

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Caihong Display Devices Co., Ltd.,

Petitioner,

v.

Corning Incorporated

Patent Owner.

Case No.: IPR2025- 00937
U.S. Patent No. 8,640,498

DECLARATION OF DR. FRANK ERNST

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I. INTRODUCTION

1. I have been retained by Caihong Display Devices Co., Ltd. (“Caihong” or “Petitioner”), as an independent expert in this proceeding before the Patent Trial and Appeal Board (“PTAB” or “Board”). I understand that Caihong is requesting that the Board institute an inter partes review (“IPR”) proceeding of U.S. Patent No. 8,640,498 (“the ‘498 Patent”) (EX 1001), currently assigned to Corning Inc (“Patent Owner” or “PO”).
2. I am not and have never been an employee of Caihong. I am being compensated at my usual and customary rate of \$280 per hour. No part of my compensation depends on the outcome of this proceeding, and I have no other interest in this proceeding.
3. I have been asked to provide my independent analysis of the ‘498 Patent in light of the prior art publications cited below. I have also been asked to consider the state of the art and prior art available as of June 28, 2005. Based on the prior art discussed in this declaration, it is my opinion that Claims 1-11 of the ‘498 Patent are unpatentable for the reasons provided below.

A. Qualifications

4. I am over 18 years of age and, if I am called upon to do so, I would be competent to testify as to the matters set forth herein. I understand that a copy of my current curriculum vitae, which details my education and professional and academic experience, is being submitted by Petitioner as EX 1011. The following provides an overview of some of my experience that is relevant to the matters

set forth in this declaration.

5. I am currently a (full) professor in the Department Chair of Materials Science and Engineering in the School of Engineering at Case Western Reserve University. For 9 years, until October 2024, I have been leading this department as department chair.
6. I have more than 40 years of experience in materials science and engineering, physics, mathematics, and computation. My scientific work contributed to several areas of material science, including ceramics. I have substantial expertise in microcharacterization of materials, including atomic-resolution imaging, diffractometry, and spectrometry using state-of-the-art sophisticated methodology and major instrumentation. I have served as the director of a microscopy center at Case Western Reserve University for about 10 years.
7. My scientific work involves ceramic/ceramic interfaces, especially grain boundaries in ceramics, as well as ceramic/metal- and ceramic/semiconductor interfaces. The list of materials my group and I researched and published on includes oxide ceramics, perovskite ceramics, carbides, nitrides, and metallic glasses. I also have expertise with the methodology and application of some of the sophisticated experimental methods that are in use to analyze the composition and microstructure of glasses, e.g. TEM, XEDS, EELS, SEM, FIB, AFM, XPS, AES, XRD, ToF-SIMS. My research group has advanced the frontier of research across a great variety of materials classes and phenomena, focusing on processing–composition–crystal/micro-structure–property relationships and with ceramic materials playing a significant role. I have extensive expertise with (and developed) advanced experimental methods of microcharacterization,

which serve to determine the microscopic structure and composition of materials, including borosilicate glasses. I am knowledgeable on glass composition and its impact on microscopic structure and glass properties.

8. Based on my experience and education, I believe that I am qualified to opine as to the knowledge and level of skill of one of ordinary skill in the art at the time of the alleged invention of the '498 Patent, as well as the state of the art at that time.

B. Materials Considered

9. In forming my opinions, I have reviewed the following documents:

EX1001	U.S. Patent No. 8,640,498 (the "'498 Patent")
EX1002	Prosecution History of the '498 Patent
EX1004	JP2003192377 ("Miwa '377")-certified English translation
EX1005	JP2004189535 ("Miwa '535")-certified English translation
EX1006	JP1998059741 ("JP '741")-certified English translation
EX1007	U.S. 20050101469 ("Peuchert '469")
EX1008	U.S. Patent No. 6,319,867 ("Chacon")
EX1009	JP2004299947 ("Takase")
EX1010	U.S. 20010034293 ("Peuchert '293")

II. LEGAL STANDARDS

10. In forming my opinions and considering the subject matter of the '498 Patent and its claim considering the prior art, I am relying on certain legal principles

that counsel in this case explained to me. My understanding of these concepts is summarized below.

11. I understand that earlier publications and patents may act to render a patent unpatentable for one of two reasons: (1) anticipation and (2) obviousness.

A. Anticipation

12. It is my understanding that the claims of a patent are anticipated by a prior art reference if each and every element of the claim is found either explicitly or inherently in the reference. I understand that inherency requires a showing that the missing descriptive matter in the claim is necessarily present in the allegedly anticipating reference, and that it would have been so recognized by a person of ordinary skill in the art (“POSITA”).
13. I understand that when a challenged claim covers several structures, either generically or as alternatives, the claim is deemed anticipated if any of the structures within the scope of the claim is found in the prior art reference.
14. Although anticipation typically involves the analysis of a single prior art reference, I understand that additional references may be used to show that the prior art reference has enabling disclosure (i.e., allows a POSITA to make the invention without undue experimentation), to explain the meaning of a term used in the prior art reference, and/or to show that a characteristic is inherent in the prior art reference.

B. Obviousness

15. I understand that a claim is invalid as obvious if it would have been obvious to

a person of ordinary skill in the art at the time the alleged invention was made. This means that even if all of the elements of the claim cannot be found in a single prior art reference that would anticipate the claim, a person of ordinary skill in the art who was aware of the prior art would have been able to come up with the claimed invention. This may be the case, for example, where the missing element represents only an insubstantial difference over the prior art or a reconfiguration of a known system. I understand that in an obviousness determination, the person of ordinary skill in the art is presumed to have knowledge of all material prior art.

16. I understand that an obviousness analysis requires an understanding of the scope and content of the prior art, any differences between the alleged invention and the prior art, and the level of ordinary skill in evaluating the pertinent art.
17. I understand that when a product is available, design incentives and other market forces can prompt variations of it, either in the same field or a different one. If a person of ordinary skill in the art can implement a predictable variation, obviousness likely bars its patentability. For the same reason, if a technique has been used to improve one device and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique would have been obvious.
18. I understand that whether a prior art reference renders a patent claim unpatentable as obvious is determined from the perspective of a person of ordinary skill in the art at the time of the alleged invention. I have been told that there is not a requirement that the prior art contain an express suggestion to combine known elements to achieve the claimed invention, but a suggestion to combine known

elements to achieve the claimed invention may come from the prior art, as filtered through the knowledge of one skilled in the art. In addition, I have been told that the inferences and creative steps a person of ordinary skill in the art would employ are relevant to the determination of obviousness.

19. I understand that one may consider, e.g., whether (1) the change was merely the predictable result of using prior art elements according to their known functions, or whether it was the result of true inventiveness; (2) there is some teaching or suggestion in the prior art to make the modification or combination of elements claimed in the patent; (3) the claimed innovation applies a known technique that had been used to improve a similar device or method in a similar way; (4) the claimed invention would have been obvious to try, meaning that the claimed innovation was one of a relatively small number of possible approaches to the problem with a reasonable expectation of success by those skilled in the art; (5) the invention merely substituted one known element for another known element in order to obtain predictable results; (6) the invention merely applies a known technique to a known device, method, or product to yield predictable results; or (7) known work in one field of endeavor may have prompted variations of it for use in either the same field or a different one based on design incentives or other market forces that would have been predictable to a person of ordinary skill in the art.
20. I further understand that certain factors may support or rebut the obviousness of a claim. I understand that such secondary considerations include, among other things, commercial success of the patented invention, skepticism of those having ordinary skill in the art at the time of the invention, unexpected results of the invention, any long-felt but unsolved need in the art that was satisfied by the alleged invention, the failure of others to make the alleged invention, praise

of the alleged invention by those having ordinary skill in the art, and copying of the alleged invention by others in the field. I understand that there must be a nexus—that is, a connection—between any such secondary considerations and the alleged invention. I also understand that contemporaneous and independent invention by others is a secondary consideration tending to show obviousness.

21. Additionally, I understand that in considering obviousness, it is important not to use the benefit of hindsight derived from the patent under consideration.

C. Level of Ordinary Skill in the Art

22. When interpreting a patent, I understand that it is important to identify the relevant art pertaining to that patent, as well as the level of ordinary skill in that art at the time of the claimed invention. The “art” is the field of technology to which the patent is related.
23. I am informed and understand that the POSITA is a hypothetical person who is presumed to know the relevant prior art. I understand that the actual inventor’s skill is not determinative of the level of ordinary skill. I further understand that factors that may be considered in determining level of skill include:
 - (i) the types of problems encountered in the art; (ii) prior art solutions to those problems; (iii) the rapidity with which innovations are made; (iv) the sophistication of the technology; and (v) the educational level of active workers in the field. I understand that not all such factors may be present in every case, and one or more of them may predominate.
24. I understand that a POSITA is one who is presumed to be aware of all pertinent

art, thinks along conventional wisdom in the art, and is a person of ordinary creativity. A POSITA would have comprehensive knowledge and deep understanding of the materials science aspects and the underlying physical, chemical, and mathematical concepts of the science of glasses, as relevant to the '498 patent. For example, this would include (but is not limited to) the concepts of liquidus temperature, viscosity, density, coefficient of thermal expansion, strain point, and fining. Further, a POSITA would have considerable understanding of and experience with design, synthesis, and characterization of silicate, borosilicate, aluminosilicate, and boroaluminosilicate glasses.

25. Based on my education and experience, I meet the criteria for a POSITA.

D. Claim Construction

26. I understand that the United States Patent and Trademark Office interprets claim terms in an *inter partes* review proceeding under the same claim construction standard that is used in a United States federal court. I understand that under this standard, the meaning of claim terms is considered from the viewpoint of a POSITA at the time of the alleged invention.
27. I have been informed that claim terms are generally given their ordinary and customary meaning as understood by one of ordinary skill in the art in light of the specification and the prosecution history pertaining to the patent. I understand, however, that claims terms are generally not limited by the embodiments described in the specification.
28. I understand that in addition to the claims, specification, and prosecution history, other evidence may be considered to ascertain the meaning of claim terms,

including textbooks, encyclopedias, articles, and dictionaries. I have been informed that this other evidence is often less significant and less reliable than the claims, specification, and prosecution history.

29. I have thus interpreted each of the terms in the claims as would be understood by one of ordinary skill in the art in light of the specification and the prosecution history pertaining to the patent.

III. SUMMARY OF GROUNDS

30. I understand that Petitioner challenges the validity of Claims 1-11 of the '498 Patent. In particular, I understand that Petitioner asserts the following grounds for challenging the claims of the '498 Patent:

Ground	Challenged Claims	Asserted Prior Art
1	1, 2, 7, 9, 10 and 11	Miwa '377
2	1, 3-11	Miwa '535 in View of JP '741 and Peuchert '469
3	1 and 4-11	Chacon in View of Takase
4	1-2, 4 and 9	Peuchert '293

IV. THE '498 PATENT

A. Overview of the '498 Patent

31. The '498 patent focuses on the development of alkali-free boroaluminosilicate glasses intended for use as substrates in flat panel displays, such as AMLCDs. EX1001, Abstract. The Applicant alleges that the invention has improved the fining (or refining) process of these glasses to achieve desirable physical and chemical properties suitable for high-quality display manufacturing. *Id.*, at 1:16-22. Specifically, the Applicant claims that the specified glass composition is tailored for a thermal expansion coefficient suitable for stress-balancing with deposited films, high liquidus viscosity, high strain point, low (mass) density, and low density of defects ("blisters" or "bubbles"), accomplished by fining with components of reduced toxicity. *Id.*, at 3:55-66.

32. Traditionally, As_2O_3 and Sb_2O_3 have been used as fining agents during glass manufacturing. *Id.*, at 12:1-26. However, since both fining agents are toxic, special handling is needed. *Id.* To solve this issue, the '498 Patent proposes to use SnO_2 as the fining agent. *Id.*, at 12:27-41.
33. Further, the '498 patent requires the liquidus temperature of the glass to be lower than 1170°C and the liquidus viscosity to be no less than 100,000P (poise). *Id.*, at 14:33-46.
34. 100,000P suggests a reliability of $\pm 0.5\text{P}$, i.e. a relative error of less than 10^{-5} . However, it is known to a POSITA that the relative error in experimentally determining a liquidus viscosity is *orders of magnitude* higher than this extremely small value, suggested by the many digits that are required to specify a quantity in units of P (poise). Moreover, it is known in the field that viscosities tend to vary exponentially with temperature. For these reasons, and because SI units are a standard that is supported in all published work in the scientific community, it is more appropriate to specify viscosities in SI units, namely in $\text{Pa}\cdot\text{s}$ (pascal-second), and to express the numerical value as a power of 10 with a reasonably small number of digits that better represents the actual experimental error / reliability. Using the SI unit prefix "d" (for "deci"), the numerical value obtained in this way corresponds to the numerical value of the viscosity in P, but can be shown with an appropriately small number of significant digits: In SI units and with reasonable precision, 100,000P corresponds to $10^{5.00}\text{dPa}\cdot\text{s}$ (decipascal-second). Three-digit precision of the exponent (here, 5.00) corresponds to a relative error of about $\pm 1\%$, i.e. error limits similar as in $(100,000 \pm 1000)\text{P}$, which is close to realistic.
35. Glass compositions can be indicated by specifying the fractions of different

atom or molecule species into which the glass can – theoretically – be decomposed. For the purpose of formulating mathematical relationships, one can index the atom or molecule species by integer numbers, e.g. SiO_2 : 1, Al_2O_3 : 2, B_2O_3 : 3, etc. (the order plays no role). The “fraction” of an atom- or molecule species i can be specified as the (normalized) share of this species within the total *number* of atoms and molecules. This way of specifying the share of an atom or molecule species i is known as its “mole fraction,” X_i , where $i=1, 2, 3, \dots$. Alternatively, the fraction of an atom- or molecule species i can be specified as the share of this species within the total *mass* (or, less preferably, the *weight*) of all atoms and molecules. This way of specifying the share of an atom or molecule species i is known as its “mass (or weight) fraction,” W_i , where $i=1, 2, 3, \dots$. The X_i and W_i are dimension-less numbers. Like any other fraction, the X_i and W_i can be indicated in many different ways, including as proper fractions, e.g. “1/40”, decimal fractions, e.g. “0.025,” percentages, e.g. “2.5%,” permillages, e.g. 25 ‰, etc. If a glass exclusively contains N different atom or molecule species, their mole fractions as well as their mass fractions must add up to one (or, e.g., 100 %):

$$\sum_{i=1}^N X_i = 1 ,$$

$$\sum_{i=1}^N W_i = 1 .$$

The mole fractions X_i and the mass fractions W_i of a given composition can be converted into each other with the help of the atomic or molecular masses m_i of the respective atom or molecule species, e.g. in units of “amu,” defined as 1/12 of the mass of a ^{12}C (carbon-12) atom, the most abundant isotope of carbon.

Mass fractions can be obtained from mole fractions according to

$$W_i = \frac{m_i X_i}{\sum_{i=1}^N m_i X_i}.$$

Mole fractions X_i can be obtained from mass fractions W_i according to

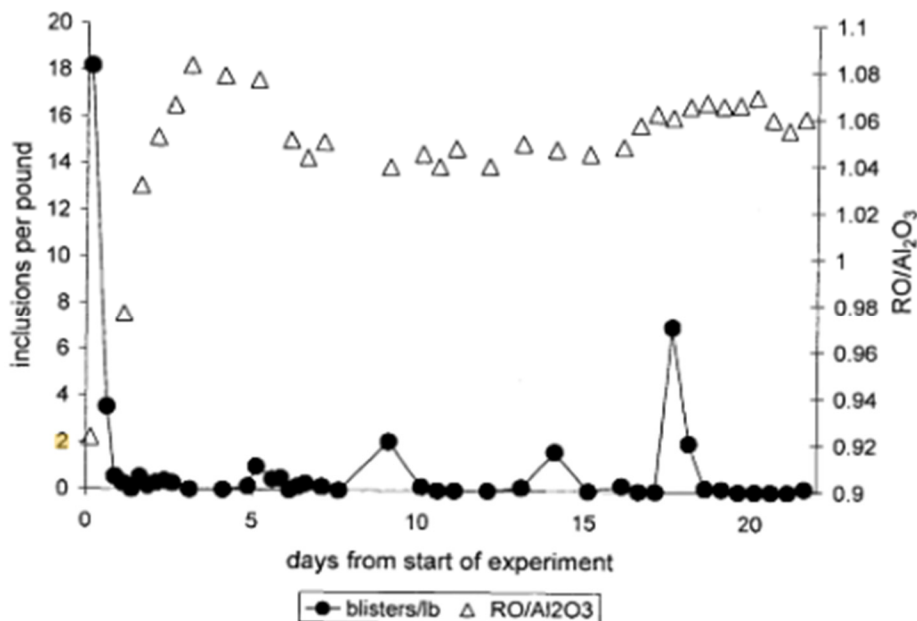
$$X_i = \frac{W_i/m_i}{\sum_{i=1}^N W_i/m_i}.$$

36. The ‘498 patent indicates that it is critical to the glass performance, meltability, and fining to control the MgO fraction and the ratio $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$. In the notation used in the patent, $\Sigma[\text{RO}]$ denotes the sum of the mole fractions X_i of $\text{RO} = \text{MgO}, \text{CaO}, \text{SrO}, \text{BaO}$ (i.e. all earth-alkaline metal oxides). $[\text{Al}_2\text{O}_3]$ denotes the mole fraction X_i of Al_2O_3 . *Id.*, at 7:24-29. In the notation used in the patent, brackets “[...]” are used to indicate “concentration.” “Concentration” can be a confusing concept, as it is sometimes used with reference to a volume, e.g. as the number of molecules (or moles thereof) per liter. Also, the bracket notation does not make it explicit that the concentration that is meant here refers to the *number* of molecules or atoms, not their masses. More clearly, the ratio $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$ can be written as $\sum_R X_i/X_{\text{Al}_2\text{O}_3}$, where $R = \{\text{MgO}, \text{CaO}, \text{SrO}, \text{BaO}\}$ is the set of the earth-alkaline oxides without BeO (toxic) and RaO (radioactive). So, $\sum_R X_i/X_{\text{Al}_2\text{O}_3}$ is a shorthand for

$$\frac{X_{\text{MgO}} + X_{\text{CaO}} + X_{\text{SrO}} + X_{\text{BaO}}}{X_{\text{Al}_2\text{O}_3}}$$

37. Further, the ‘498 patent indicates that, the MgO mole fraction X_{MgO} of should be within the range $X_{\text{MgO}} = 1$ to 3 mol%, in order to reduce the liquidus temperature, thus increase the liquidus viscosity. *Id.*, at 10:19-44. In addition, $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$ (or, preferably, $\sum_R X_i/X_{\text{Al}_2\text{O}_3}$) should be greater than 1.00 to

avoid inclusions (blisters) in the glasses and maintain high viscosity during the fining process. *Id.*, Abstract, FIG. 3 as reproduced below.



B. Prosecution History of the '498 Patent

38. I understand the '498 Patent was filed on December 10, 2010 as a divisional application of U.S. application serial no. 11/478,493 filed on June 28, 2006 that was issued as U.S. patent no. 7,851,394. I also understand that the '498 patent claims priority to a U.S. provisional application with the serial number of 60/694,478 that was filed on June 28, 2005.
39. I understand the Miwa'535 (EX1005) and Chacon (EX1008) were cited during the prosecution of the '498 Patent. None of the remaining prior art relied on in this Declaration was before the USPTO during prosecution of the '498 Patent.
40. Specifically, I understand that a machine translation of Miwa '535 was cited by

the USPTO in a rejection. EX1002, 000072.

41. I further understand in response to this rejection, it was argued that:

“In accordance with the invention, it was discovered that to achieve these goals, the glass making up the glass sheets has to have both a MgO content greater than or equal to 1.0 mole percent and an RO/Al₂O₃ ratio greater than or equal to 1.00. The criticality of the MgO content and the RO/ Al₂O₃ ratio to low gaseous inclusion levels for tin fining and high liquidus viscosities for downdraw forming is discussed at, for example, page 10, line 19, to page 15, line 26, of applicant's specification. Figure 3 further illustrates the criticality of the RO/ Al₂O₃ ratio to gaseous inclusion levels for a MgO content greater than or equal to 1.0 mole percent.”

“As we will now show, the Miwa reference cited in the May 20th Office Action does not disclose or suggest the criticality of having both a RO/ Al₂O₃ ratio 2: 1.0 and a MgO content 2: 1.0 mole%.”

“Attached hereto as Exhibit A are weight to mole conversions for the six examples of Miwa that have MgO, i.e., Examples 12, 15, 18, and 20-22. . . . Thus, in total, 19 of Miwa's 22 examples or more than 85% contain Sb₂O₃ or Sb₂O₃ + As₂O₃. When combined with the fact that more than 70% of Miwa's examples do not contain MgO, it is evident that Miwa does not render applicant's claims obvious since those claims require: (i) a MgO content greater than or equal to 1.0 mole percent, (ii) at most 0.05 mole percent As₂O₃, and (iii) at most 0.05 mole percent Sb₂O₃.” EX1002, 000046-000047

42. On this basis, I understand the USPTO Examiner allowed the application, stating:

“The prior art fail to disclose or suggest with sufficient specificity a method of making a glass by the downdraw process comprising an alkali-free glass which comprises the recited components, wherein the glass has the specific recited relationship of the alkaline earth metal oxides to the Al₂O₃ content of greater than or equal to 1, the glass has greater than or equal to 1 mole percent MgO, the glass uses SnO₂ as a fining agent in an amount greater than or equal to 0.01 mole percent, and the glass limits the amounts of As₂O₃ and Sb₂O₃ content present in the glass to at most 0.005 mole percent. Furthermore, the glass

has a liquidus viscosity that is greater than or equal to 100,000 poise.”
EX1002, 000027

43. Chacon (EX1008) was cited in the ‘498 patent at col. 2, line 48, cited in an Information Disclosure Statement, EX1002, 000156 and considered by the Examiner, EX1002, 000080.
44. However, the USPTO has not previously considered Miwa ‘377, JP ‘741, Peuchert ‘469, Takase, or Peuchert ‘293. And, more importantly, the Office has not previously considered any of the combinations of these references that form the grounds for this Declaration.
45. As such, I understand that this Declaration presents substantially new arguments that were not previously considered during prosecution in the UPSTO.

C. Technology Background and Interpretations

46. As I will describe below from a high-level functional perspective – in the next section based on specific prior art and then, in subsequent sections, on a limitation-by-limitation basis – all of these technologies and techniques were known to those of ordinary skill in the art at the time of the alleged invention claimed in the ‘498 Patent. A POSITA would have readily understood these relevant disclosures.

V. THE PRIOR ART IN THE APPLIED INVALIDITY GROUNDS

A. Miwa ‘377 (EX1004)

47. Miwa ‘377 was filed on December 21, 2001, and published on July 9, 2003. Similar to the ‘498 patent, Miwa ‘377 also relates to glass articles particularly

useful for a TFT-LCD glass substrate as the “TFT-LCDs, is substantially free of arsenic oxide and alkali metal oxides, and can be formed using the downdraw method.” EX1004, ¶0073.

48. Miwa ‘377 includes a number of embodiments specifying glass compositions on an oxide basis including the fractions of SiO₂, Al₂O₃, B₂O₃, MgO, and CaO, such as in Embodiment 8:

Oxide	Miwa ‘377 Embodiment 8 (ms%)	Miwa ‘377 Embodiment 8 (mol%)
SiO ₂	61.2	66.61
Al ₂ O ₃	17.0	10.90
B ₂ O ₃	8.0	7.52
MgO	2.0	3.24
CaO	6.0	7.00
SrO	4.0	2.52
BaO	0.5	0.21
ZnO	-	—
ZrO ₂	0.15	0.08
TiO ₂	-	-
SnO ₂	0.15	0.07
P ₂ O ₅	-	-
Sb ₂ O ₃	-	-

EX##, Table

49. Miwa '377 also describes that "*the liquid phase temperature of the glass is preferably less than 1200°C, and more preferably less than 1150°C, and the liquid phase viscosity is preferably less than 105 dPa·s, and more preferably 105.5 dPa·s.*" EX1004, ¶ 0012.

B. Miwa '535 (EX1005)

50. Miwa was filed on December 11, 2002, and published on July 8, 2004. EX1005, cover page.
51. Similar to the '498 Patent, Miwa '535 also relates to alkali-free boroalumino-silicate glass compositions primarily suitable for application as a substrate flat-panel display and thin-film photovoltaic technologies. *Id.*, at summary, [0001]-[0008]. More specifically, this Japanese patent, filed by Nippon Electric Glass Co. Ltd. (a Japanese glass manufacturer of glass for flat panel displays), concerns an alkali-free glass substrate. It can be used in various flat panel displays, such as liquid crystal displays (LCDs), electroluminescence displays (ELDs), field emission displays (FEDs), sensors, and cover glass for solid-state imaging devices. *Id.* Miwa '535 addresses the need for glass substrates that do not contain alkali-metal oxides. Uptake of alkali ions can degrade the electronic properties of the structured semiconductor layers that serve as the active components of the displays. The deposition and structuring of the semiconductor layers requires elevated temperatures, at which alkali ions from the glass substrate could readily diffuse in and destroy them. Therefore, alkali-free glasses are essential to prevent diffusion of alkali ions into the structured semiconductor layers that serve as the active components of the displays on the backside of the

display glass sheet. *Id.*

52. Miwa '535 also aims to provide glass with high etch resistance to chemicals used in photoetching processes, a high strain point (temperature up to which the glass is stable against stress-induced flow) to prevent pattern misalignment during heat treatments, excellent meltability to avoid melting defects, and low thermal-expansion coefficients to reduce thermal-shock damage. *Id.*
53. Additionally, Miwa '535 describes the necessity for high transmittance in the visible-to-ultraviolet range of the electromagnetic spectrum, crucial for device performance in displays and sensors. *Id.*, at [0001]-[0017]. Miwa '535 proposes adding SnO₂ to achieve the desired transmittance rates without significantly increasing costs, meeting all required characteristics, such as chemical durability, heat shrinkage resistance, meltability, high strain points, and minimal thermal expansion, while maintaining high clarity and absence of alkali-metal oxides. *Id.* Unlike conventional glass substrates, but similar to the '498 patent, Miwa '535 incorporates a specific amount of SnO₂ (mass fraction in percent: 0.01 to 0.3 ms%) without increasing the cost. *Id.* This fraction of SnO₂ effectively improves the substrate's transmittance rates in the visible-to-ultraviolet range of the electromagnetic spectrum, while satisfying all other required characteristics, including absence of alkali-metal oxides, chemical etch resistance, a thermal expansion coefficient suitable for stress-balancing with deposited films, high liquidus viscosity, and a high strain point. *Id.*
54. Similar to the '498 Patent, Miwa '535 specifies a continuous range of glass compositions that achieve favorable properties. Different from the '498 Patent, however, Miwa indicates the respective glass compositions by providing ranges for the *mass* (or weight – not mole) fractions of SiO₂, B₂O₃, Al₂O₃, MgO, CaO,

SrO, and BaO. *Id.* at [0022]. Glasses within the specified range of compositions are shown to possess high thermal shock resistance, high chemical resistance, high transparency across the visible-to-ultraviolet range of the electromagnetic spectrum, low mass density, and a thermal-expansion coefficient matching that of deposited semiconductor layers. The glasses demonstrate excellent mechanical stability and etch resistance to hydrochloric acid, making them ideal for TFT (thin-film transistor) displays, thin-film photovoltaics, and hard-disk substrates, while addressing disadvantages found in prior art related to mechanical stability and meltability. *Id.* at [0055]. In summary, Miwa teaches alkali-free glass substrates with similar compositions and similar physical and chemical properties as the '498 patent. Miwa '535's glass compositions are also suitable for flat panel display applications.

55. For example, Miwa '535's teaches an alkali-metal-free glass with the mass fractions W_i shown below (in percent):

	Embodiment				
	11	12	13	14	15
Composition (mass percent)					
SiO ₂	61.0	62.0	63.0	62.0	62.0
Al ₂ O ₃	16.0	15.0	16.0	16.0	16.0
B ₂ O ₃	12.0	9.4	12.0	11.0	11.0
MgO	–	0.5	–	–	1.3
CaO	7.0	7.0	7.0	8.0	8.0
SrO	1.9	4.0	1.0	0.5	1.0
BaO	1.0	0.05	0.3	1.5	0.5
ZnO	0.5	0.5	–	0.5	–
ZrO ₂	–	0.4	–	0.15	–
SnO ₂	0.1	0.25	0.15	0.15	0.1
As ₂ O ₃	–	0.1	–	–	–
Sb ₂ O ₃	0.5	0.7	0.5	–	0.1
Cl	–	0.1	0.05	0.2	–
All Fe ₂ O ₃	0.015	0.015	0.015	0.010	0.010
Transmittance (%) 300 nm	65	72	70	74	70
400 nm	91	91	91	92	91
600 nm	92	92	92	92	92
800 nm	92	92	92	92	92
Density (g/cm ³)	2.40	2.44	2.35	2.40	2.39
Coefficient of thermal expansion [30-380°C] (×10 ⁻⁷ /°C)	34	33	31	33	34
Strain point (°C)	665	671	668	669	673
Logn at 10 ²⁻³ (°C)	1555	1560	1605	1565	1560
Liquid phase temperature (°C)	1105	1055	1090	1085	1120
Acid resistance	○	○	○	○	○
Buffered hydrofluoric acid resistance	○	○	○	○	○

EX1005, Table 4.

56. Converting the mass fractions W_i in Miwa's Embodiment 15 to mole fractions X_i , according to

$$X_i = \frac{W_i/m_i}{\sum_{i=1}^N W_i/m_i},$$

Miwa '535 teaches that the glass has the following alkali-free compositions in mole fractions, shown as percentages (mol%) below:

Component	X (mol%)
SiO ₂	67.2
Al ₂ O ₃	10.2

Component	X (mol%)
B ₂ O ₃	10.3
MgO	2.1
CaO	9.3
SrO	0.63
BaO	0.21
SnO ₂	0.04
As ₂ O ₃	0.0
Sb ₂ O ₃	0.02
Fe ₂ O ₃	0.00
$\sum X_R / X_{Al_2O_3} = 1.20$	

C. JP ‘741 (EX1006)

57. JP ‘741 was filed on August 21, 1996 and published on March 3, 1998.
58. Similar to the ‘498 patent, JP ‘741 also relates to “*an alkali-free glass that does not use As₂O₃ as a clarifying agent and does not contain bubbles that cause display defects. . . . The present invention is also a method for producing an alkali-free glass comprising: melting a glass raw material mixture mixed together to become a glass having a composition comprising 40 to 70 wt% SiO₂, 6 to 25 wt% Al₂O₃, 5 to 20 wt% B₂O₃, 0 to 10 wt% MgO, 0 to 15 wt% CaO, 0 to 30 wt% BaO, 0 to 10 wt% SrO, and 0 to 10% ZnO, and being substantially free of alkali metal oxides.*” EX1006, ¶¶ 0006, 0019.
59. JP ‘741 further describes that “*As₂O₃ is highly toxic and may contaminate the environment during glass production and waste glass treatment, its use is being restricted.*”

EX1006, ¶ 0005.

60. Thus, JP ‘741 discloses a glass comprising an As_2O_3 mass/weight/mole fraction of zero, which overlaps with “at most 0.05 mole percent As_2O_3 .”

D. Peuchert ‘469 (EX1007)

61. Peuchert ‘469 was filed on March 6, 2002, published on May 12, 2005, and has a priority claim to a German application, DE 10114581.0, filed on March 24, 2001.
62. Similar to the ‘498 patent, Peuchert ‘469 also relates to alkali-free aluminoborosilicate glass. EX1007, ¶0001. Peuchert ‘469 discusses the benefits of low fractions of BaO, preferably complete absence of BaO, as well as the similar roles that SrO and BaO play for the properties of the glass. EX1007, ¶¶ 0024, 0025, 0026

E. Chacon (EX1008)

63. Chacon was filed on November 22, 1999, and published on June 27, 2001, and has a priority claim to several prior applications filed on November 22, 1999 and November 30, 1998.
64. Similar to the ‘498 patent, Chacon also relates to alkali-free, aluminosilicate glasses exhibiting desirable physical and chemical properties for substrates in flat panel display devices. EX1008, col. 1, lines 7-10.
65. Chacon describes the production of these glass articles by a fusion downdraw process with compositions including SiO_2 , Al_2O_3 , B_2O_3 , MgO , CaO , and SrO .

EX1008, col. 3, lines 32-36.

66. Chacon further discusses processing parameters, additional oxides, such as fining agents, and properties of glass articles that are substantially the same properties as described in the '498 patent. EX1008, col. 4, lines 11-19; col. 5, lines 20-29.
67. For instance, Chacon describes: "*Although substrates made from glass of the present invention can be made using other manufacturing processes such as the float process, the fusion process is preferred for several reasons.*" EX1008, col. 4, lines 29-32.
68. Chacon further describes "*The glass of the present invention has a composition consisting essentially of the following composition as calculated in mole percent on an oxide basis: ..., and essentially free of BaO. More preferably, the glass of the present invention has a composition consisting essentially of the following composition as calculated in mole percent on an oxide basis: 67-73 SiO₂, 8-11.5 Al₂O₃, 8-12 B₂O₃, 0-1 MgO, 5.5-11 CaO, and 0-5 SrO.*" EX1008, col. 3, lines 32-40.

F. Takase (EX1009)

69. Takase was filed on March 31, 2003, and published October 28, 2004.
70. Similar to the '498 patent, Takase also relates to "*alkali-free glass comprising 40 to 70 mass% SiO₂, 6 to 25 mass% Al₂O₃, 5 to 20 mass% B₂O₃, 0 to 10 mass% MgO, 0 to 15 mass% CaO, 0 to 30 mass% BaO, 0 to 10 mass% SrO, 0 to 10 mass% ZnO, 0.0001 to 0.03 mass% SO₃, 0.05 to 2 mass% SnO₂, the glass being substantially free of alkali metal oxides.*" EX1009, 0010.

71. Takase describes “*using a sulfate and stannic oxide instead of As_2O_3 as clarifying agents.*” EX1009, 0009. Takase discloses that the mass fraction of the SnO_2 fining agent is 0.05–2 ms%, corresponding to a mole fraction of at least 0.02 mol%. EX1009, 0017.

G. Peuchert ‘293 (EX1010)

72. Peuchert ‘293 was filed on January 11, 2001, and published on October 25, 2001, and has a priority claim to a German application, DE 10000837.2-45, filed on January 12, 2000.
73. Similar to the ‘498 patent, Peuchert ‘293 also relates to alkali-free aluminoborosilicate glass produced by down-draw and/or fusion methods. EX1010, ¶ 0064.
74. Peuchert ‘293 describes a number of Examples, such as Example 7. Converting the mass fractions W_i of Example 7 to mole fractions X_i yields:

Component	X (mol%)
SiO_2	65.3
Al_2O_3	10.2
B_2O_3	7.6
MgO	6.6
CaO	8.2
SrO	2.2
BaO	0
ZnO	0
SnO_2	0.1

As ₂ O ₃	0
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75. Peuchert ‘293 further discusses processing parameters, additional oxides, such as fining agents, and properties of glass articles with substantially the same properties as described in the ‘498 Patent. EX1010, Table at page 4 and ¶¶ 005, 0064.

H. Motivation to Combine

76. As set forth below in more detail in the specific relevant limitations, a POSITA would have found it obvious to combine Miwa ‘535 (EX1005), JP ‘741 (EX1006) and Peuchert ‘469 (EX1007), or Chacon (EX1008) and Takase (EX1009). In particular, the references are in the same technical field: alkali-free glasses developed primarily for use as substrates in flat-panel display technologies. Thus, Miwa ‘535, JP ‘741 and Peuchert ‘469, or Chacon and Takase are analogous references, and a POSITA would have found combining references to be one of a finite number of identified means for desired non-alkali low-density glass applicable to substrates in display technologies and would have had a reasonable expectation of success of their combination. Additionally, given the low ionic field strengths

$$F = \frac{Z}{(r_c + r_o)^2},$$

where Z is the charge on cation, r_c is the ionic radius of cation, and r_o is the ionic radius of oxide anion) of Sr^{2+} (28 nm⁻²) and Ba^{2+} (24 nm⁻²), both these cations play a *similar* role of network modifiers in the silicate glass structure. EX##. This information was well known at the time the ‘498 patent was filed, and a POSITA would have found combining Miwa ‘535, JP ‘741 and Peuchert

‘469, or Chacon and Takase to constitute combining prior art elements where the combined fraction of SrO and BaO ($X_{\text{SrO}} + X_{\text{BaO}}$) can be optimized to obtain low-density alkali-free substrate glasses according to known fabrication methods. Such modifications would have been well within the skill of a POSITA, as confirmed by the teachings of the references.

VI. GROUND 1: CLAIMS 1, 2, 7, 9 AND 11 ARE ANTICIPATED BY MIWA ‘377 AND CLAIM 10 WOULD HAVE BEEN OBVIOUS IN VIEW OF MIWA ‘377

A. Independent Claim 1

77. Limitation 1[p]: *“A method for producing alkali-free glass sheets by a drawdown process comprising: ...”*
78. Miwa’377 discloses that *“the glass in the present invention satisfies all of the[] required characteristics for use as a glass substrate[] for TFT-LCD’s [and furthermore, because it] is substantially free of arsenic oxide and alkali metal oxides, and can be formed using the drawdown method [it offers] high-quality glass substrates with low environmental impact and low cost can be obtained that are particularly suitable for use as glass substrates for liquid crystal displays.”* EX1004, ¶ 0073.
79. Limitation 1[a]: *“selecting, melting, and fining batch materials so that the glass making up the sheets comprises SiO_2 , Al_2O_3 , B_2O_3 , MgO , and CaO , and, on an oxide basis, has:”*
80. The composition of Miwa 377’s Embodiment 8 is shown in the following graphic:

[Table 3]

Sample Composition	No. 7		No. 8		No. 9	
	mass%	mol%	mass%	mol%	mass%	mol%
SiO ₂	62.0	68.62	61.2	66.61	60.0	67.72
Al ₂ O ₃	16.0	10.44	17.0	10.90	14.0	9.31
B ₂ O ₃	10.5	10.03	8.0	7.52	11.0	10.72
MgO	-	-	2.0	3.24	-	-
CaO	8.0	9.49	6.0	7.00	6.5	7.86
SrO	0.8	0.51	4.0	2.52	2.3	1.51
BaO	0.5	0.22	0.5	0.21	1.5	0.66
ZnO	-	-	-	-	0.7	0.58
ZrO ₂	0.4	0.22	0.15	0.08	0.45	0.25
TiO ₂	-	-	-	-	0.	0.42
SnO ₂	0.3	0.13	0.15	0.07	0.05	0.02
P ₂ O ₅	-	-	-	-	1.0	0.48
Sb ₂ O ₃	1.5	0.34	-	-	2.0	0.47
Cl	-	-	1.0	1.84	-	-
MCSB	9.3	10.22	12.5	12.97	10.3	10.03
0.13 x X-1		0.33		0.69		0.30
Density (g/cm ³)	2.39		2.44		2.45	
Thermal Expansion Coefficient (x 10 ⁻¹ /°C)	33		35		34	
Stress Point	669°C		693°C		650°C	
10 ^{2.5} dPa · s	1603°C		1619°C		1539°C	
Liquid Phase Temperature	1042°C		1089°C		1065°C	
SnO ₂ Opacity	No		No		No	
HCl Resistance Amount of Corrosion Appearance	1.8 μm ○		0.1 μm ○		0.8 μm ○	
BHF Resistance Amount of Corrosion Appearance	0.7 μm ○		0.6 μm Δ		0.7 μm ○	
Bubble Retention	○		○		○	

Miwa '377 (EX1004, Table 3)

81. The following table extracts the indicated mass fractions W_i and mole fractions X_i – as percentages (ms%, mol%).

Oxide	Miwa '377 Embodiment 8 (ms%)	Miwa '377 Embodiment 8 (mol%)
SiO ₂	61.62	66.61
Al ₂ O ₃	17.0	10.90

B ₂ O ₃	8.0	7.52
MgO	2.0	3.24
CaO	6.0	7.00
SrO	4.0	2.52
BaO	0.5	0.21
ZnO	-	—
ZrO ₂	0.15	0.08
TiO ₂	-	-
SnO ₂	0.15	0.07
P ₂ O ₅	-	-
Sb ₂ O ₃	-	-

82. Limitation 1[b]: “(i) a $\Sigma[RO]/[Al_2O_3]$ ratio greater than or equal to 1.0, where $[Al_2O_3]$ is the mole percent of Al_2O_3 and $\Sigma[RO]$ is the sum of the mole percents of MgO, CaO, SrO, and BaO; and”

83. Embodiment 8 of Miwa ‘377 (EX1004, Table 3) discloses:

$$\sum_R X_i = 3.24 + 7.00 + 2.52 + 0.21 = 12.97 .$$

$$X_{Al_2O_3} = 10.90 .$$

$$\sum_R X_i / X_{Al_2O_3} = 1.19 .$$

84. Limitation 1[c]: “(b) (ii) a MgO content greater than or equal to 1.0 mole per-cent”;

85. Embodiment 8 of Miwa '377 (EX1004) includes 3.24 mol% of MgO.
86. Limitation 1[d]: *“(B) producing the glass sheets from the melted and fined batch materials; wherein:”*
87. Miwa '377 discloses *“Sample No. 1, which is an example of the present invention, was melted in a test melting furnace and molded using the overflow down-draw method.”* And *“Because the glass in the present invention satisfies all of these required characteristics for use as a glass substrates for TFT-LCDs, is substantially free of arsenic oxide and alkali metal oxides, and can be formed using the downdraw method, high-quality glass substrates with low environmental impact and low cost can be obtained that are particularly suitable for use as glass substrates for liquid crystal displays.”* EX1004, ¶¶ 0072, 0073.
88. Limitation 1[e]: *“(a) on an oxide basis, the glass making up the glass sheets comprises at most 0.005 mole percent As₂O₃;”*.
89. Embodiment 8 of Miwa '377 (EX1004) includes 0 mol% of As₂O₃. See also Miwa '377 (EX1004), ¶ 0052.
90. Limitation 1[f]: *(b) on an oxide basis, the glass making up the glass sheets comprises at most 0.005 mole percent Sb₂O₃;*
91. Embodiment 8 of Miwa '377 (EX1004) includes 0 mol% of Sb₂O₃.
92. Limitation 1[g]: *“(c) SnO₂ is used in the fining and the glass making up the glass sheets has an SnO₂ content which in mole percent on an oxide basis satisfies the relationship: $0.01 \leq \text{SnO}_2$; and”*
93. Embodiment 8 of Miwa '377 (EX1004) includes 0.07 mol% of SnO₂.

94. Limitation 1[h]: *“(d) the glass making up the glass sheets has a liquidus viscosity that is greater than or equal to 100,000 poise.”*
95. Miwa ‘377 teaches *“Glass substrates for TFT-LCD are primarily molded using downdraw or float methods. Examples of downdraw methods include the slot downdraw method and the overflow downdraw method. Glass substrates formed using a downdraw method do not require polishing, which has the advantage of making it easier to reduce costs. However, when glass substrates are formed using a downdraw method, glass with excellent opacity resistance is required because glass tends to lose transparency. Specifically, in consideration of the temperature at which glass is formed using the downdraw method, the liquid phase temperature of the glass is preferably less than 1200°C, and more preferably less than 1150°C, and the liquid phase viscosity is preferably less than 10⁵ dPa·s, and more preferably 10^{5.5} dPa·s.”* EX1004, ¶ 0012.
96. Thus, all the limitations in Claim 1 are described in Miwa ‘377.

B. Dependent Claim 2

97. *“The method of claim 1 wherein the glass making up the glass sheets has an SnO₂ content which in mole percent on an oxide basis satisfies the relationship: $\text{SnO}_2 \leq 0.15$.”*
98. Embodiment 8 of Miwa ‘377 (EX1004) includes 0.07 mol% of SnO₂.
99. Thus, Claim 2 is disclosed by Miwa ‘377.

C. Dependent Claim 7

100. *“The method of claim 1 wherein the glass making up the glass sheets has a liquidus temperature less than or equal to 1170° C.”*

101. Embodiment 8 of Miwa ‘377 (EX1004) has a liquidus viscosity of 1089 °C, which is less than 1170 °C.

102. Thus, Claim 7 is disclosed by Miwa ‘377.

D. Dependent Claim 8

103. *“The method of claim 1 wherein the glass making up the glass sheets has a strain point that is greater than or equal to 650° C.”*

104. Embodiment 8 of Miwa ‘377 (EX1004) has strain point of 693 °C, which is less than 650 °C.

105. Thus, Claim 8 is disclosed by Miwa ‘377.

E. Dependent Claim 9

106. *“The method of claim 1 wherein the downdraw process is a fusion process.”*

107. Miwa ‘377, especially Embodiment 8, describes that glasses are made using a downdraw manufacturing process, such as an overflow downdraw method. The overflow downdraw method includes fusion of two downward-moving glass sheets. EX1004, ¶0012

108. Thus, Claim 9 is described by Miwa ‘377.

F. Dependent Claim 10

109. *“The method of claim 1 where in a population of 50 sequential glass sheets produced by the downdraw process from the melted and fined batch materials has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter, where each glass sheet in the population has a volume of at least 500 cubic centimeters.”*
110. The '498 Patent describes the quality of the resulting glass sheets in a non-standardized, rather arbitrary way that makes it difficult to perform quantitative comparisons with other inventors' products – unless those were examined under exactly the same experimental conditions and in the same way. Even if measurements of gaseous-inclusion content were performed in the same way as described in the '498 Patent, the results may not be comparable for the following reasons:
111. The specification of Claim 10 depends on the spatial resolution and detection sensitivity of the experimental technique of imaging or diffractometry by which the inclusions are detected. However, no corresponding technique, resolution limit, or detection sensitivity is specified in Claim 10. Generally, it is not sufficient to specify a maximum “average gaseous inclusion level.” This specification is meaningless without specifying a minimum size for a gaseous inclusion to be considered a defects.
112. Claim 10 is ambiguous regarding *“a population of 50 sequential glass sheets ... has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter.”* It is unclear whether the “average” mentioned here refers to the average over 50 individual sheets that were studied 1 time or to repeatedly making 50 sheets, counting the total number of blisters/bubbles in all 50 sheets each time, and calculating the average of that total over a larger population of

batches of 50 sheets each. In either case, specifying an upper limit for the defect count is not compatible with probability theory: For a realistic probability distribution, e.g. a Poisson distribution, there is still a finite probability for the observed number of defects to exceed the specified maximum – even for the same glass and conditions specified in the ‘498 Patent.

113. Moreover, the specification in Claim 10 relies on processing parameters that are not are not part of the claims of the ‘498 Patent, nor part of the invention background described in the ‘498 Patent. One of these additional parameters is the thickness of the resulting glass sheet. A glass sheet cannot contain gaseous inclusions larger than the sheet thickness. Moreover, inclusions close to the surface may escape more easily than inclusions deeper in the glass. For these reasons, the sheet thickness has significant impact on the number density and size distribution of blister/bubble defects, even if all other parameters are kept constant. Examples of other non-specified parameters include the melting temperature, melting time, stirring, pressure, and cooling rate.
114. While Miwa ‘377 does not provide experimental data on glass quality under the – insufficient and arbitrary – conditions of Claim 10, Miwa ‘377's Embodiment 8 fulfills all relevant specifications given in the '498 Patent. This includes the fusion downdraw process, the specified conditions for the glass composition – including a sufficient level of a fining agent and resulting meltability, as well as the condition for the liquidus temperature and liquidus viscosity. Moreover, Miwa ‘377 describes the same manner of making the glass sheets. Since the '498 Patent does not specify any further process parameters required to obtain the specified limit for defects in Claim 10, I expect that Embodiment 8 of Miwa ‘377 includes the ability to produce glass sheets of equivalent or better quality in terms of blister/bubble defects. This includes producing populations

of 50 sequential glass sheets produced by the fusion downdraw process from the melted and fined batch materials with “an average gaseous inclusion level of less than 0.05 gaseous inclusions per cm^3 , where each glass sheet in the population has a volume of at least 500 cm^3 .”

115. Thus, Claim 10 is disclosed by Miwa ‘377.

G. Dependent Claim 11

116. “*The method of claim 1 wherein the glass making up the glass sheets has a liquidus viscosity that is greater than or equal to 200,000 poise.*”

117. Miwa ‘377 teaches “*Glass substrates for TFT-LCD are primarily molded using downdraw or float methods. Examples of downdraw methods include the slot downdraw method and the overflow downdraw method. Glass substrates formed using a downdraw method do not require polishing, which has the advantage of making it easier to reduce costs. However, when glass substrates are formed using a downdraw method, glass with excellent opacity resistance is required because glass tends to lose transparency. Specifically, in consideration of the temperature at which glass is formed using the downdraw method, the liquid phase temperature of the glass is preferably less than 1200°C , and more preferably less than 1150°C , and the liquid phase viscosity is preferably less than $10^5 \text{ dPa}\cdot\text{s}$, and more preferably $10^{5.5} \text{ dPa}\cdot\text{s}$.*” EX1004, ¶ 0012.

118. 100,000 P suggests a reliability of $\pm 0.5 \text{ P}$, i.e. a relative error of less than 10^{-5} . However, it is known to a POSITA that the relative error in experimentally determining a liquidus viscosity is *much* higher than this extremely small value, suggested by the many digits that are required to specify a quantity in units of

P (poise). Moreover, it is known in the field that viscosities tend to vary exponentially with temperature. For these reasons, and because SI units are a standard that is supported in all published work in the scientific community, it is more appropriate to specify viscosities in SI units, namely in Pa·s (pascal-second), and to express the numerical value as a power of 10 with a reasonably small number of digits that better represents the actual experimental error / reliability. Using the SI unit prefix “d” (for “deci”), the numerical value obtained in this way corresponds to the numerical value of the viscosity in P, but can be shown with an appropriately small number of significant digits: In SI units and with reasonable precision, 100,000 P corresponds to $10^{5.00}$ dPa·s (decipascal-second). Three-digit precision of the exponent (here: 5.00) corresponds to a relative error of about $\pm 1\%$, i.e. error limits similar as in $(100,000 \pm 1000)$ P, which is sufficiently close to realistic.

119. The preferred viscosity of $10^{5.5}$ dPa·s specified by Miwa corresponds to 316,000 P ($\pm 36,000$), which is greater than or equal to 200,000 poise.

120. Thus, Miwa ‘377 discloses Claim 11.

VII. GROUND 2: CLAIMS 1 AND 3-11 WOULD HAVE BEEN OBVIOUS IN VIEW OF MIWA ‘535, JP ‘741 AND PEUCHERT ‘469

A. Independent Claim 1

121. Limitation 1[p]: “*A method for producing alkali-free glass sheets by a downdraw process comprising:*”

122. Miwa ‘535 describes: “[*Industrial Field of Use*] *The present invention relates*

to substrates such as flat panel displays and sensors including liquid crystal displays, electroluminescent displays, field emission displays, etc., and non-alkali glass substrates used in cover glass of solid state imagers. ... First, the raw materials for the non-alkaline glass are selected while taking into consideration the amount of Fe contained as an impurity, and the raw materials are used to make a mixture that falls within the above-mentioned glass composition range. The raw materials thus prepared are then melted in a continuous melt furnace at a temperature of 1520 to 1680°C. After that, by forming molten glass into a sheet using methods such as the slot-die draw method, overflow-die draw method, float method, and roll-out method can be used and the glass is then slowly cooled to obtain an alkali-free glass substrate.” EX1005, ¶¶ 0001, 0036

123. Miwa ‘535 discloses a continuous range of alkali-free glass compositions by specifying ranges for the mass (or weight) fractions of components on an oxide basis. EX1005, at [Claim 3], Tables 1-5. For example, Miwa teaches that “*The characteristic feature of the invention is that it comprises SiO₂ 55-70%, Al₂O₃ 12-20%, B₂O₃ 5-15%, MgO 0-5%, CaO 0-12%, SrO 0 – 10%, BaO 0-10%, ZnO 0-5%, ZrO₂ 0-5%, Cl 0-0.5% alkali-free glass substrate as described in either of the above Claims 1 or 2.*” EX1005, at [Claim 3]. Tables 4 and 5 of Miwa illustrates various embodiments, including Embodiment 15 of alkali-free glasses defined by weight percentages of each listed oxide.
124. Thus, Miwa ‘535 describes Limitation 1[p].
125. Limitation 1[a]: “*selecting, melting, and fining batch materials so that the glass making up the sheets comprises SiO₂, Al₂O₃, B₂O₃, MgO, and CaO, and, on an oxide basis, has:*”
126. Miwa specifies a continuous range of glass compositions that achieve favorable

properties. Different from the '394 Patent, however, Miwa indicates the respective glass compositions by providing ranges for the *mass* (or weight – not mole) fractions of SiO₂, B₂O₃, Al₂O₃, MgO, CaO, SrO, and BaO. EX1005 at [0022]. Glasses within the specified range of compositions are shown to possess high thermal shock resistance, high chemical resistance, high transparency across the visible-to-ultraviolet range of the electromagnetic spectrum, low mass density, and a thermal expansion coefficient matching that of deposited semiconductor layers. These glasses demonstrate excellent mechanical stability and resistance to hydrochloric acid, making them ideal for TFT (thin-film transistor) displays, thin-film photovoltaics, and hard-disk substrates, while addressing disadvantages found in prior art related to mechanical stability and meltability. *Id.* at [0055]. In summary, Miwa teaches alkali-free glass substrates with similar compositions and similar physical and chemical properties as the '394 patent. Miwa's glass compositions are also suitable for flat panel display applications.

127. For example, Miwa's Embodiment 15 teaches that the glass has the following alkali-free compositions in mass fractions, shown as percentages below:

	Embodiment				
	11	12	13	14	15
Composition (mass percent)					
SiO ₂	61.0	62.0	63.0	62.0	62.0
Al ₂ O ₃	16.0	15.0	16.0	16.0	16.0
B ₂ O ₃	12.0	9.4	12.0	11.0	11.0
MgO	–	0.5	–	–	1.3
CaO	7.0	7.0	7.0	8.0	8.0
SrO	1.9	4.0	1.0	0.5	1.0
BaO	1.0	0.05	0.3	1.5	0.5
ZnO	0.5	0.5	–	0.5	–
ZrO ₂	–	0.4	–	0.15	–
SnO ₂	0.1	0.25	0.15	0.15	0.1
As ₂ O ₃	–	0.1	–	–	–
Sb ₂ O ₃	0.5	0.7	0.5	–	0.1
Cl	–	0.1	0.05	0.2	–
All Fe ₂ O ₃	0.015	0.015	0.015	0.010	0.010
Transmittance (%) 300 nm	65	72	70	74	70
400 nm	91	91	91	92	91
600 nm	92	92	92	92	92
800 nm	92	92	92	92	92
Density (g/cm ³)	2.40	2.44	2.35	2.40	2.39
Coefficient of thermal expansion [30-380°C] (×10 ⁻⁷ /°C)	34	33	31	33	34
Strain point (°C)	665	671	668	669	673
Logn at 10 ^{-2.1} (°C)	1555	1560	1605	1565	1560
Liquid phase temperature (°C)	1105	1055	1090	1085	1120
Acid resistance	○	○	○	○	○
Buffered hydrofluoric acid resistance	○	○	○	○	○

EX1005, Table 4

128. Converting the mass fractions Miwa 535's Embodiment 15 to mole fractions,

$$X_i = \frac{W_i/m_i}{\sum_{i=1}^N W_i/m_i},$$

Miwa teaches that the glass has the following alkali-free composition in mole fractions, shown as percentages:

Component	X (mol%)
SiO ₂	67.19
Al ₂ O ₃	10.22
B ₂ O ₃	10.29

Component	X (mol%)
MgO	2.10
CaO	9.29
SrO	0.63
BaO	0.21
SnO ₂	0.04
As ₂ O ₃	0.0
Sb ₂ O ₃	0.02
Fe ₂ O ₃	0.00
$\sum X_R / X_{Al_2O_3} = 1.21$	

129. Thus, Miwa ‘535 describes Limitation 1[a].

130. Limitation 1[b]: “(i) a $\Sigma[RO]/[Al_2O_3]$ ratio greater than or equal to 1.0, where $[Al_2O_3]$ is the mole percent of Al_2O_3 and $\Sigma[RO]$ is the sum of the mole percents of MgO, CaO, SrO, and BaO; and”

131. Miwa ‘535 presents the composition in mass fractions. EX1005, Table 4.

The mole fractions X_i and the mass fractions W_i of a given composition can be converted into each other with the help of the atomic or molecular masses m_i of the respective atom or molecule species, e.g. in units of “amu,” defined as 1/12 of the mass of a ¹²C (carbon-12) atom (most abundant carbon isotope). Mass fractions can be obtained from mole fractions according to

$$W_i = \frac{m_i X_i}{\sum_{i=1}^N m_i X_i}.$$

Mole fractions X_i can be obtained from mass fractions W_i according to

$$X_i = \frac{W_i/m_i}{\sum_{i=1}^N W_i/m_i}.$$

132. The ‘498 patent indicates that it is critical to the glass performance, meltability, and fining to control the MgO fraction and the ratio $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$. In the notation used in the patent, $\Sigma[\text{RO}]$ denotes the sum of the mole fractions X_i of RO = MgO, CaO, SrO, BaO (i.e. all earth-alkaline metal oxides). $[\text{Al}_2\text{O}_3]$ denotes the mole fraction X_i of Al_2O_3 . *Id.*, at 7:24-29. In the notation used in the patent, brackets “[...]” are used to indicate “concentration.” “Concentration” can be a confusing concept, as it is sometimes used with reference to a volume, e.g. as the number of molecules (or moles thereof) per liter. Also, the bracket notation does not make it explicit that the concentration that is meant here refers to the *number* of molecules or atoms, not their masses. More clearly, the ratio $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$ can be written as $\Sigma_R X_i/X_{\text{Al}_2\text{O}_3}$, where $R = \{\text{MgO}, \text{CaO}, \text{SrO}, \text{BaO}\}$ is the set of the earth-alkaline oxides without BeO (toxic) and RaO (radioactive). So, $\Sigma_R X_i/X_{\text{Al}_2\text{O}_3}$ is a shorthand for

$$\frac{X_{\text{MgO}} + X_{\text{CaO}} + X_{\text{SrO}} + X_{\text{BaO}}}{X_{\text{Al}_2\text{O}_3}}.$$

133. Converting the mass fractions Miwa 535’s Embodiment 15 to mole fractions,

$$X_i = \frac{W_i/m_i}{\sum_{i=1}^N W_i/m_i},$$

Miwa ‘535 teaches that the glass has the following alkali-free composition in mole fractions, shown as percentages:

Component	X (mol%)
SiO ₂	67.19
Al ₂ O ₃	10.22
B ₂ O ₃	10.29
MgO	2.10

Component	X (mol%)
CaO	9.29
SrO	0.63
BaO	0.21
SnO ₂	0.04
As ₂ O ₃	0.0
Sb ₂ O ₃	0.02
Fe ₂ O ₃	0.00
$\sum X_R / X_{Al_2O_3} = 1.21$	

134. Thus, Embodiment 15 in Miwa ‘535 is the same as Limitation 1[b].

135. Limitation 1[c]: “(b) (ii) a MgO content greater than or equal to 1.0 mole per cent;”

136. As is evident from conversion from weight to mol above, Embodiment 15 in Miwa ‘535 has 2.1 mol% of MgO. Thus, Limitation 1[c] is the same as Embodiment 15 in Miwa ‘535.

137. Limitation 1[d]: “(B) producing the glass sheets from the melted and fined batch materials; wherein:”

138. Miwa ‘535 describes: “First, the raw materials for the non-alkaline glass are selected while taking into consideration the amount of Fe contained as an impurity, and the raw materials are used to make a mixture that falls within the above-mentioned glass composition range. The raw materials thus prepared are then melted in a continuous melt furnace at a temperature of 1520 to 1680°C. After that, by forming molten glass into a sheet using methods such as the slot-die draw method, overflow-die draw method, float method, and roll-

out method can be used and the glass is then slowly cooled to obtain an alkali-free glass substrate.” EX1005, ¶ 0036.

139. Thus, Miwa ‘535 describes Limitation 1[d].

140. Limitation 1[e]: “(a) on an oxide basis, the glass making up the glass sheets comprises at most 0.005 mole percent As_2O_3 ”;

141. Miwa ‘535, in Embodiment 15, discloses a glass comprising an As_2O_3 mass/weight/mole fraction of zero, which overlaps with “at most 0.05 mole percent As_2O_3 .” EX1005, Table 4.

142. JP ‘741 further describes: “However, As_2O_3 is highly toxic and may contaminate the environment during glass production and waste glass treatment, its use is being restricted.”

“Therefore, it is an object of the present invention to provide an alkali-free glass that does not use As_2O_3 as a clarifying agent and does not contain bubbles that cause display defects.”

“The result is the alkali-free glass of the present invention, which has a composition comprising 40 to 70 wt% SiO_2 , 6 to 25 wt% Al_2O_3 , 5 to 20 wt% B_2O_3 , 0 to 10 wt% MgO , 0 to 15 wt% CaO , 0 to 30 wt% BaO , 0 to 10 wt% SrO , 0 to 10% ZnO , and 0.05 to 2 wt% SnO_2 , and which is substantially free of alkali metal oxides.” EX1006, ¶¶ 0005, 0006, 0022.

143. Thus, JP ‘741 discloses a glass comprising an As_2O_3 mass/weight/mole fraction of zero, which overlaps with “at most 0.05 mole percent As_2O_3 .”

144. Limitation 1[f]: “(b) on an oxide basis, the glass making up the glass sheets comprises at most 0.005 mole percent Sb_2O_3 ; and”

145. Miwa '535 describes that the glass can comprise an Sb_2O_3 mass fraction of $W_{\text{Sb}_2\text{O}_3}=0$ to 1 ms%. EX1005, ¶0014.
146. A mass fraction of 0 implies a mole fraction of 0, which overlaps with “*at most 0.005 mole percent Sb_2O_3* ”.
147. Thus, Miwa '535 discloses Limitation 1[f] of the '498 Patent.
148. Limitation 1[g]: “(c) *SnO_2 is used in the fining and the glass making up the glass sheets has an SnO_2 content which in mole percent on an oxide basis satisfies the relationship: $0.01 \leq \text{SnO}_2$; and*”
149. Miwa '535 Embodiment 15 of Miwa (EX1005, Table 4) describes an SnO_2 mole fraction of $X_{\text{SnO}_2}=0.04$ mol%, which overlaps with “at least 0.01 mole percent SnO_2 ”. Miwa also describes that the glass can comprise a mass (or weight) fraction of $W_{\text{SnO}_2}=0.01$ to 0.3 ms%. EX1005, ¶0017.
150. In addition, Takase describes: “*Next, a sulfate and SnO_2 are added to this glass raw material mixture. ... The preferred amount of sulfate added is 0.01 to 1% in terms of SO_3 , and more preferably 0.05 to 1%. The preferred amount of SO_3 is 0.001 to 0.03%, preferably 0.005 to 0.03%. Also, the amount of SnO_2 added is 0.05 to 2 mass% per 100 mass% of glass raw material mixture. When the amount of SnO_2 is less than 0.05%, it becomes difficult to remove bubbles remaining in the glass melt during the clarification process, and when the amount exceeds 2%, the glass becomes prone to opacity. The preferred amount of SnO_2 added is 0.05 to 1%, and more preferably 0.1 to 0.5%.*” EX1009, ¶ 0017.
151. Furthermore, Takase provides the motivation for avoiding the use of toxic fining agents and instead using only SnO_2 as a fining agent. Additionally, Embodiment 15 in Miwa '535 falls within the compositional range described in Takase,

making it applicable to use the same type and content of fining agent. Takase discloses that the added mass of the SnO₂ fining agent is 0.05 to 2 ms% of the total mass of the components before adding SnO₂.

152. In the following, I investigate the *mole* fraction of SnO₂ obtained by adding SnO₂ and SO₃ with *masses* specified by Takase to the glass composition range specified by Chacon. Indexing SnO₂ and SO₃ as components 1 and 2, let $X_1 = X_{\text{SnO}_2}$ and $X_2 = X_{\text{CO}_3}$ denote the to-be-determined mole fractions of SnO₂ and SO₃, respectively. According to the above, these mole fraction X_1, X_2 are obtained by adding SnO₂ and SO₃ with *masses* that correspond to fractions $Y_1 = 0.0005..0.0200$ (i.e. 0.05 to 2.00 %) and $Y_2 = 0.00001..0.0003$ (i.e. 0.001–0.03 %) of the total mass of all other $N - 1$ glass components, indexed as components $i = 3, \dots, N$. Chacon specifies the fractions of components $i = 3, \dots, N$ as *mole* fractions X_i , each of which can range over a specific interval (e.g. $X_3 = X_{\text{SiO}_2}$: 67 to 73 mol%). However, the individual fractions X_i cannot vary independently. For a *valid* glass composition, the mole fraction must add up to 1:

$$\sum_{i=3}^N X_i = 1 .$$

153. To obtain the *mole* fractions X_1 and X_2 of the added SnO₂ and SO₃ for a *valid* glass composition $\{X_i\}, i = 3, \dots, N$, I will break down the calculation into the following steps:

- (i) Convert the mole fractions X_i of a valid glass composition to mass fractions W_i . Mass fractions can be obtained from mole fractions according to

$$W_i = \frac{m_i X_i}{\sum_{i=3}^N m_i X_i} .$$

The m_i denote the atomic or molecular masses of the respective atom

or molecule species, e.g. in units of “amu,” defined as 1/12 of the mass of a ^{12}C (carbon-12) atom, the most abundant isotope of carbon.

- (ii) Given the masses of the SnO_2 and SO_3 additions as fractions $Y_1 = 0.0005..0.0200$ (i.e. 0.05 to 2.00 %) and $Y_2 = 0.00001..0.0003$ (i.e. 0.001–0.03 %) of the glass mass without SnO_2 and SO_3 , calculate the mass fractions $W_1 = Y_1/(1 + Y_1 + Y_2)$ and $W_2 = Y_2/(1 + Y_1 + Y_2)$ of SnO_2 and SO_3 , respectively. Then, renormalize the mass fractions $W_3, \dots, W_N$ of the other oxides by multiplying them with $1/(1 + Y_1 + Y_2)$.
- (iii) Convert the mass fractions $W_i, i = 1, \dots, N$ back to mole fractions X_i to obtain a valid glass composition $\{X_i\}, i = 1, \dots, N$ including the added SnO_2 and CO_3 . Mole fractions X_i can be obtained from mass fractions W_i according to

$$X_i = \frac{W_i/m_i}{\sum_{i=1}^N W_i/m_i}.$$

Again, the m_i denote the atomic or molecular masses of the respective atom or molecule species, e.g. in units of “amu,” defined as 1/12 of the mass of a ^{12}C (carbon-12) atom, the most abundant isotope of carbon.

154. The following table demonstrates a specific example. (The numerical precision is intentionally exaggerated and does not imply corresponding reliability here.)

Index	Oxide	X	m (amu)	mX (amu)	W	Y	W_y	W_y / m	X_y
1	SnO ₂	0.00000	150.708	0.00000	0.00000	0.00050	0.00050	0.00000	0.00022
2	SO ₃	0.00000	80.057	0.00000	0.00000	0.00001	0.00001	0.00000	0.00001
3	SiO ₂	0.67190	60.083	40.36977	0.62122		0.62091	0.01033	0.67222
4	Al ₂ O ₃	0.10220	101.960	10.42031	0.16035		0.16027	0.00157	0.10225
5	B ₂ O ₃	0.10290	69.617	7.16359	0.11024		0.11018	0.00158	0.10295
6	MgO	0.02100	40.304	0.84638	0.01302		0.01302	0.00032	0.02101
7	CaO	0.09290	56.077	5.20955	0.08017		0.08013	0.00143	0.09294
8	SrO	0.00630	103.619	0.65280	0.01005		0.01004	0.00010	0.00630
9	BaO	0.00210	153.326	0.32198	0.00495		0.00495	0.00003	0.00210
11	As ₂ O ₃	0.00000	197.841	0.00000	0.00000		0.00000	0.00000	0.00000
12	Sb ₂ O ₃	0.00020	291.517	0.05830	0.00090		0.00090	0.00000	0.00020
13	Fe ₂ O ₃	0.00000	159.687	0.00000	0.00000		0.00000	0.00000	0.00000
Σ		0.99930		64.98439	1.00000		1.00000	0.01537	1.00000

Effect of adding a fraction of SnO₂ (column Y, highlighted) as mass on the mole fractions X of a valid glass composition, especially its SnO₂ mole fraction X_{SnO_2} (column X_y , highlighted.)

With reference to the above equations, column “Index” and column “Oxide” show the oxides specified by Miwa ‘535 with (arbitrary) indices and SnO₂ and SO₃ with indices 1 and 2 in row 1, respectively. Column “ X ” shows the glass composition from Miwa ‘535’s Embodiment 15. All mole and mass fractions are shown as decimal fractions, not percentages. The glass composition from Miwa ‘535’s Embodiment 15 in column “ X ” is *valid* as the mole fractions add up to 0.99930, as shown in row “ Σ .” Except for a very small rounding error, this equals the expected value of 1.00000. Column “ m ” shows the respective molecule masses in units of amu. Column “ mX ” shows the mole fractions multiplied with the corresponding molecular masses. Row “ Σ ” displays the sum of these products. Column “ W ” shows the mass fractions, obtained by the above equation, i.e. normalizing the values in column “ mX ” by their sum in row “ Σ .” Column “ Y ” shows the fractions of added SnO₂ and CO₃ masses relative to the total mass of all other components. The values shown here were *chosen by me*

from the intervals specified by Takase. Column " W_y " shows the mass fractions normalized to the new total mass, i.e. the mass obtained after adding the added masses of SnO_2 and SO_3 . As seen in row " Σ ," the re-normalized mass fractions correctly add up to 1.0000. Column " W_y/m " displays the renormalized mass fractions W divided by the corresponding molecular masses m . Row " Σ " shows their sum. According to the above equation, normalizing the values by their sum finally yields the mole fractions of all components after adding the SnO_2 and SO_3 as shown in column " X_y ."

155. Result: Adding SnO_2 and SO_3 with masses corresponding to 0.05% and 0.001%, respectively, of the mass without SnO_2 and SO_3 to the chosen valid glass composition with oxide mole fractions within the ranges specified by Chacon yields a glass with an SnO_2 mole fraction of $X_1 = X_{\text{SnO}_2} = 0.00022$ – or 0.022 mol%. This mole fraction is larger than 0.01 mol%, in agreement with Limitation 1[g]. Using the values displayed in column , $\Sigma X_R / X_{\text{Al}_2\text{O}_3} = 1.20$, in agreement with Limitation 1[b].
156. Thus, the converted values X_i for each component and the value of $\Sigma_R X_i / X_{\text{Al}_2\text{O}_3}$ fall within the values and ranges in Limitations 1[b], [c], [e], [f] and [g].
157. Limitation 1[h]: *“(d) the glass making up the glass sheets has a liquidus viscosity that is greater than or equal to 100,000 poise.”*
158. It is known in the field that for an alkali-free glass substrate to be fabricated using downdraw technique, the liquidus viscosity should be greater than or equal to 100,000 P (poise), equivalent to $10^{5.0}$ dPa·s (decipascal–seconds) in SI units. The liquidus viscosity of a glass is a direct consequence of the glass composition. The 498 Patent specifies glass compositions in Limitation 1[p] and

Limitation 1[a]. As shown above, Miwa '535 describes Limitation 1[p] and Limitation 1[a].

159. Consequently, Miwa '535 discloses Limitation 1[h].

B. Dependent Claim 3

160. *“The method of claim 1 wherein the MgO content is between 1.2 and 2.8 mole percent.”*

161. Embodiment 15 of Miwa '535 includes 2.1 mol% of MgO.

162. Thus, Claim 3 is described by Miwa '535.

C. Dependent Claim 4

163. *“The method of claim 1 wherein the glass making up the glass sheets is substantially free of BaO.”*

Peuchert '469 teaches (emphasis added): *“The glass may furthermore contain BaO, which has a positive effect on its devitrification stability. The maximum content is restricted to <2% by weight to keep the density of the glass low. The BaO content of the glass is particularly preferably between 0 and 0.5% by weight. When a very lightweight glass is required, the glass is most preferably free of BaO. The glass may furthermore contain SrO. Its presence likewise has a positive effect on the devitrification stability. The maximum SrO content is restricted to <3% by weight to keep the density of the glass low. The glass contains particularly preferably between 0 and 1% by weight and most preferably between 0 and 0.5% by weight. The sum of the two heavy alkaline earth*

metal oxides SrO and BaO is preferably limited to a maximum of 4% by weight.”
EX1007, ¶¶ 0024, 0025, 0026.

164. Thus, Peuchert ‘469 teaches that it would be reasonable to not use BaO and, as the role of SrO is similar to BaO, a fraction of BaO can be replaced with a corresponding fraction of SrO. As a result, when I consider the description in Miwa ‘535 and Peuchert ‘469, a glass as defined in claim 4 of the ‘498 patent is obvious.

D. Dependent Claim 5

165. *“The method of claim 1 wherein the glass making up the glass sheets has a density that is less than or equal to 2.41 grams/cm³.”*

166. Embodiment 15 of Miwa ‘535 teaches a glass density of 2.39 g/cm³, which overlaps with “a density that is less than or equal to 2.41 g/cm³” as in dependent claim 6. EX1005, Table 4.

167. Thus, Claim 5 is disclosed by Miwa.

E. Dependent Claim 6

168. *“The method of claim 1 wherein the glass making up the glass sheets has a linear coefficient of thermal expansion (CTE) over the temperature range 0-300° C. which satisfies the relationship: $28 \times 10^{-7}/^{\circ}C \leq CTE \leq 34 \times 10^{-7}/^{\circ}C$.”*

169. Miwa ‘535 discloses “a linear coefficient of thermal expansion (CTE) over the temperature range 30-380°C which satisfies the relationship: $28 \times 10^{-7}/^{\circ}C \leq CTE \leq 34 \times 10^{-7}/^{\circ}C$.” See EX1005, at ¶ 0047.

170. Miwa '535 further discloses (emphasis added): *“As can be seen from the table, the transmittance of all of the test samples (No. 1 to 20) was high, at 55% or more at a wavelength of 300 nm, and 90% or more at wavelengths of 400 to 800 nm. The density was low at 2.43 g/cm³ or less, making it possible to reduce the weight of the substrate. **The coefficient of thermal expansion was 30-34×10⁻⁷/°C. Because the strain point was high at 665°C or higher, a glass substrate with low heat shrinkage was obtained. In addition, the temperature corresponding to 10^{2.5} poise¹ is 1610°C or less, and the liquid phase temperature² is 1120°C or less, so it also has excellent fusibility and formability. In addition, it showed excellent in acid resistance and BHF resistance.”*** EX1005, at ¶ 0047.

171. Embodiment 15 of Miwa '535 reports a coefficient of thermal expansion (CTE) of $34 \times 10^{-7} \text{ C}^{-1}$ measured over a temperature range of 30 to 380 °C, which is in the range of $28 \times 10^{-7} \text{ C}^{-1} \leq \text{CTE} \leq 34 \times 10^{-7} \text{ C}^{-1}$ as in limitation 7[c]. EX1005, Table 4.

172. Thermal expansion arises because (i) increasing temperature increases the energy that atoms in a solid (like a glass) have available to vibrate, increasing the vibration magnitude *and* (ii) the interatomic forces that work to keep an atom in its equilibrium (ideal) position obey Hooke's Law only for small displacements from the equilibrium (ideal) position. Hooke's Law means that the restoring force increases proportionally with the displacement. However, with increasing distance from a neighbor atom, the restoring force increases less than proportional, while with decreasing distance it increases more than proportional to the displacement. Increasing temperature increases the vibration magnitude

¹ This is understood to be 10^{2.5} poise.

² This is understood to be liquidus temperature.

and makes the atom sample more of these non-Hookean regions of restoring force. As the momentary acceleration a vibrating atom experiences over a vibration cycle is proportional to the local force, it will spend more time in the region of lower restoring force, i.e. farther away from the neighbor atom. This “anharmonicity” of the vibration accounts for thermal expansion.

173. Glasses have a non-crystalline, "amorphous" atomistic structure. In an amorphous atomistic structure (different from a crystalline atomistic structure), every direction "looks" the same. Accordingly, while the exact atomistic neighborhood of individual atoms will be different, the average over a large number of atoms in a macroscopic body of glass will cause thermal expansion to be uniform and *isotropic*, i.e. of the same magnitude at any location and in in any direction. Therefore, it is sufficient to consider thermal expansion in 1D (one dimension) in any direction.
174. The coefficient of 1D thermal expansion of a glass (or any other solid) at a specific (absolute) temperature T is defined as

$$\alpha[T] = \frac{1}{L} \frac{\partial L}{\partial T}$$

where L denotes the length (of e.g. a glass rod) and $\partial L / \partial T$ the partial derivative of the length with regard to the temperature (under constant pressure). The derivative can be interpreted as the small increment of the length L that results from a small increment of the temperature T . Usually, for the same small increment of temperature, the corresponding increment of the length *increases* with increasing temperature, as expected from the physical model summarized above: $\partial \alpha / \partial T > 0$. However, certain glasses may show an anomalous behavior, where $\alpha[T]$ does not increase or even decreases over certain intervals of

temperature T .

175. Integrating $\alpha[T]$ over a temperature interval $[T_1, T_2]$ yields the “true strain” caused by thermal expansion over this temperature interval. In practice, $\alpha[T]$ is small compared to $T_2 - T_1$ for temperature intervals $[T_1, T_2]$ of interest. Therefore, it is sufficient to approximate the true strain by the “engineering strain”

$$\varepsilon = \frac{\Delta L}{L_1},$$

where $\Delta L = L_2 - L_1$, $L_1 = L[T_1]$, $L_2 = L[T_2]$.

The strain induced by a temperature increase from T_1 to T_2 can then be expressed as

$$\varepsilon = \bar{\alpha} \Delta T,$$

where $\bar{\alpha}$ is an “effective” (average) thermal expansion coefficient over the temperature interval $[T_1, T_2]$. This effective (or average) thermal expansion coefficient $\bar{\alpha}$, (not $\alpha[T]$) is denoted as “CTE” in the patents discussed here.

The normal behavior of solids is that $\alpha[T]$ *increases* with increasing temperature. Therefore, if $T_3 > T_1$ and $T_4 > T_2$,

$$\int_{T_3}^{T_4} \alpha[T] dT > \int_{T_1}^{T_2} \alpha[T] dT,$$

meaning

$$\bar{\alpha}_{34} := \frac{L[T_4] - L[T_3]}{L[T_3]} > \frac{L[T_2] - L[T_1]}{L[T_1]} =: \bar{\alpha}_{12}.$$

In other words, if the CTE (i.e. $\bar{\alpha}$) of a glass is measured over two different temperature intervals $[T_1, T_2]$ and $[T_3, T_4]$ for which the lower limit T_3 of $[T_3, T_4]$ is greater than the lower limit T_1 of $[T_1, T_2]$ and the upper limit T_4 of

$[T_3, T_4]$ is greater than the upper limit T_2 of $[T_1, T_2]$, the CTE will be *greater* within $[T_3, T_4]$ than within $[T_1, T_2]$.

176. A complication expected here arises from the known thermal-expansion anomaly of SiO_2 , especially as the SiO_2 mole fraction of the glasses considered here is high, of order $2/3$. The following figure shows that for pure SiO_2 , $\alpha[T]$ does not monotonously increase, but exhibits a maximum at $\approx 500\text{ K} \approx 200^\circ\text{C}$.

177. However, it is also obvious that $\alpha[T]$ is smaller in the range $[0, 30]^\circ\text{C} \approx [270, 300]\text{ K}$ than in the range $[330, 380]^\circ\text{C} \approx [570, 650]\text{ K}$. Markers highlighting these temperature ranges were added to the figure. Therefore, *the same* SiO_2 -containing glass will exhibit a *higher* CTE (i.e. $\bar{\alpha}$) within $[T_3, T_4] = [30, 380]^\circ\text{C}$ than within $[T_1, T_2] = [0, 300]^\circ\text{C}$.

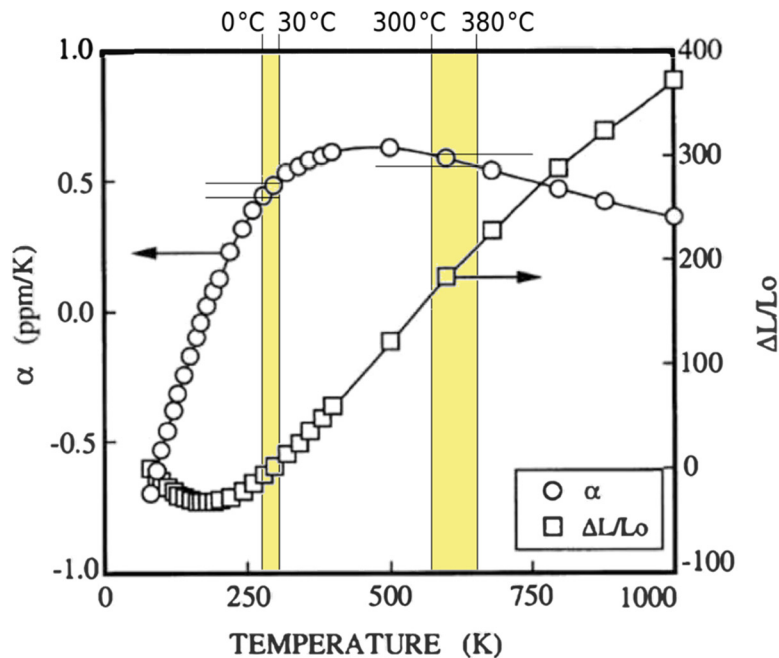


Figure 7.9 Effect of temperature on the thermal expansion coefficient and specimen length of vitreous silica.

Data from James E. Shelby: Introduction to Glass Science and Technology, Royal Society of Chemistry, 2020.

178. Consequently, the CTE reported in Miwa '535, measured for $[T_3, T_4] = [30,$

380] °C, is *greater* than it would have been found when measured for $[T_1, T_2] = [0, 300]$ °C, the temperature interval used in the 498 Patent. In other words: Had the CTE measurements in Miwa '535 been performed in the temperature interval $[T_1, T_2] = [0, 300]$ °C of the '498 Patent, the CTE would have been found *smaller* than $34 \cdot 10^{-7} \text{ C}^{-1}$, the value reported for the $[T_3, T_4] = [30, 380]$ °C.

179. As the two temperature intervals $[T_1, T_2]$ and $[T_3, T_4]$ overlap by $(300-30)/(380-0) = 71\%$, measuring the CTE of the Miwa '535 glass over $[T_1, T_2] = [0^\circ\text{C}, 300^\circ\text{C}]$ instead of $[T_3, T_4] = [30^\circ\text{C}, 380^\circ\text{C}]$ would only *slightly* decrease the value of $34 \cdot 10^{-7} \text{ C}^{-1}$ Miwa '535 reported for $[T_3, T_4] = [30, 380]$ °C.

180. Therefore, for the temperature interval $[T_1, T_2] = [0, 300]$ °C referenced in the '498 Patent, the CTE of Miwa '535's glass overlaps with the interval of $[28 \cdot 10^{-7} \text{ C}^{-1}, 34 \cdot 10^{-7} \text{ C}^{-1}]$ reported in the '498 Patent.

181. Thus, Claim 6 would have been obvious in view of Miwa '535.

F. Dependent Claim 7

182. "*The method of claim 1 wherein the glass making up the glass sheets has a liquidus temperature less than or equal to 1170° C.*"

183. Embodiment 15 of Miwa '535 provides a liquidus temperature of 1120 °C (EX1005, Table 4) which is within the range of less than or equal to 1170 °C, as in Claim 7.

G. Dependent Claim 8

184. "*The method of claim 1 wherein the glass making up the glass sheets has a*

strain point that is greater than or equal to 650° C.”

185. Embodiment 15 of Miwa ‘535 provides a strain point of 673 °C (EX1005, Table 4) which is within the range of greater than or equal to 650 °C as in Claim 8.

H. Dependent Claim 9

186. *“The method of claim 1 wherein the downdraw process is a fusion process.”*

187. Miwa ‘535 describes (emphasis added): *“First, the raw materials for the non-alkaline glass are selected while taking into consideration the amount of Fe contained as an impurity, and the raw materials are used to make a mixture that falls within the above-mentioned glass composition range. The raw materials thus prepared are then melted in a continuous melt furnace at a temperature of 1520 to 1680°C. After that, by forming molten glass into a sheet using methods such as the slot-die draw method, overflow-die draw method, float method, and roll-out method can be used and the glass is then slowly cooled to obtain an alkali-free glass substrate.”* EX1005, ¶ 0036

188. Thus, it would have been obvious to utilize a downdraw fusion process to manufacture glass sheets in Miwa ‘535.

I. Dependent Claim 10

189. *“The method of claim 1 wherein a population of 50 sequential glass sheets produced by the downdraw process from the melted and fined batch materials has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter, where each glass sheet in the population has a volume of at least*

500 cubic centimeters.”

190. The ‘498 Patent describes the quality of the resulting glass sheets in a non-standardized, rather arbitrary way that makes it difficult to perform quantitative comparisons with other inventors’ products – unless those were examined under exactly the same experimental conditions and in the same way. Even if measurements of gaseous-inclusion content were performed in the same way as described in the ‘498 Patent, the results may not be comparable for the following reasons:
191. The specification of Claim 10 depends on the spatial resolution and detection sensitivity of the experimental technique of imaging or diffractometry by which the inclusions are detected. However, no corresponding technique, resolution limit, or detection sensitivity is specified in Claim 10. Generally, it is not sufficient to specify a maximum “average gaseous inclusion level.” This specification is meaningless without specifying a minimum size for a gaseous inclusion to be considered a defects.
192. Claim 10 is ambiguous regarding “*a population of 50 sequential glass sheets ... has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter.*” It is unclear whether the “average” mentioned here refers to the average over 50 individual sheets that were studied 1 time or to repeatedly making 50 sheets, counting the total number of blisters/bubbles in all 50 sheets each time, and calculating the average of that total over a larger population of batches of 50 sheets each. In either case, specifying an upper limit for the defect count is not compatible with probability theory: For a realistic, steady probability distribution, e.g. a Poisson distribution, there is still a finite probability for the observed number of defects to exceed the specified maximum – even

for the same glass and conditions specified in the '498 Patent.

193. Moreover, the specification in Claim 10 relies on processing parameters that are not are not part of the claims of the '498 Patent, nor part of the invention background described in the '498 Patent. One of these additional parameters is the thickness of the resulting glass sheet. A glass sheet cannot contain gaseous inclusions larger than the sheet thickness. Moreover, inclusions close to the surface may escape more easily than inclusions deeper in the glass. For these reasons, the sheet thickness has significant impact on the number density and size distribution of blister/bubble defects, even if all other parameters are kept constant. Examples of other non-specified parameters include the melting temperature, melting time, stirring, pressure, and cooling rate.
194. While Miwa '535 does not provide experimental data on glass quality under the – insufficient and arbitrary – conditions of Claim 10, Miwa '535 meets all relevant specifications given in the '498 Patent. This includes the fusion downdraw process, the specified conditions for the glass composition – including a sufficient level of a fining agent and resulting meltability, as well as the condition for the liquidus temperature and liquidus viscosity. Moreover, Miwa '535 describes the same manner of making the glass sheets. Since the '498 Patent does not specify any further process parameters required to obtain the specified limit for defects in Claim 10, I expect that what Miwa '535 describes includes the ability to produce glass sheets of equivalent or better quality in terms of blister/bubble defects. This includes producing populations of 50 sequential glass sheets produced by the fusion downdraw process from the melted and fined batch materials with “an average gaseous inclusion level of less than 0.05 gaseous inclusions per cm^3 , where each glass sheet in the population has a volume of at least 500 cm^3 .”

195. Thus, Claim 10 is disclosed by Miwa '535.

J. Dependent Claim 11

196. *"The method of claim 1 wherein the glass making up the glass sheets has a liquidus viscosity that is greater than or equal to 200,000 poise."*

197. It is known in the field that for an alkali-free glass substrate to be fabricated using downdraw technique, the liquidus viscosity should be greater than or equal to 100,000 P (poise), equivalent to $10^{5.0}$ dPa·s (decipascal–seconds) in SI units. The liquidus viscosity of a glass is a direct consequence of the glass composition. The 498 Patent specifies glass compositions in Limitation 1[p] and Limitation 1[a]. As shown above, Miwa '535 describes Limitation 1[p] and Limitation 1[a]. Consequently, Miwa '535 discloses Claim 11

VIII. GROUND 3: CLAIMS 1 AND 3-11 WOULD HAVE BEEN OBVIOUS IN VIEW OF CHACON AND TAKASE

A. Independent Claim 1

198. Limitation 1[p]: *"A method for producing alkali-free glass sheets by a downdraw process comprising:"*

199. Chacon describes: *"Although substrates made from glass of the present invention can be made using other manufacturing processes such as the float process, the fusion process is preferred for several reasons."* EX1008, col. 4, lines 29-32.

200. The fusion process referred to in Chacon is a downdraw process. Thus, Limitation 1[p] is described by Chacon.
201. Limitation 1[a]: “*selecting, melting, and fining batch materials so that the glass making up the sheets comprises SiO₂, Al₂O₃, B₂O₃, MgO, and CaO, and, on an oxide basis, has:*”
202. Chacon describes: “*The glass of the present invention has a composition consisting essentially of the following composition as calculated in mole percent on an oxide basis: ..., and essentially free of BaO. More preferably, the glass of the present invention has a composition consisting essentially of the following composition as calculated in mole percent on an oxide basis: 67-73 SiO₂, 8-11.5 Al₂O₃, 8-12 B₂O₃, 0-1 MgO, 5.5-11 CaO, and 0-5 SrO.*” EX1008, col. 3, lines 32-41.
203. Chacon thus describes a composition and a manner of making a glass that includes the selection of oxides, melting and fining of batch materials as in Limitation 1[a].
204. Limitation 1[b]: “*(i) a $\Sigma[RO]/[Al_2O_3]$ ratio greater than or equal to 1.0, where $[Al_2O_3]$ is the mole percent of Al₂O₃ and $\Sigma[RO]$ is the sum of the mole percents of MgO, CaO, SrO, and BaO; and*”
205. Chacon describes: “*The RO/Al₂O₃ ratio is in the range 0.9-1.2. Within this range local minima in liquidus temperature can be found, corresponding to cotectics and/or eutectics in the base system CaO—Al₂O₃—SiO₂. The viscosity curves of the glasses in this series do not vary significantly, thus these changes in liquidus temperatures are the primary drivers for increases in liquidus viscosity.*” EX1008, col. 5, lines 13-19.

206. Thus, Chacon describes the same ratio with overlapping ranges as in Limitation 1[b].
207. Limitation 1[c]: “(A) (ii) a MgO content greater than or equal to 1.0 mole percent;”
208. Chacon describes: “MgO is present in the glasses of the present invention in an amount of 0-3 mol %, preferably 0-1 mol %. Increasing MgO decreases liquidus viscosity, and therefore, no more than 3 mol % MgO should be present in the glass. However, smaller amounts of MgO may be beneficial for reducing density.” EX1008, col. 5, lines 1-6.
209. Thus, Chacon describes an MgO content in a range that overlaps with Limitation 1[c].
210. Limitation 1[d]: “(B) producing the glass sheets from the melted and fined batch materials; wherein:”
211. Chacon describes: “The invention is further illustrated by the following examples, which are meant to be illustrative, and not in any way limiting, to the claimed invention. TABLE I sets forth exemplary glass compositions in mol percent, as calculated on an oxide basis from the glass batches. These example glasses were prepared by melting 1,000-25,000 gram batches of each glass composition at a temperature and time to result in a relatively homogeneous glass composition.” EX1008, col. 5, lines 42-49.
212. Thus, Chacon describes the production of glass in the same way as defined in Limitation 1[d].
213. Limitation 1[e]: “(a) on an oxide basis, the glass making up the glass sheets

comprises at most 0.005 mole percent As_2O_3 ;”

Limitation 1[f]: “(b) on an oxide basis, the glass making up the glass sheets comprises at most 0.005 mole percent Sb_2O_3 ”;

Limitation 1[g]: “(c) SnO_2 is used in the fining and the glass making up the glass sheets has an SnO_2 content which in mole percent on an oxide basis satisfies the relationship: $0.01 \leq SnO_2$; and”

214. Takase describes (emphasis added): “As a result of various experiments, the present applicant found that the object of the present invention could be realized by using a sulfate and stannic oxide instead of As_2O_3 as clarifying agents, and thus proposes this finding as the present invention.

Specifically, the present invention is an alkali-free glass comprising 40 to 70 mass% SiO_2 , 6 to 25 mass% Al_2O_3 , 5 to 20 mass% B_2O_3 , 0 to 10 mass% MgO , 0 to 15 mass% CaO , 0 to 30 mass% BaO , 0 to 10 mass% SrO , 0 to 10 mass% ZnO , 0.0001 to 0.03 mass% SO_3 , 0.05 to 2 mass% SnO_2 , the glass being substantially free of alkali metal oxides.”

“Therefore, by **using SnO_2** in addition to SO_3 to generate clarifying gas via changes in valence rather than decomposition, where these valence changes occur at temperatures at which non-alkaline glass melts, **high clarification effects can be obtained** over a wide range of temperatures from the vitrification reaction process that occurs at relatively low temperatures to the clarification process that occurs at high temperatures, enabling the production of low-bubble, alkali-free glass.”

“The preferred amount of sulfate added is 0.01–1% in terms of SO_3 , and more preferably 0.05–1%. The preferred SO_3 content is 0.001–0.03%, more preferably 0.005–0.03%. **Also, the amount of SnO_2 added is 0.05–2 mass% per 100 mass% of the glass raw material mixture.** When the amount of SnO_2

is less than 0.05%, it becomes difficult to remove the bubbles remaining in the glass melt during the clarification process, and if it is more than 2%, the glass becomes prone to opacity. The preferred amount of SnO₂ added is 0.05–1%, and more preferably 0.1–0.5%.” EX##, ¶¶ 0009, 0010, 0014, and 0017.

215. Considering Takase’s description of non-toxic fining agents, SO₃ and SnO₂, it would be reasonable to modify the process in Chacon to use SO₃ and SnO₂ as fining agents. This is particularly plausible as the glass compositions described in Chacon and Takase are similar: the components in the examples of Chacon all are within the compositional ranges of Takase, making it reasonable to use the same type and mass (or mole) fraction of fining agent.
216. In the following, I investigate the *mole* fraction of SnO₂ obtained by adding SnO₂ and SO₃ with *masses* specified by Takase to the glass composition range specified by Chacon. Indexing SnO₂ and SO₃ as components 1 and 2, let $X_1 = X_{\text{SnO}_2}$ and $X_2 = X_{\text{CO}_3}$ denote the to-be-determined mole fractions of SnO₂ and SO₃, respectively. According to the above, these mole fraction X_1, X_2 are obtained by adding SnO₂ and SO₃ with *masses* that correspond to fractions $Y_1 = 0.0005..0.0200$ (i.e. 0.05 to 2.00 %) and $Y_2 = 0.00001..0.0003$ (i.e. 0.001–0.03 %) of the total mass of all other $N - 1$ glass components, indexed as components $i = 3, \dots, N$. Chacon specifies the fractions of components $i = 3, \dots, N$ as *mole* fractions X_i , each of which can range over a specific interval (e.g. $X_3 = X_{\text{SiO}_2}$: 67 to 73 mol%). However, the individual fractions X_i cannot vary independently. For a *valid* glass composition, the mole fraction must add up to 1:

$$\sum_{i=3}^N X_i = 1.$$

217. To obtain the *mole* fractions X_1 and X_2 of the added SnO₂ and SO₃ for a *valid*

glass composition $\{X_i\}$, $i = 3, \dots, N$, I will break down the calculation into the following steps:

- (iv) Convert the mole fractions X_i of a valid glass composition to mass fractions W_i . Mass fractions can be obtained from mole fractions according to

$$W_i = \frac{m_i X_i}{\sum_{i=3}^N m_i X_i}.$$

The m_i denote the atomic or molecular masses of the respective atom or molecule species, e.g. in units of “amu,” defined as 1/12 of the mass of a ^{12}C (carbon-12) atom, the most abundant isotope of carbon.

- (v) Given the masses of the SnO_2 and SO_3 additions as fractions $Y_1 = 0.0005..0.0200$ (i.e. 0.05 to 2.00 %) and $Y_2 = 0.00001..0.0003$ (i.e. 0.001–0.03 %) of the glass mass without SnO_2 and SO_3 , calculate the mass fractions $W_1 = Y_1/(1 + Y_1 + Y_2)$ and $W_2 = Y_2/(1 + Y_1 + Y_2)$ of SnO_2 and SO_3 , respectively. Then, renormalize the mass fractions $W_3, \dots, W_N$ of the other oxides by multiplying them with $1/(1 + Y_1 + Y_2)$.
- (vi) Convert the mass fractions W_i , $i = 1, \dots, N$ back to mole fractions X_i to obtain a valid glass composition $\{X_i\}$, $i = 1, \dots, N$ including the added SnO_2 and CO_3 . Mole fractions X_i can be obtained from mass fractions W_i according to

$$X_i = \frac{W_i/m_i}{\sum_{i=1}^N W_i/m_i}.$$

Again, the m_i denote the atomic or molecular masses of the respective atom or molecule species, e.g. in units of “amu,” defined as 1/12 of the mass of a ^{12}C (carbon-12) atom, the most abundant isotope of carbon.

218. The following table demonstrates a specific example. (The numerical precision is intentionally exaggerated and does not imply corresponding reliability here.)

Index	Oxide	R[X] (%)	X	m (amu)	m X (amu)	W	Y	W _y	W _y / m	X _y
1	SnO ₂	0	0.00000	150.708	0.00000	0.00000	0.00050	0.00050	0.00000	0.00022
2	SO ₃	0	0.00000	80.057	0.00000	0.00000	0.00001	0.00001	0.00000	0.00001
3	SiO ₂	67-73	0.67000	60.083	40.25561	0.61774		0.61742	0.01028	0.66985
4	Al ₂ O ₃	8-11.5	0.11500	101.960	11.72540	0.17993		0.17984	0.00176	0.11497
5	B ₂ O ₃	8-12	0.09500	69.617	6.61362	0.10149		0.10144	0.00146	0.09498
6	MgO	0-1	0.01000	40.304	0.40304	0.00618		0.00618	0.00015	0.01000
7	CaO	5.5-11	0.11000	56.077	6.16847	0.09466		0.09461	0.00169	0.10998
8	SrO	0-5	0.00000	103.619	0.00000	0.00000		0.00000	0.00000	0.00000
9	BaO	0	0.00000	153.326	0.00000	0.00000		0.00000	0.00000	0.00000
Σ			1.00000		65.16614	1.00000		1.00000	0.01534	1.00000

Effect of adding a fraction of SnO₂ (column Y, highlighted) as mass on the mole fractions X of a valid glass composition, especially its SnO₂ mole fraction X_{SnO2} (column X_y, highlighted.)

With reference to the above equations, column “Index” and column “Oxide” show the oxides specified by Chacon with (arbitrary) indices and SnO₂ and SO₃ with indices 1 and 2 in row 1, respectively. Column “R[X] (%)” (read “range of X” in percent) shows the ranges Chacon specified for the mole fractions of oxide #2 – #8 in percent and 0 % for SnO₂ and SO₃, respectively. Column “X” shows *one particular* glass composition, *chosen by me*. Here, and in all columns except “R[X]”, mole and mass fractions are shown as decimal fractions, not percentages. All mole fractions showing in column “X” are within the ranges specified in column “R[X].” The chosen glass composition in column “X” is *valid* as the mole fractions add up to 1.00000, as shown in row “Σ.” Column “m” shows the respective molecule masses in units of amu. Column “mX” shows the mole fractions multiplied with the corresponding molecular masses.

Row “ Σ ” displays the sum of these products. Column “ W ” shows the mass fractions, obtained by the above equation, i.e. normalizing the values in column “ mX ” by their sum in row “ Σ .” Column “ Y ” shows the fractions of added SnO_2 and CO_3 masses relative to the total mass of all other components. The values shown here were *chosen by me* from the intervals specified by Takase. Column “ W_y ” shows the mass fractions normalized to the new total mass, i.e. the mass obtained after adding the added masses of SnO_2 and SO_3 . As seen in row “ Σ ,” the re-normalized mass fractions correctly add up to 1.0000. Column “ W_y/m ” displays the renormalized mass fractions W divided by the corresponding molecular masses m . Row “ Σ ” shows their sum. According to the above equation, normalizing the values by their sum finally yields the mole fractions of all components after adding the SnO_2 and SO_3 as shown in column “ X_y .”

219. Result: Adding SnO_2 and SO_3 with masses corresponding to 0.05% and 0.001%, respectively, of the mass without SnO_2 and SO_3 to the chosen valid glass composition with oxide mole fractions within the ranges specified by Chacon yields a glass with an SnO_2 mole fraction of $X_1 = X_{\text{SnO}_2} = 0.00022$ – or 0.022 mol%. This mole fraction is larger than 0.01 mol%, in agreement with Limitation 1[g].

220. Limitation 1[h]: “(d) the glass making up the glass sheets has a liquidus viscosity that is greater than or equal to 100,000 poise.”

221. Chacon describes (emphasis added): “The present invention is founded in the discovery of glasses exhibiting densities less than 2.45 g/cm³ and a liquidus viscosity (defined as the viscosity of the glass at the liquidus temperature) greater than about 200,000 poises, **preferably greater than about 400,000**

poises, more preferably greater than about 600,000 poises, and most preferably greater than about 800,000 poises.” EX1008, col. 3, lines 16-22.

222. Thus, Chacon describes glass with a liquidus viscosity that is greater than or equal to 100,000 P, as in Limitation 1[h].

B. Dependent Claim 3

223. *“The method of claim 1 wherein the MgO content is between 1.2 and 2.8 mole percent.”*

224. Chacon describes: *“MgO is present in the glasses of the present invention in an amount of 0-3 mol %, preferably 0-1 mol %. Increasing MgO decreases liquidus viscosity, and therefore, no more than 3 mol % MgO should be present in the glass. However, smaller amounts of MgO may be beneficial for reducing density.”* EX1008, col. 5, lines 1-6.

225. Thus, Chacon describes an MgO content in a range that overlaps with Claim 3.

C. Dependent Claim 4

226. *“The method of claim 1 wherein the glass making up the glass sheets is substantially free of BaO.”*

227. Chacon describes (emphasis added): *“However, the glasses of the invention are essentially free of BaO. As used herein, **essentially free of BaO** means that the composition contains less than 0.1 mol % of BaO in the composition.”* EX1008, col. 5, lines 27-30.

228. Thus, Claim 4 is described by Chacon.

D. Dependent Claim 5

229. *“The method of claim 1 wherein the glass making up the glass sheets has a density that is less than or equal to 2.41 grams/cm³.”*

230. Chacon describes: *“The preferred glasses in accordance with the present invention exhibit a density of less than about 2.45 gm/cm³, preferably less than about 2.40 gm/cm³. . . .”* EX1008, col. 4, lines 10-12.

231. Thus, Chacon describes the same density as Claim 5.

E. Dependent Claim 6

232. *“The method of claim 1 wherein the glass making up the glass sheets has a linear coefficient of thermal expansion (CTE) over the temperature range 0-300° C. which satisfies the relationship: $28 \times 10^{-7}/^{\circ} \text{C} \leq \text{CTE} \leq 34 \times 10^{-7}/^{\circ} \text{C}$.”*

233. Chacon describes: *“The preferred glasses in accordance with the present invention exhibit . . . a CTE over the temperature range of 0-300° C. between about $28-35 \times 10^{-7}/^{\circ} \text{C}$., preferably between about $28-33 \times 10^{-7}/^{\circ} \text{C}$., . . .* EX1008, col. 4, lines 11-16.

234. Thus, Chacon describes the same CTE as Claim 6.

F. Dependent Claim 7

235. *“The method of claim 1 wherein the glass making up the glass sheets has a liquidus temperature less than or equal to 1170° C.”*

236. Chacon describes a number of examples, EX1008, Table 1, including liquidus

temperatures and liquidus viscosities that are less than or equal to 1170 °C as in Claim 7. Thus, Claim 7 is described in Chacon.

G. Dependent Claim 8

237. *“The method of claim 1 wherein the glass making up the glass sheets has a strain point that is greater than or equal to 650° C.”*

238. Chacon describes: *“Additionally, the glasses of the present invention . . . strain points higher than about 650° C.”* EX1008, col. 3, lines 22-26.

239. Thus, Claim 8 is described by Chacon.

H. Dependent Claim 9

240. *“The method of claim 1 wherein the downdraw process is a fusion process.”*

241. Chacon describes (emphasis added): *“For more demanding manufacturing conditions such as the fusion process, described in U.S. Pat. No. 3,338,696 (Dockerty) and U.S. Pat. No. 3,682,609 (Dockerty), a glass having a high liquidus viscosity is required. Therefore, in a preferred embodiment of the present invention, the glasses should exhibit a density less than about 2.45 gm/cm³ and a liquidus viscosity greater than about 200,000 poises, preferably greater than about 400,000 poises, more preferably greater than about 600,000 poises, and most preferably greater than about 800,000 poises. Although substrates made from glass of the present invention can be made using other manufacturing processes such as the float process, the fusion process is preferred for several reasons. First, **glass substrates made from the fusion process** do not require*

*polishing. Current glass substrate polishing is capable of producing glass substrates having an average surface roughness greater than about 0.5 nm (Ra), as measured by atomic force microscopy. **Glass substrates produced according to the present invention and using the fusion process have an average surface roughness as measured by atomic force microscopy of less than 0.5 nm.***”
EX1008, col. 4, lines 20-40.

242. Thus, Chacon describes a fusion process as in Claim 9.

I. Dependent Claim 10

243. *“The method of claim 1 wherein a population of 50 sequential glass sheets produced by the downdraw process from the melted and fined batch materials has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter, where each glass sheet in the population has a volume of at least 500 cubic centimeters.”*

244. The ‘498 Patent describes the quality of the resulting glass sheets in a non-standardized, rather arbitrary way that makes it difficult to perform quantitative comparisons with other inventors’ products – unless those were examined under exactly the same experimental conditions and in the same way. Even if measurements of gaseous-inclusion content were performed in the same way as described in the ‘498 Patent, the results may not be comparable for the following reasons:

245. The specification of Claim 10 depends on the spatial resolution and detection sensitivity of the experimental technique of imaging or diffractometry by which the inclusions are detected. However, no corresponding technique, resolution

limit, or detection sensitivity is specified in Claim 10. Generally, it is not sufficient to specify a maximum “average gaseous inclusion level.” This specification is meaningless without specifying a minimum size for a gaseous inclusion to be considered a defect.

246. Claim 10 is ambiguous regarding “*a population of 50 sequential glass sheets ... has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter.*” It is unclear whether the “average” mentioned here refers to the average over 50 individual sheets that were studied 1 time or to repeatedly making 50 sheets, counting the total number of blisters/bubbles in all 50 sheets each time, and calculating the average of that total over a larger population of batches of 50 sheets each. In either case, specifying an upper limit for the defect count is not compatible with probability theory: For a realistic probability distribution, e.g. a Poisson distribution, there is still a finite probability for the observed number of defects to exceed the specified maximum – even for the same glass and conditions specified in the ‘498 Patent.
247. Moreover, the specification in Claim 10 relies on processing parameters that are not are not part of the claims of the '498 Patent, nor part of the invention background described in the '498 Patent. One of these additional parameters is the thickness of the resulting glass sheet. A glass sheet cannot contain gaseous inclusions larger than the sheet thickness. Moreover, inclusions close to the surface may escape more easily than inclusions deeper in the glass. For these reasons, the sheet thickness has significant impact on the number density and size distribution of blister/bubble defects, even if all other parameters are kept constant. Examples of other non-specified parameters include the melting temperature, melting time, stirring, pressure, and cooling rate.

248. While neither Chacon nor Takase provide experimental data on glass quality under the – insufficient and arbitrary – conditions of Claim 10, what Chacon describes meets all relevant specifications given in the '498 Patent. This includes the fusion downdraw process, the specified conditions for the glass composition – including a sufficient level of a fining agent and resulting meltability, as well as the condition for the liquidus temperature and liquidus viscosity. Moreover, Chacon describes the same manner of making the glass sheets. Since the '498 Patent does not specify any further process parameters required to obtain the specified limit for defects in Claim 10, I expect that what Chacon describes includes the ability to produce glass sheets of equivalent or better quality in terms of blister/bubble defects. This includes producing populations of 50 sequential glass sheets produced by the fusion downdraw process from the melted and fined batch materials with “an average gaseous inclusion level of less than 0.05 gaseous inclusions per cm^3 , where each glass sheet in the population has a volume of at least 500 cm^3 .” Thus, Chacon, and Takase, described Claim 10.

J. Dependent Claim 11

249. “*The method of claim 1 wherein the glass making up the glass sheets has a liquidus viscosity that is greater than or equal to 200,000 poise.*”

250. Chacon describes: “*The present invention is founded in the discovery of glasses exhibiting densities less than 2.45 g/cm^3 and a liquidus viscosity (defined as the viscosity of the glass at the liquidus temperature) greater than about 200,000 poises, preferably greater than about 400,000 poises, more preferably greater than about 600,000 poises, and most preferably greater than about 800,000*

poises.” EX1008, col. 3, lines 16-22.

251. Thus, Chacon describes Claim 11.

**IX. GROUND 4: CLAIMS 1-2, 4 AND 9 ARE ANTICIPATED BY
PEUCHERT ‘293 AND CLAIM 10 WOULD HAVE BEEN OBVIOUS
IN VIEW OF PEUCHERT ‘293**

A. Independent Claim 1

252. Limitation 1[p]: “*A method for producing alkali-free glass sheets by a
downdraw process comprising:*”

253. Peuchert ‘293 describes: “*The invention relates to alkali-free aluminoborosili-
cate glasses. The invention also relates to uses of these glasses. . . . The glasses
can be produced as flat glasses by the various drawing methods, for example
microsheet down-draw, up-draw or overflow fusion methods, . . .*” EX1010, ¶¶
0006, 0064.

254. Thus, Peuchert ‘293 describes Limitation 1[p].

255. “*Limitation 1[a]: selecting, melting, and fining batch materials so that the
glass making up the sheets comprises SiO₂, Al₂O₃, B₂O₃, MgO, and CaO, and,
on an oxide basis, has:*”

256. Peuchert ‘293 describes compositions as follows:

TABLE

Examples: Compositions (in % by weight, based on oxide) and essential properties of glasses according to the invention.							
	1	2	3	4	5	6	7
SiO ₂	58.3	58.3	63.5	62.1	62.1	63.5	60.8
B ₂ O ₃	8.5	8.5	9.0	8.2	8.2	9.1	8.2
Al ₂ O ₃	21.5	21.5	16.5	19.0	19.0	17.3	16.1
MgO	4.5	6.0	4.5	6.0	7.5	6.0	4.1
CaO	3.4	1.9	3.0	1.5	1.5	1.8	7.0
SrO	3.5	3.5	3.2	2.0	1.0	2.0	3.5
BaO	—	—	—	0.4	0.4	—	—
ZnO	—	—	—	0.5	—	—	—
$\alpha_{20/300}$ [10 ⁻⁶ /K]	3.26	3.16	3.14	2.96	2.99	2.98	3.76
ρ [g/cm ³]	2.48	2.47	2.43	2.45	2.44	n.m.	2.49
T _g [° C.]	735	737	723	740	729	725	713
T4 [° C.]	1257	1273	1300	1283	1288	1289	1255
T2 [° C.]	1613	1621	1694	1657	1652	1653	1616
n _d	1.522	1.522	1.513	1.516	1.516	1.520	1.524
BHF [mg/cm ²]	0.71	0.77	0.58	0.65	0.66	0.60	0.60

EX1010, at page 4.

257. Example 7 in this Table is presented as mass (or weight) fractions, based on oxides and indicated as percentages. The following table shows the results of converting to mole fractions and, in the last row, $\sum X_R / X_{Al2O3}$:

Component	X (mol%)
SiO ₂	65.3
Al ₂ O ₃	10.2
B ₂ O ₃	7.6
MgO	6.6
CaO	8.2
SrO	2.2
BaO	0
ZnO	0

Component	X (mol%)
SnO ₂	0.1
As ₂ O ₃	0
$\sum X_R / X_{Al_2O_3} = 1.66$	

258. Selecting, melting, and fining batch materials are mandatory steps conventionally used in the production of glass articles, such as glass sheets.

259. Thus, Peuchert '293 describes Limitation 1[a].

260. Limitation 1[b]: “(i) a $\Sigma[RO]/[Al_2O_3]$ ratio greater than or equal to 1.0, where $[Al_2O_3]$ is the mole percent of Al_2O_3 and $\Sigma[RO]$ is the sum of the mole percents of MgO , CaO , SrO , and BaO ; and”.

261. Example 7 of Peuchert '293 is shown above and applied in the calculation of Limitation 1[b] provides the following result:

$$\Sigma[RO] = 6.56 + 8.21 + 2.18 = 16.96$$

$$X_{Al_2O_3} = 10.19$$

$$\Sigma_R X_i / X_{Al_2O_3} = 1.66$$

262. Thus, Peuchert '293 describes Limitation 1[b].

263. Limitation 1[c]: “(b) (ii) a MgO content greater than or equal to 1.0 mole percent;”

264. As evident from the mol conversion above in Limitation 1[b] of Example 7 in Peuchert '293, the MgO content in Example 7 is 6.6 mol%, thus describing

Limitation 1[c].

265. Limitation 1[d]: (B) producing the glass sheets from the melted and fined batch materials; wherein:

266. Peuchert '293 describes: "*Glasses were produced in Pt/Ir crucibles at 1620 °C. from conventional raw materials which were essentially alkali-free apart from unavoidable impurities. The melt was refined at this temperature for one and a half hours, then transferred into inductively heated platinum crucibles and stirred at 1550° C. for 30 minutes for homogenization.*" EX1010, ¶0050.

267. In addition, melting, and fining batch materials are mandatory steps conventionally used in the production of glass articles, such as glass sheets.

268. Thus, Peuchert '293 describes Limitation 1[d]

269. Limitation 1[e]: "*(a) on an oxide basis, the glass making up the glass sheets comprises at most 0.005 mole percent As₂O₃;*"

270. As evident from the mol conversion above in Limitation 1[b] of Example 7 in Peuchert '293, the As₂O₃ content in Example 7 is 0 mol% thus describing Limitation 1[e]

271. "*Limitation 1[f]: (b) on an oxide basis, the glass making up the glass sheets comprises at most 0.005 mole percent Sb₂O₃;*"

272. As evident from the mol conversion above in Limitation 1[b] of Example 7 in Peuchert '293, the Sb₂O₃ content in Example 7 is 0 mol% thus describing Limitation 1[f]

273. Limitation 1[g]: "*(c) SnO₂ is used in the fining and the glass making up the*

glass sheets has an SnO₂ content which in mole percent on an oxide basis satisfies the relationship: $0.01 \leq \text{SnO}_2$; and"

274. As evident from the mass-to-mole fraction conversion above in Limitation 1[b] of Example 7 in Peuchert '293, the SnO₂ content in Example 7 is 0.13 mol% thus describing Limitation 1[g].

275. Limitation 1[h]: *"(d) the glass making up the glass sheets has a liquidus viscosity that is greater than or equal to 100,000 poise."*

276. The liquidus viscosity of a glass is a direct consequence of the glass composition. The 498 Patent specifies glass compositions in Limitation 1[p] and Limitation 1[a]. As shown above, Peuchert '293 describes Limitation 1[p] and Limitation 1[a].

277. Accordingly, Peuchert '293 discloses Limitation 1[h].

B. Dependent Claim 2

278. *"The method of claim 1 wherein the glass making up the glass sheets has an SnO₂ content which in mole percent on an oxide basis satisfies the relationship: $\text{SnO}_2 \leq 0.15$."*

279. As evident from the mol conversion above in Limitation 1[b] of Example 7 in Peuchert '293, the SnO₂ content in Example 7 is 0.1 mol%, which is the same as in Claim 2.

C. Dependent Claim 4

280. *“The method of claim 1 wherein the glass making up the glass sheets is substantially free of BaO.”*

281. As evident from the mass-to-mole fraction conversion above in Limitation 1[b] of Example 7 in Peuchert ‘293, the BaO content in Example 7 is 0 mol%, which is the same as in Claim 4.

D. Dependent Claim 9

282. *“The method of claim 1 wherein the downdraw process is a fusion process.”*

283. Peuchert ‘293 describes: *“The glasses can be produced as flat glasses by the various drawing methods, for example microsheet down-draw, up-draw or overflow fusion method”* EX2010, ¶0064.

284. Thus, Peuchert ‘293 describes a fusion process as in Claim 9.

E. Dependent Claim 10

285. *“The method of claim 1 wherein a population of 50 sequential glass sheets produced by the downdraw process from the melted and fined batch materials has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter, where each glass sheet in the population has a volume of at least 500 cubic centimeters.”*

286. The ‘498 Patent describes the quality of the resulting glass sheets in a non-standardized, rather arbitrary way that makes it difficult to perform quantitative comparisons with other inventors’ products – unless those were examined under exactly the same experimental conditions and in the same way. Even if

measurements of gaseous-inclusion content were performed in the same way as described in the '498 Patent, the results may not be comparable for the following reasons:

287. The specification of Claim 10 depends on the spatial resolution and detection sensitivity of the experimental technique of imaging or diffractometry by which the inclusions are detected. However, no corresponding technique, resolution limit, or detection sensitivity is specified in Claim 10. Generally, it is not sufficient to specify a maximum “average gaseous inclusion level.” This specification is meaningless without specifying a minimum size for a gaseous inclusion to be considered a defect.
288. Claim 10 is ambiguous regarding “*a population of 50 sequential glass sheets ... has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter.*” It is unclear whether the “average” mentioned here refers to the average over 50 individual sheets that were studied 1 time or to repeatedly making 50 sheets, counting the total number of blisters/bubbles in all 50 sheets each time, and calculating the average of that total over a larger population of batches of 50 sheets each. In either case, specifying an upper limit for the defect count is not compatible with probability theory: For a realistic probability distribution, e.g. a Poisson distribution, there is still a finite probability for the observed number of defects to exceed the specified maximum – even for the same glass and conditions specified in the '498 Patent.
289. Moreover, the specification in Claim 10 relies on processing parameters that are not are not part of the claims of the '498 Patent, nor part of the invention background described in the '498 Patent. One of these additional parameters is the thickness of the resulting glass sheet. A glass sheet cannot contain gaseous

inclusions larger than the sheet thickness. Moreover, inclusions close to the surface may escape more easily than inclusions deeper in the glass. For these reasons, the sheet thickness has significant impact on the number density and size distribution of blister/bubble defects, even if all other parameters are kept constant. Examples of other non-specified parameters include the melting temperature, melting time, stirring, pressure, and cooling rate.

290. While Peuchert '293 does not provide experimental data on glass quality under the – insufficient and arbitrary – conditions of Claim 10, Peuchert '293 meets relevant specifications given in the '498 Patent. This includes the fusion downdraw process and the specified conditions for the glass composition – including a sufficient level of a fining agent and resulting meltability. Since the '498 Patent does not specify any further process parameters required to obtain the specified limit for defects in Claim 10, I expect that what Peuchert '293 describes includes the ability to produce glass sheets of equivalent or better quality in terms of blister/bubble defects. This includes producing populations of 50 sequential glass sheets produced by the fusion downdraw process from the melted and fined batch materials with “an average gaseous inclusion level of less than 0.05 gaseous inclusions per cm^3 , where each glass sheet in the population has a volume of at least 500 cm^3 .” Thus, Claim 10 is described by Peuchert '293.

X. CONCLUSION

291. For the reasons set forth above, claims 1-11 of the 498 Patent are unpatentable in view of the prior art.

contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place in the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

290. I reserve the right to supplement my opinions in the future to respond to any arguments that the Patent Owner raises and to consider new information as it becomes available to me.

291. I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Respectfully Submitted,

A handwritten signature in black ink, appearing to read "Frank Ernst", written in a cursive style.

Dr. Frank Ernst

Date: 2025-04-24