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.

IPR2024-00761
Patent 7,487,684 B2

Before JENNIFER S. BISK, JOHN A. HUDALLA, and
ALYSSA A. FINAMORE, *Administrative Patent Judges*.

FINAMORE, *Administrative Patent Judge*.

JUDGMENT
Final Written Decision
Determining No Challenged Claim Unpatentable
Dismissing Patent Owner's Motion to Exclude
35 U.S.C. § 318(a); 37 C.F.R. § 42.64(c)

I. INTRODUCTION

The Boeing Company ("Petitioner") filed a Petition (Paper 1, "Pet.") requesting *inter partes* review of claims 1–24 of U.S. Patent No. 7,487,684 B2 ("the '684 patent") (Ex. 1001). Pet. 1. We issued a Decision granting institution of *inter partes* review (Paper 8). The Regents of the University of California ("Patent Owner") then filed a Response (Paper 19, "PO Resp."). Petitioner filed a Reply (Paper 26, "Pet. Reply"), and Patent Owner filed a Sur-reply (Paper 33, "Sur-reply").

Patent Owner filed a Motion to Exclude (Paper 35, "Mot."). Petitioner filed an Opposition (Paper 36), and Patent Owner filed a Reply (Paper 37).

An oral hearing took place July 14, 2025. We entered the transcript (Paper 41, "Tr.") into the record.

We issue this Final Written Decision pursuant to 35 U.S.C. § 318(a). For the reasons set forth below, we determine Petitioner has not proven, by a preponderance of the evidence, that the challenged claims of the '684 patent are unpatentable. We also dismiss as moot Patent Owner's Motion to Exclude.

A. Real Parties in Interest

Petitioner identifies itself as real party in interest. Pet. 1. Patent Owner identifies itself and Laser Spallation Technologies, LLC as real parties in interest. Paper 4, 2.

B. Related Matters

The parties identify the following district court litigation as a related matter: *Laser Spallation Technologies, LLC v. The Boeing Company*, No. 2:23-cv-02294 (C.D. Cal. filed Mar. 28, 2023). Pet. 1; Paper 4, 2.

C. The ’684 Patent

The invention set forth in the ’684 patent measures the tensile strength, i.e., adhesion, of very thin film interfaces deposited on engineering substrates. Ex. 1001, 5:36–39. The invention achieves separation and lift of thin films from the substrates using glass-modified stress waves. *Id.* at 5:39–42.

To measure the interface tensile strength, the laser spallation technique is commonly used. Ex. 1001, 2:16–18. Typically, a high energy laser pulse impinges upon a planar arrangement of a confining plate, a metallic layer, and a substrate plate with a coating. *Id.* at 2:18–21, 7:6–7, Fig. 2A. The laser pulse passes through the transparent confining plate and causes a sudden expansion in the metallic layer, which, due to the axial constraints of the planar arrangement, results in a compressive shock wave directed toward the coating interface. *Id.* at 2:21–29. A part of the compressive pulse is transmitted into the coating and reflects from the free surface of the coating as a tension wave. *Id.* at 2:29–34. The reflected tension wave causes the coating to separate from the substrate plate. *Id.* at 2:31–34. The interface tensile stress is obtained by measuring the transient displacement history of the coating’s free surface during pulse reflection with an optical interferometer. *Id.* at 7:33–37.

“A typical stress pulse profile has a rise-time of 1–2 ns and a gradual post-peak decay of about 16–20 ns.” Ex. 1001, 7:60–64. “If the film is very thin compared to the length of the stress wave, then the tail end of the initial compression pulse is still at the interface while its front end has returned as a tensile wave after reflecting from the film’s free surface.” *Id.* at 7:64–8:2. The tail end of the compressive pulse causes destructive interference with the tensile wave, and consequently the peak interface tensile stress is always less than the amplitude of the initial compression wave. *Id.* at 8:2–5. To avert this destructive interference and increase peak interface tensile stress, the tail end of the compressive pulse, i.e., post-peak decay time, should be reduced. *Id.* at 8:45–49. "Indeed, 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. In accordance with the present invention, this theoretical possibility has been realized experimentally with sample assemblies using glass layers." *Id.* at 8:45–51.

Figure 4, reproduced below, illustrates an exemplary sample assembly. Ex. 1001, 8:52–53.

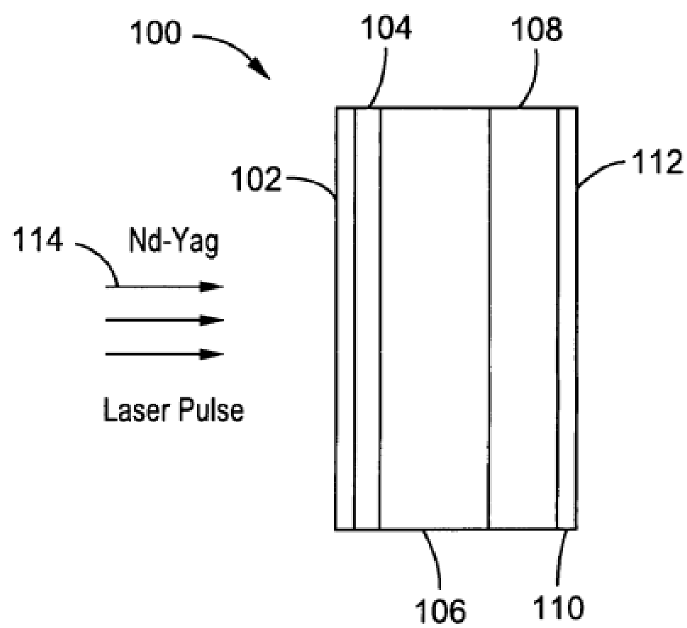

FIG. 4

Figure 4 is a cross-section of a thin-film sample assembly. *Id.* at 4:60–61. Sample assembly 100 includes constraining element 102, energy absorbing layer 104, glass substrate element 106, silicon substrate element 108, and coating 110 having free surface 112. *Id*. at 8:52–58. Glass substrate element 106 comprises Pyrex, soda lime, quartz, or borosilicate glasses. *Id.* at 3:18–20; 9:17–21, 10:10–13.

The stress wave profile of sample assembly 100, which includes glass substrate element 106 in addition to silicon substrate element 108, compared with that of a sample assembly having only a silicon substrate is shown in Figure 5B, reproduced below. Ex. 1001, 9:41–44.

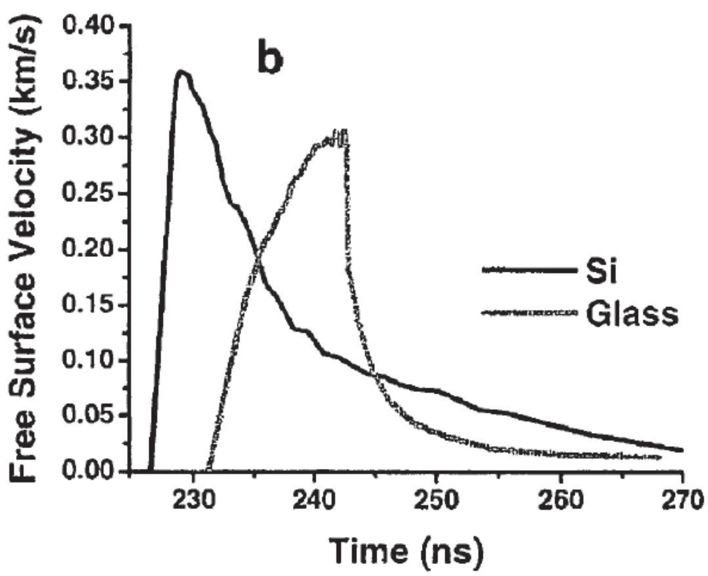

FIG. 5B

Figure 5B shows a graph comparing the stress wave profiles of a sample assembly including a soda lime glass substrate in addition to a silicon substrate and a sample assembly including only a silicon substrate. *Id.* at 5:64–65, 9:30–44. The stress wave profile of the sample assembly including the glass substrate shows the post-peak stress drops virtually instantaneously, much like a "rarefaction shock." *Id.* at 9:38–41.

D. Challenged Claims

Petitioner challenges claims 1–24 of the ’684 patent. Pet. 1. Claims 1 and 13 are independent. Ex. 1001, 13:34–48, 14:44–58. Independent claim 1 is illustrative of the claimed subject matter and is reproduced below with Petitioner’s labeling and emphasis added to the pertinent limitation.

> 1. [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; and
>
> [1.c] a glass element disposed on the second side of the substrate and axially spaced along the first axis;
>
> [1.d] ***wherein the glass element is configured to propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating***.

Id. at 13:34–48 (emphasis added).

Independent claim 13 is similar to independent claim 1 and recites a method for separating a coating from a substrate. *Compare* Ex. 1001, 14:44–58, *with id.* at 13:34–48. Claims 2–12 depend from independent claim 1, and claims 14–24 depend from independent claim 13. *Id.* at 13:49–14:43, 14:59–15:28.

E. Asserted Grounds of Unpatentability

Petitioner asserts claims 1–24 are unpatentable on the grounds listed in the table below. Pet. 3–4.

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

In support of these asserted grounds, Petitioner submits declarations by Junlan Wang, Ph.D. (Exs. 1003, 1030). Patent Owner deposed and

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[1] The Leahy-Smith America Invents Act ("AIA"), Pub. L. No. 112-29, 125 Stat. 284, 287–88 (2011), amended certain sections of this statute, including §§ 102 and 103, and the effective date of the relevant amendment is March 16, 2013. The filing date of the '684 patent, August 15, 2006, is before the effective date of the amendment. Ex. 1001, code (22). We, therefore, apply the pre-AIA version of the statute.

[2] Junlan Wang, *Thin-Film Adhesion Measurement by Laser-Induced Stress Waves* (2002) (Ph.D. dissertation, University of Illinois at Urbana-Champaign) (ProQuest) ("Wang-Dissertation") (Ex. 1005). Consistent with the parties' citations, our citations to Wang-Dissertation are to its native pagination, unless otherwise indicated.

[3] V. Gupta et al., *Measurement of Interface Strength by a Laser Spallation Technique*, 40(1) J. Mech. Phys. Solids 141 (1992) ("Gupta-1992") (Ex. 1011). Consistent with the parties' citations, our citations to Gupta-1992 are to its native pagination.

[4] J. Yuan, V. Gupta, and A. Pronin, *Measurement of interface strength by the modified laser spallation technique. III. Experimental optimization of the stress pulse*, 74(4) J. Appl. Phys. 2405 (1993) ("Gupta-1993") (Ex. 1013).

[5] Junlan Wang et al., *A Parametric Study of Laser Induced Thin Film Spallation*, 42(1) Exp. Mech. 74 (2002) ("Wang-2002") (Ex. 1016).

cross-examined Dr. Wang and submits transcripts of Dr. Wang's depositions (Exs. 2009, 2013).

In opposition, Patent Owner submits a declaration of Vijay Gupta, Ph.D. (Ex. 2011). Petitioner deposed and cross-examined Dr. Gupta and submits a transcript of Dr. Gupta's deposition (Ex. 1040).

II. ANALYSIS

Petitioner bears the burden to demonstrate unpatentability by a preponderance of the evidence. *Dynamic Drinkware, LLC v. Nat'l Graphics, Inc.,* 800 F.3d 1375, 1378 (Fed. Cir. 2015). That burden never shifts to Patent Owner, except in limited circumstances not present here. *See id.*

A. Level of Ordinary Skill in the Art

The level of ordinary skill in the art is "a prism or lens" through which we view the prior art and the claimed invention. *Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001). The prior art may reflect the level of ordinary skill in the art. *Id.*

Petitioner asserts that a person of ordinary skill in the art ("POSITA") at the time of the invention of the '684 patent "would have had an M.S. in Mechanical Engineering or a related field, and at least five years of experience using laser systems to characterize and test mechanical behavior in materials" and that "[m]ore education may supplement practical experience or vice versa." Pet. 5 (citing Ex. 1003 ¶ 38). Patent Owner

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Consistent with the parties' citations, our citations to Wang-2002 are to its native pagination.

argues "[i]n addition to these qualifications, a POSITA developing new laser-based methodologies for mechanical behavior of materials would also have had education or training in wave mechanics and shock physics." PO Resp. 21 (citing Ex. 2011 ¶¶ 21–22).

Petitioner does not refute Patent Owner's proffered additional requirements for a POSITA. Moreover, the '684 patent and the cited references are directed to laser spallation techniques, which involve generating a compressive shock wave in a substrate. Ex. 1001, 2:16–34; Ex. 1005, 7–8; Ex. 1011, 142–43; Ex. 1016, 75. As the '684 patent and the cited references reflect the additional requirements set forth in Patent Owner's definition for a POSITA, we adopt Patent Owner's definition in this Final Written Decision. The outcome, however, would be the same under either party's definition for a POSITA.

B. Claim Construction

We interpret a claim "using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b)." 37 C.F.R. § 42.100(b) (2023). Under this standard, we construe the claim "in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent." *Id.*; *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312–14 (Fed. Cir. 2005) (en banc). Furthermore, we expressly construe the claims only to the extent necessary to determine whether Petitioner has shown that the challenged claims are unpatentable. *See Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017) ("[W]e need only construe terms 'that are in controversy, and only to the extent necessary to resolve the controversy.'"

(quoting *Vivid Techs., Inc. v. Am. Sci. & Eng'g, Inc.*, 200 F.3d 795, 803 (Fed. Cir. 1999))).

Both parties maintain that no claim term needs to be construed. Pet. 4 (citing Ex. 1003 ¶ 40); PO Resp. 20. Patent Owner, however, provides an express construction for limitation [1.d] of independent claim 1 and the similar limitation of independent claim 13, namely limitation [13.c]. PO Resp. 20 (citing Ex. 2011 ¶ 25). To resolve the controversy before us, we determine that these limitations require express construction.

1. "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" (limitation [1.d]) and "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" (limitation [13.c])

Patent Owner argues these limitations mean "changing the profile of the laser generated compressive wave and propagating the wave profile as modified to the free surface of the coating, which upon reflection from the free surface as a tension wave generates a tensile stress at the coating/substrate interface." PO Resp. 20 (citing Ex. 2011 ¶ 25). Petitioner does not refute this proposed construction and, during the oral argument, Petitioner confirmed it agrees with the proposed construction. Tr. 8:16–9:12.

We so no reason to depart from the parties agreed-upon construction of limitations [1.d] and [13.c]. Accordingly, for purposes of this Final Written Decision, we adopt the parties' construction of limitations [1.d] and [13.c].

C. Anticipation by Wang-Dissertation

Petitioner challenges claims 1–22 under 35 U.S.C. § 102(b) as anticipated by Wang-Dissertation. Pet. 20–35; Pet. Reply 13–23. Patent Owner asserts that Wang-Dissertation does not anticipate the claims. PO Resp. 21–50; Sur-reply 13–23. We begin our analysis of this asserted ground of unpatentability with an overview of Wang-Dissertation and then turn to the parties' contentions for each of the claims.

1. Wang-Dissertation

Wang-Dissertation is a dissertation authored by Petitioner's declarant, Dr. Wang.[6] Ex. 1005, 3. Wang-Dissertation is directed to measuring interfacial adhesion between a thin film and a substrate using laser-generated stress waves in accordance with laser spallation techniques. Ex. 1005, Abstr. According to Wang-Dissertation, interfaces are typically subject to only one mode of loading, namely tensile loading, but thin-film interfaces fail under mixed-mode loading conditions. *Id.* Wang-Dissertation measures interfacial adhesion under mixed-mode conditions and compares interfacial adhesion measurements under mixed-mode conditions and tensile loading. *Id.*

Wang-Dissertation discloses a tensile laser spallation technique shown in Figure 2.1, reproduced below. Ex. 1005, 7.

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[6] Patent Owner disputes that Wang-Dissertation is prior art under 35 U.S.C. § 102(b), because, according to Patent Owner, Wang-Dissertation was not publicly available before the earliest-effective filing date of the '684 patent. PO Resp. 4–20; Sur-reply 2–13. For the reasons set forth in this Final Written Decision, we find Wang-Dissertation does not disclose pertinent claim limitations, and, therefore, we need not address whether Wang-Dissertation is prior art under § 102(b).

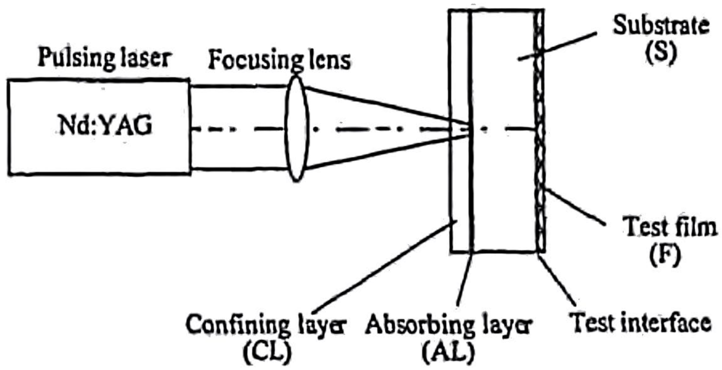


Figure 2.1: Schematic of the tensile laser-spallation techniqu.

As shown in Figure 2.1, a Nd:YAG laser pulse is directed to a sample comprising of a confining layer, an energy absorbing layer, a substrate, and a test film. *Id.* at 7–8. The laser pulse passes through the confining layer and strikes the metallic energy absorbing layer, which generates a compressive stress wave that propagates toward the film/substrate interface and is reflected back from the free surface of the film into a tensile wave, loading the film/substrate interface in tension. *Id.* at 8.

The compressive stress pulse is a copy of the laser pulse deposited at the interface of the confining layer and the energy absorbing layer, and the material properties of the substrate will affect the amplitude of the compressive pulse as it passes therethrough. Ex. 1005, 24. If the substrate material generates a shock with a sub-nanosecond rise or fall time, the peak stress on the substrate/film interface can equal the peak stress of the compressive pulse. *Id.* at 26. Accordingly, substrate materials with nonlinear properties that enhance shock development, such as fused silica, are desirable for measuring the interfacial adhesion between the film and the substrate. *Id.* at 26, 38.

Wang-Dissertation further discloses a tensile spallation experiment using this tensile laser spallation technique. Ex. 1005, 42. The thin-film sample used in this experiment comprises a waterglass confining layer, an aluminum absorbing layer, a fused silica substrate, and an aluminum test film. *Id.* at 44–46, Fig. 3.2. Figure 3.15, reproduced below, shows the data obtained from the experiment. *Id.* at 62.

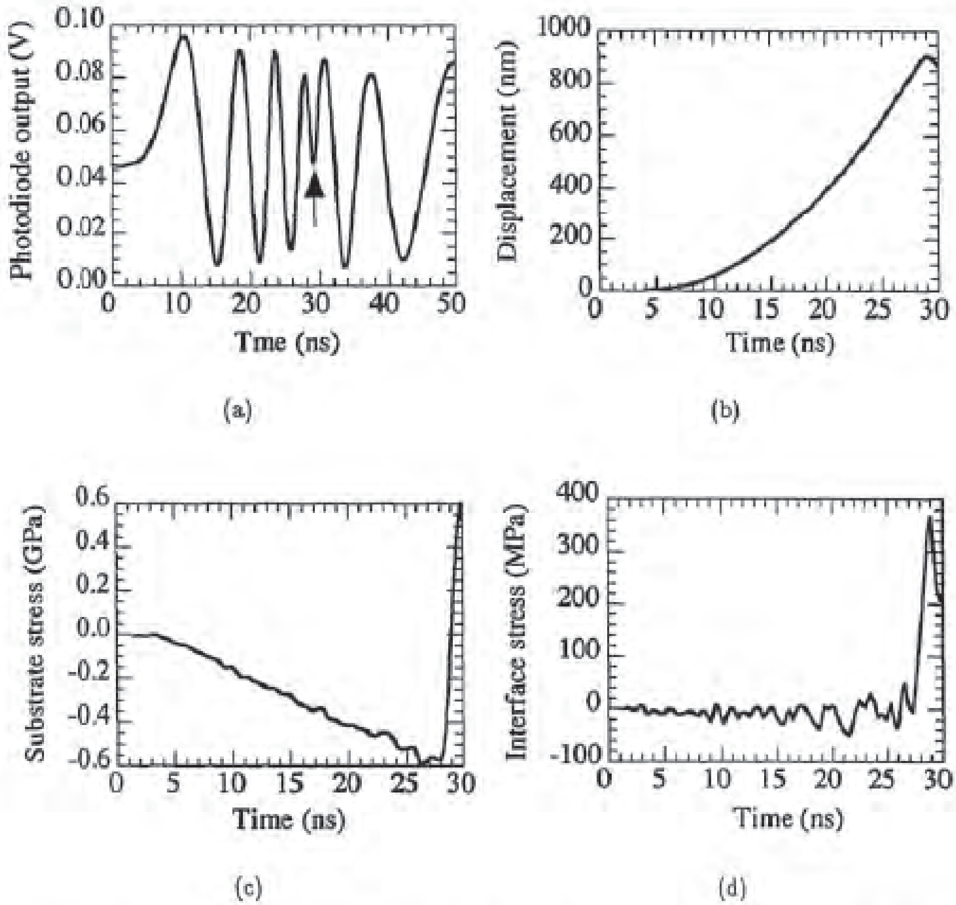


Figure 3.15: Typical data profile for a 1.0 μm thick aluminum film deposited on a 3000 μm thick fused silica substrate (laser fluence of 0.140 J/mm^2): (a) interferometric fringe pattern, arrow points to turning point; (b) displacement profile; (c) substrate stress profile; (d) interface stress profile.

Figure 3.15 includes four graphs labeled (a)–(d). Figure 3.15(a) shows the interferometric fringe pattern, and Figure 3.15(b) shows the displacement profile. *Id.* at Fig. 3.15. Figure 3.15(c) shows the substrate stress profile, and Figure 3.15(d) shows the interface stress profile. *Id.* According to Wang-Dissertation, these figures show the compression pulse evolves into a shock before it reaches the test film. *Id.* at 65. Figure 3.15(a) shows a turning point, which is marked by an arrow, at about 30 ns where the material velocity changes direction. *Id.* at 62–64. The turning point indicates the compression pulse turns into a shock long before it reaches the test film. *Id.* at 64. As shown in Figure 3.15(c) the rising part of the initial compression pulse evolves into a linear ramp, and the slope of the ramp is a material property of the substrate. *Id.* The tail of the compression pulse evolves in a very different manner. *Id.* The tail propagates more quickly and overtakes the peak, resulting in a decompression shock, namely a discontinuity in stress and material velocity. *Id.*; *see also id.* at 120 ("In fused-silica-substrates, the compressive pulse evolved into a decompression shock. The existence of a shock created a large stress at the film interface, promoting failure. The development of the shock was due to the nonlinear elastic properties of fused silica. This shock mechanism was advantageous for failing thin-film interfaces of thick substrates.").

Wang-Dissertation explains that "[t]he experimental picture is complicated somewhat by the presence of a tensile wave, reflected from the back of the confining layer." Ex. 1005, 65. The tensile wave propagates faster than the compression pulse and eventually overtakes the compressive pulse, and linear dissipative mechanisms govern the final thickness of the shock. *Id.* at 65–66. "In Fig[ure] 3.15, the shock is followed by a regime in which the velocity has changed sign indicating that the tensile pulse has overtaken the compression pulse." *Id.* at 66.

In its concluding remarks and discussion of future work, Wang-Dissertation discloses "[f]used silica is found to be an ideal substrate material for launching high-amplitude shock waves (its negative nonlinear elasticity being critical for the development of a decompression shock)." *Id.* at 124. Wang-Dissertation also discloses "[b]y inserting an extra layer of the desired substrate material between the fused silica and the thin film, the current technique can be used to test a variety of substrates and films." *Id.*

2. *Independent claim 1*

Petitioner relies on Wang-Dissertation's thin-film sample investigated in the tensile spallation experiment and the suggestion to add an extra layer of the desired substrate material to the sample to disclose the substrate, coating, and glass element recited in limitations [1.a]–[1.c]. Pet. 21–24 (citing Ex. 1003 ¶¶ 93–103; Ex. 1005, 44–45, 56–59, 124, Figs. 2.1, 3.2). More specifically, Petitioner relies on Wang-Dissertation's fused silica substrate, aluminum film, and additional layer of fused silica to disclose the recited substrate, coating, and glass element, respectively. *Id.*

Limitation [1.d] recites "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." Ex. 1001, 13:44–48. As set forth in section II.B.1, we construe this limitation to mean changing the profile of the laser generated compressive wave and propagating the wave profile as modified to the free surface of the coating, which upon reflection from the free surface as a tension wave generates a tensile stress at the coating/substrate interface.

Petitioner alleges Wang-Dissertation discloses limitation [1.d]. Pet. 24 (citing Ex. 1003 ¶¶ 104–112). According to Petitioner, Wang-Dissertation discloses that, "in fused silica, the initial stress pulse generated at the absorbing layer evolves into a shock after traveling a short distance." *Id.* at 25 (citing Ex. 1005, 30, 38, 65, 81). Petitioner also argues

"[Wang-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).'" *Id.* (citing Ex. 1005, 124). Petitioner further argues "[Wang-Dissertation] discloses that fused silica was chosen for investigation because there was known evidence of the formation of 'rarefaction' shocks." *Id.* (citing Ex. 1005, 26; Ex. 1021). Petitioner posits "[a] POSITA would have understood that fused silica propagates a shock wave and forms a 'decompression shock' or 'rarefaction shock.'" *Id.* (citing Ex. 1003 ¶¶ 108–109).

Patent Owner contends Wang-Dissertation fails to show shock in the compression pulse waveform in the fused silica. PO Resp. 23 (citing Ex. 2011 ¶¶ 49–84). Per Patent Owner, "[Wang-Dissertation] erroneously interprets the unloading due to the un-modified stress of a direct tension wave as a 'decompression shock.'" *Id.* (citing Ex. 1003 ¶ 77; Ex. 2011 ¶¶ 65–66). Patent Owner explains that, in the experiments disclosed in Wang-Dissertation, two compression waves are generated when the laser pulse strikes the energy absorbing layer: compression-wave-1 which travels toward the substrate and compression-wave-2 which has the same magnitude as compression-wave-1 and travels in the opposite direction toward the confining layer. *Id.* (citing Ex. 1005, 66; Ex. 2011 ¶ 53). Compression-wave-2 is reflected from the free surface of the confining layer as tension-wave-1, which has the same amplitude as compression-wave-2 and travels toward the substrate, chasing compression-wave-1. *Id.* (citing Ex. 2011 ¶¶ 53–55).

Patent Owner argues Wang-Dissertation does not disclose any modification of compression-wave-1 by the fused silica. PO Resp. 23 (citing Ex. 2011 ¶¶ 63–64, 94); *id.* at 29–40; Sur-reply 15–18. According to Patent Owner, Dr. Wang agrees that it is impossible to tell from the data in Wang-Dissertation whether the fused silica modifies compression-wave-1 to include a shock profile. PO Resp. 23 (citing Ex. 2009, 152:17–153:1). Patent Owner also argues that, even if the fused silica were to modify compression-wave-1 and create a rarefied compression wave, the modified compression wave would not propagate to the free surface of the coating and generate a tensile stress at the coating/substrate interface, as limitation [1.d] requires, because tension-wave-1 would overtake compression-wave-1 and neutralize it before it reached the coating/substrate interface. *Id.* at 24 (citing Ex. 2011 ¶¶ 62, 64, 115, 123); *id.* at 43–46; Sur-reply 19–21. Patent Owner further argues fused silica attenuates laser generated stress waves with shock profiles such that the stress waves are unable to maintain any shock. PO Resp. 40–41 (Ex. 1005, Fig. 2.12; Ex. 2011 ¶¶ 89, 94, 138–39); *id.* at 25–26, 41–43; Sur-reply 21.

In reply, Petitioner maintains Wang-Dissertation discloses that the fused silica both modifies the stress wave and propagates the modified stress wave to the free surface of the coating to generate a tensile stress at the coating/substrate interface. Pet. Reply 14–22. Petitioner argues a comparison of Figure 3.14(c) depicting the stress wave in a silicon substrate with Figure 3.15(c) depicting the stress wave in a fused silica substrate shows that fused silica modifies the stress wave to a long linear ramp of approximately 26 ns and a sharp decompression shock of only a few nanoseconds. *Id.* at 15–16 (citing Ex. 1005, Figs. 3.14(c), 3.15(c); Ex. 2009, 90:4–12, 90:17–91:8). Petitioner also argues it is illogical to suggest that compression-wave-2 would have time to travel through the confining layer, reflect from the free surface of the confining layer as tension-wave-1 and travel through the substrate before compression-wave-1 reaches the coating/substrate interface. *Id.* at 17 (citing Ex. 1038 ¶ 5). In support of this argument, Petitioner points to Dr. Wang's testimony that the peak stress from tension-wave-1 is about 2 ns behind the peak of compression-wave-1 and will not reach the interface before the reflected tensile peak of compression-wave-1 reaches the interface in 0.3 ns. *Id.* Petitioner further argues that, to the extent the modified wave experiences any attenuation, a POSITA would have known how to counter the effects of attenuation by optimizing the laser power or substrate thickness. *Id.* at 18 (citing Ex. 1038 ¶ 6).

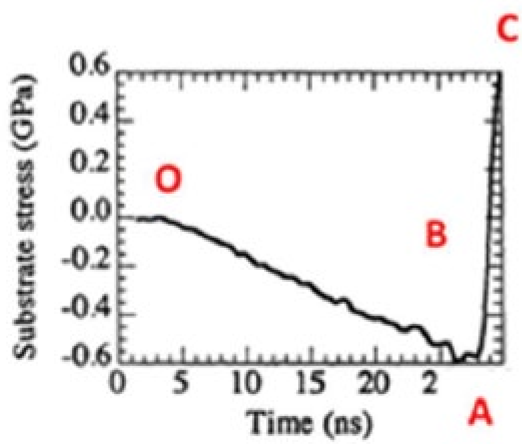
Additionally, Petitioner argues Dr. Wang's subsequent publication, Wang-2009,[7] confirms fused silica modifies the stress wave. Pet. Reply 19–22. Specifically, Petitioner argues a comparison of Figure 3 depicting substrate stress profiles in the absence of a fused silica glass element positioned between the energy absorbing layer and a tungsten substrate with Figure 5 depicting substrate stress profiles with such a fused silica glass element demonstrates the fused silica modifies the stress wave to a ramp load of approximately 18 ns and an unloading portion of about 10 ns. *Id.* at 20–21 (citing Ex. 1038 ¶¶ 12–14; Ex. 1056, 75–76, Figs. 3, 5).

[7] Lili Hu, Phillip Miller, and Junlan Wang, *High strain-rate spallation and fracture of tungsten by laser-induced stress waves*, 504 Materials Sci. & Eng'g A 73 (2009) ("Wang-2009") (Ex. 1056).

Most of Petitioner's arguments focus on Wang-Dissertation disclosing a shock in the compression wave in the fused silica substrate. Even if we were to agree with Petitioner that Wang-Dissertation's fused silica substrate modifies the compression waveform, we would not be persuaded that the fused silica substrate propagates the modified wave to the free surface of the coating, which upon reflection from the free surface as a tension wave generates a tensile stress at the coating/substrate interface, as limitation [1.d] requires. In view of the presence of tension-wave-1 in Wang-Dissertation's experiments, we find Petitioner has not demonstrated persuasively that the fused silica substrate propagates a modified stress wave to the free surface of the coating to generate a tensile stress at the coating/substrate interface. Also, we find credible Dr. Gupta's unrebutted testimony that any modified compression wave would attenuate in the substrate and not propagate to the free surface coating or generate a tensile stress at the coating/substrate interface. Ex. 2011 ¶¶ 93–98.

Petitioner does not dispute that the experiments in Wang-Dissertation include tension-wave-1. *See* Ex. 1005, 65 ("The experimental picture is complicated somewhat by the presence of a tensile wave, reflected from the back of the confining layer."). Nor does Petitioner dispute that Wang-Dissertation discloses that the tension-wave-1 propagates faster than the compression-wave-1 and eventually overtakes compression-wave-1. *See id.* at 65–66 ("Being tensile, it propagates faster that the peak compressive stress, and faster than the low stress tail of the main pulse. It eventually overtakes the compressive pulse and linear dissipative mechanisms govern the final thickness of the shock."). Rather, Petitioner relies on Dr. Wang's testimony regarding the timing of the waves through the sample and argues that tension-wave-1 does not overtake compression-wave-1 in the fused silica substrate. Pet. Reply 17 (citing Ex. 1038 ¶ 5). Dr. Wang testifies that the peak stress from tension-wave-1 is about 2 ns behind the peak of compression-wave-1 and will not reach the interface before the reflected tensile peak of compression-wave-1 reaches the interface in 0.3 ns. Ex. 1038 ¶ 5. However, as Dr. Gupta persuasively explains, the delay between tension-wave-1 and compression-wave-1 depends on the properties of the confining layer, and Wang-Dissertation acknowledges that these properties are not well controlled. Ex. 2011 ¶ 54; *see also* Ex. 1005, 65 ("The surface properties of that confining layer are not well controlled.").

Moreover, Dr. Gupta provides a detailed explanation why Figure 3.15(c) of Wang-Dissertation shows tension-wave-1 overtakes compression-wave-1 in the fused silica substrate. Ex. 2011 ¶¶ 71–80. Dr. Gupta's explanation refers to his annotated version of Wang-Dissertation's Figure 3.15(c), reproduced below. *Id.* ¶ 57.



(c)

Wang-Dissertation's Figure 3.15 shows the data obtained from the tensile spallation experiment. Ex. 1005, 62. Figure 3.15(c) is a graph showing the substrate stress profile in terms of substrate pressure over time. *Id.* at 64,

Fig. 3.15(c). Figure 3.15(c) shows a linear ramp in pressure and then a sharp pressure change from -0.6 GPa to 0.6 GPa. *Id.* at 65, Fig. 3.15(c). Dr. Gupta annotated Figure 3.15(c) to include an "O" at the initial pressure of 0 GPa, an "A" at the peak compressive stress at -0.6 GPa, a "B" at about the middle of the sharp pressure change where the pressure is 0 GPa, and a "C" at the peak tensile stress at 0.6 GPa. Ex. 2011 ¶¶ 57–58. Dr. Gupta testifies that the entire sharp pressure change from A to C is caused by tension-wave-1 overtaking compression-wave-1 in the substrate. *Id.* ¶¶ 58, 71–80. Petitioner argues the portion of the sharp pressure change from -0.6 GPa to 0 GPa, namely the portion from A to B, is a shock in compression-wave-1 from the fused silica. Pet. Reply 15. Although there is a dispute as to whether the portion of the sharp pressure change from A to B is a shock in compression-wave-1 or tension-wave-1 overtaking compression-wave-1, it is undisputed that the portion of the sharp pressure change from B to C represents tension-wave-1 overtaking compression-wave-1 in the substrate. *See e.g.*, Ex. 2009, 94:18–20 (Dr. Wang testifying: "The very last portion, from zero, continue to rise to about positive .6. That's due to tensile."); Tr. 54:6–8 (Petitioner explaining: "And then BC, which is I guess the positive stress, is what results from the tensile wave that has overtaken that compressive force.").

Dr. Gupta also credibly explains that Wang-Dissertation's Figure 3.15(d) shows tension-wave-1, not any modified compression-wave-1, causes the tensile stress at the coating/substrate interface. Ex. 2011 ¶¶ 81–82, 85. Dr. Wang testifies that it is unclear from the experimental data in Wang-Dissertation whether tension-wave-1 or a modified compression-wave-1 causes the tensile stress at interface and acknowledges that tension-wave-1 could cause the tensile stress at the interface shown in Figure 3.15(d). Ex. 2009, 151:19–153:1.

Summarizing this evidence, Dr. Gupta credibly explains the effect of tension-wave-1 on any modified compression-wave-1 in the fused silica substrate, and Dr. Wang acknowledges that tension-wave-1 overtakes compression-wave-1 in the substrate and could cause the tensile stress at the coating/substrate interface.

Turning to attenuation in fused silica, Dr. Gupta credibly explains that Wang-Dissertation's fused silica attenuates laser generated stress waves such that the stress waves cannot maintain any shock. Ex. 2011 ¶¶ 93–98. Petitioner does not refute Dr. Gupta's explanation, other than to assert a POSITA would have known how to counter the effects of attenuation by optimizing the laser power or substrate thickness. Pet. Reply 18 (citing Ex. 1038 ¶ 6). Thus, Petitioner acknowledges that fused silica attenuates stress waves.

After considering the parties' arguments and evidence, we find the evidence supports Patent Owner's argument that Wang-Dissertation discloses tension-wave-1 overtaking compession-wave-1 in the substrate and before compression-wave-1 can reflect from the free end of the coating as tension wave and generate a tensile stress at the coating/substrate interface. We further find the evidence supports Patent Owner's argument that Wang-Dissertation's fused silica substrate attenuates the stress waves such that the stress waves cannot maintain any shock. In view of the presence of tension-wave-1 and the attenuation of stress waves in fused silica, Petitioner has not persuaded us that Wang-Dissertation's fused silica substrate propagates a modified wave to the free surface of the coating, which upon reflection from the free surface as a tension wave generates a tensile stress at the coating/substrate interface, as limitation [1.d] requires. Therefore, Petitioner has not shown, by a preponderance of the evidence, that Wang-Dissertation anticipates independent claim 1.

3. Independent claim 13

Limitation [13.c] of independent claim 13 is similar to limitation [1.d]. *Compare* Ex. 1001, 14:53–55, *with id.* at 13:44–48. As set forth above in section II.B.1, we construe limitation [13.c] to have the same meaning as limitation [1.d].

Petitioner argues Wang-Dissertation discloses limitation [13.c] for the same reasons it discloses limitation [1.d]. Pet. 33 (citing Ex. 1003 ¶¶ 104–112, 136–137; Ex. 1005, 124). Petitioner has not persuaded us that Wang-Dissertation discloses limitation [13.c] for the reasons set forth above in section II.C.2 with respect to limitation [1.d]. Therefore, Petitioner has not shown, by a preponderance of the evidence, that Wang-Dissertation anticipates independent claim 13.

4. Claims 2–12 and 14–22

As discussed in sections II.C.2–3, Petitioner has not shown, by a preponderance of the evidence, that Wang-Dissertation anticipates independent claims 1 and 13. Petitioner thus has not shown, by a preponderance of the evidence, that Wang-Dissertation anticipates claims 2–12 and 14–22 depending therefrom.

D. Obviousness Based on Wang-Dissertation

Petitioner challenges claims 4, 6, 9, 15, 17, 20, 23, and 24 under 35 U.S.C. § 103(a), contending Wang-Dissertation renders obvious the claimed subject matter. Pet. 35–38; Pet. Reply 23–24. In doing so, Petitioner continues to rely on Wang-Dissertation to disclose limitation [1.d] of independent claim 1 and limitation [13.c] of independent claim 13. Pet. 35–38; Pet. Reply 23–24. Petitioner does not put forth any further obviousness rationale in this ground based on Wang-Dissertation for teaching these limitations.

For the same reasons discussed in sections II.C.2–3, Petitioner has not persuaded us that Wang-Dissertation teaches or suggests limitations [1.d] and [13.c]. Thus, Petitioner has not shown, by a preponderance of the evidence, that Wang-Dissertation renders obvious the subject matter set forth in claims 4, 6, 9, 15, 17, 20, 23, and 24, which depend from independent claims 1 and 13.

E. Obviousness Based on Wang-Dissertation and Gupta-1992

Petitioner challenges claims 1–24 under 35 U.S.C. § 103(a), contending the combined teachings of Wang-Dissertation and Gupta-1992 render obvious the claimed subject matter. Pet. 38–43; Pet. Reply 24. In doing so, Petitioner continues to rely on Wang-Dissertation to disclose limitation [1.d] of independent claim 1 and limitation [13.c] of independent claim 13. Pet. 38 (citing Ex. 1003 ¶ 166), 43 (citing Ex. 1003 ¶ 182). Petitioner does not put forth any further obviousness rationale in this ground based on Wang-Dissertation or Gupta-1992 for teaching these limitations.

For the same reasons discussed in sections II.C.2–3, Petitioner has not persuaded us that Wang-Dissertation teaches or suggests limitations [1.d] and [13.c]. Thus, Petitioner has not shown, by a preponderance of the evidence, that the combined teachings of Wang-Dissertation and Gupta-1992 render obvious the subject matter set forth in independent claims 1 and 13, and claims 2–12 and 14–24 depending therefrom.

F. Anticipation by Gupta-1992

Petitioner challenges claims 1–8, 10–19, 21, and 22 under 35 U.S.C. § 102(b) as anticipated by Gupta-1992. Pet. 44–56; Pet. Reply 25. Patent Owner asserts that Gupta-1992 does not anticipate the claims. PO Resp. 50–60; Sur-reply 23. We begin our analysis of this asserted ground of unpatentability with an overview of Gupta-1992 and then turn to the parties' contentions for the claims.

1. Gupta-1992

Gupta-1992 is an article authored by Patent Owner's declarant, Dr. Gupta. Ex. 1011, 141. Gupta-1992 discloses a laser spallation experiment to measure the strength of the interface between a substrate and a thin coating. *Id.* at Abstr. Laser spallation probes used in the experiment are shown in Figure 2, reproduced below. *Id.* at 144–45, Fig. 2.

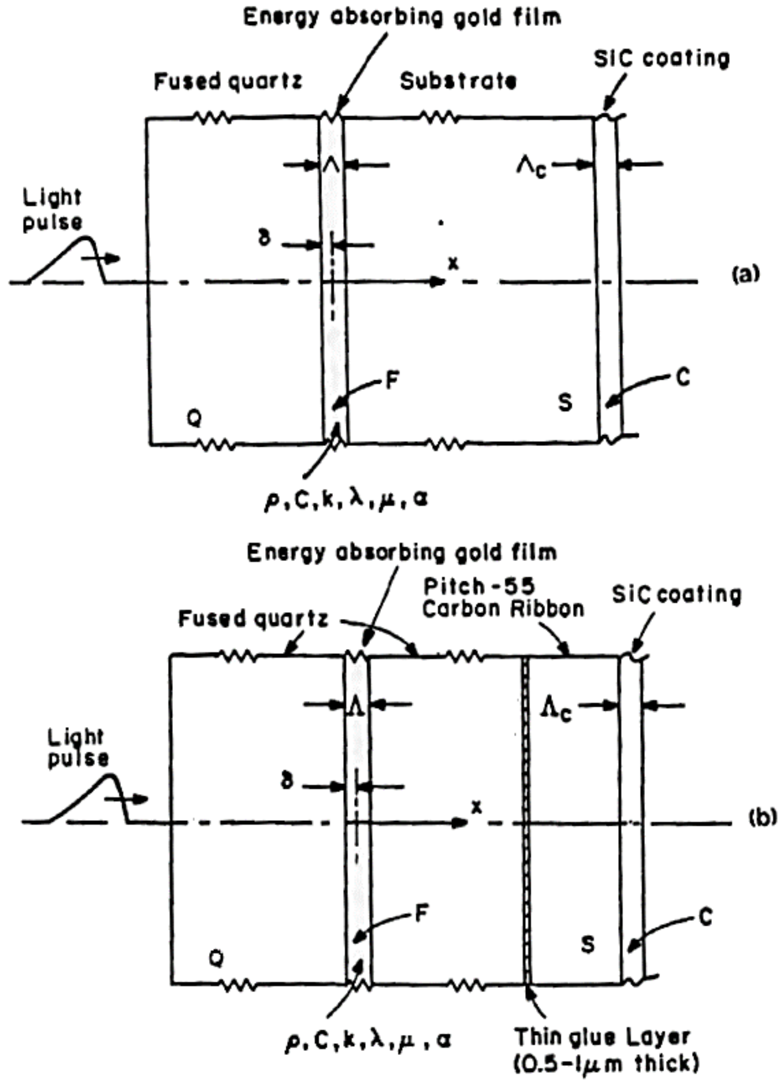


FIG. 2. (a) Configuration of the laser spallation probe with a homogeneous substrate. (b) Configuration for testing the Pitch-55 Ribbon/SiC system.

Figure 2 includes two schematics of laser spallation probes labeled (a)–(b). *Id.* at Fig. 2. Figure 2(a) is a laser spallation probe comprising a fused quartz confining layer, an energy absorbing gold film, a substrate, and a coating, and Figure 2(b) is a laser spallation probe comprising a fused quartz confining layer, an energy absorbing gold film, an additional fused quartz layer, a substrate, and a coating. *Id.*

2. Claims 1–8, 10–19, 21, and 22

Petitioner relies on Gupta-1992's additional layer of fused quartz located between the energy absorbing gold film and the substrate to disclose the glass element recited in independent claims 1 and 13. Pet. 47–48 (citing Ex. 1003 ¶¶ 194–195; Ex. 1011, Fig. 2(b)), 55 (citing Ex. 1003 ¶¶ 214–215; Ex. 1011, Fig. 2(b)). For limitations [1.d] and [13.c], Petitioner argues fused quartz, as disclosed in Gupta-1992, is equivalent to fused silica, which is known to cause rarefaction shock and consequently propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress between the substrate and the coating. *Id.* at 49–50 (citing Ex. 1003 ¶¶ 199–200; Exs. 1014–1018; Ex. 1021, Abstr., Fig. 1), 55 (citing Ex. 1003 ¶¶ 196–200, 217–218).

Patent Owner confirms the fused quartz in Gupta-1992 is the same material as the fused silica in Wang-Dissertation. PO Resp. 53. Patent Owner contends that, for the same reasons the fused silica in Wang-Dissertation fails to disclose limitations [1.d] and [13.c], which require propagating a modified wave to the free surface of the coating to generate a tensile stress at the coating/substrate interface upon reflection from the free surface, Gupta-1992's fused quartz also does not disclose these limitations. *Id.* Specifically, Patent Owner argues Gupta-1992's fused quartz attenuates the stress waves such that the stress waves lose their shock profiles before reaching the coating. *Id.* at 53–55 (citing Ex. 1011, Figs. 11, 15; Ex. 2011 ¶¶ 183, 190, 210). According to Patent Owner, neither Petitioner nor Dr. Wang is able to identify any shock profiles in Gupta-1992. *Id.* at 56 (citing Ex. 2009, 187:14–15, 188:13–189:2).

In reply, Petitioner maintains Gupta-1992's fused quartz is the same as Wang-Dissertation's fused silica. Pet. Reply 25. Petitioner also acknowledges that its arguments regarding the fused quartz in Gupta-1992 will have the same outcome as its arguments regarding Wang-Dissertation's fused silica. Tr. 19:15–20.

As set forth in section II.C.2, we find the evidence supports Patent Owner's argument that fused silica attenuates the stress waves such that the stress waves cannot maintain any shock. Given the undisputed likeness of fused quartz to fused silica, we similarly find the evidence supports Patent Owner's argument that fused quartz attenuates the stress waves. In view of the attenuation of stress waves in fused quartz, we are not persuaded that Gupta-1992's fused quartz propagates a modified wave to the free surface of the coating, which upon reflection from the free surface as a tension wave generates a tensile stress at the coating/substrate interface, as limitations [1.d] and [13.c] require. Petitioner, therefore, has not shown, by a preponderance of the evidence, that Gupta-1992 anticipates independent claims 1 and 13 and claims 2–8, 10–12, 14–19, 21, and 22 depending therefrom.

G. Obviousness Based on Gupta-1992 and Gupta-1993

Petitioner challenges claims 9 and 20 under 35 U.S.C. § 103(a), contending the combined teachings of Gupta-1992 and Gupta-1993 render obvious the claimed subject matter. Pet. 56–58; Pet. Reply 25. In doing so, Petitioner continues to rely on Gupta-1992 to disclose limitation [1.d] of independent claim 1 and limitation [13.c] of independent claim 13. Pet. 56–58; Pet. Reply 25. Petitioner does not put forth any further obviousness rationale in this ground based on Gupta-1992 or Gupta-1993 for teaching these limitations.

For the same reasons discussed in section II.F.2, Petitioner has not persuaded us that Gupta-1992 teaches or suggests limitations [1.d] and [13.c]. Thus, Petitioner has not shown, by a preponderance of the evidence, that the combined teachings of Gupta-1992 and Gupta-1993 render obvious the subject matter set forth in claims 9 and 20, which depend from independent claims 1 and 13, respectively.

H. Obviousness Based on Gupta-1992

Petitioner challenges claims 4, 6, 10, 15, 17, 23, and 24 under 35 U.S.C. § 103(a), contending Gupta-1992 renders obvious the claimed subject matter. Pet. 58–60; Pet. Reply 26. In doing so, Petitioner continues to rely on Gupta-1992 to disclose limitation [1.d] of independent claim 1 and limitation [13.c] of independent claim 13. Pet. 58–60; Pet. Reply 26. Petitioner does not put forth any further obviousness rationale in this ground based on Gupta-1992 for teaching these limitations.

For the same reasons discussed in section II.F.2, Petitioner has not persuaded us that Gupta-1992 teaches or suggests limitations [1.d] and [13.c]. Thus, Petitioner has not shown, by a preponderance of the evidence, that Gupta-1992 renders obvious the subject matter set forth in claims 4, 6, 10, 15, 17, 23, and 24, which depend from independent claims 1 and 13.

I. Obviousness Based on Wang-2002 and Gupta-1992

Petitioner challenges claims 1–24 under 35 U.S.C. § 103(a), contending the combined teachings of Wang-2002 and Gupta-1992 render obvious the claimed subject matter. Pet. 61–77; Pet. Reply 26. Patent

Owner asserts the claimed subject matter is not obvious in view of Wang-2002 and Gupta-1992. PO Resp. 70–71. We begin our analysis of this asserted ground of unpatentability with an overview of Wang-2002 and then turn to the parties' contentions for the claims.

1. Wang-2002

Wang-2002 is an article by Petitioner's declarant, Dr. Wang. Ex. 1016, 74. Wang-2002 reports parametric studies of elastic wave generation by a pulsed laser and the associated spalling of thin surface films. *Id.* at Abstr. Figure 3, reproduced below, shows a thin film sample for the spallation experiment. *Id.* at 76.

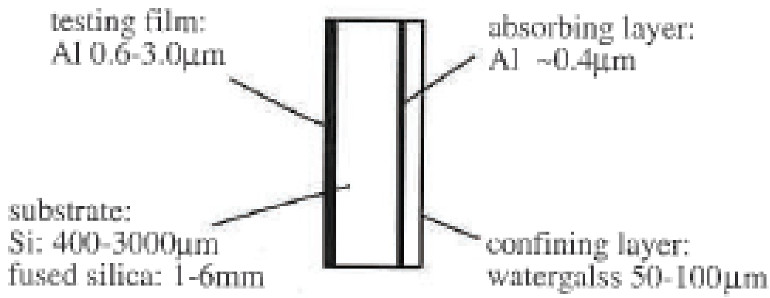


Fig. 3—Schematic of thin film sample for spallation experiment

Figure 3 is a schematic of a thin film sample. *Id.* at Fig. 3. As shown in Figure 3, the sample comprises a waterglass confining layer, an aluminum absorbing layer, a fused silica substrate, and thin aluminum testing film. *Id.*

2. Claims 1–24

Petitioner argues both Wang-2002 and Gupta-1992 suggest the glass element recited in independent claims 1 and 13. Pet. 63–65 (citing Ex. 1003 ¶¶ 244–249; Ex. 1011, Abstr., 142; Ex. 1016, 74–75, 82, Fig. 3) 74 (citing Ex. 1003 ¶¶ 282–283). For limitations [1.d] and [13.c], Petitioner argues

Wang-2002's fused silica develops shock in the stress wave and propagates the modified stress wave to generate a tensile stress between the substrate and the coating. *Id.* at 66 (citing Ex. 1003 ¶¶ 250–252; Ex. 1016, Abstr., 78–80, 82), 74 (Ex. 1003 ¶¶ 285–286; Ex. 1016, Abstr., 78–80, 82).

Patent Owner argues Wang-2002 is cumulative of Wang-Dissertation and does not include any additional information. PO Resp. 70–71 (citing Ex. 2009, 190:16–191:9; Ex. 2011 ¶¶ 215–219[8]). Patent Owner argues Wang-2002's fused silica does not disclose limitations [1.d] and [13.c] for the same reasons Wang-Dissertation's fused silica and Gupta-1992's fused quartz do not disclose these limitations. *Id.* at 71.

In reply, Petitioner maintains the combination of Wang-2002 and Gupta-1992 renders obvious the claimed subject matter for the same reasons Wang-Dissertation and Gupta-1992 disclose the claimed subject matter. Pet. Reply 26. Petitioner does not dispute that Wang-2002 is merely cumulative of the Wang-Dissertation. According to Petitioner, Wang-2002 "is a starting point for the Wang-Dissertation." Tr. 5:10–11.

As set forth in sections II.C.2–3, we find Wang-Dissertation does not disclose limitations [1.d] and [13.c]. We also find Gupta-1992 does not disclose these limitations as set forth in section II.F.2. For the reasons set forth in these sections, we are not persuaded that the combined teachings of Wang-2002, which is cumulative of Wang-Dissertation, and Gupta-1992 would have resulted in a glass element that propagates a modified wave to the free surface of the coating, which upon reflection from the free surface

[8] Patent Owner cites to "Ex-2011, ¶¶ 315–219." PO Resp. 71. The citation to paragraph 315 appears to be is a typographical error, and we understand Patent Owner is instead citing to paragraph 215.

as a tension wave generates a tensile stress at the coating/substrate interface, as limitations [1.d] and [13.c] require. Thus, Petitioner has not shown, by a preponderance of the evidence, that the combination of Wang-2002 and Gupta-1992 renders obvious the subject matter of independent claims 1 and 13 and claims 2–12 and 14–24 depending therefrom.

IV. PATENT OWNER'S MOTION TO EXCLUDE

Patent Owner moves to exclude Petitioner's Exhibits 1041–1051. Mot. 1. Petitioner relies on these exhibits in its Reply to support its argument that Wang-Dissertation qualifies as prior art. *Id.*

As discussed above, we are not persuaded by any of Petitioner's unpatentability grounds based on Wang-Dissertation. Thus, we need not address whether Wang-Dissertation qualifies as prior art, and we do not rely on any of the evidence Patent Owner seeks to exclude from this proceeding. We dismiss as moot Patent Owner's Motion to Exclude.

V. CONCLUSION

Claims Challenged	35 U.S.C. §	Reference(s)/Basis	Claims Shown Unpatentable	Claims Not Shown Unpatentable
1–22	102(b)	Wang-Dissertation		1–22
4, 6, 9, 15, 17, 20, 23, 24	103(a)	Wang-Dissertation		4, 6, 9, 15, 17, 20, 23, 24
1–24	103(a)	Wang-Dissertation, Gupta-1992		1–24
1–8, 10–19, 21, 22	102(b)	Gupta-1992		1–8, 10–19, 21, 22
9, 20	103(a)	Gupta-1992, Gupta-1993		9, 20
4, 6, 10, 15, 17, 23, 24	103(a)	Gupta-1992		4, 6, 10, 15, 17, 23, 24
1–24	103(a)	Wang-2002, Gupta-1992		1–24
Overall Outcome				1–24

VI. ORDER

In consideration of the foregoing, it is:

ORDERED that Petitioner has not proven, by a preponderance of the evidence, that claims 1–24 of the ’684 patent are unpatentable;

FURTHER ORDERED that Petitioner’s Motion to Exclude Evidence is dismissed as moot; and

FURTHER ORDERED that, as this is a Final Written Decision, a party seeking judicial review of the Decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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