

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

THE BOEING COMPANY
Petitioner,

v.

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA
Patent Owner.

**DECLARATION OF JUNLAN WANG, PH.D.
IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 7,487,684**

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I, Dr. Junlan Wang, declare as follows:

I. INTRODUCTION

1. I have been retained as an independent expert consultant on behalf of The Boeing Company (“Petitioner”) 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. My compensation in this case is in no way contingent on the nature of my findings, the presentation of my findings in testimony, or the outcome of this or any other proceeding. I have no other interest in this proceeding.

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 Regents of the University of California (“Patent Owner”) or its experts that I have not been provided yet,

¹ In this Declaration, I reference documents by exhibit numbers that, as I understand, are attached to Exhibits in this *Inter Partes* Review of the ’684 Patent.

including any secondary consideration evidence that Patent Owner or its expert may consider and present.

3. In my view, the prior art discloses or suggests the features recited in Claims 1-24 (what I understand are the “Challenged Claims”) of the ’684 Patent. The ’684 Patent is invalid based on the following grounds:

Ground	Claims	Basis for Unpatentability
1	1-22	§ 102 – Wang-Dissertation (Ex-1005)
2	4, 6, 9, 15, 17, 20, 23-24	§ 103 – Wang-Dissertation
3	1-24	§ 103 – Wang-Dissertation in view of Gupta-1992 (Ex-1011)
4	1-8, 10-19, 21-22	§ 102 – Gupta-1992
5	9, 20	§ 103 – Gupta-1992 in view of Gupta-1993 (Ex-1013)
6	4, 6, 10, 15, 17, 23-24	§ 103 – Gupta-1992
7	1-24	§ 103 – Wang-2002 (Ex-1016) in view of Gupta-1992

II. EXPERIENCE AND QUALIFICATIONS

4. I have summarized in this section my educational background, career history, publications, and other relevant qualifications. My full *curriculum vitae* is attached as Ex-1004 to this proceeding.

5. I am a Professor of Mechanical Engineering at the University of Washington. I received my B.S. and M.S. in Mechanics and Mechanical Engineering from the University of Science and Technology of China, and Ph.D. in Theoretical and Applied Mechanics from the University of Illinois at Urbana-Champaign. After a year of postdoctoral research at Brown University, I joined the Mechanical Engineering faculty at the University of California, Riverside in 2003, and moved to UW in December 2008.

6. My teaching is in the areas of mechanics, materials and manufacturing. I teach several courses at UW, including Introduction to Manufacturing Processes, Mechanics of Thin Films, Experimental Stress Analysis I and II, and Structural Engineering in Commercial Aircraft.

7. I have been recognized by a number of awards including CAREER Award from the National Science Foundation, Hetenyi, Durelli and Frocht Awards from the Society for Experimental Mechanics (SEM), Beer and Johnston Outstanding New Mechanics Educator Award from the American Society of Engineering Education (ASEE), and Teaching Excellence Award from UCR Bourns College of Engineering.

8. I am the author or co-author of 61 peer-reviewed journal publications.

9. I have also authored or co-authored 22 conference and workshop publications, 4 book chapters, edited a proceedings book entitled “Mechanics of

Additive and Advanced Manufacturing” and am a named inventor on multiple U.S. invention disclosures and provisional patents.

10. My research is in the general area of experimental mechanics with applications in energy, health and advanced manufacturing. In particular, I am interested in developing novel experimental techniques complemented by numerical and analytical approaches to study the mechanics and physics of materials and structures at small length and time scales, which have profound impacts in semiconductor, biomedical, aerospace and transportation systems.

11. Through grants to the University of Washington, my research has been sponsored by funding agencies such as National Science Foundation, Department of Defense, Department of Energy, Army Research Office, Naval Warfare Surface Center, Joint Center of Aerospace Technology Innovation (a Washington state funding agency), and private consortium and companies such as Semiconductor Research Corporation, Blue Origin, Boeing, Intel PACCAR (a truck designer), and Microsoft. I have research projects currently funded by the Petitioner. One of these grants involves using the laser spallation technology discussed in this Declaration. However, my funding by Petitioner is in no way contingent on the nature of my findings in this IPR, and my research for Petitioner has no impact on my opinions provided in this IPR. All sponsored research funding from Petitioner (and others who have funded my research) goes to the University of Washington, not me

personally. The University uses the funding to cover research expenses (e.g. materials, supplies, student assistant's tuition and stipend) and part of my summer salary. However, my salary and other compensation are capped and I cannot receive compensation above the cap if the grants funding my work are larger or more numerous. And I also have some administrative roles in the department which already pay part of my summer salary. Even if Petitioner ceased sponsoring my research through the University of Washington, my research has been sponsored by numerous companies and government entities (as described above) and other grants to the University of Washington would likely replace the funding Petitioner provides. During my career, I have had various other professional contacts with Petitioner, such as having Petitioner's employees guest lecture in classes I have taught, and on one occasion delivering a lecture to Petitioner's employees. These contacts are comparable to contacts I have had with other companies interested in my research and none of these contacts involved payments from Petitioner to me or, to my knowledge, my employer.

III. MATERIALS REVIEWED AND TIME OF ALLEGED INVENTION

12. The opinions contained in this Declaration are based on the documents that I reviewed, my professional judgment, as well as my education, experience, and knowledge regarding technologies related to the '684 Patent.

13. In forming my opinions expressed in this Declaration, I reviewed:

- the '684 Patent (Ex-1001);
- the file history of the '684 Patent (Ex-1002);
- Junlan Wang, 2002 Ph.D., Dissertation at University of Illinois at Urbana-Champaign, "Thin-film Adhesion Measurement by Laser-Induced Stress Waves" ("Wang-Dissertation") (Ex-1005);
- Gupta, V., Argon, A., Parks, D., and Cornie, J., 1992, "Measurement of Interface Strength by a Laser Spallation Technique," J. Mech. Phys. Solids, 40(1), pp. 141-180 ("Gupta-1992") (Ex-1011);
- J. Yuan, V. Gupta, A. Pronin, "Measurement of interface strength by the modified laser spallation experiment. III," Journal of Applied Physics, vol. 74, no. 4, pp. 2405-2410, 1993 ("Gupta-1993") (Ex-1013);
- Wang, J., Weaver, R. L., and Sottos, N. R., 2002, "A Parametric Study of Laser Induced Thin Film Spallation," Exp. Mech., 42(1), pp. 74-83 ("Wang-2002") (Ex-1016); and
- other materials that I refer to in this Declaration in support of my opinions, including Exhibits to the Petition.

14. I have been asked to consider the time of the alleged invention to be around March 5, 2004, which I understand is the filing date of the application (U.S. Patent Application No. 60/550,803) to which the '684 Patent claims priority (Ex-1001, Cover). My opinions reflect how a person of ordinary skill in the art (as I define in Section V below) would have understood the claims and the specification of the '684 Patent, the prior art to the patent, and the state of the art, at the time of the alleged invention.

15. As I discuss in detail below, it is my opinion that the Challenged Claims of the '684 Patent are disclosed or suggested by the prior art references cited by Petitioner in this *Inter Partes* Review.

IV. LEGAL STANDARDS

16. I am not an attorney or a legal expert. The legal standards I applied in reaching the conclusions expressed throughout this declaration were provided to me by counsel. In preparing this declaration, I have endeavored to faithfully apply these legal standards. I do not intend to offer opinions on the law. Below, I describe the law I applied in considering whether the Challenged Claims are patentable.

17. I have been informed that an issued patent is presumed valid and that the challenger of the validity bears the burden of proving invalidity of the patent.

A. Patent Claims

18. Patent claims describe the invention made by the inventors and describe what the patent owner owns and what the owner may prevent others from doing.

19. Claims may describe products, such as machines or chemical compounds, or processes for making or using a product. Claims are usually divided into parts or steps called limitations.

20. There are two types of claims: independent claims and dependent claims. An independent claim sets forth all the requirements that must be met in order to be covered by that claim. Thus, it is not necessary to look at any other claim to determine what an independent claim covers. A dependent claim does not itself recite all of the requirements of the claim, but refers to another claim for some of its requirements. In this way, the claim depends on another claim. The law considers a dependent claim to incorporate all of the requirements of the claims to which it refers.

21. The dependent claim then adds its own additional requirements. To determine what a dependent claim covers, it is necessary to look at both the dependent claim and any other claims to which it refers.

22. In that case, the dependent claims incorporate the limitations of the independent claim upon which they depend and, if a reference fails to disclose any

of the limitations of an independent claim, the claims which depend on that claim cannot be made invalid by that reference.

B. Burden of Proof for Invalidity

23. I understand that the party challenging the validity of an issued U.S. patent in an IPR bears the burden of proving invalidity through facts supported by a preponderance of the evidence. I understand that a “preponderance of the evidence” means evidence sufficient to prove that a fact is more likely true than it is not.

C. Claim Construction

24. I understand that the first step in determining validity is to properly construe the claims. I further understand that, in this proceeding, the Board must determine the scope of the claims by using the same claim construction standard that United States District Courts use. Under this standard, words of a claim are given their “ordinary” and “customary” meaning as understood by a person of skill in the art at the time of the invention. I understand that such a person looks to the claims, specification, and file history in understanding the meaning of the claim terms. I have applied this understanding in this Declaration.

D. Person of Ordinary Skill in the Art

25. I understand that a person having ordinary skill in the art may be defined by factors such as: (a) the levels of education and experience of the inventor and other persons actively involved in the field; (b) the types of problems

encountered in the field; (c) prior art solutions to those problems; (d) rapidity with which innovations are made; and (e) the sophistication of the technology.

E. Anticipation

26. I understand that a patent claim can be found invalid as anticipated if each and every element of the claim, as properly construed, is found either explicitly or inherently in a single prior art reference. If the single prior art reference does not disclose any one claim limitation, then that claim is not anticipated. I further understand that the single prior art reference cannot merely disclose each element; rather, it must disclose all of the elements as arranged in the claim.

27. I have been informed that for a prior art reference to “inherently” disclose something, the reference must necessarily function in accordance with, or include the claimed limitations, to anticipate. The missing descriptive matter cannot merely probably or possibly include the claimed limitations. I further understand that, with respect to an anticipation analysis, it is improper to combine separate, distinct embodiments of a single prior art reference.

28. I understand that for a claim to be anticipated, each claim limitation must be disclosed in a single prior art reference, and the claimed arrangement or combination of those limitations must also be disclosed in that same prior art reference. I understand that for a reference to be anticipatory, the reference must

contain an enabling disclosure. I understand that merely naming or describing the subject matter is insufficient if it cannot be produced without undue experimentation.

F. Obviousness

29. I understand that a patent claim can be found invalid as obvious if the differences between the claim and the prior art references would have been obvious to a person of ordinary skill in the art at the time of the invention, taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any objective indicia of non-obviousness. I further understand that a claim can be found to be obvious in light of either a single prior art reference or multiple prior art references.

30. I understand that references qualify as prior art for an obviousness determination only when they are analogous to the claimed invention. Two separate tests define the scope of analogous prior art: (1) whether the art is from the same field of endeavor, regardless of the problem addressed; and (2) if the reference is not within the field of the inventor's endeavor, whether the reference still is reasonably pertinent to the particular problem with which the inventor is involved.

31. To be obvious in light of a single prior art reference or multiple prior art references, there must be a reason either to modify either the single prior art reference or to combine the two or more prior art references to achieve the claimed invention. I understand that this reason may come from a teaching, suggestion, or

motivation to combine or may come from the reference or references themselves, the knowledge or “common sense” of one skilled in the art, or from the nature of the problem to be solved, and may be explicit or implicit from the prior art as a whole.

32. The combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results.

33. I further understand that there is no suggestion to combine, however, if a reference teaches away from its combination with another source. A reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, or would be led in a direction divergent from the path that was taken by the patent inventor, or if it suggests that the line of development flowing from the reference’s disclosure is unlikely to be productive of the result sought by the applicant. If when combined, the references would produce a seemingly inoperative device, then they teach away from their combination. I understand that it is improper to combine references where the references teach away from their combination.

34. I understand that the degree of teaching away will depend on the particular facts; in general, a reference will teach away if it suggests that the line of development flowing from the reference’s disclosure is unlikely to be productive of the result sought by the applicant. I understand that a reference teaches away, for example, if (1) the combination would produce a seemingly inoperative device, or

(2) the references leave the impression that the product would not have the property sought by the applicant.

35. I understand that if the teachings of a prior art reference would lead one skilled in the art to make a modification that would render another prior art device inoperable, then such a modification would generally not be obvious. I understand that if a proposed modification would render the prior art device unsatisfactory for its intended purpose, then the proposed modification would generally not be obvious.

36. I understand that it is improper to use hindsight in making the obviousness determination.

37. I understand that some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness must be made. For example, I understand that there may be no rational underpinning to support the legal conclusion of obviousness where systems are already complete and the party challenging validity seeks to mix and match components, which each exist in the separate systems, from these complete systems.

V. PERSON OF ORDINARY SKILL IN THE ART (POSITA)

38. Based on my review of the '684 Patent, the types of problems encountered in the art at and prior to the time of the alleged invention, prior solutions to those problems, the pace with which innovations were made during the relevant

time period, the sophistication of the technology, and the educational level of active professionals in the field, I believe that a person of ordinary skill in the art (POSITA), at the time of the alleged invention, would have had at least a master's degree in Mechanical Engineering or a related field, and at least five years of experience using laser systems to characterize and test mechanical behavior of materials. The key experience is in laser-material interaction, optical interferometry, and wave mechanics. More education may supplement practical experience or *vice versa*.

39. All of my opinions in this declaration are from the perspective of a person of ordinary skill in the art, as I have defined it above and during the relevant time frame (*e.g.*, 2002 to early 2003). During this time frame, I possessed at least the qualifications of a POSITA, as defined above.

VI. CLAIM CONSTRUCTION

40. I understand that claim terms are typically given their ordinary and customary meaning, as would have been understood by a person of ordinary skill in the art at the time of the alleged invention. In considering the meaning of the claims, I also understand that one must consider the claim language, specification, prosecution history, and the knowledge of a person of ordinary skill in the art at the relevant time. In my opinion, none of the terms require construction and should be given their ordinary and customary meaning. I applied this understanding in my analysis.

VII. BACKGROUND OF LASER SPALLATION TECHNIQUES

41. Thin films play an important role in many technological applications, including multilayer microelectronic devices and optical devices. In thin film applications, the structural integrity and mechanical reliability of multilayered systems are governed by their interfacial properties. Interfacial adhesion is a critical parameter governing the mechanical behavior and reliability of a thin film on a substrate. Thus, the ability to quantify film adhesion is essential for design and evaluation of layered media.

42. Laser spallation is a technique developed in the 1970s to understand the adhesion of films with substrates. Ex-1008; Ex-1010. A schematic of tensile laser-spallation technique from one of my publications is shown below (*see* Ex-1017, 6):

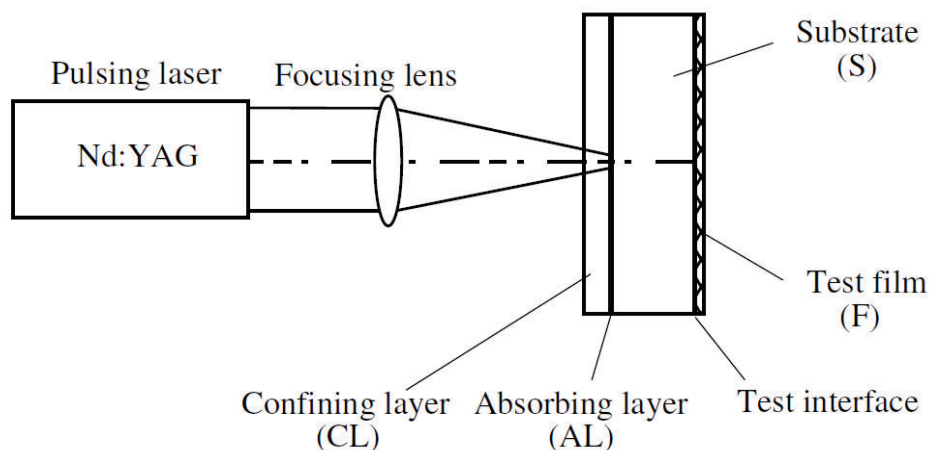
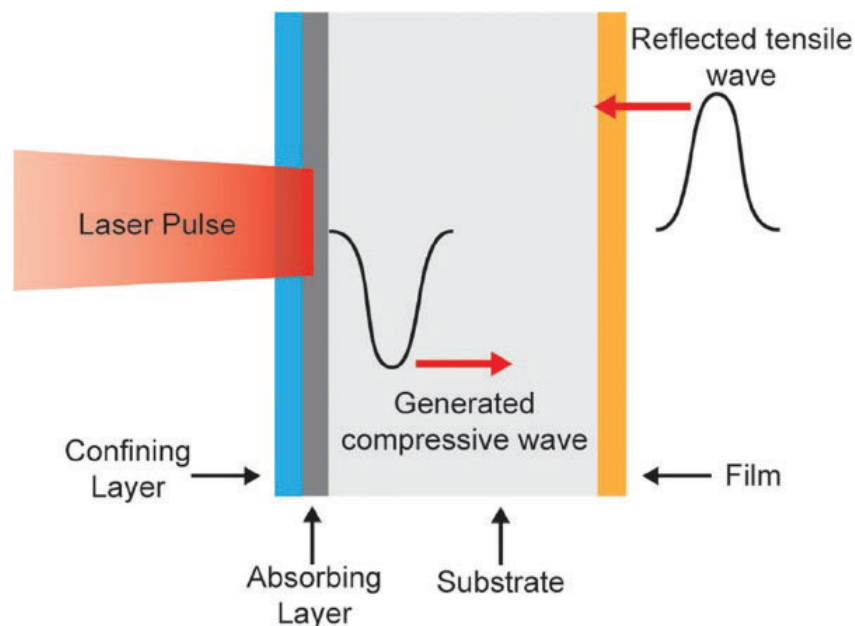


Figure 1: Schematic of the tensile laser-spallation technique.

43. A high-energy pulsed laser, typically neodymium-doped yttrium aluminum garnet (i.e., Nd:YAG), is used to vaporize an energy absorbing material held under a confining layer. The expansion of the vaporized material constrained by the confining layer creates a compressive stress wave directed at a substrate, where it propagates and reflects as a tensile stress wave at the free surface of a testing film. This tensile stress wave spalls (i.e., separates) the testing film while propagating back towards the substrate if the magnitude of the tensile stress wave at the film-substrate interface is greater than the interface bonding strength. Ex-1014, 3-4; Ex-1010, 38-39.

44. This compressive wave generation and reflected tensile wave is shown in my figure below:



45. Through knowledge of wave propagation in solids, the strength of the bond between the test film and the substrate can then be quantified. The advantage of laser spallation is the non-contact application of the load to the film surface, which makes this technique well suited for ultra-thin films (e.g., on the order of 1 micrometer in thickness or less).

46. The evolution of laser spallation began with the generation of shock waves produced by laser vaporization of metal surfaces. *See* Ex-1007. The ability of a pulsed laser beam to generate stress waves was first recognized in the early 1960s. Studies were conducted that generated high-amplitude stress waves in metals by striking a high-energy pulsed laser beam on the surface. It was known that when the energy from a high power pulsed laser is impinged on an uncovered metal surface, a high amplitude stress wave is generated.

47. In 1970, a technique was developed for confinement of plasma and presented that stresses on the order of gigapascals (GPa) could be generated by placing a quartz overlay, transparent to the laser light pulse, on top of the substrate surface. This technique is shown in the Figure below (*see* Ex-1007, 114):

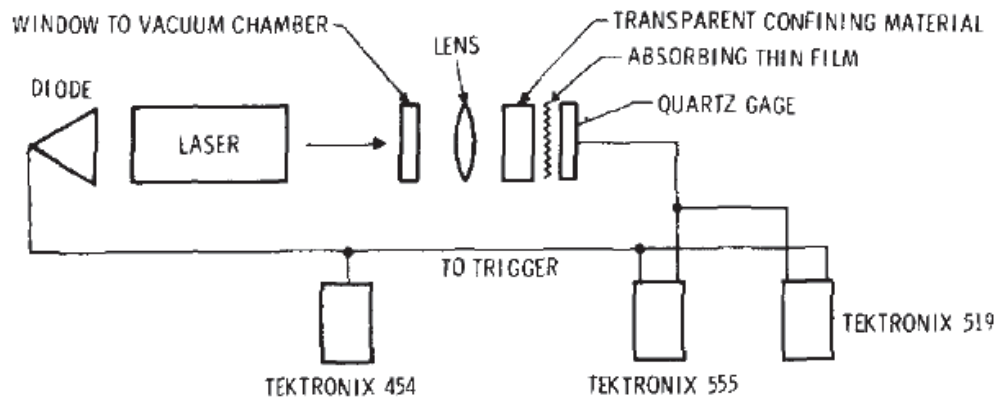


FIG. 1. Schematic of the experimental configuration.

48. An aluminum film was vapor deposited on the back of a quartz disk, and to the back of the aluminum film, a thick quartz gage was epoxy bonded. Ex-1007, 114. This configuration confined the vaporized materials in the vicinity of the metal surface and significantly increased the peak stresses developed.

49. During the 1970s, a number of methods to increase the magnitude of the stress waves emerged, and several different transparent overlays were developed. Ex-1007, 113-15; Ex-1009, 2601-07. Results of detailed experimental studies on peak stress generation as a function of film properties and laser parameters utilizing a transparent glass overlay and a variety of metal absorbers were reported. Ex-1009, 2601-07.

50. Laser spallation of thin films due to laser impingement was introduced in 1970s. *See* Ex-1008, 594-96. In 1976, the first measurement of interfacial adhesion strength by laser spallation was proposed. *See* Ex-1010, 38-39.

51. In the laser spallation technique, a nanosecond pulsed laser, classically Nd:YAG, is utilized to create a high amplitude compressive stress pulse in the substrate. The compressive stress pulse, on the scale of a few GPa, propagates through the substrate and then reflects as a tensile wave at the free boundary with sufficient magnitude to cause deformation of a monolithic material surface. For thin film–substrate systems, if the magnitude of the tensile stress wave at the film–substrate interface is greater than the interface bonding strength, then spallation of the film will occur (i.e., the film separates from the substrate).

52. Laser spallation research exploded from the 1990s to the very early 2000s, with several prolific groups contributing to its body of work. Some of the key well-known groups involved in the United States were led by Ali Argon at Massachusetts Institute of Technology (Ex-1011, Ex-1029), Vijay Gupta at Dartmouth University (Ex-1011 – Ex-1013) and University of California at Los Angeles (Ex-1019, Ex-1032), Nancy Sottos and Richard Weaver at University of Illinois at Urbana–Champaign (Ex-1014 – Ex-1018) and myself with Dr. Sottos and Dr. Weaver, and later at University of California-Riverside and University of

Washington. During this time, Dr. Gupta also filed the first patent for a laser spallation technique in 1995. Ex-1034.

53. By the early 1990s, laser spallation experiments included a laser pulse made to impinge on an absorbing layer, such as a thick gold film, placed between the back surface of the substrate and a fused quartz confining plate transparent to the wavelength of the laser (typically Nd:YAG laser) in an arrangement as shown below (see Ex-1011, 143):

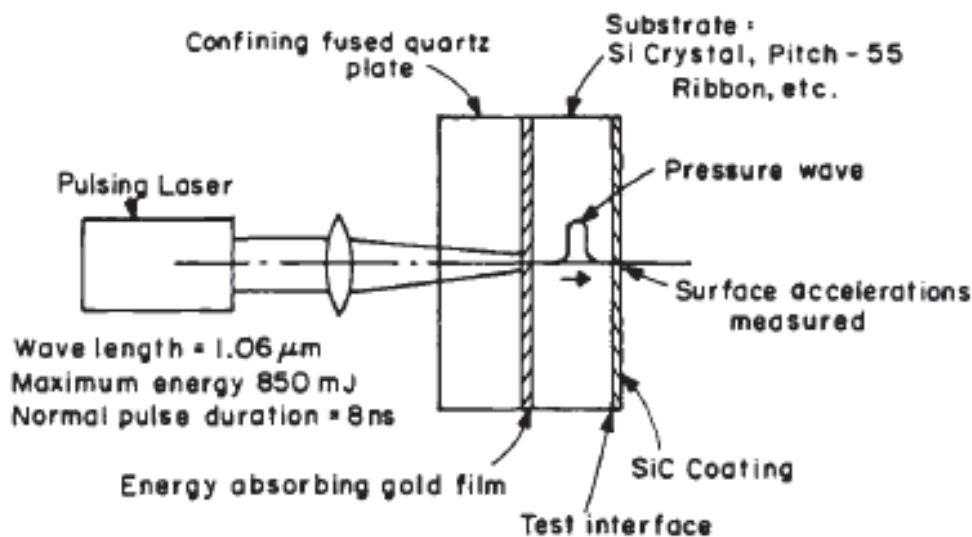


FIG. 1. Schematic view of the laser spallation experiment.

54. Absorption of the laser energy in the gold film layer, confined by the fused quartz plate, leads to sudden expansion of the gold film, which leads to the generation of a compressive shock wave directed toward the film coating-substrate interface. See Ex-1011, 142. Spallation experiments were carried out for several thin

film coating/substrate interfaces (*e.g.*, SiC/C, SiC/Si, and epoxy/C interfaces). Ex-1011, 141-180; Ex-1012, 2388-96; Ex-1028, 119.²

55. Modifications of this experimental setup were made in 1990s, including the replacement of the fused quartz plate by a thin layer of waterglass as a constraining layer. *See* Ex-1013, 2407. The solid waterglass layer was obtained by applying a thin layer of $\text{H}_2\text{SiO}_3:(\text{H}_2\text{O})_x$ to the absorbing metal film, and after several minutes exposure to the air, the water evaporates from the waterglass leaving behind a layer of SiO_2 (*i.e.*, silica) that is transparent to the laser wavelength. The waterglass was found to generate the strongest stress pulse. Ex-1013, 2407. It was known that the peak decay time of the stress pulse is critical in maximizing the interfacial tensile stress. Ex-1013, 2407. The stress pulse in waterglass had a shorter rise time and a “much sharper decay,” which increased the interface tensile stress. Ex-1013, 2407.

56. Significant advancements in laser spallation techniques were developed in the early 2000s, which include adhesion measures of submicron to a few micron thick films (0.1-10 μm) with strong interfaces, previously deemed impossible. Through my research, I determined that thinner film testing could be

² These techniques were known in the 1990s to be applicable to any type of substrate or composite, whether metal-, polymer- or ceramic-matrix-based, including graphite/epoxy composites. *See generally* Ex-1032.

accomplished by using non-linear elastic substrates, such as fused silica. Ex-1014 – Ex-1018. Due to the negative nonlinear elasticity of a substrate such as fused silica, the laser-generated compressive stress wave will evolve into a decompression shock after traveling a certain distance, which will significantly increase the interfacial stress produced and the subsequent failure of the thin film/substrate interface. It was determined that thinner film testing could be accomplished by using non-linear elastic substrates, such as fused silica. *E.g.*, Ex-1016, Abstract.

57. Fused silica is a glass consisting of almost pure silica (SiO_2). In fused silica, the laser-generated compressive stress wave evolves over a distance into a linear ramp followed by a weak shock that has a fast fall time. Ex-1016, 78-82 (“The falling rear of the pulse has therefore compressed by the same amount; an initial fall time of a few nanoseconds has therefore been reduced to zero and this occurs long before the pulse arrives at the test film.”). This decompression or “rarefaction shock,” a known property of fused silica, is critical for significant loading of a surface/thin-film interface. Ex-1016, 78-82; Ex-1021.

58. This research was part of my Ph.D. dissertation in 2002. Ex-1005. I also published the research leading up to my Ph.D. in the early 2000s. Ex-1014 – Ex.1018. These publications included “TAM” (Theoretical and Applied Mechanics) reports that were department publications that were physically printed hardcopies and also available online to the public. For example, my TAM report “Laser induced

thin film spallation” (Ex-1014) was publicly available in May 2000 and my TAM report “Thin Film Adhesion Measurement by Laser Induced Stress Waves” (Ex-1017) was publicly available in April 2003. These dates are provided at the end of each document.

59. My work was presented during this timeframe, including by my former Ph.D. advisor at the November 2002 ASME International Mechanical Engineering Congress & Exposition in New Orleans, Louisiana, during the AMD-16D: Damages and Failure at Coating Interfaces session that also included presentation of Dr. Gupta’s work. Ex-1030, 110-11; *see also* Ex-1015 (presenting on laser-induced weak shock in fused silica in May 2001). My work has also been cited by Dr. Gupta, including in his articles “Resonance in Polyurea-Based Multilayer Structures Subjected to Laser-Generated Stress Waves,” *Experimental Mechanics* (2013) 53:145-154, and “Measurement of anisotropic fracture energies in periodic template silica/polymer composite coatings,” *Journal of Applied Physics* (2008) 104:083515.

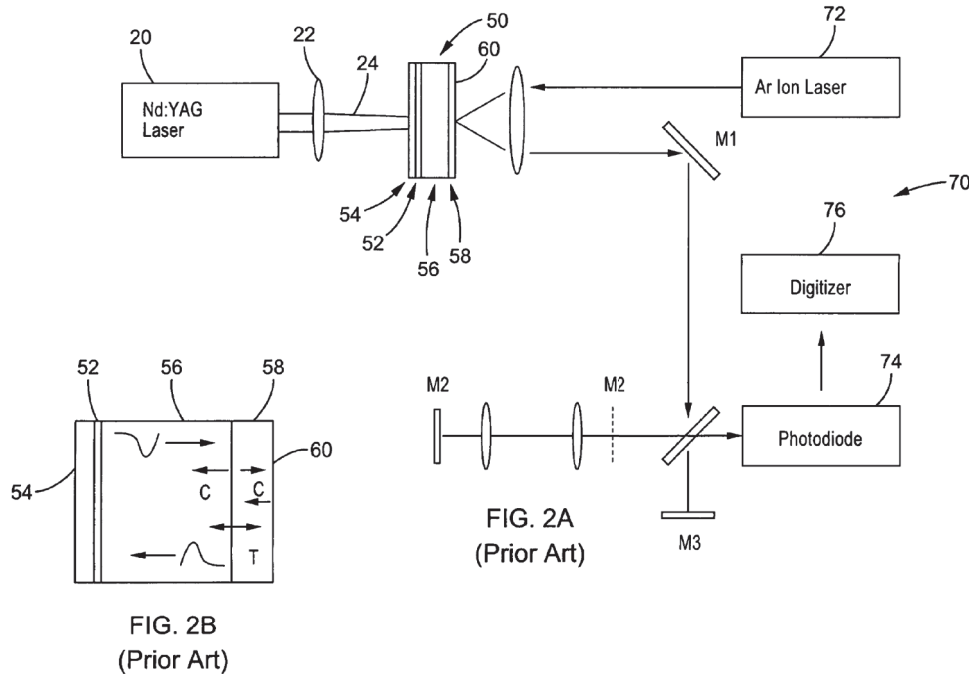
VIII. THE ’684 PATENT

60. The ’684 Patent generally relates to known properties of glass and the use of glass to modify stress waves in laser spallation techniques. Ex-1001. The ’684 Patent describes its Field of the Invention as a “method and system for generating

spallation of ultra thin films and measuring the interface tensile strength between a substrate and the thin film.” Ex-1001, 1:50-52.

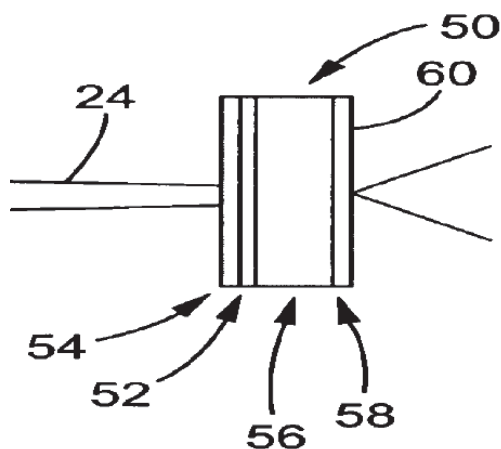
61. The ’684 Patent describes laser spallation as a technique “commonly applied in the art” and describes the typical arrangement of a high-energy laser pulse made to impinge upon a planar arrangement of a confining plate, a metallic layer, a substrate plate, and a coating combination. *See* Ex-1001, 2:16-34. The “laser pulse impinges on a thick metal film that is sandwiched between the back surface of a substrate of interest and a fused quartz confining plate.” Ex-1001, 2:21-24.

62. Absorption of laser energy in the confined metal film leads to a sudden expansion of the film and leads to a generation of a compressive shock wave directed toward the test coating interface. Ex-1001, 2:25-29. “A part of the compressive pulse is transmitted into the coating as the compression pulse strikes the interface,” and its reflection into a tension pulse upon reaching the film free surface leads to removal of the coating, given a sufficiently high amplitude. Ex-1001, 2:29-34. This well-known prior art technique and apparatus are shown in Figures 2A and 2B of the ’684 Patent:



63. The '684 Patent states that “an object of the present invention is to measure the tensile strength of interfaces between such very thin films.” Ex-1001, 2:46-48. The '684 Patent teaches that it was known that “for a given coating thickness the post-peak decay time is the most critical in maximizing the inter-facial tensile stress.” Ex-1001, 8:43-45. Therefore, “if the post-peak decay time is reduced to zero, i.e. the wave profile has a ‘rarefaction shock,’ then the interface tensile stress for a film of arbitrarily small thickness theoretically will equal the amplitude of the incoming compression pulse.” Ex-1001, 8:45-49. The '684 Patent claims that “this theoretical possibility has been realized experimentally with sample assemblies using glass layers.” Ex-1001, 8:49-51.

64. The '684 Patent discloses the addition of a “glass substrate element (106)” on the back side of the substrate (108), as I have shown in red on Figure 4 (annotated) compared to the prior art sample assembly shown in Figure 2A:



Prior Art (Figure 2A)

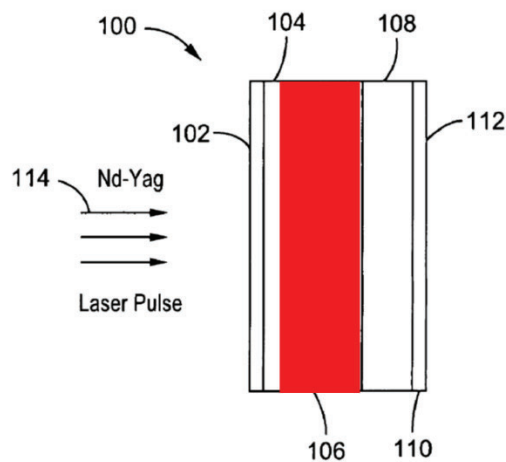


Figure 4 (Annotated)

65. The '684 Patent discloses that, similar to prior art laser spallation techniques described above, a laser pulse is directed at the sample assembly in Figure 4, with the pulse passing through a waterglass constraining layer 102 to heat up the energy absorbing layer 104. Ex-1001, 8:52-67. The expansion of the aluminum layer 104 generates a compressive shock wave that “propagates through the glass substrate 106 and silicon substrate 108” and the “pulse wave is transmitted into the coating 110 to form a tension pulse.” Ex-1001, 8:63-67. As shown in Figure 5A, “the rise-time of the stress wave 120 gets longer but the post-peak stress profile starts 122 to decay rather quickly.” Ex-1001, 9:32-38, Fig. 5A.

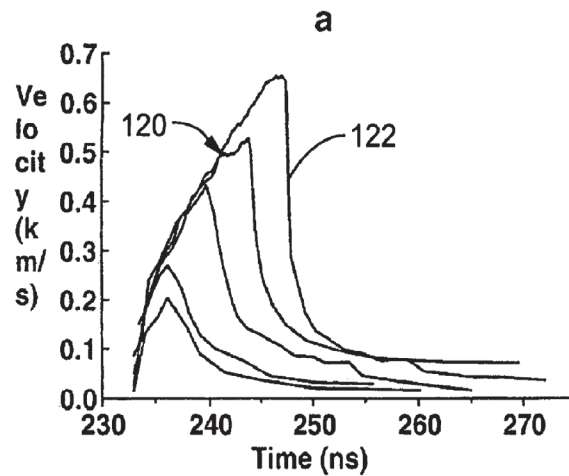


FIG. 5A

66. The '684 Patent states that “[u]ltimately, a profile is attained with the post-peak stress dropping virtually instantaneously (the drop time is within the resolution limit of our instrumentation), much like ‘rarefaction shock.’” Ex-1001, 9:38-41. In the glass substrates of the apparatus and method of the '684 Patent, while the magnitude of the modification of the stress wave profile varies from glass to glass, “all showed the formation of rarefaction shock.” Ex-1001, 9:47-49.

67. Each of the Challenged Claims require a glass element configured to “propagate and modify” a stress wave, as amended by the Patent Owner during prosecution (as discussed below). When performing my analysis, I evaluated the claim language of each claim separately and in its entirety, including each dependent claim. Claim 1 is an exemplary claim with the “propagate and modify” language:

1. An apparatus for generating a tensile stress between a substrate and a coating, comprising:

a substrate having a thickness, said thickness defined by a first side and a second side in a first axis;

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

a glass element disposed on the second side of the substrate and axially spaced along the first axis;

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.

IX. THE PROSECUTION HISTORY

68. During prosecution, the Examiner initially rejected all claims under § 102(b) based on U.S. Patent No. 5,438,402 to Gupta (“*Gupta*”). Ex-1002, 91-93. The Examiner found that *Gupta* disclosed the apparatus and method as claimed, including a glass element propagating a stress wave to the coating and substrate. Ex-1002, 91-93. I have reviewed the ’402 Patent and agree that it discloses waterglass, which is a glass element, and as discussed above, was known to propagate a stress wave to the coating and substrate, and the stress wave had a shorter rise time and

much sharper decay when compared to the previously used fused quartz plates in prior art, thus creating much higher interface tensile stress. Ex-1005, 69 (“[C]ertain range of waterglass can be strong enough [for] shock [to] be developed and propagated to the thin-film interface.”); Ex-1013, 2407.

69. In response, the Applicant argued that the glass stress wave modification is “particularly important to this invention, as it has been found that with sufficiently high pulse pressures, glass materials tend to modify an input stress wave to where it has a virtually instantaneous post-peak drop time, resulting in ‘rarefaction shock.’” Ex-1002, 77.

70. The Applicant further argued that “an important principle of operation in this invention, which is that the stress wave propagates through a glass substrate, rather than merely using a glass substrate as a confinement for generating a wave launched directly into a substrate.” Ex-1002, 79. The Applicant described the glass substrate element 106 as “used to modify the stress wave as it propagates through the glass layer 106. After the wave has been modified by the glass substrate (into a rarefaction shock) it is transmitted through the substrate 108 to coating 110.” Ex-1002, 80.

71. The Examiner rejected this argument, as the solid waterglass confining layer disclosed in *Gupta* propagates a stress wave to the coating and substrate. Ex-1002, 62. In its response, the Applicant amended the claims to add the word

“modify” to the wherein clause in Claim 1 and similar limitations in the other independent claims. Ex-1002, 37-43. The Applicant argued that the glass materials have “the effect of compressing the tail end of a propagated shock, **thereby modifying the input stress wave**, resulting in a ‘rarefied shock’ pulse tail.” Ex-1002, 44-45. The Examiner allowed the application. Ex-1002, 18.

72. Based on the statements made during the prosecution, I understand that the additional “modify” claim language aims to distinguish the function of the glass element from the previous waterglass such that the glass element has the effect of compressing the tail end of a propagated shock wave to result in a rarefaction shock or decompression shock.

X. THE PRIOR ART REFERENCES

A. Wang-Dissertation (Ex-1005)

73. I submitted a dissertation entitled “Thin-film Adhesion Measurement by Laser-Induced Stress Waves” in 2002 after finishing my PhD defense at the University of Illinois at Urbana-Champaign (“Wang-Dissertation”). Ex-1005. I was aware of ProQuest at the time, as ProQuest is a world renowned information and data provider who provides access to dissertation, thesis, periodicals, historicals, etc. I am aware that my dissertation was made available to the public through ProQuest.

74. My dissertation describes my tensile laser spallation techniques for measuring thin-film adhesion, and is in the same field of invention as identified in

the '684 Patent and focused on the same object to measure the tensile strength of interfaces between substrates and thin films. I investigated laser-generated stress waves to characterize interfacial strength of thin films and, as a part of this analysis, the mechanism for shock development in fused silica substrates was studied. Ex-1005, 1-5, 24-39, 40-81, 119-124. At the time, the development of “rarefaction shocks” in fused silica was known, as opposed to the more common compression shocks found in other materials. Ex-1005, 24-39, 119-124; Ex-1021. My work adopted this known phenomenon into the laser spallation technique to effectively test the interfacial strength of micron and sub-micron thin films.

75. I performed tensile laser spallation techniques using fused silica. Ex-1005, 40-81. My tensile laser spallation apparatus is shown in Figure 2.1 (Ex-1005, 7-8, 42):

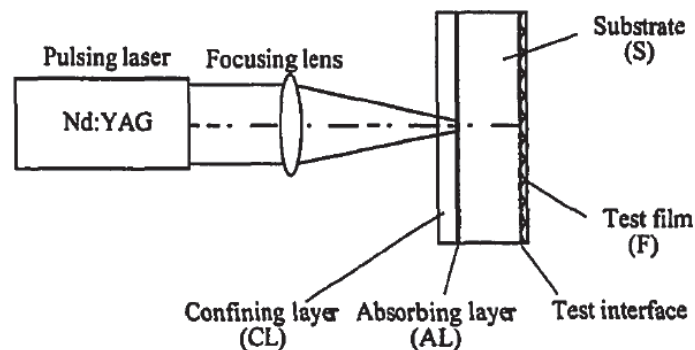


Figure 2.1: Schematic of the tensile laser-spallation technique.

76. I investigated both fused silica and single crystal silicon as substrate materials, with aluminum layers used as both the test film and absorbing layer. Ex-

1005, 45. A large number of tests were performed to investigate the effects of laser power, substrate thickness, film thickness, and confining layer thickness. Ex-1005, 46-81.

77. In my investigation, as described in my dissertation, I identified a laser-induced weak shock formation in fused silica. Ex-1005, 62-66. Specifically, I determined that an initial fall time of a few nanoseconds has been reduced to nearly zero and occurs long before the pulse arrives at the test film by using fused silica in tensile laser spallation technique. Ex-1005, 65. This is consistent with the known rarefaction shocks in fused silica. Ex-1005, 26. I observed that a decompression shock occurred that is especially beneficial for tensile thin film tests, where the optimal compressive pulse (i.e., the incoming substrate stress wave) ought to have a rapid fall time. *See* Ex-1005, 65-66, 81, 120 (“The existence of a shock created a large stress at the film interface, promoting failure.”).

78. Based on my investigation, I determined that fused silica is an ideal substrate material for launching high-amplitude shock waves, as its negative nonlinear elasticity is critical for the development of a decompression shock. Ex-1005, 124. Therefore, because laser spallation is a technique used to test different substrate/coating interfaces depending on application, by inserting an extra layer of the desired substrate material between the fused silica and the thin film, my technique can be used to test a variety of substrates and thin films. Ex-1005, 124.

B. Gupta-1992 (Ex-1011)

79. Gupta-1992 relates to tensile laser spallation techniques for measuring thin-film adhesion, and is in the same field of invention as identified in the '684 Patent and focused on the same object to measure the tensile strength of interfaces between substrates and thin films. Ex-1011, Abstract. This is an article that I have cited in my past work from the early 2000s. *See* Ex-1005, Ex-1016, Ex-1017.

80. Gupta-1992 discloses that laser spallation is a “technique [that] can be used to determine the strength of planar interfaces between coatings ($>0.3\ \mu\text{m}$ in thickness) and substrates in general.” Ex-1011, 142. Gupta-1992 discloses a standard laser spallation technique wherein “a laser pulse of a high enough energy and a pre-determined duration is converted into a pressure pulse of a critical amplitude and width that is sent through the substrate toward the free surface with the coating.” Ex-1011, Abstract. The reflected tensile wave from the surface with the coating pries-off (e.g., spalls) the coating. Ex-1011, Abstract, Fig. 1.

81. Gupta-1992 discloses application of the technique to different substrates—Si single crystal wafers, pyrolytic graphite (PG) platelets, and Pitch-55 (P-55) type carbon ribbons. Ex-1011, 163-169. Gupta-1992 discloses two different sample configurations for the experiments, as shown in Figure 2(a) and 2(b),

including an additional layer of fused quartz between the energy absorbing layer and the desired substrate (Ex-1011, 145):³

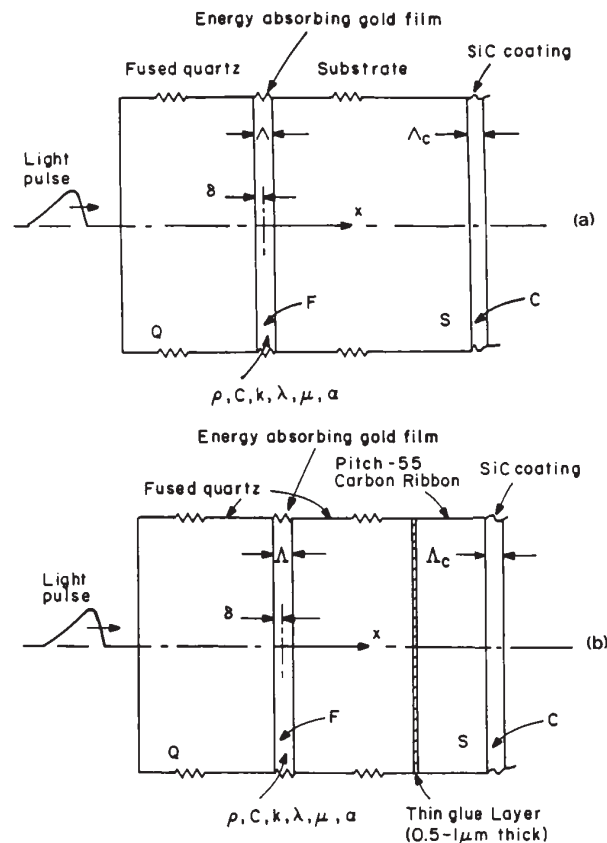


FIG. 2. (a) Configuration of the laser spallation probe with a homogeneous substrate. (b) Configuration for testing the Pitch-55 Ribbon/SiC system.

82. The Si/SiC and PG/SiC systems shown in Figure 2(a) demonstrated high interface stress values, in the range of 3.7 to 10.5 GPa for the Si/SiC system and an average of 7.2 GPa for the PG/ SiC system. Ex-1011, Abstract, Table 3, Table 5. Table 6 shows the P-55/SiC system demonstrated lower interface stress values, and the testing used much lower laser fluence than the other two systems. Ex-1011, Table 6.

³ The same configuration was also found in a previous publication. Ex-1029.

C. Gupta-1993 (Ex-1013)

83. Gupta-1993 relates to tensile laser spallation techniques for measuring thin-film adhesion, and is in the same field of invention as identified in the '684 Patent and focused on the same object to measure the tensile strength of interfaces between substrates and thin films. Ex-1013, Abstract. Gupta-1993 is a part of a three-series experimental optimization of the laser spallation technique. Ex-1013, Abstract. I have also cited this article or the related parts of this series in my past work from the early 2000s. *See* Ex-1005, Ex-1016. Part III of the optimization focused on changing the type and thickness of the laser-absorbing film and the constraining medium. Ex-1013, 2405. Fused quartz, free-standing water, and waterglass were tested as constraining materials. Ex-1013, 2405-10. This work seems to support the initial denial of the '684 Patent as waterglass here is serving the function of propagating a stress wave with shorter rise time and sharper decay towards the substrate/coating interface.

D. Wang-2002 (Ex-1016)

84. My article "A Parametric Study of Laser Induced Thin Film Spallation," with Dr. Sottos and Dr. Weaver, published in *Experimental Mechanics* in 2002. Ex-1016, 74-83. This article relates to my experimental tensile laser spallation techniques for measuring thin-film adhesion that led to my dissertation, and is in the same field of invention as identified in the '684 Patent and focused on

the same object to measure the tensile strength of interfaces between substrates and thin films. Ex-1016, Abstract. Specifically, my article discloses a study of laser-induced thin-film spallation. Ex-1016, Abstract. A schematic of my laser spallation apparatus is shown in Figure 1 of my parametric study (Ex-1016, 76):

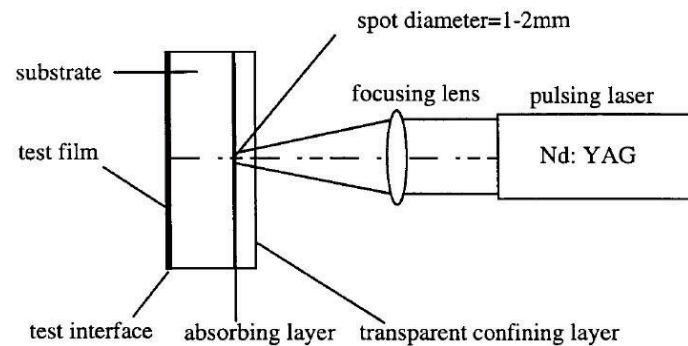


Fig. 1—Schematic of laser spallation technique: absorbing layer thicknesses are typically between $0.4 - 1.0 \mu\text{m}$, test film thicknesses are between $0.6 - 3.0 \mu\text{m}$ and the substrate has a thickness between $400 - 6000 \mu\text{m}$

85. Two different substrate materials, single crystal silicon and fused silica, were considered. Ex-1016, Abstract. The spallation of aluminum thin-film coatings was investigated as a function of substrate thickness, film thickness, laser energy and various parameters governing the source. Ex-1016, Abstract. In this study, as disclosed, I determined that the maximum stress at the interface increases with increasing laser fluence, and in some conditions, is large enough to damage the silicon. Ex-1016, Abstract.

86. I also found of particular significance the development of a “decompression shock” in the fused silica substrates, which resulted in very high tensile stresses at the interface and enhances the failure of thin film interfaces. Ex-

1016, Abstract, 80 (“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 of the pulse has stretched from about 2.9 ns to 20 or 30 ns. The falling rear of the pulse has therefore compressed by the same amount; an initial fall time of a few nanoseconds has therefore been reduced to zero, and this occurs long before the pulse arrives at the test film.”). I observed a decompression shock for all three thicknesses of the fused silica. Ex-1016, 81.

87. I found that this shock mechanism is advantageous in the design of laser spallation tests of thin film interface adhesion. Ex-1016, 82 (“This shock mechanism is advantageous in the design of laser spallation tests of thin film interface adhesion. Moreover, fused silica is an ideal material for studying the mechanics of the spallation tests in that it is intrinsically strong and no substrate damage occurs before the interfacial failure.”). 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.

XI. THE PRIOR ART RENDERS THE CLAIMS ANTICIPATED OR OBVIOUS

88. In my opinion, each of the prior art references are in the same field of laser spallation techniques and would have been considered by a POSITA in addressing the problem addressed by the '684 Patent at the time of the invention—

optimizing laser spallation techniques for thin-films. Furthermore, in my opinion, the prior art references cited in the Petition disclose or suggest all of the elements of the Challenged Claims of the '684 Patent. Also, a POSITA would have been motivated to combine the references as proposed in the Petition, and there would have been a reasonable expectation of success in such combinations.

A. Ground 1 – Claims 1-22 Are Anticipated By Wang-Dissertation

1. Claim 1

a. [1.pre] “An apparatus for generating a tensile stress between a substrate and a coating”

89. I understand that a preamble may be limiting, meaning that it is treated like a claim limitation, or it may not be limiting. I am not a lawyer to make that determination. To the extent the preamble is limiting, however, my dissertation discloses an apparatus for generating a tensile stress between a substrate and coating.

90. My dissertation discloses my tensile spallation experiment designed to measure thin-film adhesion. Ex-1005, 40-81; Section X.A. Figure 2.1 shows a schematic of my tensile laser spallation apparatus:

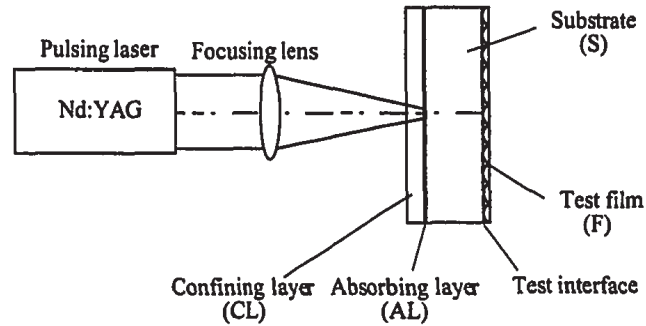


Figure 2.1: Schematic of the tensile laser-spallation technique.

91. The thin-film sample consists of a confining layer (CL), a thin energy absorbing layer (AL), a substrate (S), and test film (F) coating. Ex-1005, 7-8. Fused silica and single crystal silicon substrates were investigated in my work and aluminum films were either evaporated or sputtered onto both sides of the substrate. Ex-1005, 45.

92. A Nd:YAG laser pulse is incident on the metallic aluminum absorbing layer sandwiched between the confining layer and the substrate to create a stress wave. Ex-1005, 8, Fig. 2.1. The wave propagates toward the film/substrate interface and is reflected back from the film into a tensile wave, which then loads the test interface in tension and generates a tensile stress between a substrate and the test film coating. Ex-1005, 8.

b. [1.a] “a substrate having a thickness, said thickness defined by a first side and a second side in a first axis”

93. My dissertation discloses a substrate having a thickness, said thickness defined by a first side and a second side in a first axis.

94. Figure 2.1 from my dissertation (annotated below) shows the thin-film sample is sequentially spaced along a first axis. Ex-1005, Fig. 2.1. A substrate having a thickness is shown, with the thickness defined by a first side and a second side in the first axis:

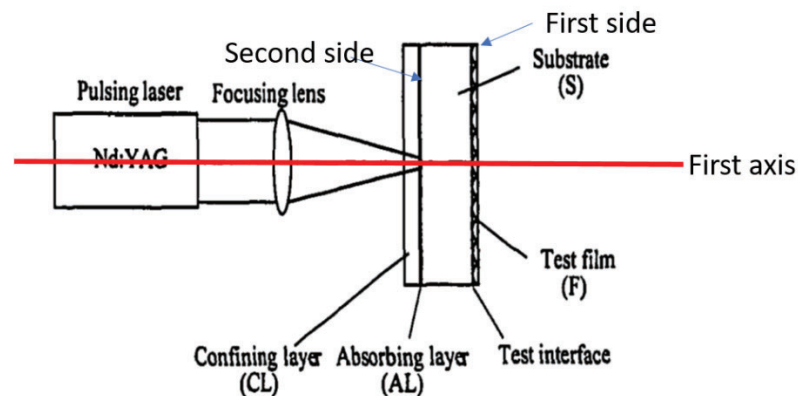


Figure 2.1: Schematic of the tensile laser-spallation technique.

Fused silica and single crystal silicon substrates were investigated as the substrate material, including different thicknesses of the substrates. *E.g.*, Ex-1005, 45, 56-59.

95. My dissertation discloses that fused silica is an ideal substrate material for launching high-amplitude shock waves (its negative nonlinear elasticity being critical for the development of a decompression shock). Ex-1005, 124. My dissertation further discloses inserting an extra layer of substrate material between the fused silica and the thin film to test a variety of substrates and thin films:

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 thin films, especially those of interest to the

microelectronics industry, such as polyimide, copper, aluminum and polysilicon on single-crystal silicon substrates.

Ex-1005, 124. This extra layer is a substrate having a thickness, said thickness defined by a first side and a second side in a first axis. My dissertation expressly discloses that a desired substrate of interest is single-crystal silicon substrate, which is one of the substrate materials that I describe throughout my dissertation, including testing of different thicknesses. Ex-1005, 56 & 59.

96. A POSITA would have understood the inserted substrate to have a thickness defined by a first side and second side in a first axis, as shown in the figures of my dissertation that show the placement of a substrate, e.g., silicon, in the sample and apparatus. Ex-1005, 124, Fig. 2.1, Fig. 3.2.

c. [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”

97. My dissertation discloses 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.

98. My dissertation discloses using an aluminum film for both the absorbing layer (AL) and the test film (F) coating. Ex-1005, 44-45. My dissertation discloses that an aluminum test film was either evaporated or sputtered onto the first side of the substrate. Ex-1005, 45. This is a coating and shown in Figure 3.2:

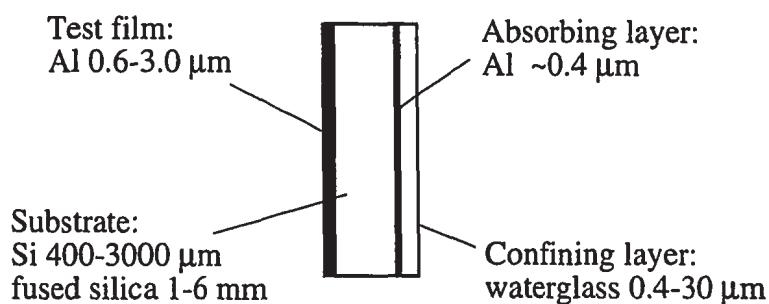


Figure 3.2: Schematic of thin film sample for spallation experiment.

The test film is shown applied to the first side of the substrate such that the coating and the substrate are axially spaced along the first axis in intimate facing contact and form a film/substrate interface. Ex-1005, Fig. 2.1 (showing placement of the substrate and coating axially spaced along the first axis). The initial test film coating was 0.6-3 μm thick. Ex-1005, 45.

99. My dissertation further discloses that fused silica is an ideal substrate material for launching high-amplitude shock waves (its negative nonlinear elasticity being critical for the development of a decompression shock). Ex-1005, 124. My dissertation discloses inserting an extra layer of substrate material between the fused silica and the thin film coating to test a variety of substrates and thin films. Ex-1005, 124.

100. As shown in Figures 2.1 and 3.2, a POSITA would have understood that by inserting the extra layer of substrate, the coating is on the first side of the inserted substrate (opposite of the fused silica) and 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. Ex-1005, 124, Fig. 2.1, Fig. 3.2. At the time, inserting an extra layer of substrate would have been known and easy to do, for example, by depositing the testing film on one side of the substrate, and bonding the other side of the substrate to the fused silica by a thin layer of superglue or two-part epoxy. I also cited Gupta-1992 in my dissertation, which as discussed above, shows how to create a sample with the inserted desired extra layer of substrate and a glass element using glue. Ex-1005, 4.

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

101. My dissertation discloses a glass element disposed on the second side of the substrate and axially spaced along the first axis.

102. As discussed above, fused silica is a glass consisting of almost pure silica (silicon dioxide, SiO_2). 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-1005, 26; Ex-1021.

103. My dissertation discloses that fused silica is an ideal substrate material for launching high-amplitude shock waves (its negative nonlinear elasticity being critical for the development of a decompression shock). Ex-1005, 124. My dissertation further discloses inserting an extra layer of desired substrate material between the fused silica and the thin film to test a variety of substrates and thin films.

Ex-1005, 124. A POSITA would have understood in this configuration disclosed in my dissertation, the fused silica would be a glass element disposed on the second side of the inserted layer of desired substrate material, e.g., silicon, and axially spaced along the first axis, as shown in the figures. Ex-1005, 124, Fig. 2.1, Fig. 3.2.

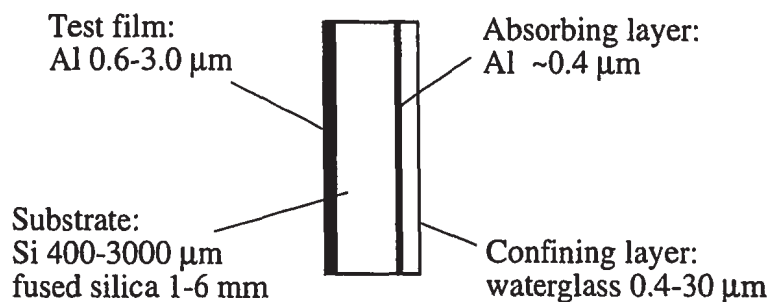


Figure 3.2: Schematic of thin film sample for spallation experiment.

- e. [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.”**

104. My dissertation discloses 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.

105. The '684 Patent teaches that it was known “for a given coating thickness the post-peak decay time is the most critical in maximizing the interfacial tensile stress.” Ex-1001, 8:43-45. The '684 Patent teaches if “post-peak decay time [of the stress wave] is reduced to zero, i.e. the wave profile has a ‘rarefaction shock,’

then the interface tensile stress for a film of arbitrarily small thickness will be equal to the amplitude of the incoming compression pulse.” Ex-1001, 8:45-49.

106. During prosecution, the claimed glass-propagated and modified stress wave was identified as the creation of a “rarefaction shock.” Ex-1002, 44-45, 80. The ’684 Patent states that all tested glass substrates “showed the formation of the rarefaction shock.” Ex-1001, 9:47-49.

107. My dissertation discloses the claimed fused silica glass element is configured to propagate and modify a stress wave in the same way as the patent. My dissertation discloses that in fused silica, the initial stress pulse generated at the absorbing layer evolves into a shock after traveling a short distance. Ex-1005, 30, 38, 65 (“That sufficient time has occurred in the present case for a decompression shock to develop is evident.... An initial fall time of a few nanoseconds has therefore been reduced to nearly zero.”), 81 (“In fused silica substrates, the compressive pulse evolved into a decompression shock.”). My dissertation further discloses that fused silica is an ideal substrate material for launching high-amplitude shock waves (its negative nonlinear elasticity being critical for the development of a decompression shock). Ex-1005, 124.

108. The fused silica propagates a shock wave and forms a “decompression shock,” which is the same as the “rarefaction shock” identified in the patent and during the prosecution history. These terms are often interchangeably used in

literature and are known to mean the same thing, e.g., rapid transition from high pressure to low pressure, and opposite of a common compression shock.

109. I also expressly disclose in my dissertation that fused silica was chosen for investigation because there was known evidence of formation of “rarefaction” shocks. Ex-1005, 26; Ex-1021.

110. My dissertation also discloses, like the '684 Patent, this decompression shock is especially beneficial for tensile thin film tests. Ex-1005, 66, 81; Ex-1001, 8:45-51. The fused silica glass element disclosed in my dissertation is thus 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 claimed. Ex-1005, 81, 120 (“This shock mechanism was advantageous for failing thin-film interfaces on thick substrates.”).

111. Figure 3.2 (annotated) below shows how my dissertation discloses the apparatus of Claim 1 and dependent Claims 11 and 12, as discussed below.

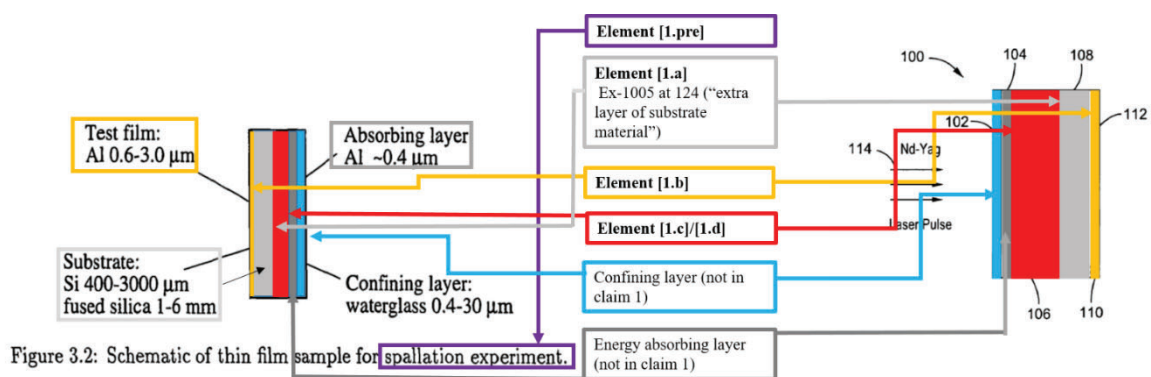


Fig. 3.2 from Wang Dissertation Ex-1005 (Prior Art) (Annotated)

Fig. 4 '684 Patent (Annotated)

112. Shown in blue is the confining (i.e., constraining) layer (Ex-1005, Fig. 3.2), dark gray is the energy absorbing film (Ex-1005, Fig. 3.2), red is the glass element (Ex-1005, Fig. 3.2, 124), light gray is the substrate (Ex-1005, Fig. 3.2, 124) and the orange layer is the coating (Ex-1005, Fig. 3.2, 124).

2. Claim 2

113. My dissertation further discloses “[a]n apparatus as recited in claim 1, wherein the tensile strength is configured to separate the coating from the substrate at the coating/substrate interface.” My dissertation discloses that the existence of a decompression shock created a large stress at the substrate/film interface, promoting failure to separate the coating from the substrate. Ex-1005, 120. In the disclosed laser spallation techniques using fused silica and silicon, the laser energy was increased until the longitudinal wave is generated with an amplitude sufficient to fail the film/substrate interface. Ex-1005, 42.

3. Claim 3

114. My dissertation further discloses “[a]n 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 to the first axis.” This is shown in Figure 2.1 in my dissertation (annotated):

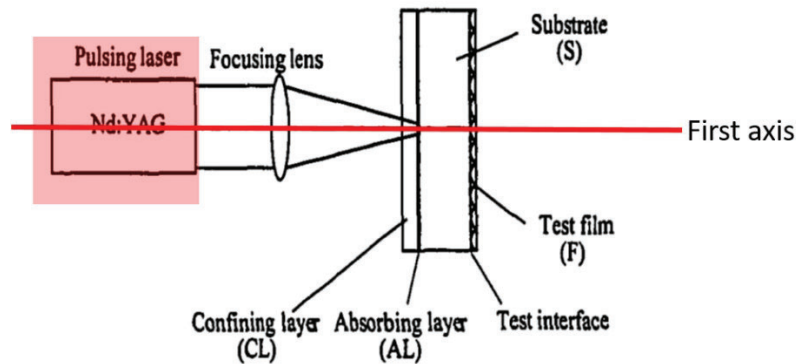


Figure 2.1: Schematic of the tensile laser-spallation technique.

Ex-1005, 7. My dissertation discloses a Nd:YAG laser pulse is incident on the metallic absorbing layer sandwiched between the waterglass and the substrate. Ex-1005, 8. The tested substrate is disclosed as either fused silica or silicon. Ex-1005, 45. As discussed above, my dissertation further discloses adding an additional layer of substrate material, such as silicon, between the fused silica substrate and the test film coating. Ex-1005, 124. My dissertation thus discloses the fused silica (the claimed “glass”) is configured to propagate a stress wave as a result of the Nd:YAG laser impingement, as shown in Figure 2.1.

4. Claim 4

115. My dissertation discloses “[a]n apparatus as recited in claim 1, wherein the stress wave has a length ranging from approximately 5 nanoseconds to approximately 1 microsecond.” My dissertation discloses that the shape of the stress pulse is determined by that of the deposited laser pulse. Ex-1005, 19, Equation (2.46). Thus the length of the stress wave would naturally influenced by the duration

of the laser pulse used. From Equation (2.44), it is known that the theoretical length of the stress wave generated at the energy absorbing layer for the laser used in my work is around 6-8 nanoseconds (ns).

116. My dissertation discloses a stress wave between 10 to 30 ns, which depends on the duration of the laser pulse used and the substrate material. Ex-1005, 19. The fringes developed over 20 to 30 ns in fused silica, whereas in silicon, the full waveform was confined to a duration of about 10 ns comparable to the duration of the laser pulse. Ex-1005, 62. This information can also be seen in the following figures of my dissertation: Figure 3.15c, 3.16, 3.17, 3.18, 3.19, 3.20b, 3.21b and 3.22. *See* Ex-1005, 63-79.

117. These disclosed stress wave lengths are specific points in the claimed length range of 5 nanoseconds to approximately 1 microsecond.

5. Claim 5

118. My dissertation discloses “[a]n apparatus as recited in claim 4, wherein the stress wave comprises a rarefaction shock formation.” As discussed above and in my dissertation, there was known evidence of formation of “rarefaction” shocks in fused silica. Ex-1005, 26; Limitation [1.d]. My dissertation discloses that fused silica is “an ideal substrate material for launching high-amplitude shock waves (its negative nonlinear elasticity being critical for the development of a decompression shock).” Ex-1005, 124; *see also* 65 (“That

sufficient time has occurred in the present case for decompression shock to develop is evident... 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.”); 81 (“In fused silica substrates, the compressive pulse evolved into a decompression shock.”). As discussed above, a POSITA would have understood my disclosure of the formation of a “decompression shock” to be the claimed “rarefaction shock.”

6. Claim 6

119. My dissertation discloses “[a]n apparatus as recited in claim 1, wherein the coating has a thickness of less than approximately 0.5 μ m.” For my spallation experiments, I investigated aluminum test films (“coating”) of 0.6-3 μ m thick. Ex-1005, 45. Although the thinnest film shown here was 0.6 μ m rather than 0.5 μ m, a POSITA would have considered these thicknesses approximately the same in the context of this technology as there is no fundamental difference between the two, and they are both in the sub-micron regime where the shock wave loading is desired. A POSITA would also appreciate that even if you are targeting 0.5 μ m you may end up with 0.6 μ m or 0.4 μ m due to challenges in precisely controlling the deposition rate.

120. As my dissertation further discloses, I also tested different film thicknesses of 0.3 μ m on the fused-silica substrate and 0.4 μ m for the silicon

substrate, which are both less than 0.5 μm , thus falling within the range of this claim.

Ex-1005, 53-56.

121. These coating thicknesses disclose the claim limitation as they are each less than approximately 0.5 μm .

7. Claim 7

122. My dissertation discloses “[a]n apparatus as recited in claim 1, wherein the glass element is bonded to the second side of the substrate.”

123. A POSITA would have understood that to insert an extra layer of the desired substrate material between the fused silica and the thin film as I disclose in my dissertation (Ex-1005, 124), the fused silica glass element would have to be bonded to the second side of the substrate, as there can be no air gap between the fused silica and the substrate. It would have been understood to use a space-filling material such as a thin layer of superglue or two-part epoxy, or if one can make the fused silica and the substrate infinitely smooth, the two would be bonded by van der Waals force, but this would incur significantly higher cost due to the stringent surface preparation requirement.

8. Claim 8

124. My dissertation discloses “[a]n apparatus as recited in claim 1, wherein the glass element comprises one of the following: Pyrex, soda lime, quartz, or borosilicate.” A POSITA would have understood that fused silica

(interchangeably used with fused quartz) is quartz (*e.g.*, SiO₂) or quartz derivatives (*e.g.*, sodium silicate) in the context of this technology and exhibit the same properties in a laser spallation technique. Ex-1005, Fig. 3.2, 124; *see also* Ex-1014, 24 (same experiments using fused quartz).

9. Claim 9

125. My dissertation discloses “[a]n apparatus as recited in claim 1, wherein the glass element has a thickness ranging from approximately 0.1mm and approximately 5mm.” As disclosed in my dissertation, my investigation involved testing different thicknesses of the fused silica glass element, including 1.5 mm, 3.0 mm and 6.0 mm (1500, 3000, and 6000μm), that are specific points in this claimed range of thickness. Ex-1005, 56-59. The results are summarized in Table 3.4.

10.Claim 10

126. My dissertation discloses “[a]n apparatus as recited in claim 1, wherein the substrate comprises silicon.” As disclosed in my dissertation, I investigated single crystal silicon as a substrate material with the thin-film aluminum coating as the test film and waterglass as the confining layer. Ex-1005, 45. Silicon is also disclosed as a desired substrate material to insert for the substrate/thin film interface (of interest to the microelectronics industry) with the fused silica glass element. Ex-1005, 124.

11.Claim 11

127. My dissertation discloses “[a]n apparatus as recited in claim 1, further comprising a constraining element disposed adjacent to the glass element.” My thin-film sample is shown in Figure 3.2 of my dissertation, with a confining layer of waterglass, which is the claimed “constraining element,” disposed adjacent to the fused silica glass element:

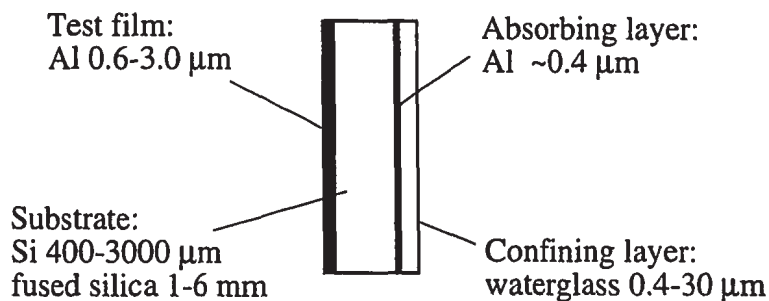


Figure 3.2: Schematic of thin film sample for spallation experiment.

Ex-1005, 44-45.

128. I also disclose adding an additional layer of desired substrate material between the fused silica and test film. Ex-1005, 124. Therefore, with the insertion of the desired substrate, the confining layer (“constraining layer”) of waterglass would remain disposed adjacent to the fused silica glass element. Figure 3.2 (annotated) above shows how my dissertation discloses the apparatus of Claim 1 and Claim 11.

12.Claim 12

129. My dissertation discloses “[a]n apparatus as recited in claim 1, further comprising an energy absorbing layer disposed between the constraining layer and

glass element.” As I have shown for Claim 11 above, Figure 3.2 in my dissertation discloses an aluminum energy absorbing layer disposed between the waterglass and the fused silica glass element. Ex-1005, 44-45.

130. I also disclose adding an additional layer of desired substrate material between the fused silica and test film. Ex-1005, 124. Therefore, with the insertion of the desired substrate, the aluminum energy absorbing layer would remain disposed between the confining layer (“constraining layer”) of waterglass and the fused silica glass element. Figure 3.2 (annotated) above shows how my dissertation discloses the apparatus of Claim 1 and Claim 12.

13.Claim 13

- a. [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:”**

131. To the extent the preamble is limiting, my dissertation discloses the preamble.

132. As I discussed for limitations [1.pre], [1.a], and Claim 2 above, my dissertation discloses a method for separating a test film coating from a substrate with a first and second side transversely disposed in a first axis, with the coating applied to a first side of the substrate such that the coating and substrate are axially

spaced along the first axis in intimate facing contact, by sputtering an aluminum film coating on the free side of the substrate to form a film/substrate interface. Ex-1005, 7-8, 44-45, 124, Fig. 2.1, Fig. 3.2; Section X.A.

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

133. My dissertation discloses positioning a glass element along the first axis on the second side of the substrate.

134. My dissertation discloses a sample including a confining layer, an absorbing layer, a substrate of fused silica, and thin-film coating. Ex-1005, Fig. 3.2. My dissertation further discloses inserting an extra layer of desired substrate material between the fused silica glass element and the thin film, thus positioning the fused silica glass element on the second side of the desired substrate material (opposite side of the thin film coating, with the desired substrate in between). Ex-1005, 124, Fig. 3.2, *see also* Fig. 2.1 (showing positioning of the sample with the fused silica along the first axis). This is also shown in Figure 3.2 (annotated above) and described in my analysis of Claim 1 above.

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

135. My dissertation discloses directing a laser pulse in the first axis at the glass element for at least the reasons I presented for Claim 3 above, and as shown in Figure 2.1, which shows directing a Nd:YAG laser pulse in the first axis at the fused

silica glass element. *See also* Ex-1005, 124 (disclosing adding an extra layer of substrate such that the fused silica is the “glass element”).

d. [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”

136. My dissertation discloses 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.

137. As I discussed for limitation [1.d] above, my dissertation discloses propagating and modifying a stress wave through the fused silica “glass element” into a rarefaction shock or decompression shock to generate a tensile stress (which a POSITA would understand this corresponds to a “tensile force”) between the substrate and the thin-film coating. *See* Ex-1005, 26, 30, 38, 65-66, 81, 124; *see also* Fig. 2.1 (showing laser pulse impinging on sample with confining layer and energy absorbing layer for propagating a stress wave).

e. [13.d] “separating the coating from the substrate as a result of the stress wave-generated tensile force.”

138. My dissertation discloses separating the coating from the substrate as a result of the stress wave-generated tensile force for at least the reasons I presented for Claim 2 above. As discussed in my dissertation, my experiments were designed to separate the coating from the substrate as a result of the stress-wave generated tensile force, especially with the use of a fused silica glass element. Ex-1005, 42; *see*

also 120 (“This shock mechanism was advantageous for failing thin-film interfaces on thick substrates.”).

14.Claim 14

139. My dissertation discloses “[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” for at least the reasons I presented for Claim 3 above. This is shown in Figure 2.1 of my dissertation, showing a Nd:YAG laser directing a laser pulse in the first axis toward the sample configuration. Ex-1005, Fig. 2.1.

15.Claim 15

140. My dissertation discloses “[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” for at least the reasons I presented for Claim 4 above. Propagated stress waves in the claimed range are shown in several figures of my dissertation. *See* Ex-1005, 63-79.

16. Claim 16

141. My dissertation discloses “[a] method as recited in claim 15, wherein the stress wave comprises a rarefaction shock formation” for at least the reasons I presented for Claim 5 above. As discussed above and in my dissertation, there was known evidence of formation of “rarefaction” shocks in fused silica. Ex-1005, 26; Limitation [1.d].

142. My dissertation also discloses that fused silica is an ideal substrate material for launching high-amplitude shock waves (its negative nonlinear elasticity being critical for the development of a decompression shock). Ex-1005, 124; *see also* 65 (“That sufficient time has occurred in the present case for a decompression shock to develop is evident.”), 81 (“In fused silica substrates, the compressive pulse evolved into a decompression shock.”). A POSITA would have understood the formation of the “decompression shock” to be the claimed “rarefaction shock.”

17.Claim 17

143. My dissertation discloses “[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 μ m” for at least the reasons I presented for Claim 6 above.

144. For my spallation experiments, I investigated aluminum test films (“coating”) of 0.6-3 μ m thick. Ex-1005, 45. As my dissertation further discloses, I also tested (and spalled/separated) different film thicknesses of 0.3 μ m on the fused-silica substrate and 0.4 μ m for the silicon substrate. Ex-1005, 53-56; *see also* 42 (“The laser energy is increased until a longitudinal wave is generated with an amplitude sufficient to fail the film/substrate interface.”).

145. These coating thicknesses are less than approximately 0.5 μ m as explained above for Claim 6 and the stress waves were configured by laser energy to separate these coatings as disclosed in my dissertation. Ex-1005, 53-56.

18.Claim 18

146. My dissertation discloses “[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” for at least the reasons I presented for Claim 7 above. A POSITA would have understood that to insert an extra layer of the desired substrate material between the fused silica and the thin film as I disclose in my dissertation (Ex-1005, 124), the fused silica glass element would have to be bonded to the second side of the substrate, as there can be no air gap between the fused silica and the substrate for a laser spallation technique.

19.Claim 19

147. My dissertation discloses “[a] method as recited in claim 13, wherein the glass element comprises one of the following: Pyrex, soda lime, quartz, or borosilicate” for at least the reasons I presented for Claim 8 above. A POSITA would have understood that fused silica is quartz in the context of this technology and exhibits the same properties in a laser spallation technique. Ex-1005, Fig. 3.2, 124.

20.Claim 20

148. My dissertation discloses “[a] method as recited in claim 19, wherein the glass element has a thickness ranging from approximately 0.1 mm to approximately 5 mm” for at least the reasons I presented for Claim 9 above. As disclosed in my dissertation, my investigation involved testing different thicknesses

of the fused silica glass element, including 1500, 3000, and 6000 μm that are in this claimed range of thickness. Ex-1005, 56-59.

21.Claim 21

149. My dissertation discloses “[a] method as recited in claim 13, further comprising positioning a constraining element adjacent to a free side of the glass element” for at least the reasons I presented for Claim 11 above. Figure 3.2 (annotated) shows the waterglass constraining element adjacent to the free side of the fused silica glass element (opposite of the substrate/film layer). Ex-1005, Fig. 3.2, Fig. 2.1; *see also* 124 (disclosing further inserting a desired layer of substrate).

22.Claim 22

150. My dissertation discloses “[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.”

151. My dissertation discloses using an aluminum layer as both the testing film coating and the energy absorbing layer and coating this aluminum layer on the free side of the fused silica glass element. Ex-1005, 45 (disclosing coating aluminum on both sides of the fused silica glass element); *see* Claim 12 above. The figures in my dissertation further show that the Nd:YAG laser pulse is directed in the first axis

toward the sample and the aluminum energy absorbing layer coated on the free side of the fused silica glass element. Ex-1005, Fig. 2.1 (showing directing a laser pulse to an aluminum energy absorbing layer coated on the fused silica glass element), Fig. 3.2 (showing the energy absorbing layer coated on the free side of the fused silica between a waterglass constraining layer and the fused silica).

152. Figure 3.2 (annotated) above further shows how my dissertation discloses the method of Claim 22.

B. Ground 2 – Wang-Dissertation Renders Obvious Claims 4, 6, 9, 15, 17, 20, 23-24

1. Claims 4, 6, 9, 15, 17, 20

153. As discussed above for each claim, my dissertation discloses specific points within the claimed ranges of these dependent claims. A POSITA would have understood this disclosure and my work to at least overlap with the claimed ranges for the stress wave lengths, glass thickness, and film thickness, which I understand at least makes these claims obvious.

154. I also understand that where the general conditions of a claim were known in the prior art, it is not inventive to discover optimum or workable ranges by routine experimentation. I understand when there is a design need to solve a problem (such as measuring thin-film adhesion) and there are a finite number of identified, predictable solutions, a POSITA has good reason to pursue the known options within his or her technical grasp. The configuration of Claims 1 and 13 were

disclosed in my dissertation, as discussed above. Each of the claimed ranges of stress waves, film thickness and glass element thickness were known and easily accessible to a POSITA through standard laser spallation techniques and experimentation.

155. At the time of the invention, my work involved testing different lengths of stress waves and substrate/film thickness, as recited throughout my dissertation. Ex-1005, 51-69. Each of these different parameters were tested for impact on the laser spallation techniques, including using fused silica and its known rarefaction shock, and to optimize the techniques for thin films. It was known that each substrate thickness (fused silica in my work), film thickness, and laser energy were design parameters for improving laser spallation techniques for thin film adhesion. Ex-1005, 5 (“The parametric study results reveal important design parameters for improving the tensile spallation tests.”); *see also* Ex-1028, 12-26 (discussing optimization of stress pulse generation by changing type and thickness of absorbing film and constraining medium, and substrate and laser fluence), Ex-1013, 2405-10 (also investigating optimizing stress pulse conditions).

156. A POSITA would have known to use the same parameters I tested for fused silica, including substrate thickness, film thickness and stress waves, in my configuration with the extra substrate layer (Ex-1005, 124) with routine experimentation or been motivated to optimize the same parameters with this

configuration to optimize the laser spallation techniques I disclose for thin films using fused silica and the advantageous decompression shock.

157. My dissertation teaches the successful investigation of different fused silica thicknesses to optimize the desired result of spallation, all within the claimed range. Ex-1005, 45, 56-59. The thicknesses I used had the desired formation of the decompression shock and no damage was observed. Ex-1005, 61-62, 69 (“A decompression shock was observed for all three thicknesses of the fused silica.”). It would have been within the skill and ordinary creativity of a POSITA to test different thicknesses and optimize the thickness of the glass element disclosed in my configuration with the extra substrate layer. Ex-1005, 124. A POSITA would have known to optimize the thickness through routine experimentation for Claims 9 and 20 and would have been motivated to start with the thicknesses for the fused silica that I successfully tested (and achieved the desired decompression shock) in my configuration with the fused silica glass element and extra substrate. Ex-1005, 124.

158. My dissertation also teaches successful investigation of different film thicknesses. Ex-1005, 45, 53. It also would have been within the skill and ordinary creativity of a POSITA to test different thin-film thicknesses, including the thicknesses I tested in my dissertation and less than 0.5 μm as claimed in Claim 6 and 17, in my configuration with the fused silica glass element and extra substrate. Ex-1005, 124. A POSITA would have been motivated to try different thin film

thicknesses, as my dissertation teaches that fused silica and the shock mechanism is advantageous in the design of laser-spallation tests of thin-film interface adhesion and the shock created a large stress at the film interface, promoting failure. Ex-1005, 81. My dissertation also teaches that fused silica is an ideal material for studying the mechanics of the spallation test as it is intrinsically strong. Ex-1005, 81. A POSITA therefore would have been motivated to try different thin films with my configuration (Ex-1005, 124) with a reasonable expectation of success.

159. As discussed for Claims 23-24 further below, it would have been known to adjust the laser pulse to achieve the desired stress wave lengths (Claims 4 and 15). A POSITA would have known to start with my teachings to generate stress waves for the claimed range in my disclosed configuration (Ex-1005, 124) because I was able to achieve the advantageous decompression shock with the disclosed stress waves generated in my fused silica samples, and a POSITA would have been motivated to do so to fail different substrate/film interfaces using fused silica and to measure the adhesion of different interfaces.

160. 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 μm .

2. Claims 23-24

161. My dissertation combined with the knowledge of a POSITA at the time of the invention discloses or suggests “[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” and “[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.”

162. I discuss in my dissertation that the stress pulse propagating away from the interface is a copy of and is proportional to the impinging laser fluence $q(t)$. Ex-1005, 19. $q(t)$ is defined by Equation (2.44), with its coefficient proportional to the maximum pulse energy. Ex-1005, 18. Figure 2.7 shows the interfacial stress is also proportional to the pulse energy. Ex-1005, 21-22. This shows that the stress wave amplitude depends on the Nd:YAG pulse energy. Thus, the stress generated at the coating/substrate interface depends on the power of the laser source.⁴

⁴ I did not see any disclosure of the pulse energy in the '684 Patent specification for the techniques involving the glass elements.

163. Though my dissertation does not expressly disclose an experimentally-observed stress generated by the stress wave in excess of approximately 1.0 or 2.0 GPa, such features would have been obvious to implement. A POSITA would have known how to vary the pulse energy to increase or change the stress generated at the coating/substrate interface, and would have been motivated to do so to fail different thin-film/substrate interfaces to measure the adhesion of different interfaces. Ex-1005, 42 (“The laser energy is increased until a longitudinal wave is generated with an amplitude sufficient to fail the film/substrate interface.”).

164. It was known that peak stresses of gigapascals (GPa) could be developed using lasers. Ex-1007, 115 (disclosing stress waves with a magnitude of 34 kbar (3.4 GPa)); Ex-1020, Abstract (“Peak pressures greater than 5 GPa are generated in a metal or alloy when it is covered with a transparent material.”). It was also known that high interface stress values, in the range of 3.7 to 10.5 GPa, could be reached for a Si/SiC substrate/thin film system. Ex-1011, Table 3.

165. It was within the skill and ordinary creativity of a POSITA to adjust the laser energy to achieve a stress exceeding approximately 1.0 or 2.0 GPa to induce failure in different coating/substrate interfaces, and a POSITA would have had a reasonable expectation of successfully implementing such stresses because they were well-known to be achieved in the art.

C. Ground 3 – Wang-Dissertation in View of Gupta-1992 Renders Obvious Claims 1-24

1. Claim 1

a. [1.pre] “An apparatus for generating a tensile stress between a substrate and a coating”

[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”

[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.”

166. My dissertation discloses these limitations for at least the reasons I set forth above. *See* Sections XI.A.1.a-c, e.

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

167. My dissertation in view of Gupta-1992 discloses or suggests a glass element disposed on the second side of the substrate and axially spaced along the first axis.

168. My dissertation discloses that laser spallation techniques were developed to test a wide-variety of different combinations of substrate/interfaces. Ex-1005, 4 (“This technique was used to measure the tensile strength of a wide variety of metal/ceramic interfaces, ceramic/ceramic interfaces thermal-barrier

coatings, ice/metal interfaces and fiber/matrix interfaces.”) (discussing Gupta-1992). I tested two different substrates. Ex-1005, 5 (“Two different substrate materials—single crystal silicon (100) and fused silica—were studied.”). My dissertation discloses that a fused silica glass element is an ideal material for studying the mechanics of the spallation test as it is intrinsically strong and the shock mechanism is advantageous for testing thin-film interface adhesion. Ex-1005, 81. My dissertation further discloses 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 thin films. Ex-1005, 124.

169. Based on these teachings, a POSITA would have understood that I disclose that a variety of substrate/coating interfaces could be studied with the fused silica by simply inserting an extra layer of a substrate in Figure 3.2 to test a desired substrate/thin film interface. A POSITA would have envisaged a sample where the “substrate,” such as silicon/coating interface, is positioned with the fused silica “glass element” on the second side to allow the interface adhesion strength of the substrate/coating interface to be studied in a laser spallation technique, and my dissertation discloses this claim limitation. Ex-1005, 124.

170. To the extent Patent Owner argues that my dissertation does not disclose a fused silica glass element on the second side of a substrate, it would have been obvious to a POSITA at the time of the invention to implement my fused silica

glass element with a desired substrate as disclosed in Gupta-1992 and to create the configuration shown in Figure 3.2 (annotated) above.

171. Gupta-1992 is directed to tensile laser spallation techniques for thin films (Ex-1011, Abstract), so a POSITA would have had reason to look to Gupta-1992's teachings when implementing a tensile laser spallation technique for thin films and using fused silica to increase interfacial stress for thin films as taught by my dissertation. My dissertation discusses Gupta-1992 and its tensile laser spallation techniques. Ex-1005, 4, 149. As I also discussed above, there were limited key players in this niche field in the 1990s and early 2000s. A POSITA looking to develop tensile laser spallation techniques for thin films at the time of the invention would know to look to the research of key players such as Dr. Gupta and myself.

172. A POSITA would have looked to Gupta-1992 for guidance as Gupta-1992 discloses (as my dissertation states) using laser spallation techniques to test various substrate/film interfaces and discloses experiments for testing various substrates. Ex-1011, Abstract, 142 ("[T]he technique can be used to determine the strength of planer interfaces between coatings ($>0.3\text{ }\mu\text{m}$ in thickness) and substrates in general"). Gupta-1992 shows bonding fused quartz to the second side of a desired substrate for testing. Ex-1011, Fig. 2(b). This is the same configuration that my dissertation discloses for using fused silica to increase the interfacial failure in thin-

films in laser spallation techniques and test a variety of substrate/interfaces. Ex-1005, 81, 124.

173. A POSITA would have been motivated to combine my disclosure of the advantages of fused silica and adding an extra layer of substrate to test a variety of substrate/coating interfaces (Ex-1005, 124) with Gupta-1992's teaching of testing different substrates to position the fused silica on the second side of a desired substrate/coating interface, and with a reasonable expectation of success, as Gupta-1992 in Figure 2(b) explains how to create a sample with fused silica on the second side of a desired substrate. Ex-1011, Fig. 2(b). Thus, using the teachings of Gupta-1992, a POSITA would have successfully created my disclosed fused silica/extra substrate layer sample to test a variety of substrate/coating interfaces with the advantageous decompression shock formed by the fused silica.

174. This would have been a mere combination of known components and technologies (fused silica, glass elements, and substrates), according to known methods, to produce predictable results (creating the configuration shown in Figure 2(b)), as shown by the teachings of Gupta-1992 and my dissertation.

2. Claims 2-6, 8-12

175. My dissertation discloses these limitations for at least the reasons I set forth above for these claims. *See* Sections XI.A.2-6, 8-12, XI.B.1.

3. Claims 7, 18

176. My dissertation in view of Gupta-1992 discloses or suggests the limitations of Claims 7 and 18.

177. As I discussed for Claim 7 in Section XI.A above, a POSITA would have understood that to add an extra layer of substrate as disclosed in my dissertation, it would need to be bonded to the second side of the fused silica. Ex-1005, 124. A POSITA would understand there could be no air gap between the fused silica and extra layer of substrate. Using glue or epoxy would have been a known, predictable option to bond fused silica to a substrate of choice, e.g., silicon. Ex-1005, 45; Ex-1031 (discussing the bonding strength of epoxy resin).

178. To the extent Patent Owner argues that my dissertation does not disclose that the fused silica is bonded to the desired substrate, it would have been obvious to a POSITA at the time of the invention to implement my fused silica glass element with a desired substrate as disclosed in Gupta-1992 and Figure 2(b).

179. As discussed above, Gupta-1992 is directed to tensile laser spallation techniques for thin-films (Ex-1011, Abstract), so a POSITA would have had reason to look to Gupta-1992's teachings when implementing tensile laser spallation technique for thin films and using my fused silica to improve measuring adhesion for thin films. My dissertation discusses Gupta-1992 and its tensile laser spallation techniques. Ex-1005, 4, 149. As I also discussed above, there were limited key

players in this niche field in the 1990s and early 2000s. A POSITA looking to develop tensile laser spallation techniques at the time of the invention would know to look to the research of key players such as Dr. Gupta and myself.

180. As discussed above, Gupta-1992 discloses testing different substrates in laser spallation techniques. Gupta-1992 discloses fused quartz glued (“bonded”) to the second side of a P-55 substrate. Ex-1011, Fig. 2(b). It would have been obvious to apply the teachings of Gupta-1992 to my disclosed configuration (Ex-1005, 124) to glue the fused silica to the desired substrate and create the sample as shown in Gupta-1992’s Figure 2(b). A POSITA would have been motivated to combine the teachings of Gupta-1992 and my dissertation as Gupta-1992 shows the same sample described in my dissertation (Ex-1005, 124; Ex-1011, Fig. 2(b)) and shows a successful way in which a desired substrate can be bonded to fused silica, as a POSITA would have known is required to create my sample for laser spallation. Ex-1011, Fig. 2(b) (showing thin-glue layer between the fused quartz and substrate).

181. This would have been a mere combination of known components and technologies (fused silica, glass elements, glue/epoxy, and substrates), according to known methods, to produce predictable results (creating the configuration shown in Figure 2(b)), as shown by the teachings of Gupta-1992 and my dissertation.

4. Claim 13

- a. [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.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”

b. [13.d] “separating the coating from the substrate as a result of the stress wave-generated tensile force.”

182. My dissertation discloses these limitations for at least the reasons I set forth above. *See* Sections XI.A.13.a, c-e.

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

183. My dissertation in view of Gupta-1992 discloses or suggests positioning a glass element along the first axis on the second side of the substrate.

184. As I discussed for limitation [1.c] above, to the extent Patent Owner argues my dissertation does not explicitly disclose that the fused silica is positioned along the first axis on the second side of the substrate, such arrangement is implicitly disclosed because a POSITA would at once envisage the claimed arrangement or combination. My dissertation describes the typical laser spallation sample and then simply adding an additional layer of substrate. *See* Figure 3.2 (annotated) above. To

the extent Patent Owner argues otherwise, this would nevertheless have been obvious in view of Gupta-1992. *See* Limitation [1.c] above.

5. Claims 14-17, 19-24

185. My dissertation discloses these claim limitations for at least the reasons I set forth above. *See* Sections XI.A.14-17, 19-22; Section XI.B.1-2.

D. Ground 4 – Claims 1-8, 10-19, 21-22 Are Anticipated By Gupta-1992

1. Claim 1

a. [1.pre] “An apparatus for generating a tensile stress between a substrate and a coating”

186. To the extent the preamble is limiting, Gupta-1992 discloses an apparatus for generating a tensile stress between a substrate and a coating.

187. As I discussed above, Gupta-1992 discloses a tensile spallation experiment to measure thin-film adhesion. Ex-1011, Abstract; Section X.B. Figure 1 shows a schematic of Gupta-1992’s tensile laser spallation experiment apparatus (Ex-1011, 142-43):

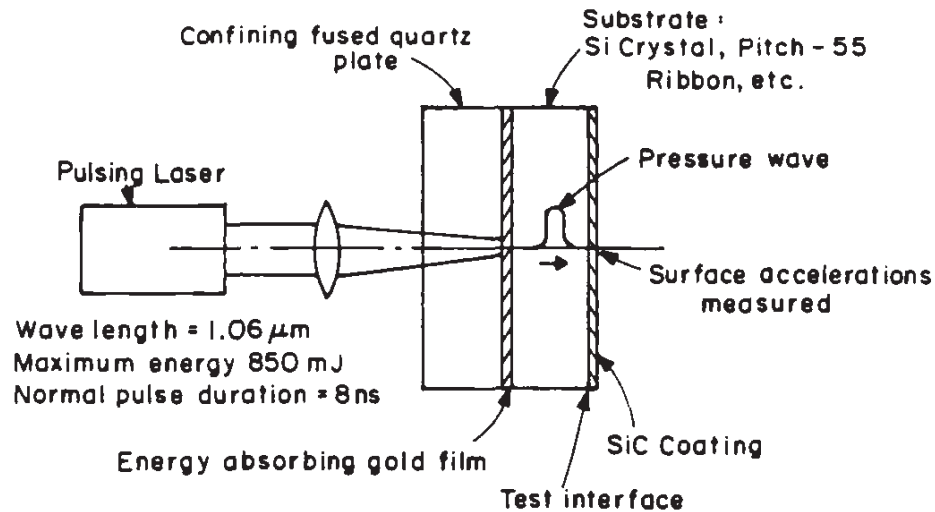


FIG. 1. Schematic view of the laser spallation experiment.

188. The sample consists of a confining fused quartz plate, an energy absorbing layer, a substrate, and an SiC coating. Ex-1011, 144-45. Si crystal, pyrolytic graphite (PG) platelets, and Pitch-55-type (P-55)⁵ substrates were investigated. Ex-1011, 163.

189. Gupta-1992 describes and shows (Figure 1) a Nd:YAG laser pulse incident on the metallic absorbing layer sandwiched between the confining layer and the substrate to create a stress wave. Ex-1011, 142, 144. The wave propagates toward the film/substrate interface and is reflected back from the film surface into a tensile wave, which then loads the test interface in tension and generates tensile stress between a substrate and a coating. Ex-1011, 142.

⁵ Pitch-55 is a highly anisotropic layered structure with graphitic planes.

b. [1.a] “a substrate having a thickness, said thickness defined by a first side and a second side in a first axis”

190. Gupta-1992 discloses a substrate having a thickness, said thickness defined by a first side and a second side in a first axis.

191. Gupta-1992 discloses that the laser spallation technique was applied to three substrates consisting of Si crystal wafers, PG platelets, and P-55-type carbon ribbons of 600 μ m width and 35 μ m thickness. Ex-1011, 163-64. Figure 2 shows two samples for the experiments. Ex-1011, Fig. 2, 145. Figure 2(a) shows the configuration for the Si/SiC and PG/SiC substrate/coating systems, and Figure 2(b) shows the P-55/SiC system, with each substrate shown with a thickness defined by a first side and a second side in a first axis x:

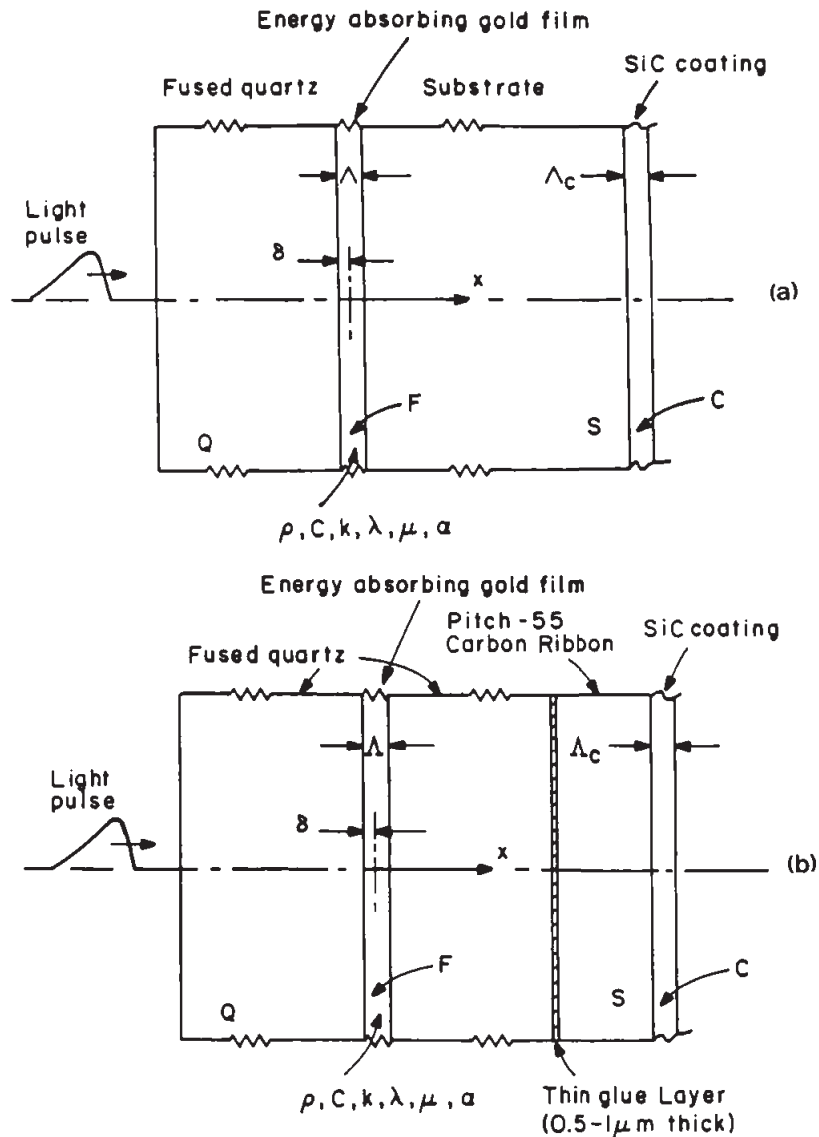


FIG. 2. (a) Configuration of the laser spallation probe with a homogeneous substrate. (b) Configuration for testing the Pitch-55 Ribbon/SiC system.

Ex-1011, Fig. 2; *see also* Ex-1011, 144 (“Figure 2(a) shows schematically the configuration of the laser spallation probe consisting from left to right of: fused quartz confining plate (Q), the thin energy absorbing film (F) of thickness Λ , the substrate (S), and the coating (C) of interest of thickness Λ_c .”), 165 (“The Si/SiC, PG/Si interface systems were tested in an experimental configuration shown in Fig.

2a, whereas for the P-55/SiC systems, the configuration shown in Fig. 2b was employed.”).

c. [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”

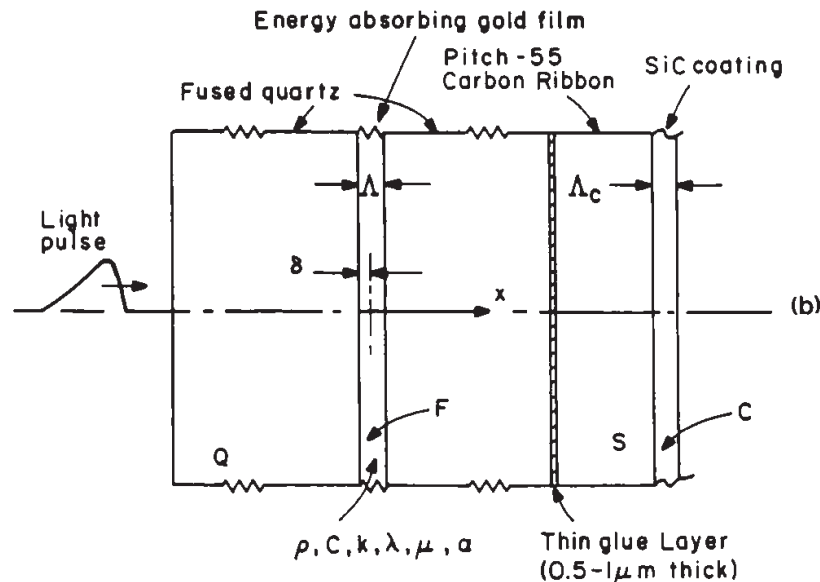
192. Gupta-1992 discloses a coating applied to the first side of the substrate such that the coating and substrate are axially spaced along the first axis in intimate facing contact with each other such to form a coating/substrate interface.

193. As I discussed for limitations [1.pre] and [1.a] above, Gupta-1992 discloses an SiC test coating applied to the first side of the different substrates. Ex-1011, Fig. 1, 143 (“a test coating of interest applied to the front surface of the substrate”), 164 (“In all these cases, the coatings to be removed were amorphous SiC coatings prepared by the plasma assisted chemical vapor deposition technique.”). The coating is in intimate facing contact with the substrate as to form a coating/surface interface. Ex-1011, 165 (“The Si/SiC, PG/SiC interface systems were tested in an experimental configuration of the type shown in Fig. 2a, whereas for the P-55/SiC system, the configuration shown in Fig. 2b was employed”).

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

194. Gupta-1992 discloses a glass element disposed on the second side of the substrate and axially spaced along the first axis.

195. As shown in Figure 2(b), an additional layer of the fused quartz glass element is glued to the second side of the P-55 substrate and therefore is disposed on the second side of the substrate and axially spaced along the first axis x as claimed. Ex-1011, Fig. 2(b), 145.



e. [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.”

196. Gupta-1992 discloses 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. Although its intended function and the scientific mechanisms were not explicitly discussed in the paper at the time, it is anticipated based on the known knowledge of shock development in this material (Ex-1021) and this specific configuration.

197. The configuration of Figure 2(b) and the glass element (the fused quartz glued to the P-55 substrate) in Gupta-1992 is the exact same as the configuration shown in Figure 4 of the '684 Patent. I show this in the annotated figures below:

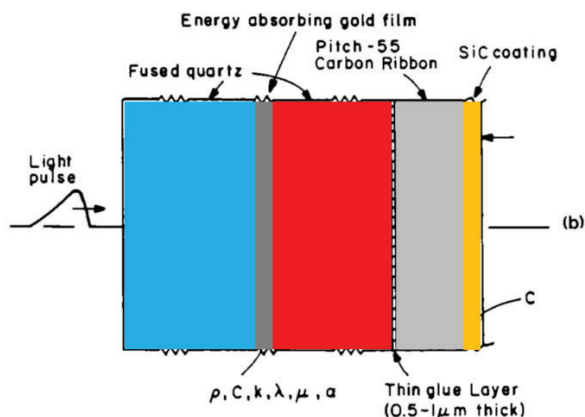


Figure 2(b) PRIOR ART (annotated)

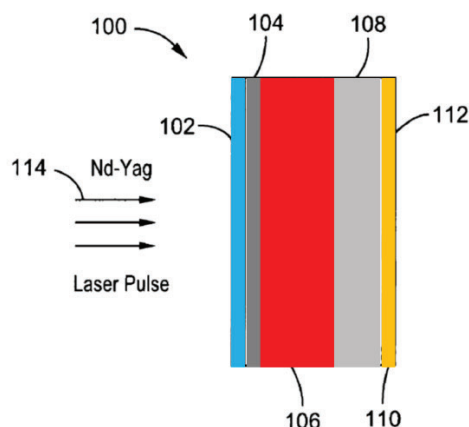


Figure 4 CLAIMED INVENTION (annotated)

Shown in blue on both figures is the confining (i.e., constraining) layer (Ex-1011, Fig. 2(b), 144; Ex-1001, 8:52-67), dark gray is the energy absorbing film (Ex-1011, Fig. 2(b), 144; Ex-1001, 8:52-67), red is the glass element (Ex-1011, Fig. 2(b); Ex-1001, 8:52-67), light gray is the substrate (Ex-1011, Fig. 2(b), 144; Ex-1001, 8:52-67) and the orange layer is the coating (Ex-1011, Fig. 2(b), 144; Ex-1001, 8:52-67).

198. As shown above, all structural limitations recited in Claim 1 are found in Gupta-1992. Figure 2(b) is the same as the '684 Patent, with fused quartz glued to the back of the substrate, and this second fused quartz in between the energy absorbing layer and the substrate is equivalent to the glass element in the '684 Patent.

The same glass element (i.e., quartz) and configuration are disclosed in Gupta-1992 as claimed in the '684 Patent, and Claim 1 does not require any additional specific conditions or configuration. The second fused quartz disclosed in Gupta-1992 in Figure 2b is therefore functioning the same as glass element 106 in the '684 Patent.

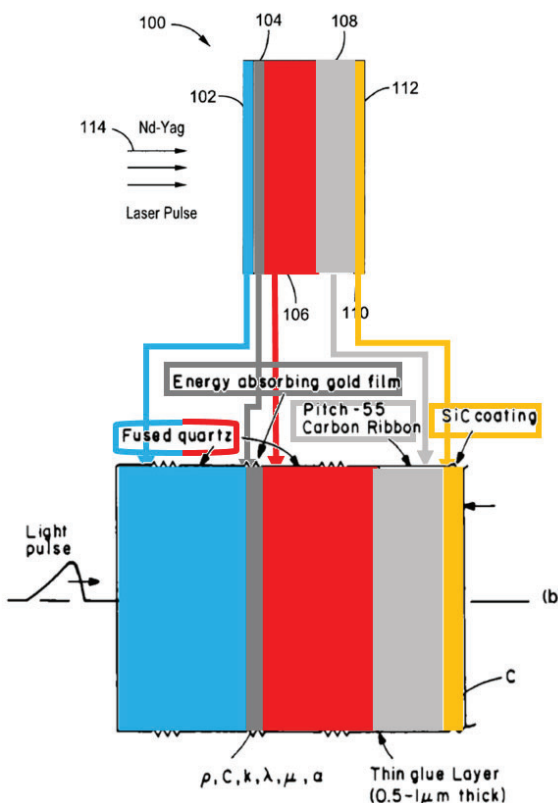
199. Moreover, it was a well-known property that glass elements such as fused silica (i.e., quartz) propagate and modify a stress wave to cause a rarefaction shock in experimental laser techniques. *See* Ex-1021, Abstract (“The fused silica is very well characterized as a nonlinear elastic material having the interesting property of propagating stable rarefaction shock waves.”), Fig. 1 (experimental setup). The natural result of using a glass element, i.e. fused quartz, as shown in Figure 2(b) is the modification of the stress wave to form a rarefaction shock to generate a tensile stress between the substrate and the coating, and I understand this element is inherently disclosed in Gupta-1992.

200. This application of fused quartz, i.e., fused silica, to generate a rarefaction shock and tensile stress between a substrate and a coating was also known for use in laser spallation techniques prior to the '684 Patent through my work, including disclosed in my dissertation discussed above and my 2002 Parametric Study discussed below. Ex-1014-Ex-1018. This existing, inherent property of a glass element to propagate and modify a stress wave, and for the specific application to generate tensile stress between a coating and substrate, was known and I understand

this element is inherently disclosed in Gupta-1992. How Gupta-1992 discloses all claim limitations is further shown in the annotated figure below:

Fig. 4 from Patent (annotated)

Fig. 2(b) from Gupta 1992 Ex-1011
(Prior Art) (Annotated)



2. Claim 2

201. Gupta-1992 discloses the limitation of Claim 2. Gupta-1992 discloses that “a laser pulse of a high enough energy and a pre-determined duration is converted into a pressure pulse of a critical amplitude and width that is sent through the substrate toward the free surface with the coating” and “[t]he reflected tensile wave from the free surface of the coating pries-off the coating.” Ex-1011, Abstract, 165 (“The coating could be successfully spalled off in all cases with appropriate levels of laser pulse energies.”).

3. Claim 3

202. Gupta-1992 discloses the limitation of Claim 3. Gupta-1992 discloses that “[t]he laser pulse impinging on the energy absorbing film (gold) is generated by a Nd-YAG laser emitting at a wavelength of 1.06 μm .” Ex-1011, 144; *see also* Fig. 1 (showing the laser positioned in the first axis and directed at each glass element, *i.e.*, fused quartz in Fig. 2(a) and Fig. 2(b)).

4. Claim 4

203. Gupta-1992 discloses the limitation of Claim 4. Figure 7’s (Ex-1011, 153) x-axis shows normalized time and, based on the gold film thickness of 1 μm (Ex-1011, 152), wave speed $c=3230$ (Ex-1011, Table 2) and using Equations (6) and (7a), yields a stress wave of about 30 nanoseconds (ns).

204. Figure 11 (Ex-1011, 157) shows that the stress wave lasts about 100 ns. Figure 14 (Ex-1011, 163) also shows about 100 ns in length for the stress wave including the long tail of gradual decay. Figure 15 (Ex-1011, 164) shows that the major part of the experimentally measured stress wave to be about 30 ns. These propagated stress waves are within the claimed range.

5. Claim 5

205. Gupta-1992 discloses the limitation of Claim 5. As I discussed in limitation [1.d] above, it is a natural result and well-known that using fused silica,

i.e., quartz, as a glass element in laser experimental techniques would produce a stress wave that comprises a rarefaction shock formation.

6. Claim 6

206. Gupta-1992 discloses the limitation of Claim 6. Gupta-1992 states that his “laser spallation experiment has been developed to measure the strength of planar interfaces between a substrate and a thin coating (in the thickness range of 0.3-3 μm).” Ex-1011, Abstract; *see also* Table 3 (showing SiC coating thickness of 0.3 μm); 165 (“The coating could be successfully spalled off in all cases with appropriate levels of laser pulse energies.”).

7. Claim 7

207. Gupta-1992 discloses the limitation of Claim 7. This is shown in Figure 2(b), where a “[t]hin glue layer (0.5 - 1 μm thick)” between the fused quartz (“glass element”) and the P-55 substrate is shown. Ex-1001, Fig. 2(b). This shows that the glass element is bonded to the substrate.

8. Claim 8

208. Gupta-1992 discloses the limitation of Claim 8. Figure 2(b) shows fused quartz both as a confining layer and positioned to the second side of the P-55 substrate (the “glass element”). Ex-1011, Figs. 2(a), 2(b).

9. Claim 10

209. Gupta-1992 discloses the limitation of Claim 10. Gupta-1992 discloses a sample with a Si/SiC substrate/film interface and a laser spallation technique with interchangeable substrates. *See* Ex-1011, Fig. 1 (identifying “Substrate Si Crystal, Pitch-55 Ribbon, etc.”), 165-67 (stating results for spallation experiment for a Si/SiC interface system); *see also* 142 (“[T]he technique can be used to determine the strength of planar interfaces between coatings ($>0.3\mu\text{m}$ in thickness) and substrates in general.”).

10.Claim 11

210. Gupta-1992 discloses the limitation of Claim 11. This is shown in Figure 2(b), where another layer of fused quartz (“constraining element” or “Q”) is disposed adjacent to the other layer of fused quartz (on the free side of the “glass element”). Ex-1011, Fig. 2(b); *see also* Fig. 1 (identifying “confining fused quartz plate”), 144 (identifying the “fused quartz confining plate (Q)”).

11.Claim 12

211. Gupta-1992 discloses the limitation of Claim 12. This is shown in Figure 2(b), where an energy absorbing gold film (F) layer is disposed between the layer of fused quartz (“constraining element” or “Q”) and the other layer of fused quartz (the “glass element”). Ex-1011, Fig. 2(b); *see also* Fig. 1 (identifying “energy absorbing gold film”), 144 (identifying the “fused quartz confining plate (Q)”).

12.Claim 13

- a. [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:”**

212. To the extent the preamble is limiting, Gupta-1992 discloses 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.

213. As I discussed for limitations [1.pre], [1.a] and Claim 2 *supra*, Gupta-1992 discloses a method for separating a thin test film (“a coating”) from a substrate with a first and second side transversely disposed in a first axis, with the coating applied to a first side of the substrate in intimate facing contact, by a plasma assisted chemical vapor deposition technique, on the free side of the substrate to form a film/substrate interface. Ex-1011, Fig. 1, 142-44, 163-64; Section X.B.

- b. [13.a] **“positioning a glass element along the first axis on the second side of the substrate”**

214. Gupta-1992 discloses positioning a glass element along the first axis on the second side of the substrate.

215. As shown in Figure 2(b), fused quartz is used as the confining layer, but an additional layer of fused quartz (“a glass element”) is also glued and positioned to the second side of the P-55 substrate (“positioning a glass element along the first axis on the second side of the substrate”). Ex-1011, 145, Fig. 2(b).

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

216. Gupta-1992 discloses limitation [13.b] for at least the same reasons I presented for Claim 3 above and shown in Figure 1.

d. [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”

217. Gupta-1992 discloses 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.

218. As I discussed for limitation [1.d] above, all structural limitations recited in Claim 1 are found in Gupta-1992. The same glass element (*i.e.*, fused quartz) and configuration are disclosed in Gupta-1992 as claimed in the '684 Patent, and it was a natural result and well-known property that a stress wave propagates and modifies through glass elements such as fused silica (*i.e.*, quartz) to cause a rarefaction shock or decompression shock in laser experimental techniques, including laser spallation, to generate a tensile stress at a substrate/coating interface. This limitation of Claim 13 is also inherently disclosed in Gupta-1992.

e. [13.d] “separating the coating from the substrate as a result of the stress wave-generated tensile force.”

219. Gupta-1992 discloses limitation [13.d] for at least the same reasons I presented for Claim 2 above.

13.Claims 14-19, 21

220. Gupta-1992 discloses the limitations of Claims 14-19 and 21 for at least the same reasons I presented above for corresponding dependent Claims 3-9 and 11. *See* above Claim 3 (Claim 14); Claim 4 (Claim 15); Claim 5 (Claim 16); Claim 6 (Claim 17); Claim 7 (Claim 18); Claim 8 (Claim 19); Claim 11 (Claim 21).

14.Claim 22

221. Gupta-1992 discloses the limitations of Claim 22. *See* Claim 12 above; Ex-1011, Fig. 1 (showing directing a laser pulse to an aluminum energy absorbing layer coated on the fused quartz (“the glass element”), Fig. 2(b) (showing the energy absorbing layer on the free side of the fused quartz between a confining layer (“the constraining layer”) and the fused quartz).

E. Ground 5 – Gupta-1992 in View of Gupta-1993 Renders Obvious Claims 9 and 20

222. Gupta-1992 alone or in view of Gupta-1993 discloses the limitations of Claims 9 and 20. Gupta-1992 shows the fused quartz (“the glass element”) on both sides of the energy absorbing layer of the same thickness. *See* Ex-1011, Fig. 2(b). Though Gupta-1992 does not identify the exact thickness of the fused quartz

glass elements shown in Figure 2(b), a POSITA working on laser spallation techniques for thin-film adhesion, and building a sample like shown in Figure 2(b) of Gupta-1992, would have been motivated to test and optimize the glass element thickness. A POSITA would have known that the fused quartz forms an advantageous rarefaction shock in a laser spallation technique, and would have been motivated to test different thicknesses within the claimed range to successfully spall thin films using Figure 2(b) as taught by Gupta-1992.

223. It was generally known that rarefaction shocks formed in fused silica (Ex-1021) and it would have been routine experimentation for a POSITA to test different thicknesses of the fused quartz glass element as shown in Figure 2(b) to achieve the desired shock and increase the interface tensile stress. It was known at the time of the invention through my work (as discussed above) that fused silica in the claimed range of thickness formed the desired rarefaction shock, and a POSITA would be motivated to test those thicknesses in Figure 2(b) to achieve the shock and increase interfacial tensile stress to test various thin films.

224. Gupta-1992 teaches successful investigation of different substrates to optimize the desired result of spallation. *See generally* Ex-1011; *see also* 165 (“The coating could be successfully spalled off in all cases with appropriate levels of laser pulse energies.”). A POSITA also would have been motivated to look to Dr. Gupta’s other work to determine the thickness and optimize Figure 2(b) to successful spall

thin films as taught by Gupta-1992. Gupta-1993 refers to the assembly of Gupta-1992 and confirms the fused quartz was 3mm in thickness. Ex-1013, 2406, 2410. Gupta-1993 further discloses testing the influence of using different thicknesses of elements of the laser spallation setup, including different fused quartz thicknesses within the claimed range. *See generally* Ex-1013. A POSITA would have recognized the thickness of the fused quartz to be a design parameter for the laser spallation experiment, and would have been motivated to test different thicknesses to optimize the technique to achieve the successful spallation disclosed in Gupta-1992 using Figure 2(b). It would have been within the skill and ordinary creativity of a POSITA to test different thicknesses of the fused quartz glass element in Gupta-1992's configuration and obvious to start with the 3mm for the fused quartz disclosed in Gupta-1993 for the glass element, which is within the claimed range.

F. Ground 6 – Gupta-1992 Renders Obvious Claims 4, 6, 10, 15, 17, 23-24

1. Claims 4, 6, 10, 15, 17

225. As discussed above for each claim, Gupta-1992 discloses specific points within the claimed ranges of Claims 4, 6, 15 and 17. A POSITA would have understood this disclosure to at least overlap with the claimed ranges for the stress waves and film thickness, which I understand at least makes the claims obvious. As I discussed above, the '684 Patent does not disclose that the claimed ranges are critical to operability of the invention.

226. I also understand that where the general conditions of a claim were known in the prior art, it is not inventive to discover optimum or workable ranges by routine experimentation. I understand when there is a design need to solve a problem (such as measuring thin-film adhesion) and there are a finite number of identified, predictable solutions, a POSITA has good reason to pursue the known options within his or her technical grasp. The configuration of Claims 1 and 13 were disclosed in Gupta-1992, as discussed above. Each of the claimed ranges of stress waves and film thickness were known and easily accessible to a POSITA through standard laser spallation techniques. At the time of the invention, my work as discussed above, and that of others, as shown in Gupta-1992 (Ex-1011) and Gupta-1993 (Ex-1013), involved testing different lengths of stress waves (or laser fluence) and substrate/film thickness. Each of these parameters were tested for impact on laser spallation techniques and to optimize the techniques for thin films. It was known that laser energy, substrate thickness, and film thickness were design parameters for improving laser spallation tests. The formation of rarefaction shocks in fused silica were also well-known by the time of the invention. Ex-1021.

227. A POSITA would have known to use the same parameters Gupta-1992 tested for the configuration shown in Figure 2(b) with routine experimentation or been motivated to optimize the parameters with this configuration to optimize the laser spallation techniques for thin films.

228. Gupta-1992 teaches that for each substrate system tested “[t]he coating could be successfully spalled off in all cases with appropriate levels of laser pulse energies.” Ex-1011, 165. As I also discuss for Claims 23 and 24 below, it would have been within the skill and ordinary creativity of a POSITA to test and achieve the range of stress wave lengths in Claims 4 and 15 to spall thin films using Figure 2(b) by adjusting the laser energy. A POSITA would have been motivated to do so based on Gupta-1992’s teachings of success in spalling thin films by adjusting the laser pulse and the known development of rarefaction shocks in the fused quartz.

229. Gupta-1992 further discloses a sample with a Si/SiC substrate/film interface and a laser spallation technique with interchangeable substrates. Ex-1011, Fig. 1, 142. It would have been within the skill and ordinary creativity of a POSITA to utilize a silicon substrate in Figure 2(b)’s configuration as claimed in Claim 10. A POSITA would have been motivated to do so to test different substrate/interfaces with the fused quartz glass element and its advantageous shock formation. At the time of the invention, a known use of laser spallation was testing for microelectronics applications, which utilize silicon substrates. *See* Ex-1005, iii, 124.

230. A POSITA also would have known of the capability to test coatings in the range of 0.3-3 μm (and Claims 6, 17) as Gupta-1992 states that his experiments can measure the strength of the interface in that range. Ex-1011, Abstract. Gupta-1992 teaches how SiC coatings in this range can be made on the configuration of

Figure 2(a) (Ex-1011, Table 3), and a POSITA would have been motivated to test different coatings thicknesses to design laser-spallation tests of thin-film interface adhesion using the known advantage of the shock formation in the fused quartz and have a reasonable expectation of success using the coatings disclosed in Gupta-1992 with Figure 2(b).

2. Claims 23-24

231. Gupta-1992 in view of the knowledge of a POSITA discloses or suggests the limitations of Claims 23-24. Gupta-1992 discloses that “the stress itself is related to the time rate of production of thermal misfit, which in turn is proportional to the laser fluence in a pulse with a given duration.” Ex-1011, 155-56. Gupta-1992 further discloses that in each substrate system tested “[t]he coating could be successfully spalled off in all cases with appropriate levels of laser pulse energies.” Ex-1011, 165. Thus, Gupta-1992 discloses that the stress generated at the coating/substrate interface depends on the power of the laser source, and it can be adjusted to successfully spall off a coating for any system. Gupta-1992 discloses high interface stress values, in the range of 3.7 to 10.5 GPa for the Si/SiC system, and thus discloses these limitations. Ex-1011, Abstract, Table 3.

232. To the extent Patent Owner argues that Gupta-1992 does not disclose that the stress generated by the stress wave exceeds approximately 1.0 or 2.0 GPa for the configuration of Figure 2(b), such features would have been obvious to

implement. A POSITA would have known how to vary the pulse energy to increase or change the stress generated at the coating/substrate interface and would have been motivated to do so to spall or fail different coating/substrate interfaces.

233. It was known that peak stresses of gigapascals could be developed using lasers. Ex-1007, 115; Ex-1020. It was therefore within the skill of a POSITA to adjust the laser energy to achieve a stress exceeding approximately 1.0 GPa or 2.0 GPa to induce failure in different coating/substrate interfaces, and a POSITA would have reasonably expected such an implementation to work successfully because such stress levels were well-known to be achieved in the art.

G. Ground 7 – Wang-2002 in View of Gupta-1992 Renders Obvious Claims 1-24

3. Claim 1

a. [1.pre] “An apparatus for generating a tensile stress between a substrate and a coating”

234. To the extent the preamble is limiting, my 2002 Parametric Study (Ex-1016) publication discloses an apparatus for generating a tensile stress between a substrate and a coating.

235. My 2002 Parametric Study discloses a tensile spallation experiment to measure thin-film adhesion. Ex-1016, 75-77; Section X.D. Figure 1 shows a schematic of my tensile laser spallation apparatus:

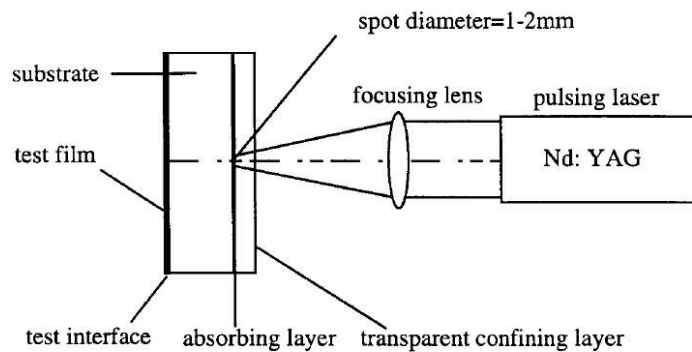


Fig. 1—Schematic of laser spallation technique: absorbing layer thicknesses are typically between $0.4 - 1.0 \mu\text{m}$, test film thicknesses are between $0.6 - 3.0 \mu\text{m}$ and the substrate has a thickness between $400 - 6000 \mu\text{m}$

236. The thin-film sample consists of a transparent confining layer, a thin energy absorbing layer, a substrate, and test film (“coating”). Ex-1016, 75. Fused silica and single crystal silicon substrates were investigated and aluminum films were sputtered onto both sides of the substrate. Ex-1016, Abstract, 76.

237. A Nd:YAG laser pulse is incident on the metallic aluminum absorbing layer sandwiched between the confining layer and the substrate to create a stress wave. Ex-1016, 75, Fig. 1. The wave propagates toward the film/substrate interface and is reflected back from the film surface into a tensile wave, which then loads the test interface in tension and generates tensile stress between a substrate and a coating. Ex-1016, 75.

b. [1.a] “a substrate having a thickness, said thickness defined by a first side and a second side in a first axis”

238. My 2002 Parametric Study discloses a substrate having a thickness, said thickness defined by a first side and a second side in a first axis.

239. Figure 1 (annotated below) shows my thin-film sample is sequentially spaced along a first axis. Ex-1016, Fig. 1, Fig. 3. A substrate having a thickness is shown, with the thickness defined by a first side and a second side in the first axis.

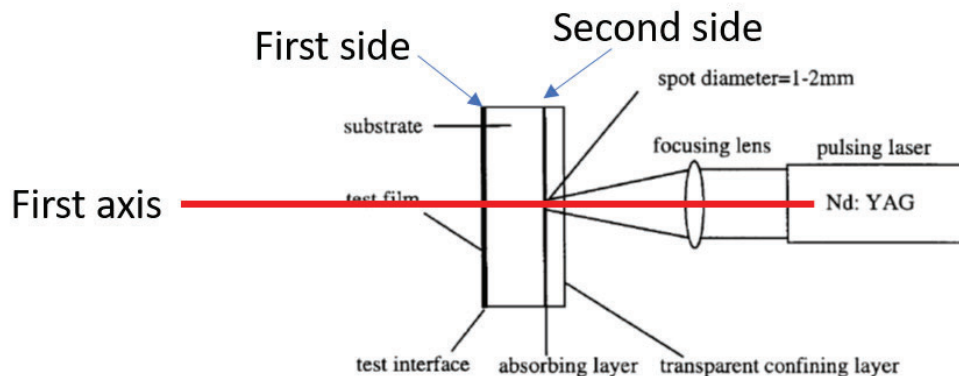


Fig. 1—Schematic of laser spallation technique: absorbing layer thicknesses are typically between $0.4 - 1.0 \mu\text{m}$, test film thicknesses are between $0.6 - 3.0 \mu\text{m}$ and the substrate has a thickness between $400 - 6000 \mu\text{m}$

Fused silica and single crystal silicon substrates were investigated as candidates for the substrate material, (Ex-1016, Abstract), including different thicknesses of the substrates. Ex-1016, 77-82.

- c. [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”

240. My 2002 Parametric Study discloses 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.

241. My 2002 Parametric Study discloses using an aluminum film for both the absorbing layer and the test film (the “coating”). Ex-1016, 76. I disclose that an

aluminum test film was sputtered onto the first side of the substrate. Ex-1016, 76.

This is shown in Figure 3:

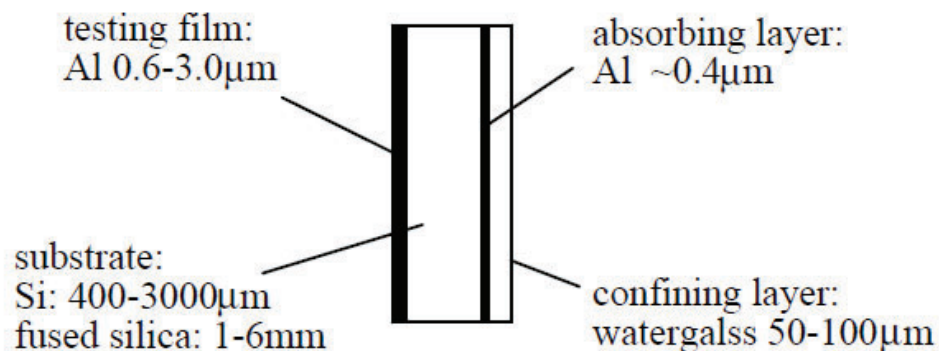


Fig. 3—Schematic of thin film sample for spallation experiment

The test film (“coating”) is shown applied to the first side of the substrate, including a silicon (Si) (“substrate”), such that the coating and the substrate are axially spaced along the first axis in intimate facing contact and form a film (“coating”)/substrate interface. For my samples the test film was 0.6-3 μ m thick. Ex-1016, 77.

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

242. My 2002 Parametric Study in view of Gupta-1992 discloses or suggests a glass element disposed on the second side of the substrate and axially spaced along the first axis.

243. My 2002 Parametric Study discloses that laser spallation techniques were developed to test a wide-variety of different combinations of

substrate/interfaces. Ex-1016, 74-75 (“This technique was used to measure the tensile strength of a wide variety of metal/ceramic interfaces, and ceramic/ceramic interfaces with film thickness typically between 0.3-3 μm .”) (discussing Gupta-1992). I tested two different substrates. Ex-1016, 75 (“Here we report on a series of spallation experiments for Al thin films on both (100) Si and fused silica substrates of varying thickness.”). I also disclose that fused silica (“a glass element disposed on the second side of the substrate and axially spaced along the first axis”) is an ideal material for studying the mechanics of the spallation test in that it is intrinsically strong and the shock mechanism is advantageous for testing thin-film interface adhesion. Ex-1016, 82.

244. Based on these teachings, a POSITA would have understood that I disclosed that a variety of substrate/coating interfaces could be studied with the fused silica. A POSITA would have envisaged a sample where the “substrate” (such as a silicon/coating interface) is positioned with the fused silica “glass element” on the second side to allow the adhesion interface strength to be studied, and my 2002 Parametric Study discloses this claim limitation.

245. To the extent Patent Owner argues that my 2002 Parametric Study does not disclose or suggest fused silica (“a glass element”) on the second side of a substrate, it would have been obvious to a POSITA at the time of the invention to

implement my fused silica glass element with a desired substrate, e.g. silicon, as disclosed in Gupta-1992.

246. Gupta-1992 is directed to tensile laser spallation techniques for thin films (Ex-1011, Abstract), so a POSITA would have had reason to look to Gupta-1992's teachings when implementing a tensile laser spallation technique and using fused silica to increase interfacial stress for thin films as taught by my 2002 Parametric Study. My 2002 Parametric Study discusses Gupta-1992 and its tensile laser spallation techniques. Ex-1016, 74, 83. As I also discussed above, there were limited key players in this niche field in the 1990s and early 2000s. A POSITA looking to develop tensile laser spallation techniques for thin films at the time of the invention would know to look to the research of key players such as Dr. Gupta and myself.

247. A POSITA would have looked to Gupta-1992 for guidance as Gupta-1992 discloses (as I mention in my study) using laser spallation techniques to test various substrate/film interfaces and discloses experiments for testing various substrates. Ex-1011, Abstract, 142 (“[T]he technique can be used to determine the strength of planer interfaces **between coatings** (>0.3 μm in thickness) **and substrates in general**”). Gupta-1992 shows bonding fused quartz to the second side of a desired substrate for testing. Ex-1011, Fig. 2(b). My 2002 Parametric Study discloses using fused silica to increase the interfacial failure in thin-films in laser

spallation techniques. Ex-1016, 82. Gupta-1992 and my 2002 Parametric Study disclose the same use of glass elements and substrates to test thin-films.

248. A POSITA would have been motivated to combine my disclosure of the advantages of fused silica with Gupta-1992's teaching of testing different substrates to position the fused silica on the second side of a desired substrate/coating interface, and with a reasonable expectation of success, as Gupta-1992 in Figure 2(b) explains how to create a sample with fused silica on the second side of a desired substrate. Ex-1011, Fig. 2(b). Thus, using the teachings of Gupta-1992, a POSITA would have successfully created a fused silica/substrate/thin film interface configuration to test a variety of substrate/coating interfaces with the advantageous decompression shock formed by the fused silica.

249. This would have been a mere combination of known components and technologies (fused silica, glass elements and substrates), according to known methods, to produce predictable results (creating the configuration shown in Figure 2(b)), as shown by the teachings of Gupta-1992 and my 2002 Parametric Study.

e. [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."

250. My 2002 Parametric Study discloses 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.

251. My 2002 Parametric Study teaches the development of decompression shock in fused silica substrates, which results in very high tensile stresses at the interface. Ex-1016, Abstract. Rarefaction shocks in fused silica glass were known. Ex-1016, 78 (citing Ex-1021). My 2002 Parametric Study discloses that in fused silica, the initial stress pulse generated at the absorbing layer evolves into a shock after traveling a short distance and “an initial fall time of a few nanoseconds has reduced to zero.” Ex-1016, 78-80. A POSITA would have understood that the fused silica propagates a shock wave and the formation of the “decompression shock” to be a “rarefaction shock.”

252. My 2002 Parametric Study discloses, like the '684 Patent, that the fused silica (“the glass element”) propagates and modifies the stress waves in tensile laser spallation experiments to generate a tensile stress between the substrate and coating. Ex-1016, 82 (“The existence of the shock created a large stress at the film interface, promoting failure.”).

4. Claim 2

253. My 2002 Parametric Study discloses the limitation of Claim 2. My 2002 Parametric Study discloses that the existence of a decompression shock in the fused silica glass element created a large stress at the film interface, promoting failure to separate the coating from the substrate. Ex-1016, 82; *see also* Abstract (“This shock enhances the failure of thin film interfaces, especially in thicker

samples.”); 75 (“The laser energy is increased until a longitudinal wave is generated with an amplitude sufficient to fail the film/substrate interface.”).

5. Claim 3

254. My 2002 Parametric Study discloses the limitation of Claim 3. This is shown in annotated Figure 1:

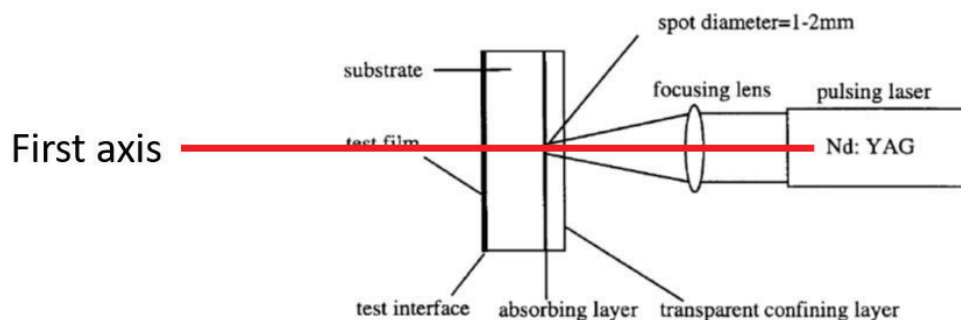


Fig. 1—Schematic of laser spallation technique: absorbing layer thicknesses are typically between 0.4 – 1.0 μm , test film thicknesses are between 0.6 – 3.0 μm and the substrate has a thickness between 400 – 6000 μm

Ex-1016, 76. My 2002 Parametric Study discloses a Nd:YAG laser pulse is incident on the metallic absorbing layer sandwiched between the confining layer and the substrate. Ex-1016, 75. My 2002 Parametric Study thus discloses the propagation of the stress wave by the fused silica (the claimed “glass”) as a result of impingement by the Nd:YAG laser shown in Figure 1 directed in the first axis.

6. Claim 4

255. My 2002 Parametric Study discloses the limitation of Claim 4. My 2002 Parametric Study discloses a stress wave between 10 to 30 ns, which depends on the duration of the laser pulse used and the substrate material. Ex-1016, 78 (“The fringes develop over 20 to 30 ns in fused silica, whereas in Si, the full waveform was

confined to a duration of about 10 ns comparable to the duration of the YAG pulse”). This falls within the claimed range.

256. To the extent Patent Owner argues these specific points do not disclose this limitation, this claim is obvious in view of the same disclosures because they at least overlap with the claimed ranges and as discussed above, the '684 Patent does not disclose that the claimed range is critical to the operability of the invention.

257. I also understand that where the general conditions of a claim were known in the prior art, it is not inventive to discover optimum or workable ranges by routine experimentation. I understand when there is a design need to solve a problem (such as measuring thin-film adhesion) and there are a finite number of identified, predictable solutions, a POSITA has good reason to pursue the known options within his or her technical grasp. The configuration of Claims 1 and 13 were disclosed in the prior art, as discussed above. Each of the claimed ranges of stress waves, film thickness and glass element thickness were known and easily accessible to a POSITA through standard laser spallation techniques and experimentation.

258. At the time of the invention, my work involved testing different lengths of stress waves and substrate/film thickness. Ex-1016, Abstract. Each of these different parameters were tested for impact on the laser spallation techniques, including with fused silica and its known rarefaction shock, and to optimize the

techniques for thin films. Ex-1016, 75. My results revealed important design parameters for laser spallation tests. Ex-1016, 75.

259. A POSITA would have known to use the same parameters I tested for fused silica, including thickness, film thickness and stress waves, in the envisaged sample with the fused silica and extra layer of substrate, or in combination with Gupta-1992 with routine experimentation, or been motivated to optimize the same parameters with this configuration to optimize the laser spallation techniques I disclose for thin films using fused silica and the advantageous decompression shock.

260. My 2002 Parametric Study teaches successful investigations using fused silica to achieve different stress wave lengths, all within the claimed ranges. Ex-1016, 78. It would have been within the skill and ordinary creativity of a POSITA to achieve the claimed stress wave lengths in the configuration of Claim 1 as discussed below for Claims 23 and 24 by adjusting the laser energy to achieve the desired spallation.

7. Claim 5

261. My 2002 Parametric Study discloses the limitation of Claim 5. My 2002 Parametric Study discloses that a “decompression shock” was observed for all tested thicknesses of the fused silica. Ex-1016, 81. My 2002 Parametric Study also incorporates discussion of Barker and Hollenbach (Ex-1021), which confirmed known rarefaction shocks in fused silica. Ex-1016, 78, 82. As discussed above, a

POSITA would have understood that the fused silica propagates a shock wave and the formation of the “decompression shock” to be the claimed “rarefaction shock.”

8. Claim 6

262. My 2002 Parametric Study alone or in view of Gupta-1992 discloses or suggests the limitation of Claim 6. My 2002 Parametric Study discloses the aluminum test film (“coating”) for samples for the spallation experiments was 0.6-3 μm thick. Ex-1016, 77; *see also* 75 (“The laser energy is increased until a longitudinal wave is generated with an amplitude sufficient to fail the film/substrate interface.”). As discussed above, although the thinnest film was 0.6 μm rather than 0.5 μm , a POSITA would have considered these thicknesses approximately the same in the context of this technology as there is no fundamental difference between the two, and they are both in the sub-micron regime where the shock wave loading is desired. A POSITA would also appreciate that even if you are targeting 0.5 μm you may end up with 0.6 μm or 0.4 μm due to challenges in precisely controlling the deposition rate.

263. To the extent Patent Owner argues these specific points do not disclose this limitation, this claim is obvious in view of the same disclosures because they at least overlap with the claimed ranges and as discussed above, the ’684 Patent does not disclose that the claimed range is critical to the operability of the invention.

264. I also understand that where the general conditions of a claim were known in the prior art, it is not inventive to discover optimum or workable ranges by routine experimentation. I understand when there is a design need to solve a problem (such as measuring thin-film adhesion) and there are a finite number of identified, predictable solutions, a POSITA has good reason to pursue the known options within his or her technical grasp. The configuration of Claims 1 and 13 were disclosed in the prior art, as discussed above. Each of the claimed ranges of stress waves, film thickness and glass element thickness were known and easily accessible to a POSITA through standard laser spallation techniques and experimentation.

265. At the time of the invention, my work involved testing different lengths of stress waves and substrate/film thickness. Ex-1016, Abstract. Each of these different parameters were tested for impact on the laser spallation techniques, including with fused silica and its known rarefaction shock, and to optimize the techniques for thin films. Ex-1016, 75. My results revealed important design parameters for laser spallation tests. Ex-1016, 75.

266. A POSITA would have known to use the same parameters I tested for fused silica, including thickness, film thickness and stress waves, in the envisaged sample with the fused silica and extra layer of substrate, or in combination with Gupta-1992 with routine experimentation, or been motivated to optimize the same

parameters with this configuration to optimize the laser spallation techniques I disclose for thin films using fused silica and the advantageous decompression shock.

267. It further would have been obvious to combine the teachings of my 2002 Parametric Study and Gupta-1992 to meet this limitation. Gupta-1992 states that the “laser spallation experiment has been developed to measure the strength of planar interfaces between a substrate and a thin coating (in the thickness range of 0.3-3 μm).” Ex-1011, Abstract. A POSITA would have turned to Gupta-1992 as discussed above and would test thinner films ($<0.6\mu\text{m}$ thick) in the combined configuration of my fused silica with a substrate/coating interface based on Gupta-1992’s disclosure and my teaching of using fused silica for the advantageous decompression shock.

9. Claim 7

268. My 2002 Parametric Study in view of Gupta-1992 discloses or suggests the limitation of Claim 7. My 2002 Parametric Study discloses that fused silica is an ideal material for studying the mechanics of the spallation test. Ex-1016, 82. A POSITA would have turned to Gupta-1992 as discussed above for adding a desired substrate, and Gupta-1992 discloses fused quartz (the “glass element”) glued (“bonded”) to the second side of a P-55 substrate. Ex-1011, Fig. 2(b). It would have been obvious to apply the teachings of Gupta-1992 to bond a desired substrate to the

fused silica and create the sample as shown in Gupta-1992's Figure 2(b) for a tensile laser spallation technique.

269. A POSITA would have been motivated to combine the teachings of Gupta-1992 and my 2002 Parametric Study as Gupta-1992 shows a successful way in which a desired substrate can be bonded to fused silica. Ex-1011, Fig. 2(b) (showing thin glue layer between the fused quartz and P-55 substrate). This would have been a mere combination of known components and technologies (glass elements, glue and substrates), according to known methods, to produce predictable results (configuration shown in Figure 2(b)).

10.Claim 8

270. My 2002 Parametric Study discloses the limitation of Claim 8. A POSITA would have understood that fused silica is the same as quartz in the context of this technology and exhibits the same properties in a laser spallation technique. *See* Ex-1016, 75 (confirming testing of fused silica substrates); ¶124 above.

11.Claim 9

271. My 2002 Parametric Study discloses the limitation of Claim 9. My 2002 Parametric Study discloses testing and using different thicknesses of fused silica, including 1531, 3063, and 6125 μm , that fall within this claimed range of thickness. Ex-1016, 81.

272. To the extent Patent Owner argues these specific points do not disclose this limitation, this claim is obvious in view of the same disclosures because they at least overlap with the claimed ranges and as discussed above, the '684 Patent does not disclose that the claimed range is critical to the operability of the invention.

273. I also understand that where the general conditions of a claim were known in the prior art, it is not inventive to discover optimum or workable ranges by routine experimentation. I understand when there is a design need to solve a problem (such as measuring thin-film adhesion) and there are a finite number of identified, predictable solutions, a POSITA has good reason to pursue the known options within his or her technical grasp. The configuration of Claims 1 and 13 were disclosed in the prior art, as discussed above. Each of the claimed ranges of stress waves, film thickness and glass element thickness were known and easily accessible to a POSITA through standard laser spallation techniques and experimentation.

274. At the time of the invention, my work involved testing different lengths of stress waves and substrate/film thickness. Ex-1016, Abstract. Each of these different parameters were tested for impact on the laser spallation techniques, including with fused silica and its known rarefaction shock, and to optimize the techniques for thin films. Ex-1016, 75. My results revealed important design parameters for laser spallation tests. Ex-1016, 75.

275. A POSITA would have known to use the same parameters I tested for fused silica, including substrate thickness, film thickness and stress waves, in the envisaged sample with the fused silica and extra layer of substrate, or in combination with Gupta-1992 with routine experimentation, or been motivated to optimize the same parameters with this configuration to optimize the laser spallation techniques I disclose for thin films using fused silica and the advantageous decompression shock.

276. My 2002 Parametric Study teaches successful investigation of different fused silica thicknesses to optimize the desired result of spallation, all within the claimed range. Ex-1016, 81. It would have been within the skill and ordinary creativity of a POSITA to test different thicknesses and optimize the thickness of the glass element disclosed in the configuration of Claims 1 and 13.

12.Claim 10

277. My 2002 Parametric Study alone or in view of with Gupta-1992 discloses or suggests the limitation of Claim 10. Silicon is identified as a material that can be used as a substrate in my 2002 Parametric Study. *See* Ex-1016, 75 (confirming testing Si substrates of varying thicknesses). To the extent my 2002 Parametric Study does not disclose this limitation, as discussed above for limitation [1.c], a POSITA would have been motivated to add a desired substrate to my configuration based on the teachings of Gupta-1992 and Gupta-1992 also teaches

using silicon substrates. Ex-1011, 163 (confirming testing Si single wafer substrate). As discussed above, a POSITA also would have been motivated to use silicon because of its applicability in microelectronics and the known use of tensile laser spallation techniques for microelectronics at the time of the invention. *See* Ex-1005, iii, 124. It would have been within the skill and ordinary creativity of a POSITA to utilize a silicon substrate as claimed in Claim 10 with my fused silica glass element.

13.Claim 11

278. My 2002 Parametric Study discloses the limitation of Claim 11. My 2002 Parametric Study's experimental thin-film sample is shown in Figure 3, with a confining layer of waterglass ("a constraining element") disposed adjacent to the fused silica ("the glass element"):

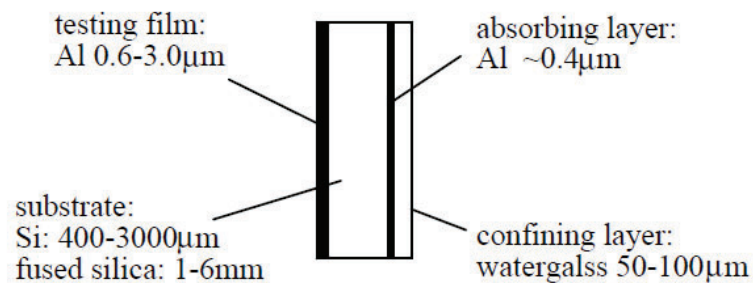


Fig. 3—Schematic of thin film sample for spallation experiment

Ex-1016, 75-77. With the addition of the substrate as envisaged by the POSITA based on my teaching or the combination of Gupta-1992's teachings, the confining layer of waterglass ("constraining layer") would remain disposed adjacent to the fused glass elements.

14.Claim 12

279. My 2002 Parametric Study discloses the limitation of Claim 12. As I have shown in Claim 11 above, Figure 3 discloses an aluminum energy absorbing layer disposed between the waterglass constraining layer and the fused silica (the “glass element”). Ex-1016, 75-77. With the addition of the substrate as envisaged by the POSITA based on my teaching or the combination of Gupta-1992’s teachings, the aluminum energy absorbing layer would remain disposed between the confining layer (“constraining layer”) of waterglass and the fused silica glass element.

15.Claim 13

- a. [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:”**

280. To the extent the preamble is limiting, my 2002 Parametric Study discloses 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.

281. As I discussed for limitations [1.pre], [1.a] and Claim 2 above, my 2002 Parametric Study discloses a method for separating a thin test film (“a coating”)

from a substrate with a first and second side transversely disposed in a first axis, with the coating applied to a first side of the substrate in intimate facing contact by sputtering an aluminum film on the free side of the substrate to form a film/substrate interface. Ex-1016, 75-77, Figs. 1, 3; Section X.D.

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

282. My 2002 Parametric Study in view of Gupta-1992 discloses or suggests positioning a glass element along the first axis on the second side of the substrate.

283. As I discussed for limitation [1.c] above, to the extent my 2002 Parametric Study does not explicitly disclose that the fused silica is positioned along the axis on the second side of the substrate, such arrangement is implicitly disclosed because a POSITA would at once envisage the claimed arrangement or combination. To the extent Patent Owner argues otherwise, this would nevertheless have been obvious in view of Gupta-1992. *See* Limitation [1.c].

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

284. My 2002 Parametric Study discloses limitation [13.b] for at least the same reasons I presented for Claim 3 and shown in Figure 1.

d. [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”

285. My 2002 Parametric Study discloses 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.

286. As I discussed in limitation [1.d], my 2002 Parametric Study discloses using fused silica as the glass element and that a stress wave propagates and modifies through the fused silica into a rarefaction shock to generate a tensile force between the substrate and the thin-film coating. Ex-1016, Abstract, 78-80, 82.

e. [13.d] “separating the coating from the substrate as a result of the stress wave-generated tensile force.”

287. My 2002 Parametric Study discloses limitation [13.d] for at least the reasons I presented for Claim 2. Ex-1016, Abstract, 75-76, 82.

16.Claims 14-21

288. My 2002 Parametric Study alone or in view of Gupta-1992 discloses or suggests the limitations of Claims 14-21 for at least the reasons I presented for corresponding dependent Claims 3-9 and 11. *See* above Claim 3 (Claim 14); Claim 4 (Claim 15); Claim 5 (Claim 16); Claim 6 (Claim 17); Claim 7 (Claim 18); Claim 8 (Claim 19); Claim 9 (Claim 20); Claim 11 (Claim 21).

17.Claim 22

289. My 2002 Parametric Study discloses the limitations of Claim 22. *See* Claim 12; Ex-1016, 76 (disclosing fused silica substrate), Fig. 1 (showing directing a laser pulse to an aluminum energy absorbing layer coated on the fused silica (“the glass element”)), Fig. 3 (showing the energy absorbing layer on the free side of the fused silica between a confining layer (“the constraining layer”) and the fused silica).

18.Claims 23-24

290. My 2002 Parametric Study in view of the knowledge of a POSITA discloses the limitations of Claims 23-24.

291. My 2002 Parametric Study discloses that “[a] longitudinal stress wave of rise time comparable to that of the laser pulse is emitted from the absorbing layer.” Ex-1016, 75. My 2002 Parametric Study further discloses that “the maximum stress in the substrate and at the film/substrate interface increase with increasing laser fluence.” Ex-1016, Abstract. Thus, my 2002 Parametric Study discloses that the stress generated at the coating/substrate interface depends on the power of the laser source and it can be adjusted to successfully spall off a coating for any system.⁶

⁶ Gupta-1992 also shows that it was known the stress generated at the coating/substrate interface depends on the power of the laser source and it can be adjusted to successfully spall off a coating for any system. Ex-1011, 155-56, 165.

292. Though my 2002 Parametric Study does not expressly disclose that the stress exceeds approximately 1.0 or 2.0 GPa, such features would have been obvious to implement. A POSITA would have known how to vary the pulse energy to increase or change the stress generated at the coating/substrate interface, and would have been motivated to do so to fail different thin-film/substrate interfaces. As discussed above, it was known that peak stresses of gigapascals could be developed using lasers. Ex-1007, 115; Ex-1020. It was also known that high interface stress values, in the range of 3.7 to 10.5 GPa, could be reached for a Si/SiC system. Ex-1011, Table 3.

293. It was therefore within the skill of a POSITA to adjust the laser energy to achieve a stress exceeding approximately 1.0 GPa or 2.0 GPa to induce failure in different coating/substrate interfaces, and a POSITA would have had a reasonable expectation of success because such stress levels were well-known to be achieved in the art.

XII. CONCLUSION

294. This Declaration represents the opinions that I have formed up to date based on the material currently available to me. I reserve the right to revise, supplement, and/or amend my opinions stated in this Declaration based on new information that becomes available to me and on my continuing analysis of the materials available to me.

295. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine, imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: March 31, 2024



Dr. Junlan Wang