to my analysis for claim 1. First and foremost the compression stress wave is not modified. See my claim 1 analysis why this is so. Next, the tensile force in Dr. Wang's dissertation was generated by the direct tension wave and had nothing to do with the modified compression wave which did not even exist let alone it creating a tensile force at the film interface. It can be concluded without doubt that the tension is created by the direct tension wave for all of the reasons I have already discussed as to why claim 1 is not anticipated by the Wang-Dissertation.

269. With respect to element [13d], as described in the Wang Dissertation and above, all film separations in the Wang Dissertation are caused by the direct tension wave. The tension wave is not modified by the glass element for the various reasons I have discussed in my claim 1 analysis. A compression wave with

rarefaction shock profile is required by this claim element to generate the tensile force for film separation upon reflection from the free surface of the coating. The ramp portion of the compression wave cannot generate any tension at the interface. The fringe record does not support any late arrivals of any decompression shock as the fringe frequency is very low as per Dr. Wang's own admission in her deposition. Fig. 3.19 proves that a rarefaction shock profile is never generated inside the fused silica material in Dr. Wang's dissertation. The tension at the film interface is built by the direct tension wave and not even by the unmodified compression wave let alone by the modified compression wave which does not exist anywhere in the Wang-Dissertation.

270. Since the alleged combination of the Wang Dissertation and Gupta 1992 fails to render obvious every element of claim 1, in my opinion the combination fails to render obvious claim 13 of the '684 Patent.

271. Claim 3 recites: "An apparatus as recited in claim 1, wherein the glass is configured to propagate the stress wave as a result of impingement by a Nd-Yag laser beam directed in the first axis." In my opinion neither the Wang Dissertation nor the Gupta-1992 reference discloses this claim limitation and as such there is no teaching in any of these references to direct a POSITA to come up with a glass element that would modify a compression stress wave into one having a rarefaction shock profile. The fused silica and fused quartz in these two references are not

glass and there are no teachings in them to motivate a POSITA to look for alternative glass elements.

272. Claim 5 of the '684 Patent recites: "An apparatus as recited in claim 4, wherein the stress wave comprises a rarefaction shock formation." In my opinion neither the Wang Dissertation nor the Gupta-1992 reference discloses this claim limitation and as such there is no teaching in any of these references to direct a POSITA to come up with a glass element that would modify a compression stress wave into one having a rarefaction shock profile and then use it to perform the '684 experiments. It is noteworthy that the knowledge that fused silica can form decompression shock was known from the Barker and Hollenbeck's work from the 1970 so the fact that it took me several years to come up with the '684 invention is tell-tale evidence that finding a new glass element was outside the scope of a POSITA through routine experimentation.

273. Claim 15 of the '684 Patent recites: "A method as recited in claim 13, wherein propagating a stress wave comprises propagating a stress wave having a length ranging from approximately 5 nanoseconds to approximately 1 microsecond." In my opinion the Wang Dissertation in combination with Gupta 1992 reference fails to teach the limitations of claim 15. As explained above, both the Wang dissertation and the Gupta 1992 reference together cannot render claim 13 obvious. Thus, for this reason alone the Wang dissertation cannot render claim

15 obvious. There is no disclosure of any glass modified wave in these two references. Therefore, a POSITA has no basis to even imagine the profile of this wave for which he or she would be trying to optimize its length through routine experimentation! If the POSITA does not even know what the wave profile looks like then the question of experimenting with numerous experimental parameters to modify its length would appear a random exercise. I do not know how this person would arrive at the invention disclosed in this dependent claim but if history is any guide it took me more than 25 years after the laser-generated stress profiles to be changed by inventing a thin waterglass layer to significantly reduced the size of the laser pulse. For Dr. Wang to claim that such a reduction in the pulse length can be achieved by a POSITA even without knowing the profile of the wave is pure speculation and not credible.

274. Claim 2 of the '684 Patent recites: "An apparatus as recited in claim 1, wherein the tensile stress is configured to separate the coating from the Substrate at the coating/substrate interface. " In my opinion the Wang Dissertation in combination with Gupta 1992 reference fails to teach the limitations of claim 2. Claim 2 depend from claim 1 and therefore it inherits all limitations of claim 1 which as I have already analyzed is not rendered obvious by the combination of these two references. Claim 2 has the additional requirement that the "tensile stress is so configured" to separate the coating from the coating/substrate interface.

By depending upon claim 1, this claim requires that the tension be generated by the modified compression wave with the rarefaction shock profile upon reflection from the free surface of the coating. As already discussed, the tension is generated by the direct tension wave and not even by the unmodified compression wave in the Wang dissertation let alone by the modified wave. Therefore, all film separations discussed in the Wang-Dissertations fall outside the scope of this claim limitation. Similarly, all film separations are caused by the unmodified wave in the Gupta 1992 reference. There are no teachings in these two references to direct a POSITA to make the limitations of this claim element obvious. Essentially what Dr. Wang and Boeing are expecting from a POSITA to do is to essentially invent the glass elements disclosed in the '684 invention based on the knowledge of decompression shock in fused silica that already existed from 1970 and the results of spallation experiments disclosed in the Gupta 1992 reference. I would certainly qualify as a POSITA in 1992. I certainly had the knowledge of decompression shock in fused silica from the Barker and Hollenbeck's work. In fact, I was even aware of that fact that the very combination Dr. Wang is basing her entire declaration on did not result in the generation of tensile force at the interface to cause failure of coatings at the interface. With all that knowledge I still took several years before coming up with the '684 invention. This clearly shows that '684 invention was not

something a POSITA could come up with by merely performing routine experimentation based on the prior art '402 technology.

275. Claim 4 recites: "An apparatus as recited in claim 1, wherein the stress wave has a length ranging from approximately 5 nanoseconds to approximately 1 microsecond." In my opinion the Wang Dissertation in combination with Gupta 1992 reference fails to teach the limitations of claim 4. As explained above, both Gupta 1992 and the Wang dissertation fail to teach each and every element of claim 1, from which claim 4 depends. Thus, for this reason alone, these two references cannot render claim 4 obvious. Furthermore, both Wang dissertation and Gupta 1992 fail to teach the specific limitations of this claim as the length of the wave this claims refers to is the glass modified wave which as already discussed is not disclosed anywhere in these references. There are no teachings in these two references to direct a POSITA to arrive at the invention claimed by claim 4 limitation. Essentially what Dr. Wang and Boeing are expecting from a POSITA to do is to essentially invent the glass elements disclosed in the '684 invention based on the knowledge of decompression shock in fused silica that already existed from 1970 and the results of spallation experiments disclosed in the Gupta 1992 reference. I would certainly qualify as a POSITA in 1992. I certainly had the knowledge of decompression shock in fused silica from the Barker and Hollenbeck's work. In fact, I was even aware of that fact that the very

combination Dr. Wang is basing her entire declaration on did not result in the generation of tensile force at the interface to cause failure of coatings at the interface. With all that knowledge I still took several years before coming up with the '684 invention. This clearly shows that claim 2 invention was not something a POSITA could come up with by merely performing routine experimentation based on the prior art.

276. Claim 6 recites: "An apparatus as recited in claim 1, wherein the coating has a thickness less than approximately 0.5 μm ." As explained above, both the Gupta 1992 and Wang dissertation fail to teach each and every element of claim 1, from which claim 6 depends. Thus, for this reason alone, these two references cannot render claim 6 obvious to a POSITA. Furthermore, these references fail to teach this limitation because it requires the coatings with the claimed thicknesses to be separated from the interface by the glass modified wave. It is not merely sufficient to point out the coating thicknesses that are tested by the setup and stress waves used in these two references as they use the technique which was disclosed as prior art in the '684 patent. The USPTO examiner agreed with this characterization. Essentially what Dr. Wang and Boeing are expecting from a POSITA to do is to essentially invent the glass elements disclosed in the '684 invention based on the knowledge of decompression shock in fused silica that already existed from 1970 and the results of spallation experiments disclosed in the

Gupta 1992 reference. I would certainly qualify as a POSITA in 1992. I certainly had the knowledge of decompression shock in fused silica from the Barker and Hollenbeck's work. In fact, I was even aware of that fact that the very combination Dr. Wang is basing her entire declaration on did not result in the generation of tensile force at the interface to cause failure of coatings at the interface. With all that knowledge I still took several years before coming up with the '684 invention. This clearly shows that claim 6 invention was not something a POSITA could come up with by merely performing routine experimentation based on the prior art.

277. Claim 7 recites: "An apparatus as recited in claim 1, wherein the glass element is bonded to the second side of the substrate." As explained above, both the Wang dissertation and Gupta 1992 fail to teach each and every element of claim 1, from which claim 7 depends. Thus, for this reason alone, these references cannot make claim 7 obvious. Claim 7 requires that the glass element be bonded to the second side of the substrate. Both these references fail to teach a glass element that is able to modify a compression stress wave so that it results in the formation of rarefaction shock. None of the substrate materials, fused silica, or fused quartz disclosed in these references modify the stress wave with the profile as required by this claim. There is no direction to a POSITA as to how he or she would carry out a search for new glass elements. What Dr. Wang and Boeing are expecting from a

POSITA to do is to essentially invent the glass elements disclosed in the '684 invention based on the knowledge of decompression shock in fused silica that already existed from 1970 and the results of spallation experiments disclosed in the Gupta 1992 reference. I would certainly qualify as a POSITA in 1992. I certainly had the knowledge of decompression shock in fused silica from the Barker and Hollenbeck's work. In fact, I was even aware of that fact that the very combination Dr. Wang is basing her entire declaration on did not result in the generation of tensile force at the interface to cause failure of coatings at the interface. With all that knowledge I still took several years before coming up with the '684 invention. This clearly shows that claim 7 invention was not something a POSITA could come up with by merely performing routine experimentation based on the prior art.

278. Claim 8 recites: "An apparatus as recited in claim 1, wherein the glass element comprises one of the following: Pyrex, soda lime, quartz, or borosilicate." As explained above, both the Wang dissertation and Gupta 1992 fail to teach each and every element of claim 1, from which claim 8 depends. Thus, for this reason alone, these references cannot anticipate claim 8. Claim 8 requires that the glass element be made from Pyrex, quartz, borosilicate, or soda lime materials. Through its dependency on claim 1 it requires that these glass elements be able to modify a compression wave into a wave with rarefaction shock profile. The fused quartz in

the Gupta-1992 and fused silica in the Wang-dissertation do not modify the stress wave. They simply disclose ordinary substrates. Dr. Wang in her declaration simply points to the presence of fused quartz in Fig. 2 (b) of this reference. While analyzing this reference for claim 8, she is driven by her erroneous conclusion from her own dissertation that fused silica is a glass element because it modifies the stress wave to result in a profile with the rarefaction shock. By analyzing the data in the Wang-thesis, I have already shown that those claims are false as what she calls a rarefaction shock is an unloading caused by the tension wave. The same is true for the Gupta 1992 reference which shows no evidence of any glass modified wave. Essentially what Dr. Wang and Boeing are expecting from a POSITA to do is to essentially invent the glass elements disclosed in the '684 invention based on the knowledge of decompression shock in fused silica that already existed from 1970 and the results of spallation experiments disclosed in the Gupta 1992 reference. I would certainly qualify as a POSITA in 1992. I certainly had the knowledge of decompression shock in fused silica from the Barker and Hollenbeck's work. In fact, I was even aware of that fact that the very combination Dr. Wang is basing her entire declaration on did not result in the generation of tensile force at the interface to cause failure of coatings at the interface. With all that knowledge I still took several years before coming up with the '684 invention. This clearly shows that claim 8 invention was not something a

POSITA could come up with by merely performing routine experimentation based on the prior art.

279. Claim 9 recites, “An apparatus as recited in claim 1, wherein the glass element has a thickness ranging from approximately 0.1 mm to approximately 5 mm.” As explained above, both the Wang dissertation and Gupta 1992 fail to teach each and every element of claim 1, from which claim 9 depends. Thus, for this reason alone, these references cannot make claim 9 limitations obvious to a POSITA. It is not clear how a POSITA would be guided in performing this routine experimentation if the profile of the wave is not even taught by these references. In fact, even if such a profile was known to the POSITA then these claims require that a POSITA know for each of the glass element type how the stress wave profile is not only maintained but it does not deteriorate in its amplitude significantly prior to reaching the coating interface. That is, a POSITA would have to do all of the theoretical analysis performed in chapter 2 of Wang dissertation and perform associated experiments detailed in chapter 3 for each of the glass element with the hope that the experimental data does not yield the negative surprise that Dr. Wang encountered where she failed to observe the decompression shock profile in the fused silica substrate. This is a non-trivial exercise, with unpredictable results. Essentially what Dr. Wang and Boeing are expecting from a POSITA to do is to essentially invent the glass elements disclosed in the ‘684 invention based on the

knowledge of decompression shock in fused silica that already existed from 1970 and the results of spallation experiments disclosed in the Gupta 1992 reference. I would certainly qualify as a POSITA in 1992. I certainly had the knowledge of decompression shock in fused silica from the Barker and Hollenbeck's work. In fact, I was even aware of that fact that the very combination Dr. Wang is basing her entire declaration on did not result in the generation of tensile force at the interface to cause failure of coatings at the interface. With all that knowledge I still took several years before coming up with the '684 invention. This clearly shows that claim 9 invention was not something a POSITA could come up with by merely performing routine experimentation based on the prior art.

280. Claim 10 recites: "An apparatus as recited in claim 1, wherein the substrate comprises silicon," As explained above, both the Wang dissertation and Gupta 1992 reference fail to teach each and every element of claim 1, from which claim 10 depends. Thus, for this reason alone, these references cannot make claim 10 limitations obvious to a POSITA. Gupta 1992 fails to disclose or suggest the specific limitations of this claim because Si was not tested in the arrangement shown in Fig. 2 (b). Even if for whatever reasons it is considered tested as part of that arrangement the Gupta-1992 reference would still not meet this limitation because it requires that silicon be a part of an apparatus where a glass modified wave enters its thickness from the side opposite to where the test coating interface

is located. That would be the side attached to the fused quartz disc. Since fused quartz is not a glass element it cannot propagate and modify a wave into the Si substrate. For all these reasons the Gupta-1992 reference does not have any teachings that would guide a POSITA to come up with the arrangement shown in Fig. 2 (b) and then find a glass element that would modify the wave as the disclosed fused quartz does not modify the compression stress wave and hence does not qualify as a glass element of the '684 invention. The Wang dissertation suffers from the same deficiency in that the silicon substrate is not attached to a glass element as required by the claim 1 limitation as the fused silica does not modify the stress wave. Furthermore there are no teachings in the Wang dissertation that would motivate a POSITA to search for new glass elements that would generate and propagate a modified wave with a rarefaction shock profile into a silicon substrate. Therefore in light of the above discussion, this claim element cannot be rendered obvious by the Wang dissertation in view of the Gupta-1992 reference.

281. Claim 11 recites: "An apparatus as recited in claim 1, further comprising a constraining element disposed adjacent to the glass element." As explained above, both the Wang dissertation and Gupta 1992 fail to teach each and every element of claim 1, from which claim 11 depends. Thus, for this reason alone, these references cannot make claim 11 obvious. None of these references disclose

a glass element. Both use fused quartz or fused silica as a wave propagation medium and none show that these materials are able to modify a wave with a rarefaction shock profile. Since the aim of these references is not to search for alternative glass elements, a POSITA would not be motivated to search for a glass element that would modify a wave with a rarefaction shock. Without that goal, the learnings from these two references will not take a POSITA to the claimed invention through routine experimentation. Therefore these two references in combination cannot render claim 11 obvious.

282. Claim 12 recites: “An apparatus as recited in claim 11, further comprising an energy absorbing layer disposed between the constraining layer and the glass element.” As explained above, both the Wang dissertation and Gupta 1992 fail to render claim 11 obvious by not being able to take a POSITA to come up with an alternative glass element through routine experimentation. Absent the glass element, the question of locating the energy absorbing film would not even arise and a POSITA would end up placing such a film between the constraining layer and an ordinary substrate to yield prior art. Routine experimentation by changing the experimental variables taught in the Gupta 1992 and Wang-Dissertation would not take a POSITA to the claim 12 invention.

283. Claim 14 recites: “A method as recited in claim 13, wherein directing a laser pulse in the first axis comprises directing a Nd-Yag laser beam in the first

axis.” As explained above, both the Wang dissertation and Gupta 1992 fail to teach each and every element of claim 13, from which claim 14 depends. Thus, for this reason alone, these references cannot make claim 14 obvious. This claim element requires that the laser pulse be directed along the axis of an assembly that contains a wave modifying glass element. None of these references disclose a glass element. Both use fused quartz or fused silica as a wave propagation medium and none show that these materials are able to modify the stress wave into one with a rarefaction shock profile. Since the aim of these references is not to search for alternative glass elements, a POSITA would not be motivated to search for a glass element that would modify a wave with a rarefaction shock. Without that goal, the learnings from these two references will not take a POSITA to the claimed invention through routine experimentation. Therefore these two references in combination cannot render claim 14 obvious.

284. Claim 15 recites: “A method as recited in claim 13, wherein propagating a stress wave comprises propagating a stress wave having a length ranging from approximately 5 nanoseconds to approximately 1 microsecond.” As explained above, both these references fail to teach each and every element of claim 13, from which claim 15 depends. Thus, for this reason alone, these references cannot render claim 15 as obvious to a POSITA. Furthermore, both these references specifically fail to teach this claim limitation as there is no wave disclosed in these

references with a rarefaction shock profile that is generated by a glass element. Therefore, any length of the stress wave that is disclosed in these references fall outside the scope of this claim which requires these waves to have a rarefaction shock profile. While analyzing these references, Dr. Wang is driven by her erroneous conclusion from her own dissertation that both fused silica and fused quartz are glass elements because they modify the stress wave to result in a profile with the rarefaction shock. By analyzing the data in the Wang-thesis, I have already shown that those claims are false as what she calls a rarefaction shock is an unloading caused by the tension wave. In the absence of such a teaching, a POSITA would be merely optimizing the experimental variables to control the length of the stress waves without the rarefaction profile. What Dr. Wang and Boeing are expecting from a POSITA to do is to essentially invent the glass elements disclosed in the '684 invention based on the knowledge of decompression shock in fused silica that already existed from 1970 and the results of spallation experiments disclosed in the Gupta 1992 reference. I would certainly qualify as a POSITA in 1992. I certainly had the knowledge of decompression shock in fused silica from the Barker and Hollenbeck's work. In fact, I was even aware of that fact that the very combination Dr. Wang is basing her entire declaration on did not result in the generation of tensile force at the interface to cause failure of coatings at the interface. With all that knowledge I still took several years before coming

up with the '684 invention. This clearly shows that claim 15 invention was not something a POSITA could come up with by merely performing routine experimentation based on the prior art.

285. Claim 16 recites: “A method as recited in claim 15, wherein the stress wave comprises a rarefaction shock formation.” As explained above, both these references fail to teach the claim limitations of claim 13, from which claim 15 depends. Thus, for this reason alone, these references cannot render claim 15 as obvious to a POSITA. Furthermore, both these references specifically fail to teach this claim limitation as there is no wave disclosed in these references with a rarefaction shock profile. Since the aim of these references is not to search for alternative glass elements, a POSITA would not be motivated to search for a glass element that would modify a wave with a rarefaction shock profile. Without that goal, the learnings from these two references will not take a POSITA to the claimed invention through routine experimentation. Therefore these two references in combination cannot render claim 16 obvious.

286. Claim 17 of the '684 patent recites: “A method as recited in claim 15, wherein the stress wave is configured to separate a coating having a thickness less than approximately 0.5 μm .” As explained above, both Gupta 1992 and Wang dissertation fail to render both claims 13 and 15 obvious to a POSITA on which claim 17 depends. Thus, for this reason alone these two references cannot render

claim 17 obvious. Furthermore, without knowing the profile of the glass modified wave, which clearly is not present in these two references, it is unclear as to how a POSITA would randomly reduce the thickness of the film with predictable results. In fact, In Dr. Wang's own thesis, there are several tests where the failure is in the substrate. In some instances, a thicker film could not be separated but a thinner film could. Ability to separate a film depends upon numerous interdependent parameters. Interface tension is controlled not only by the thickness of the film but by its elastic constant that depends upon its atomic structure, the intrinsic tensile strength of the interface, the dispersion characteristics of the wave that is formed by the laser pulse, the rise time of the laser pulse, the energy of the laser pulse and the thickness and properties of the constraining waterglass layer. I wish it was so easy to test the interface strength of thinner films via routine experimentation because then I would have done so by using the '402 technology and there would not have been any need to invent the '684 technology.

287. Claim 18 recites: "A method as recited in claim 15, wherein positioning a glass element along the first axis comprises bonding the glass element to the second side of the substrate." As explained above, both these references fail to teach each and every element of independent claim 13 and dependent claim 15, from which claim 18 depends. Thus, for this reason alone, the teachings in these references would not make claim 18 invention obvious to a POSITA. Furthermore,

both these references fail to teach this limitation as fused quartz is bonded to the substrate in the Fig. 2(b) of the Gupta-1992 reference. As already discussed, fused quartz is not a glass element as used in this reference. Similarly the suggestion made by Dr. Wang in the future work section of her thesis does not have a glass element bonded to the substrate. There are no teachings that would guide a POSITA to arrive at this claim limitation as it would first require the POSITA to invent a new glass element which would be tantamount to essentially asking the POSITA to make the '684 invention back in 1992 through routine experimentation. This is because the formation of decompression shock was already known to a POSITA like myself, and experimental results from Gupta 1992 reference were known soon after its publication. If it was that easy I would have arrived at the '684 invention fairly easily as I have continuously researched this field from 1986 till today.

288. Claim 19 recites: "A method as recited in claim 13, wherein the glass element comprises one of the following: Pyrex, soda lime, quartz, or borosilicate." As explained above, both these references fail to teach each and every element of the independent claim 13, from which claim 19 depends. Thus, for this reason alone, these references cannot render claim 19 obvious. Claim 19 requires that the glass element be made from Pyrex, quartz, borosilicate, or soda lime materials. Through its dependency on claim 1 it requires that these glass elements be able to

modify a compression wave into a wave with rarefaction shock profile. The fused quartz and fused silica in the Gupta-1992 and Wang dissertation references do not modify the stress wave. They would just teach a POSITA an ordinary substrate that does not modify the compression stress wave. Dr. Wang in her declaration simply points to the presence of fused quartz in Fig. 2 (b) of the Gupta 1992 reference. While analyzing this reference for claim 19, she is driven by her erroneous conclusion from her own dissertation that fused silica is a glass element because it modifies the stress wave to result in a profile with the rarefaction shock. By analyzing the data in the Wang-Dissertation, I have already shown that those claims are false as what she calls a rarefaction shock is an unloading caused by the tension wave. In the absence of any teachings of glass element, what Boeing and Dr. Wang are essentially expecting from a POSITA is to invent a new glass element which as already discussed cannot be obtained through routine experimentation of prior art.

289. Claim 20 of the '684 patent recites: "A method as recited in claim 19, wherein the glass element has a thickness ranging from approximately 0.1 mm to approximately 5 mm." As explained above, both the Wang dissertation and Gupta 1992 reference fail to render both claim 13 and claim 19 obvious to a POSITA. Thus, for this reason alone these two references cannot render claim 20 obvious.

290. It is not clear how a POSITA would be guided in performing this routine experimentation if the profile of the wave is not even taught by these two references. In fact, even if such a profile was known to the POSITA then these claims require that a POSITA know for each of the glass element-type how the stress wave profile is not only maintained but it does not deteriorate in its amplitude significantly prior to reaching the coating interface. That is, a POSITA would have to do all of the theoretical analysis performed in chapter 2 of Wang dissertation and perform associated experiments detailed in chapter 3 for each of the glass element with the hope that the experimental data does not yield the negative surprise that Dr. Wang encountered where she failed to observe the decompression shock profile in the fused silica substrate. This is a non-trivial exercise, with unpredictable results.

291. With no teachings of any glass element in these references, it is impossible to imagine how a POSITA would even start as the goal is not even known! What Dr. Wang and Boeing are expecting from a POSITA to do is to essentially invent the glass elements disclosed in the '684 invention based on the knowledge of decompression shock in fused silica that already existed from 1970 and the results of spallation experiments disclosed in the Gupta 1992 reference. I would certainly qualify as a POSITA in 1992. I certainly had the knowledge of decompression shock in fused silica from the Barker and Hollenbeck's work. In

fact, I was even aware of that fact that the very combination Dr. Wang is basing her entire declaration on did not result in the generation of tensile force at the interface to cause failure of coatings at the interface. With all that knowledge I still took several years before coming up with the '684 invention. This clearly shows that claim 15 invention was not something a POSITA could come up with by merely performing routine experimentation based on the prior art.

292. Claim 21 recites: “A method as recited in claim 13, further comprising positioning a constraining element adjacent to a free side of the glass element.” As explained above, both the Wang dissertation and Gupta 1992 reference fail to render both claim 13 obvious to a POSITA. Thus, for this reason alone these two references cannot render claim 21 obvious. This claim requires that the constraining element be placed next to the glass element. The problem is none of these references disclose a glass element. Both use fused quartz or fused silica as a wave propagation medium and none show that these materials are able to modify the stress wave into one with a rarefaction shock profile. Since the aim of these references is not to search for alternative glass elements, a POSITA would not be motivated to search for a glass element that would modify a wave with a rarefaction shock. Without that goal, the learnings from these two references will not let POSITA bring in a glass element into the sample assembly and therefore it would not be possible to position the constraining element adjacent to the glass

element. A routine experimentation will not lead to solving this problem.

Therefore these two references in combination cannot render claim 21 obvious.

293. Claim 22 recites: “ A method as recited in claim 21, further comprising:

294. coating an energy absorbing layer on the free side of the glass element between the constraining layer and the glass element;

295. wherein directing a laser pulse in the first axis comprises directing the laser pulse the energy absorbing layer coated on the glass element.” As explained above, both the Wang dissertation and Gupta 1992 reference fail to render claim 21 obvious to a POSITA. Thus, for this reason alone these two references cannot render claim 22 obvious. This claim requires that the energy absorbing layer be first placed between the constraining layer and the glass element, and then directing a laser pulse on the energy absorbing layer. This arrangement requires identification of the glass element first and only after that the constraining layer and the energy absorbing layer can be placed relative to the glass element. As already discussed with respect to several claims, the problem is that none of these references disclose a glass element. Both use fused quartz or fused silica as a wave propagation medium and none show that these materials are able to modify the stress wave into one with a rarefaction shock profile. Since the aim of these references is not to search for alternative glass elements, a POSITA would not be motivated to search for a glass element that would modify a wave with a

rarefaction shock profile. Without that goal, the learnings from these two references will not let POSITA bring in a glass element into the sample assembly and therefore it would not be possible to position the energy absorbing film in between the constraining layer and the glass element. A routine experimentation will not lead to solving this problem. Therefore these two references in combination cannot render claim 22 obvious.

296. Claim 23 of the '684 patent recites: "A method as recited in claim 13, wherein the stress generated by the stress wave at the coating/substrate interface exceeds approximately 1.0 GPa." As explained above, Gupta 1992 and Wang dissertation fail to render claim 13 obvious in light of the teachings contained therein. Thus, for this reason alone these two references cannot render claim 23 obvious. A POSITA after reading the Wang-Dissertation would probably focus on enhancing the amplitude of the direct tension wave that causes all of the failures seen in that reference. The enhancement of the interface stress amplitude is not merely dependent upon the laser fluence as all of the parameters that I discussed above with respect to the length of the stress wave, and thickness of the film that can be tested, also govern the amplitude of the stress wave. Additionally, if one were to simply increase the laser energy, there comes a point when the efficiency to the stress wave energy conversion decreases as the vaporized plume of laser absorbing material is ionized by the still incoming laser pulse and therefore its

entire energy is not deposited into the laser absorbing layer. These are fairly sophisticated laser-material interaction effects governed by material's ionized states and as such not amenable to routine experimentation with predictable results for the generation of stress wave amplitude.

297. Claim 24 of the '684 patent recites: "A method as recited in claim 23, wherein the stress generated by the stress wave at the coating/substrate interface exceeds approximately 2.0 GPa." As explained above, both these references fail to render either the independent claim 13 or the dependent claim 23 obvious to a POSITA through their teachings. Thus, for this reason alone these two references cannot render claim 24 obvious. A POSITA after reading the Wang-Dissertation would probably focus on enhancing the amplitude of the direct tension wave that causes all of the failures seen in that reference. The enhancement of the interface stress amplitude is not merely dependent upon the laser fluence as all of the parameters that I discussed above with respect to the length of the stress wave, and thickness of the film that can be tested, also govern the amplitude of the stress wave. Additionally, if one were to simply increase the laser energy, there comes a point when the efficiency to the stress wave energy conversion decreases as the vaporized plume of laser absorbing material is ionized by the still incoming laser pulse and therefore its entire energy is not deposited into the laser absorbing layer. These are fairly sophisticated laser-material interaction effects governed by

material's ionized states and as such not amenable to routine experimentation with predictable results for the generation of stress wave amplitude.

XI. THE CHALLENGED CLAIMS OF THE '684 PATENT ARE NOT RENDERED OBVIOUS BASED ON GUPTA 1992 IN VIEW OF GUPTA 1993 (GROUND 5)

298. As explained below, it is my opinion that the alleged combination of Gupta 1992 and Gupta 1993 fails to render obvious claims 9 and 20 of the '684 Patent.

299. Claim 9 of the '684 Patent recites: "An apparatus as recited in claim 1, wherein the glass element has a thickness ranging from approximately 0.1 mm to approximately 5 mm."

300. Similarly, claim 20 recites: "A method as recited in claim 19, wherein the glass element has a thickness ranging from approximately 0.1 mm to approximately 5 mm."

301. As explained above, Gupta 1992 fails to disclose each and every element of independent claim 1, from which claim 9 depends; as well as independent claim 13 and dependent claim 19, from which claim 20 depends. I understand that neither Petitioner nor Dr. Wang alleges that Gupta 1993 cures the deficiencies of Gupta 1992 in this regard. Thus, for this reason alone, I am of the opinion that the combination of Gupta 1992 and Gupta 1993 cannot render claims 9 and 20 obvious.

302. If a POSITA does not see any teachings of glass modified stress wave in these references then it is difficult to imagine what exactly would motivate the POSITA to start changing the glass element thickness? That is, if a POSITA does not even know the presence of a glass modified wave, which is clearly the final result he or she wants to realize, then absent this, what goal he would be optimizing the glass element thickness to?

303. There is therefore no motivation to even pursue this combination let alone talk about success of such an endeavor.

XII. THE CHALLENGED CLAIMS OF THE '684 PATENT ARE NOT RENDERED OBVIOUS BY GUPTA 1992 (GROUND 6)

304. As explained below, it is my opinion that Gupta 1992 fails to render obvious claims 4, 6, 10, 15, 17, 23 and 24 of the '684 Patent.

305. As explained above, Gupta 1992 fails to disclose or otherwise suggest all of the features of independent claims 1 and 13, from which claims 4, 6, 10, 15, 17, and 23-24 respectively depend. I understand that neither Petitioner nor Dr. Wang contents that Gupta 1992 renders these missing features obvious or otherwise (in Ground 6) cures the deficiencies in Ground 4. For this reason alone, Gupta 1992 cannot render obvious claims 4, 6, 10, 15, 17, and 23-24 of the '684 Patent.

306. Additionally, with respect to claim 4 which recites: "An apparatus as recited in claim 1, wherein the stress wave has a length ranging from approximately 5 nanoseconds to approximately 1 microsecond,"

307. As explained above, Gupta 1992 fails to anticipate independent claim 1. Thus, for this reason alone the Gupta 1992 reference cannot render claim 4 obvious.

308. Furthermore, a POSITA has no basis to even imagine the profile of this wave for which he or she would be trying to optimize its length through routine experimentation. If the POSITA does not even know what the wave profile looks like then the question of playing with numerous experimental parameters to modify its length would appear a totally random exercise. I do not know how this person would arrive at the invention disclosed in this dependent claim but if history is any guide it took me more than 25 years after the laser-generated stress profiles to be changed by inventing a thin waterglass layer to significantly reduced the size of the laser pulse. For Dr. Wang to claim that such a reduction in the pulse length can be achieved by a POSITA even without knowing the profile of the wave is pure speculation and not credible.

309. Additionally, with respect to claim 6, which recites “An apparatus as recited in claim 1, wherein the coating has a thickness less than approximately 0.5 μm ,” Gupta 1992 fails to disclose or suggest this limitation. Without knowing the profile of the glass modified wave, which clearly is not present in the Gupta 1992 reference, it is unclear as to how a POSITA would randomly reduce the thickness of the film with predictable results. In fact, in the Gupta 1992 reference, there are

several tests especially those performed by using the arrangement shown in Fig. 2 (b) where the failures are inside the substrate and not at the interface. In some instances, a thicker film could not be separated but a thinner film could. Ability to separate a film depends upon numerous interdependent parameters. Interface tension is controlled not only by the thickness of the film but by its elastic constant that depends upon its atomic structure, the intrinsic tensile strength of the interface, the dispersion characteristics of the wave that is formed by the laser pulse, the rise time of the laser pulse, the energy of the laser pulse and the thickness and properties of the constraining waterglass layers. I wish it was so easy to test the interface strength of thinner films via routine experimentation because then I would have done so by using the '402 technology and there would not be any need to invent the '684 technology.

310. Additionally, with respect to claim 10 which recites: “ An apparatus as recited in claim 1, wherein the substrate comprises silicon,” Gupta 1992 fails to disclose or suggest the specific limitations of this claim because Si was not tested in the arrangement shown in Fig. 2 (b). Even if for whatever reasons it is considered tested as part of that arrangement the Gupta-1992 reference would still not meet this limitation because it requires that silicon be a part of an apparatus where a glass modified wave enters its thickness from the side opposite to where the test coating interface is located. That would be the side attached to the fused

quartz disc. Since fused quartz is not a glass element it cannot propagate and modify a wave into the Si substrate. For all these reasons the Gupta-1992 reference does not have any teachings that would guide a POSITA to come up with the arrangement shown in Fig. 2 (b) and then find a glass element that would modify the wave as the disclosed fused quartz does not modify the compression stress wave and hence does not qualify as a glass element of the '684 invention.

311. Claim 15 of the '684 patent recites: "A method as recited in claim 13, wherein propagating a stress wave comprises propagating a stress wave having a length ranging from approximately 5 nanoseconds to approximately 1 microsecond." As explained above, the Gupta 1992 reference fails to teach a glass modified wave. Thus, for this reason alone the Wang dissertation cannot render claim 15 obvious. A POSITA has no basis to even imagine the profile of this wave for which he or she would be trying to optimize its length through routine experimentation! If the POSITA does not even know what the wave profile looks like then the question of playing with numerous experimental parameters to modify its length would appear a totally random exercise. I do not know how this person would arrive at the invention disclosed in this dependent claim but if history is any guide it took me more than 25 years after the laser-generated stress profiles to be changed by inventing a thin waterglass layer to significantly reduced the size of the laser pulse. For Dr. Wang to claim that such a reduction in the pulse length can be

achieved by a POSITA even without knowing the profile of the wave is pure speculation and not credible.

312. Claim 17 of the '684 patent recites: "A method as recited in claim 15, wherein the stress wave is configured to separate a coating having a thickness less than approximately 0.5 μm ." As explained above, the Gupta 1992 reference fails to render independent claim 13 and dependent claim 15 obvious based on the teachings contained therein. Thus, for this reason alone the Gupta reference cannot render claim 17 obvious. Furthermore, without knowing the profile of the glass modified wave, which clearly is not present in the Gupta 1992 reference, it is unclear as to how a POSITA would randomly reduce the thickness of the film with predictable results. In fact, in Dr. Wang's own thesis, and in the Gupta 1992 reference there are several tests where the failure is in the substrate. In some instances, a thicker film could not be separated but a thinner film could. Ability to separate a film depends upon numerous interdependent parameters. Interface tension is controlled not only by the thickness of the film but by its elastic constant that depends upon its atomic structure, the intrinsic tensile strength of the interface, the dispersion characteristics of the wave that is formed by the laser pulse, the rise time of the laser pulse, the energy of the laser pulse and the thickness and properties of the constraining waterglass layers. I wish it was so easy to test the interface strength of thinner films via routine experimentation because then I

would have done so by using the '402 technology and there would not be any need to invent the '684 technology.

313. Claim 23 of the '684 patent recites: "A method as recited in claim 13, wherein the stress generated by the stress wave at the coating/substrate interface exceeds approximately 1.0 GPa." As explained above, the Gupta 1992 reference fails to render the independent claim 13 obvious through its teachings. Thus, for this reason alone the Gupta 1992 reference cannot render claim 23 obvious. A POSITA after reading the Gupta 1992 reference would only be enhancing the amplitude of the unmodified compression wave that causes all of the failures seen in that reference. Even then, the enhancement of the interface stress amplitude is not merely dependent upon the laser fluence as all of the parameters that I discussed above with respect to the length of the stress wave, and thickness of the film that can be tested, also govern the amplitude of the stress wave. Additionally, if one were to simply increase the laser energy, there comes a point when the efficiency to the stress wave energy conversion decreases as the vaporized plume of laser absorbing material is ionized by the still incoming laser pulse and therefore its entire energy is not deposited into the laser absorbing layer. These are fairly sophisticated laser-material interaction effects governed by material's ionized states and as such not amenable to routine experimentation with predictable results for the generation of stress wave amplitude.

314. Claim 24 of the '684 patent recites: "A method as recited in claim 23, wherein the stress generated by the stress wave at the coating/substrate interface exceeds approximately 2.0 GPa." As explained above, the Gupta 1992 reference fails to render independent claim 13 or the dependent claim 23 obvious based on its teachings. Thus, for this reason alone the Gupta 1992 reference cannot render claim 24 obvious. The key deficiency in the Gupta 1992 reference is that it does not disclose a modified stress wave as required by this claim limitation. A POSITA after reading this reference would probably focus on enhancing the amplitude of the unmodified compression wave that causes all of the failures seen in that reference. Even then, the enhancement of the interface stress amplitude is not merely dependent upon the laser fluence as all of the parameters that I discussed above with respect to the length of the stress wave, and thickness of the film that can be tested, also govern the amplitude of the stress wave. Additionally, if one were to simply increase the laser energy, there comes a point when the efficiency to the stress wave energy conversion decreases as the vaporized plume of laser absorbing material is ionized by the still incoming laser pulse and therefore its entire energy is not deposited into the laser absorbing layer. These are fairly sophisticated laser-material interaction effects governed by material's ionized states and as such not amenable to routine experimentation with predictable results for the generation of stress wave amplitude.

XIII. THE CHALLENGED CLAIMS OF THE'684 PATENT ARE NOT RENDERED OBVIOUS BY WANG-2002 IN VIEW OF GUPTA 1992 (GROUND 7)

315. As explained above, neither the Wang Dissertation, nor Gupta 1992 anticipates nor renders obvious any of the challenged claims. Wang-2002 is a condensed, less detailed version of the Wang Dissertation, and no new information or disclosure, as admitted by Dr. Wang.). Ex-2009, 190.

316. Figures 6, 8, and 9 in the Wang-2002 reference are identical to Figs. 3.14, 3.15, and 3.16, respectively, in the Wang-Dissertation. This reference also acknowledges the formation of the direct tension wave in exactly the same manner and described using the same phrases as used on page 66 in the Wang-Dissertation. Like in the Wang dissertation, the Wang-2002 reference teaches that this tension wave is generated by the second compression wave of comparable magnitude that is generated inside the constraining waterglass layer when it reflects from its free surface. This tension wave then enters the fused silica substrate, behind the main compression wave, with a delay but soon overruns the back end of the compression wave because it travels with a velocity faster than the shockwave velocity.

317. I therefore have identical information from the Wang-2002 reference as I had from the Wang dissertation. The same analysis I performed using the data in the Wang dissertation is also applicable to the Wang-2002 reference. That analysis showed that what Dr. Wang calls a decompression shock in her experiments is

essentially the unloading caused by the direct tension wave. Therefore, like in the Wang dissertation there is no glass modified compression stress wave with the rarefaction shock profile in the Wang-2002 reference. It is noteworthy that the statement Dr. Wang makes in the “Future Work” section of her dissertation, which is the key basis for Boeing to challenge the claims of the ‘684 patent, is completely missing from the Wang-2002 reference. Thus, it can be concluded that the Wang-2002 reference provides no new information than what is already provided in the Wang dissertation. If anything, the Wang dissertation provides extra information in its Future Work section. Therefore, Wang-Dissertation is cumulative of the Wang-2002 reference. Since I have already concluded using a detailed analysis that the Wang-Dissertation alone (Ground 2) or in combination with the Gupta 1992 reference (Ground 3) cannot render claims 1-24 of the ‘684 patent obvious, I must also conclude for at least the exact same reasons that the Wang-2002 reference in view of Gupta-1992 reference cannot render any of the claims 1-24 obvious.

318. Thus, the challenged claims cannot be rendered obvious in view of Wang 2002 and Gupta 1992, for at least the same reasons that the challenged claims are not rendered obvious in view of the Wang Dissertation and Gupta 1992.

319. Because of the aforesaid reasons, I incorporate herein my entire analysis from Ground 3 analysis, with “Wang dissertation” replaced by “Wang-2002” wherever it appears in that analysis.

XIV. THE WANG DISSERTATION ABSTRACT DOES NOT MATCH WHAT IS SHOWN ON THE PROQUEST DATABASE

320. I have obtained the version of the abstract of the Wang Dissertation that is listed on ProQuest's PQDT database on January 22, 2025. See Ex. 2010. This version is inconsistent with the version of the abstract that appears on the face of the Wang Dissertation. For example the PQDT Wang Dissertation abstract contains 100 fewer words than what is contained in the abstract in the Wang Dissertation itself.

XV. ADDITIONAL COMMENTS ON DR. WANG THESIS

321. "Thinner film testing" – I disagree with Dr. Wang's characterization in paragraph 56 of her declaration that through her research she determined that "thinner film testing could be accomplished by using non-linear elastic substrates, such as fused silica." She cites the Abstract of her publication (Ex-1016) in support of this statement. I have reproduced her abstract in its entirety below.

ABSTRACT—We report parametric studies of elastic wave generation by a pulsed laser and associated spalling of thin surface films by the corresponding high stresses. Two different substrate materials, single crystal Si (100) and fused silica, are considered. Spallation behavior of Al thin films is investigated as a function of substrate thickness, film thickness, laser energy, and various parameters governing the source. Surface displacement due to the stress wave is measured by Michaelson interferometry and used to infer the stresses on the film interface. Consistent with previous studies, the maximum stress in the substrate and at the film/substrate interface increases with increasing laser fluence. For many of the conditions tested, the substrate stress is large enough to damage the Si. Moreover, the maximum interface stress is found to increase with increasing film thickness, but decrease with increasing substrate thickness due to geometric attenuation. Of particular significance is the development of a decompression shock in the fused silica substrates, which results in very high tensile stresses at the interface. This shock enhances the failure of thin film interfaces, especially in thicker samples.

KEY WORDS—Laser spallation, thin film, interface adhesion, stress wave, decompression shock

322. The abstract does not state anything about the ability of the fused silica to test “thinner films,” which implies a comparative study contained within the reference. In fact there is no place in the entire body of any of the references that Dr. Wang has cited that provides a comparative study that would allow making the conclusion that thinner films could be tested by use of a fused silica substrate.

323. To be able to claim that decompression shock allows “thinner films” to be separated would require Dr. Wang to separate the exact same interface, one with a thicker film and one with a thinner film on the same substrate and send an

unmodified wave and a modified wave with the decompression shock to test both the thick and thin film interfaces. Only after the results of such a testing, could Dr. Wang assess whether “thinner” films can be tested more efficiently by the use of a shock wave with a decompression shock profile. Nowhere in her work has Dr. Wang performed such tests. She tested a silicon/aluminum interface and a fused silica/aluminum interface. These two interfaces are totally different and the tensile strengths from these two systems cannot be compared. Therefore the results on the fused silica/Al samples by itself do not provide any comparative data to bring out the benefits of using a wave with the decompression shock profile. A POSITA would be further discouraged by the data on page 56 of Wang’s dissertation, reproduced below, where Dr. Wang discusses the results of interfaces between 1.0 μm thick and 1.8 μm thick aluminum films on fused silica substrates.

3.3.4 Effect of Substrate Thickness on Film Spallation

To study the effect of substrate thickness on film failure, samples were fabricated using silicon wafers of thickness 400 μm , 500 μm , 700 μm , and 3000 μm while keeping the absorbing layer thickness at 1.0 μm . Several different test film thicknesses—0.6 μm , 1.0 μm , 1.5 μm , and 3.0 μm —were studied sequentially for each of the different substrate thicknesses. The results are summarized in Table 3.1. At full YAG power, spallation always occurred for the thinnest 0.6 μm film on the 400 μm and 500 μm substrates. No spallation was observed for the 0.6 μm film on the 700 μm and 3000 μm substrate. For the thicker 1.0 μm film, spallation occurred for all of the 400 μm and 500 μm substrate samples, for only a few samples with 700 μm substrate, and for no samples with a 3000 μm substrate. After increasing the film thickness to 1.5 μm , spallation was observed for all 400 μm , 500 μm , and 700 μm substrate samples but not for the 3000 μm substrate. Finally, for a film thickness of 3.0 μm , some spallation appeared on the 3000 μm sample.

Three different thicknesses of the fused-silica substrate samples—1500 μm , 3000 μm and 6000 μm —were also investigated. For an aluminum test film thickness of 1.0 μm , film spallation was observed for the 1500 μm fused-silica substrate at all laser fluences greater than 0.056 J/mm². No damage was observed on the 3000 μm and 6000 μm samples regardless of fluence. When a thicker test film of 1.8 μm was used, huge amounts of film damage were observed on the 1500 μm sample at very low YAG power. A tiny area of film failed on the 3000 μm sample under full YAG power (laser fluence of 0.140 J/mm²), while no damage was observed in the test film deposited on the 6000 μm substrate, even at full power.

324. As she notes, “No damage was observed on the 3000 μm and 6000 μm samples regardless of the fluence.” This is for a 1.0 μm thick Al film, which Dr. Wang is unable to separate from the interface and Dr. Wang is making claims that a fused silica allows much thinner films-less than 0.5 μm -can be separated using the fused silica substrate. Moreover, Dr. Wang was unable to separate a 1.8 μm thick aluminum film from a 6000 μm thick substrate even at full laser power-“A tiny area of film failed on the 3000 μm sample under full YAG power (laser

fluence of 0.140 J/mm²), while no damage was observed in the test film deposited on the 6000 μ m substrate, even at full power.” Even at full power only a tiny bit of film was damaged on the 3000 μ m thick substrate. Dr. Wang’s claims in her Declaration that she is able to test thinner films using the decompression shock profile in fused silica are contradicted by her own Dissertation. A POSITA reading the Wang Dissertation would have understood that the decompression shock in fused silica does not allow even films as thick as 1.8 μ m to be separated from the interface. All this data is evidence that there is no shock wave profile developed in Dr. Wang’s work and therefore the attenuated wave does not have the glass modified rarefaction shock profile to cause the separation that is taught by the ‘684 technology.

325. Similarly Dr. Wang suggests that she experimented with several materials with non-linear elastic substrates when she writes “It was determined that thinner film testing could be accomplished by using non-linear elastic substrates, such as fused silica.” I disagree. Nowhere in any of the references she cites in her Declaration has she tested anything other than fused silica.

326. **Critical Ranges** – In paragraph 160 of her declaration Dr. Wang states, “The ‘684 Patent does not disclose that any claimed range is critical to the operability of the invention nor in my opinion are the ranges critical to the operability of the invention. As I have shown in my dissertation, a rarefaction or

decompression shock occurred in my fused silica substrate at multiple points in these claimed ranges, e.g., in multiple thickness or with multiple stress wave lengths, and successfully spalled thin films less than $0.5\mu\text{m}$.” In light of the experimental observations made by Dr. Wang on page 56 of her Dissertation, here statement is not correct. As Dr. Wang discussed on page 56 of her Dissertation, she was unable to fail films as thick as 1mm and 1.8 mm from the fused silica substrate any level of laser energy. This further confirms that in the laser spallation experiment there is a complex interdependency between many variables, such as the thickness and elastic properties of the confining medium, laser absorbing coating, substrate and the test film itself, along with the laser pulse rise-time, its temporal profile and energy levels that ultimately decides the profile of the stress wave which eventually pries off the coating after generating a tensile force after reflecting from the free surface of the coating. Many of these interactions span multi-scale multi-phase physical phenomenon that are governed by totally different physical laws. For example, if the laser pulse is made a bit longer the tail portion of it would start to interact with the plume of ionized plasma created by its front portion and reduce the efficiency of the stress wave generation process and eventually alter the profile of the stress wave that propagates towards the free surface of the film to cause its separation. There is nothing routine about the experimentation nor are there predictable results.

327. **Usefulness of the shocks in laser spallation** – In paragraph 87 of her Declaration, Dr. Wang states, “Even though shock developed in fused silica was known (Ex-1021), my study was the first to report the usefulness of such shocks in laser spallation applications. Ex-1016, 82.” Then several paragraphs later in paragraph 199 she states, “Moreover, it was a well-known property that glass elements such as fused silica (i.e., quartz) propagate and modify a stress wave to cause a rarefaction shock in experimental laser techniques. See Ex-1021,” These statements are contradictory.

328. **Mixed reasoning** – In her invalidity analysis, Dr. Wang mixed reasoning that violates the basic science of laser spallation experiment. For example, for dependent claims dealing with film thickness, pulse length, pulse amplitude, level of interface stress, etc., Dr. Wang points to specific data in her dissertation, ignoring that all her data was acquired an arrangement that is not what she has proposed in the Future Work section, but rather by using a conventional arrangement. This is a scientific error, as what she is attempting to bring in the data from experimental setup that has nothing to do with the ‘684 arrangement and force it to satisfy the dependent claim, which, by virtue of their dependencies from claims 1 or 13, require testing to be performed using an apparatus having an arrangement she planned for the future.

XVI. CONCLUSION

I hereby declare that all statements made herein of 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, under section 1001 of Title 18 of the Unites States Code.

Respectfully submitted,



Vijay Gupta, PhD.

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