

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.: IPR2025-01017
U.S. Patent No. 8,642,491

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. 8,642,491 (“the ‘491 Patent”) (EX1001), 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 ‘491 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 1-24 of the ‘491 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 EX1012. 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 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 perovskite ceramics, oxides, 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, including borosilicate 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

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 '491 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. 8,642,491 (the "491 Patent")
EX1002	Prosecution History of the '491 Patent
EX1004	JP2004-189535A ("Miwa '535") Certified Translation
EX1005	JP1998059741 ("JP-741") Certified Translation
EX1006	U.S. 2005/0101469 ("Peuchert '469")
EX1007	JP2002308643 ("JP '643") Certified Translation
EX1008	JP2003192377 ("Miwa '377") Certified Translation
EX1009	Introduction to Glass Science and Technology, 2 nd Ed. (2005)
EX1010	Foshan Ceramics Research Institute Testing Co., Ltd, Test Report: Sample #5
EX1011	Foshan Ceramics Research Institute Testing Co., Ltd, Test Report: Sample #6
EX1012	<i>Curriculum Vitae</i> of Dr. Frank Ernst
EX1013	U.S. Patent No. 4,018,965
EX1014	U.S. PG PUB 2004/0224834
EX1015	W. Vogel, Glass Chemistry, 2 nd Ed., Chapter 4: Classical The of Glass Structure, Springer-Verlag (1994)

II. LEGAL STANDARDS

10. In forming my opinions and considering the subject matter of the '491 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 '491 patent. For example, this would include (but is not limited to) the concepts of liquidus temperature, viscosity, coefficient of thermal expansion, strain point, density. 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 1-24 of the '491 Patent. In particular, I understand that Petitioner asserts the following grounds for challenging the claims of the '491 Patent:

Ground	Challenged Claims	Asserted Prior Art
1	1-24	Miwa '535, Peuchert '469, and JP '741
2	1-24	JP '643, JP '741, and Peuchert '469
3	13-14, 16, and 19-23	Miwa '377 and Peuchert '469

IV. THE '491 PATENT

A. Overview of the '491 Patent

31. The '491 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 '491 Patent 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 '491 Patent claims that the specified glass composition is tailored for low thermal expansion, high liquidus viscosity, high strain point, and low density. *Id.*, at 3:55-67.

32. Traditionally, As_2O_3 and Sb_2O_3 have been used as fining agents during glass manufacturing. *Id.*, at 12:2-38. However, since both fining agents are toxic, special handling is needed. *Id.* To solve this issue, the '491 Patent proposes to use SnO_2 as the fining agent.
33. Further, the '491 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 14:40-45.
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 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 $\text{Pa}\cdot\text{s}$ (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, 100,000 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 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. SiO₂: 1, Al₂O₃: 2, B₂O₃: 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 exactly 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

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

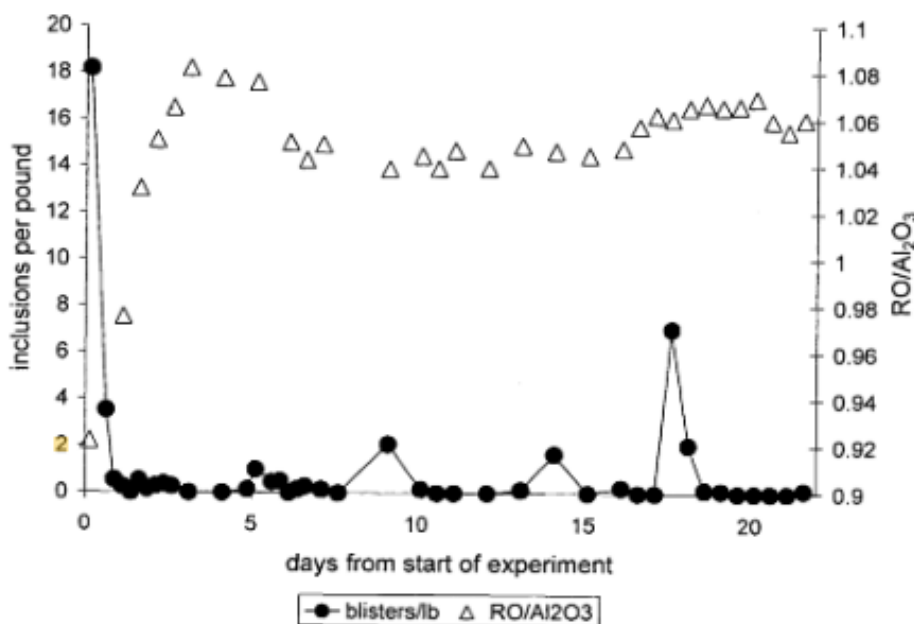
The mass or mole fractions obtained by these conversions will add up to exactly one, even if the original mole fractions X_i or mass fractions W_i do not, e.g. because small fractions of certain components are omitted because they are not of interest..

36. The ‘491 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. alkaline earth 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 mole

fractions, not mass fractions. More clearly, the ratio $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$ can be written as $\Sigma_{i \in R} X_i/X_{\text{Al}_2\text{O}_3}$, where summing is performed over the alkaline earth metal oxides of the set $R = \{\text{MgO}, \text{CaO}, \text{SrO}, \text{BaO}\}$. So, $\Sigma_{i \in R} X_i/X_{\text{Al}_2\text{O}_3}$ is a shorthand for

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

37. Further, as described in the '491 Patent, 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 10:54-64. In addition, $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$ (or, preferably, $\Sigma_{i \in R} X_i/X_{\text{Al}_2\text{O}_3}$) 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 – reproduced below.



B. Prosecution History of the '491 Patent

38. I understand the '491 Patent was filed on December 10, 2010, and claims priority to U.S. Patent No. 7,851,394 filed on June 28, 2006, and 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 relied on in this Declaration was before the USPTO during prosecution of the '491 Patent.
40. Specifically, the USPTO rejected all of the claims as obvious in view of Miwa '535 as follows:

“Miwa fails to teach any examples or compositional ranges in terms of molar percentages that are sufficiently specific to anticipate the compositional limitations of claims 1-20. However, it is believed that the weight percent ranges taught by Miwa if converted to molar percentages would have overlapping compositional ranges with instant claims 1-20.” See Abstract and the entire specification, specifically, paragraphs [0013]-[0014], [0022], and [0047].

EX1002, ¶¶ 000063-000064.

41. I 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 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 10th Office Action does not disclose or suggest the criticality of having both a

RO/Al₂O₃ ratio ≥ 1.0 and a MgO content ≥ 1.0 mole%.”

“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 each of 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, ¶¶ 000047-000048.

42. I understand that the USPTO thus allowed the claims based on the view that:

“The prior art fail to disclose or suggest with sufficient specificity an alkali-free glass comprising in mole percentages the recited components, wherein the glass has the specific recited relationship of the alkaline earth metal oxides to the As₂O₃ content, the glass has greater than or equal to 1 mole percent MgO, and the glass limits the amounts of As₂O₃ and Sb₂O₃ content present in the glass. Furthermore, the glass has a liquidus viscosity that is greater than or equal to 100,000 poise and is made for the downdraw process.”

EX1002, ¶ 000017.

43. However, my analysis takes into consideration the fact that the USPTO did not fully appreciate the relevance of the teachings of Miwa ‘535, despite having been cited in the prosecution history.

44. As clearly explained below, Miwa ‘535, considered with the other citations (e.g., EX1005, EX1006 and EX1007), is relevant to Claims 1-20 of the ‘491 patent.

45. Further, none of JP ‘741, Peuchert ‘469, JP ‘643 and Miwa ‘377 were cited or considered during prosecution.

46. As such, I understand that this Declaration presents substantially new arguments that were not properly considered during prosecution in the UPSTO.

C. Technology Background and Interpretations

47. 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 ‘491 Patent. A POSITA would have readily understood these relevant disclosures.

V. THE PRIOR ART IN THE APPLIED INVALIDITY GROUNDS

A. Miwa ‘535 (EX1004)

48. Miwa ‘535 was filed on December 11, 2002, and published on July 8, 2004. Therefore, it is a prior art at least under 35 U.S.C. § 102(a) (pre-AIA). EX1004, cover page. Similar to the ‘491 Patent, Miwa ‘535 also relates to alkali-free boroaluminosilicate 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 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.* It 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 compo-

nents of the displays. The deposition and structuring of the semiconductor layers require elevated temperatures, at which alkali ions from the glass substrate could readily diffuse in and contaminate them. Alkali-free glasses are essential to eliminate this problem. *Id.*

49. Miwa '535 also aims to provide glass with a high etch resistance to chemicals used in photoetching processes for semiconductor structuring, 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.*
50. 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.*, ¶¶ [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 '491 patent, Miwa '535 incorporates a specific amount of SnO₂ (as 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.*

51. Similar to the '491 Patent, Miwa '535 specifies a continuous range of glass compositions that achieve favorable properties. Different from the '491 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 '491 patent. Miwa '535's glass compositions are also suitable for flat panel display applications.
52. For example, Miwa '535's Embodiment 15 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 ^{2.5} (°C)	1555	1560	1605	1565	1560
Liquid phase temperature (°C)	1105	1055	1090	1085	1120
Acid resistance	○	○	○	○	○
Buffered hydrofluoric acid resistance	○	○	○	○	○

EX1004, Table 4.

53. 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%) in Table 1 below:

Table 1

Component	X (mol%)
SiO ₂	67.2

Component	X (mol%)
Al ₂ O ₃	10.2
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
$\sum_{i \in R} X_i / X_{\text{Al}_2\text{O}_3} = 1.20 \sum_{i \in R} \frac{X_i}{X_{\text{Al}_2\text{O}_3}} = 1.20$	

B. JP ‘741

54. JP ‘741 was filed on August 21, 1996 and published on March 3, 1998. Therefore, it is a prior art at least under 35 U.S.C. § 102(b) (pre-AIA). EX1005, cover page. Similar to the ‘491 Patent, JP ‘741 relates to alkali-free boroaluminosilicate glass compositions primarily suitable for application as a substrate for displays. *Id.*, ¶¶ [0001]-[0005].
55. JP ‘741 describes that a key finding is the use of SnO₂ instead of As₂O₃ as a clarifying agent “because As₂O₃ is highly toxic and may contaminate the environment during glass production and waste glass treatment, its use is being restricted”. *Id.*, ¶¶ [0005] and [0007].

56. Similar to the '491 Patent, JP '741 describes processes “[f]or display applications, the fusion method, down-draw method, float method, or roll-out method, etc. is used to mold the glass into thin sheets. *Id.*, ¶ [0021].

C. Peuchert '469

57. Peuchert '469 was filed on March 06, 2002 and published on May 12, 2005. Therefore, it is a prior art at least under 35 U.S.C. § 102(b) (pre-AIA). EX1006, cover page. Similar to the '491 Patent, Peuchert '469 relates to alkali-free borosiluminosilicate glass compositions primarily suitable for application as a substrate for TFT-LCD flat-panel displays. *Id.*, ¶¶ [0001]-[0005].
58. In Peuchert '469, the inventors have identified a continuous range of glass compositions that they consider satisfying the various properties required for glass substrates used in TFT-LCDs. The glass can be made by drawing methods. It is alkali-free. As_2O_3 and Sb_2O_3 can be omitted as fining agents. *Id.*, [0030]. Expressed as *mass* fractions (in percent) in terms of oxides, the glass contains SiO_2 : (58..70)ms%, B_2O_3 : (0.5..9)ms%, Al_2O_3 : (10..25)ms%, MgO : (8..15)ms%, CaO : (0..10) ms%, SrO : (0..3)ms%, BaO : (0..2)ms%, with a sum $\sum_{i \in R} W_i$, $R = \{\text{MgO}, \text{CaO}, \text{SrO}, \text{BaO}\}$ equal to (8..18)ms% and ZnO : (0..2)ms%.
59. Here and in the following ($x_1..x_2$) denotes a value in the continuous range from x_1 to x_2 . For example, (58..70)ms% denotes a value in the continuous range from 58 ms% to 70 ms%.
60. For example, Peuchert '469's Example A1 teaches an alkali-metal-free glass with the mass fractions W_i shown below (in percent):

Examples: Compositions (in % by weight, based on oxide) and essential properties of glasses according to the invention (A1–A8) and a comparative glass (C).					
	A1	A2	A3	A4	A5
SiO ₂	62.1	61.1	62.1	61.1	63.0
B ₂ O ₃	4.0	5.0	3.0	5.0	6.0
Al ₂ O ₃	17.4	17.9	18.4	17.9	15.9
MgO	10.0	9.0	11.0	9.0	8.1
CaO	5.1	5.6	5.1	5.6	5.6
SrO	1.0	—	—	0.8	0.8
BaO	—	1.0	—	0.2	0.2
ZnO	—	—	—	—	—
As ₂ O ₃	—	—	—	—	—
SnO ₂	0.4	0.4	0.4	0.4	0.4
$\alpha_{20/300}$ [10 ⁻⁶ /K]	3.76	3.72	3.78	3.75	3.67
T _g [° C.]	745	739	749	739	725
ρ [g/cm ³]	2.52	2.513	2.53	2.510	2.486
T ₄ [° C.]	1227	1225	1225	1222	1228
E [GPa]	88	87	91	87	85
HCl [mg/cm ²]	0.09	0.19	0.07	0.20	0.21
NaOH [mg/cm ²]	1.0	1.1	1.0	n.m.	n.m.
BHF [mg/cm ²]	0.93	n.m.	0.92	n.m.	n.m.

Table from Peuchert '469.

61. Converting the mass (weight) fractions W_i in Peuchert '469's Example A1 to mole fractions X_i , according to

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

Peuchert '469 teaches that the glass has the following alkali-free compositions in mole fractions, shown as percentages (mol%) below:

Component	X (mol%)
SiO ₂	64.1
Al ₂ O ₃	10.6
B ₂ O ₃	3.6
MgO	15.4
CaO	5.6
SrO	0.6
BaO	0
ZnO	0
As ₂ O ₃	0
SnO ₂	0.17
$\sum_{i \in R} X_i / X_{\text{Al}_2\text{O}_3} = 2.04 \sum_{i \in R} \frac{X_i}{X_{\text{Al}_2\text{O}_3}} = 2.04$	

D. JP ‘643

62. JP ‘643 was filed on May 17, 2001 and published on October 23, 2002. Therefore, it is a prior art at least under 35 U.S.C. § 102(b) (pre-AIA). EX1007, cover page. Similar to the ‘491 Patent, JP ‘643 relates to alkali-free boroaluminosilicate glass compositions primarily suitable for application as a substrate for TFT-LCD flat-panel displays. *Id.*, ¶¶ [0001]-[0005].
63. Since these glasses need to be very thin, no thicker than 0.7 mm, special requirements arise for their mechanical properties. They need to have a low mass density (to reduce weight) and a high Young modulus (to reduce deflection/sagging). To ensure a sufficient transparency, they need to be free of internal defects, which requires melting at high temperature for extended periods of time.

Id., ¶¶ [0005]-[0010]. In order to minimize excessive wear on furnace equipment, the glass needs good meltability. *Id.*, [0010]. In order to enable sheet production by a downdraw process, its liquidus temperature needs to be low, while its viscosity at this temperature (“liquidus viscosity”) needs to be high. *Id.*, ¶ [0030]. Also important is good thermal-shock resistance. *Id.*, ¶ [0011].

64. Special requirements arise from the role of the glass as substrate for depositing semiconductor layers structured to become the pixels of the display. The deposition technology requires etching and heating. Therefore, the glass needs to have sufficient resistance against chemical-etching. *Id.*, ¶¶ [0015]-[0020]. Further, the glass needs to exhibit sufficient heat resistance, quantified as the strain point (temperature above which stress-induced plastic deformation can occur). Also, the CTE (coefficient of thermal expansion) of the glass substrate needs to match that of the semiconductor layers in order to minimize thermal stress buildup during heating and cooling as required for semiconductor layer deposition and structuring. *Id.*, ¶¶ [0022]-[0023].
65. In JP ‘643, the inventors have identified a continuous range of glass compositions that they consider satisfying the various properties required for glass substrates used in TFT-LCDs. The glass is alkali-free and has a composition, expressed as *mass* fractions (in percent), comprising SiO₂: (SiO₂: 58..–70)ms%, Al%, Al₂O₃: (10..19)ms%, B%, B₂O₃: (6.5..15) ms%, MgO: (0..2) ms%, CaO: (3..12) ms%, BaO: (0.1..5) ms%, SrO: (0..4)ms%, BaO+SrO: (0.1..6)ms%, ZnO: (0..5)ms%, MgO+CaO+BaO+SrO+ZnO: (5..15)ms%, ZrO₂: (% , ZrO₂: 0..5)ms%, TiO₂: (0..5)ms%, P₂O₅: (0..5)ms%. It has density of ≤ 2.45 g/cm³ or less, an average thermal expansion coefficient of $(25..36) \cdot 10^{-7} \text{ K}^{-1}$ in the temperature range of (30..380) °C, and a strain point ≥ 640 °C. *Id.*, ¶ [0025].

66. For example, JP '643's Sample 5 teaches an alkali-metal-free glass with the mass and mole fractions shown below (in percent):

	Sample No. 4		Sample No. 5		Sample No. 6	
	Mass %	mol%	Mass %	mol%	Mass %	mol%
SiO ₂	61.2	67.4	61.2	67.2	61.7	68.2
Al ₂ O ₃	16.8	10.9	16.8	10.9	17.0	11.1
B ₂ O ₃	11.8	11.3	11.8	11.2	10.5	10.0
MgO	0.5	0.8	1.0	1.6	-	-
CaO	7.4	8.7	6.9	9.3	8.0	9.5
SrO	0.5	0.3	0.5	0.3	1.0	0.6
BaO	0.5	0.2	0.5	0.2	0.5	0.2
ZnO	-	-	-	-	-	-
P ₂ O ₅	-	-	-	-	-	-
As ₂ O ₃	-	-	-	-	-	-
SnO ₂	-	-	-	-	-	-
Sb ₂ O ₃	1.0	0.2	1.0	0.2	1.0	0.2
ZrO ₂	0.3	0.2	0.3	0.2	0.3	0.2
Cl	-	-	-	-	-	-
(BaO + SrO)/BaO	2		2		3	
Density (g/cm ³)	2.382		2.379		2.400	
Thermal expansion coefficient [30-380°C] (x10 ⁻⁷ /°C)	33		32		34	

Table 3 (Part 1/2) from JP 643.

Thermal expansion coefficient [30-380°C] (x10 ⁻⁷ /°C)	33	32	34
Viscosity	669	670	674
Strain point (°C)			
Annealing point (°C)	724	724	731
Softening point (°C)	973	973	984
10 ^{4.0} (°C)	1301	1301	1322
10 ^{3.0} (°C)	1467	1467	1488
10 ^{2.5} (°C)	1573	1573	1597
Young's modulus	70	70	71
Specific Young's modulus	29.3	29.5	29.4
BHF resistance	0.6	0.6	0.6
Corrosion (μm)			
Visual appearance evaluation	○	○	○
HC resistance	7.3	7.3	4.6
Corrosion (μm)			
Visual appearance evaluation	○	○	○
Liquidus temperature (°C)	1128	1146	1094
Liquidus viscosity	10 ^{5.6}	10 ^{5.4}	10 ^{6.1}

Table 3 (Part 2/2) from JP 643.

67. Isolating the data of Sample No 5 in JP 643's Table 3 and calculating its $\sum_{i \in R} X_i / X_{Al_2O_3} \sum_{i \in R} X_i / X_{Al_2O_3}$ yields the following alkali-free composition in mole fractions, shown as percentages (mol%):

Component	X (mol%)
SiO ₂	67.2
Al ₂ O ₃	10.9
B ₂ O ₃	11.2
MgO	1.6
CaO	9.3
SrO	0.3
BaO	0.2
ZnO	0
P ₂ O ₅	0
As ₂ O ₃	0
SnO ₂	0
Sb ₂ O ₃	0.2
ZrO ₂	0.2
Cl	0
$\sum_{i \in R} X_i / X_{\text{Al}_2\text{O}_3} = 1.03 \sum_{i \in R} \frac{X_i}{X_{\text{Al}_2\text{O}_3}} = 1.03$	

E. Miwa ‘377

68. Miwa ‘377 was filed on December 21, 2001 and published on July 9, 2003. Therefore, it is a prior art at least under 35 U.S.C. § 102(b) (pre-AIA). EX1008, cover page. Similar to the ‘491 patent, Miwa ‘377 also relates to glass articles particularly useful for a TFT-LCD glass substrate that does not substantially contain arsenic oxide or alkali metal oxides and can be formed using the drawdown method. EX1008, ¶ 0073.

69. In Miwa '377, the inventors have identified a continuous range of glass compositions that they consider satisfying the various properties required for glass substrates used in TFT-LCDs and can be made by the overflow down-draw method. The glass is alkali-free, arsenic-free. It has a composition, expressed as *mass* fractions (in percent), comprising SiO₂: (50..70)ms%, Al₂O₃: (10..19)ms%, B₂O₃: (5..15)ms%, MgO: (0..3)ms%, CaO: (0..12)ms%, SrO: (0..6)ms%, BaO: (0..5)ms%, ZnO: (0..2)ms%, ZrO₂: (0..1)ms%, TiO₂: (0..5)ms%, P₂O₅: (0..5)ms%, Sb₂O₃: (0..5)ms%. The glass also contains SnO₂ with a mass fraction of 0.005 to 0.4 ms%. It has a liquidus temperature of less than 1150 °C, has density of $\leq 2.45 \text{ g/cm}^{-3}$ or less, an average thermal expansion coefficient of $35 \cdot 10^{-7} \text{ K}^{-1}$ in the temperature range of (30..380) °C, and a strain point $\geq 650 \text{ °C}$. *Id.*, ¶ [0062].
70. For example, Miwa 377's Sample No. 8 teaches an alkali-metal-free glass with the mass and mole fractions shown below (in percent):

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	○		○		○	

Table 3 from Miwa '377.

71. Isolating the data of Sample No 8 in Miwa 377's Table 3 and calculating its $\sum_{i \in R} X_i / X_{\text{Al}_2\text{O}_3} \sum_{i \in R} X_i / X_{\text{Al}_2\text{O}_3}$ yields the following alkali-free composition in mole fractions, shown as percentages (mol%):

Component	X (mol%)
SiO ₂	66.61
Al ₂ O ₃	10.90
B ₂ O ₃	7.52
MgO	3.24
CaO	7.00
SrO	2.52

Component	X (mol%)
BaO	0.21
ZnO	0.0
ZrO ₂	0.08
TiO ₂	0.0
SnO ₂	0.07
P ₂ O ₅	0.0
Sb ₂ O ₃	0.0
Cl	1.84
$\sum_{i \in R} X_i / X_{\text{Al}_2\text{O}_3} = 0.99 \sum_{i \in R} \frac{X_i}{X_{\text{Al}_2\text{O}_3}} = 0.99$	

F. Motivation to Combine

72. As set forth below in more detail in the specific relevant limitations, a POSITA would have found it obvious to combine the references in the manner presented in each of Grounds 1, 2 and 3. In particular, the publications are in the same technical field: alkali-free glasses developed primarily for use as substrates in flat panel display technologies. Thus, the references 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.
73. Additionally, a POSITA would know that SrO and BaO play *similar* roles of network modifiers in the atomistic structure of silicate glass. This is understood

from the network theory introduced by Dietzel, EX1015, Section 4.4. Assuming that the anion is oxygen, the effect of a single cation, such as Sr^{2+} or Ba^{2+} , is characterized by its electric-field strength

$$F = \frac{Z_c}{a^2},$$

where Z_c is the cation charge ((2– for Sr or Ba) and $a = r_c + r_a$ is the distance between the (point-like) nuclei of the anion (oxygen, radius r_a) and the cation (Sr or Ba, radius r_c). EX1015, Section 4.4, Table 4.2 shows corresponding data for the field strengths of Sr and Ba at the distance of an O^{2-} ion (highlighting added):

Table 4.2. Classification of cations according to their field strength (Dietzel)

Element	Valence Z	Ionic Radius (for CN = 6 r in Å ^a)	Most Frequent Coordination Number CN	Ionic Distance for Oxides a in Å	Field Strength at Distance of O ²⁻ Ions Z/a ²	Function in Glass Structure
K	1	1.33	8	2.77	0.13	Network-modifier Z/a ² ≈ 0.1 . . . 0.4
Na	1	0.98	6	2.30	0.19	
Li	1	0.78	6	2.10	0.23	
Ba	2	1.43	8	2.86	0.24	
Pb	2	1.32	8	2.74	0.27	
Sr	2	1.27	8	2.69	0.28	
Ca	2	1.06	8	2.48	0.33	
Mn	2	0.91	6	2.23	0.40	
Fe	2	0.83	6	2.15	0.43	
Mn	2	0.83	4	2.03	0.49	Intermediate Z/a ² ≈ 0.5 . . . 1.0
Mg	2	0.78	6	2.10	0.45	
			4	1.96	0.53	
Zr	4	0.87	8	2.28	0.77	
Be	2	0.34	4	1.53	0.86	
Fe	3	0.67	6	1.99	0.76	
			4	1.88	0.85	
Al	3	0.57	6	1.89	0.84	
			4	1.77	0.96	
Ti	4	0.64	6	1.96	1.04	
B	3	0.20	4	1.50	1.34	Network-former Z/a ² ≈ 1.5 . . . 2.0
Ge	4	0.44	4	1.66	1.45	
Si	4	0.39	4	1.60	1.57	
P	5	0.34	4	1.55	2.1	
B	3	0.20	3		1.63	

74. According to these quantitative data, the field strengths of different ions can vary widely, e.g. from 0.13, “weak,” for potassium to 2.10, “strong,” for phosphorous. However, the field strengths of Sr and Ba are both “weak” and very *similar*: 28 nm⁻² and 24 nm⁻², respectively. (This is shown in the table as 0.28 Å⁻² and 0.24 Å⁻², respectively, but Å is no SI unit.)
75. Therefore, Sr and Ba play a *similar* role of network modifiers in the silicate glass structure. This information was well known at the time the ‘491 patent was filed. Combining the references outlined in each of Grounds 1, 2, and 3 to

constitute combining prior art elements, aa POSITA would have found that when making alkali-free substrate glasses according to known fabrication methods, glass properties can be optimized for specific applications by balancing the fractions of SrO versus BaO (e.g. the SrO mole fraction X_{SrO} versus the BaO mole fraction X_{BaO}) within a *constant combined* fraction of SrO and BaO (e.g. $X_{\text{SrO}} + X_{\text{BaO}} = \text{const}$). Such modifications would have been well within the skill of a POSITA, as confirmed by the teachings of the references.

VI. GROUND 1: CLAIMS 1-10 AND 12 WOULD HAVE BEEN OBVIOUS OVER MIWA '535 IN VIEW OF PEUCHERT '469, CLAIM 11 WOULD HAVE BEEN OBVIOUS OVER MIWA '535 IN VIEW OF JP '741 AND PEUCHERT '469, CLAIMS 13, 15 AND CLAIMS 17-24 WOULD HAVE BEEN OBVIOUS OVER MIWA '535, CLAIM 14 WOULD HAVE BEEN OBVIOUS OVER MIWA '535 IN VIEW OF JP '741, AND CLAIM 16 WOULD HAVE BEEN OBVIOUS OVER MIWA '535 IN VIEW OF PEUCHERT '469

A. Independent Claim 1

76. **Limitation 1[p]:** *An alkali-free glass for a downdraw process comprising in mole percent on an oxide basis:*
77. Miwa '535 discloses a continuous range of alkali-free glass compositions, specified as *mass* fractions on an oxide basis. EX1004, 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 Claim 1.” EX1004, at [Claim 3]. The glass can be produced by a down draw method, for example. EX1004, ¶00336. Table 4

of Miwa illustrates various embodiments, including Embodiment 15 of alkali-free glass defined by mass fractions (in percent) of each listed oxide.

78. **Limitations 1[a]-1[f]:** *SiO₂: 64.0-71.0; Al₂O₃: 9.0-12.0; B₂O₃: 7.0-12.0; MgO: 1.0-3.0; CaO: 6.0-11.5; SrO: 0-2.0;*

79. The composition of Embodiment 15 of Miwa '535 was converted from mass fractions W_i to mole fractions X_i , according to

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

80. The resulting mole fractions X_i are shown in the following Table 2 – as percentages (mol%).

Table 2: Glass Composition

Oxide	Miwa '535 Embodiment 15 (mol%)	'4491 Patent (mol%)
SiO ₂	67.2	64.0 - 71.0
Al ₂ O ₃	10.2	9.0 - 12.0
B ₂ O ₃	10.3	7.0 - 12.0
MgO	2.1	1.0 - 3.0
CaO	9.3	6.0 - 11.5
SrO	0.63	0 - 2.0
BaO	0.21	0 - 0.1
SnO ₂	0.04	0.01 – 0.15
As ₂ O ₃	0.0	0

Sb_2O_3	0.02	0
Fe_2O_3	0.00	0

81. All mole fractions of Limitation 1[a] are disclosed by Miwa in Embodiment 15, except the mole fraction of BaO. However, it is clear from Miwa ‘535 and Peuchert ‘469 that the mole fraction of BaO was known to be used in amounts as defined in Limitation 1[g], as is discussed below.

82. **Limitation 1[g]: *BaO*: 0-0.1**

83. Miwa ‘535 discloses that the glass composition can comprise a mass fraction of “BaO 0-10%,” Ex1004, ¶[0022]. Further, again referring to mass fractions, Miwa ‘535 discloses that “BaO, like SrO, is an ingredient that improves the chemical resistance and impermeability of glass.” However, Miwa ‘535 also teaches the adverse effects that *too much* BaO can have on glass properties: “The foregoing effects can be obtained when the content is 10% or less. The preferred range is 0-5%. As the BaO increases, the density of the glass and the coefficient of thermal expansion tend to increase, and its fusibility tends to deteriorate significantly.” EX1004, [0030].

84. According to paragraph 72-75, Sr and Ba play a *similar* role of network modifiers in the silicate glass structure. Therefore, BaO can be replaced by SrO without compromising essential properties of the glass. ThisThis means that their *combined* mass fraction ($W_{\text{SrO}} + W_{\text{BaO}}$) or, equivalently, *combined* mole fraction ($X_{\text{SrO}} + X_{\text{BaO}}$) can be optimized to obtain glasses with desired mass density, coefficient of thermal expansion, and refractive index. For example, completely replacing BaO with SrO could be used to obtain non-alkali glasses with somewhat lower mass density. (The reduction may be somewhat less than suggested

by the atom mass ratio $m_{\text{Sr}}/m_{\text{Ba}} = 0.64$: Sr^{2+} are smaller ions than Ba^{2+} . The reduced Sr–O bond length, compared to Ba–O, will increase the volume number density of ions. This will work to diminish the actual effect of replacing BaO with SrO on reducing mass density compared to just replacing every Ba^{2+} ion 1:1 with an Sr^{2+} ion without changing the atomistic structure.)

85. For replacing BaO entirely by SrO in a given total mass of glass (or components to be melted), there are (at least) two different approaches, which will lead to slightly different results:

(i) “Mole-wise”: Replacing each Ba atom by a Sr atom, meaning to *replace the mole fraction* $X_{\text{BaO}} = X_0$ of BaO by an additional mole fraction $\Delta X_{\text{SrO}} = X_0$ of SrO. Since $m_{\text{Sr}}/m_{\text{Ba}} = 0.64$, this will reduce the total mass. As the total mass is the reference for mass fractions, the mass fractions W_i of all other components will increase.

(ii) “Mass-wise:” Replacing the mass of BaO entirely by a corresponding mass fraction of SrO, meaning to *replace the mass fraction* $W_{\text{BaO}} = W_0$ of BaO by an additional mass fraction $\Delta W_{\text{SrO}} = W_0$ of SrO. Since $m_{\text{Sr}}/m_{\text{Ba}} = 0.64$, this will increase the total number of SrO moles, and, since the total number of moles is the reference for mole fractions, decrease the mole fractions X_i of all other components.

86. To apply approach (i) to Miwa ‘535’s Embodiment 15, consider a glass with SrO and BaO mole fractions $X_{\text{SrO}} = X_1$ and $X_{\text{BaO}} = X_2$, respectively. Replace the BaO mole fraction $X_{\text{BaO}} = X_2$ by a corresponding, additional mole fraction of $\Delta X_{\text{SrO}} = X_2$ of SrO:

$$\begin{array}{ccc} X_{\text{SrO}} = X_1 & \xrightarrow{\text{Replace}} & X_{\text{SrO}} = X_1 + X_2 \\ X_{\text{BaO}} = X_2 & & X_{\text{BaO}} = 0 \end{array}$$

The mole fractions of all other components remain unchanged and the *combined* mole fraction ($X_{\text{SrO}} + X_{\text{BaO}}$) of SrO and BaO remains constant. For Miwa '535's Embodiment 15, where $X_{\text{BaO}} = 0.21$ mol%, this means setting $X_{\text{BaO}} = 0$, while increasing the mole fraction $X_{\text{SrO}} = 0.63$ mol% of SrO to $X_{\text{SrO}} = 0.84$ mol%. This will change the *mass* fractions of all components as shown in the third (rightmost) column of following Table 3 compared to the original mass fractions of Miwa '535's Embodiment 15 in the second column.

Table 3 Glass Composition

Oxide	Miwa '535 Embodiment 15 (ms%)	Replacing X_{BaO} by ΔX_{SrO} (ms%)
SiO ₂	62.0	62.11
Al ₂ O ₃	16.0	16.0
B ₂ O ₃	11.00	11.0
MgO	1.3	1.3
CaO	8.00	8.0
SrO	1.0	1.33
BaO	0.55	0.0

87. To apply approach (ii) to Miwa '535's Embodiment 15, consider a glass with SrO and BaO mass fractions $W_{\text{SrO}} = W_1$ and $W_{\text{BaO}} = W_2$, respectively. Replace the BaO mass fraction $W_{\text{BaO}} = W_2$ by a corresponding, additional mass fraction of $\Delta W_{\text{SrO}} = W_2$ of SrO:

$$\begin{array}{l} W_{\text{SrO}} = W_1 \\ W_{\text{BaO}} = W_2 \end{array} \xrightarrow{\text{Replace}} \begin{array}{l} W_{\text{SrO}} = W_1 + W_2 \\ W_{\text{BaO}} = 0 \end{array}$$

The mass fractions of all other components remain unchanged and the *combined* mass fraction ($W_{\text{SrO}} + W_{\text{BaO}}$) of SrO and BaO remains constant. For Miwa ‘535’s Embodiment 15, where $W_{\text{BaO}} = 0.5 \text{ ms\%}$, this means setting $W_{\text{BaO}} = 0$, while increasing the mass fraction $W_{\text{SrO}} = 1 \text{ ms\%}$ of SrO to $X_{\text{SrO}} = 1.5 \text{ ms\%}$. This will change the *mole* fractions of all components as shown in the third (rightmost) column of following Table 4, compared to the original mass fractions of Miwa ‘535’s Embodiment 15 in the second column.

Table 4: Glass Composition

Oxide	Miwa ‘535 Embodiment 15 (mol%)	Replacing W_{BaO} by ΔW_{SrO} (mol%)
SiO ₂	67.22	67.1
Al ₂ O ₃	10.22	10.22
B ₂ O ₃	10.33	10.33
MgO	2.11	2.10
CaO	9.33	9.33
SrO	0.63	0.94
BaO	0.21	0.00

As Miwa ‘535 presents in mass percentage in the following, the default will be replacing BaO with SrO “by mass.”

88. Since a *zero* mass fraction of BaO in Table 4 implies a zero mole fraction of BaO, it overlaps the BaO mole fraction of $X_{\text{BaO}} = (0..0.1) \text{ mol\%}$ in limitation 1[g].

89. The approach of replacing BaO with SrO is obvious from the known theory described in paragraphs 72-75 and would have had a reasonable expectation of success.
90. Additionally, Peuchert '469 describes (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."

EX1006, ¶¶ 0024, 0025, 0026.

91. Thus, when Miwa '535 and Peuchert '469 are understood, it would be reasonable for a POSITA to optimize and/or optimize the fraction of BaO, including having a mole- or mass fraction of BaO equal to zero. This overlaps the BaO mole fraction of $X_{\text{BaO}} = (0..0.1)\text{mol\%}$ in limitation 1[g].
92. **Limitation 1[h]:** *wherein: (a) $1.00 \leq \Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$, where $[\text{Al}_2\text{O}_3]$ is the mole percent of Al_2O_3 and $\Sigma[\text{RO}]$ equals the sum of the mole percents of MgO, CaO, SrO, and BaO;*

93. For the glass composition disclosed in Miwa '535's Embodiment 15, $\sum_{i \in R} X_i / X_{\text{Al}_2\text{O}_3} = 1.20$, where summing is performed over the alkaline earth metal oxides of the set $R = \{\text{MgO}, \text{CaO}, \text{SrO}, \text{BaO}\}$. This value is within the range of 1.00 to 1.25 specified in Limitation 1[h]. Therefore, limitation 1[h] "1.00 $\leq \sum[\text{RO}]/[\text{Al}_2\text{O}_3] \leq 1.25$, where $[\text{Al}_2\text{O}_3]$ is the mole percent of Al_2O_3 and $\sum[\text{RO}]$ equals the sum of the mole percents of MgO, CaO, SrO, and BaO" is disclosed by Miwa '535. EX1004, Table 4.
94. **Limitation 1[j]-[l]:** *(b) the glass has the following compositional characteristics:*
(i) on an oxide basis, the glass comprises at most 0.05 mole percent As_2O_3 ;
(ii) on an oxide basis, the glass comprises at most 0.05 mole percent Sb_2O_3 ;
and
(iii) on an oxide basis, the glass comprises at least 0.01 mole percent SnO_2 ;
and
95. Embodiment 15 of Miwa '535 includes an As_2O_3 mole fraction of $X_{\text{As}_2\text{O}_3} = 0$ mol%; an Sb_2O_3 mole fraction of $X_{\text{Sb}_2\text{O}_3}$ of an SnO_2 mole fraction of $X_{\text{SnO}_2} = 0.04$ mol%, which overlaps with each of limitations [j]-[l]. Therefore, each of limitations 1[j]-[l] are disclosed by Miwa '535. EX1004, Table 4.
96. **Limitation 1[m]:** *(c) the glass has a liquidus viscosity that is greater than or equal to 100,000 poise*
97. 100,000 P corresponds to $10^{5.00}$ dPa·s (decipascal-second).
98. The need for a minimum viscosity of $10^{5.00}$ dPa·s (100,000 P) is common knowledge. For example, two Corning disclosures U.S. Patent No. 4,018,965 (EX1013) and U.S. 20040224834 (EX1014) teach that the downdraw method

requires a liquidus viscosity of at least $10^{5.00}$ dPa·s (100,000 P). EX1013. Col. 3, lines 3-15 EX1014, 0006

99. EX1010, “Attachment 2.3 High-temperature viscosity (5#-LJJ)_EN,” provides experimental data on the liquidus viscosity of a glass with a composition corresponding to Miwa ‘535’s Embodiment 15. The composition is shown in EX1010, “Attachment 2.2 ICP TEST_EN,” and summarized in the following Table 6 – in comparison with that in Miwa ‘535’s Embodiment 15 and the composition range specified in Limitation 1[a]. The compositions of Miwa ‘535’- Embodiment 15 and EX1010, “Attachment 2.2 ICP TEST_EN,” were converted from mass fractions W_i to mole fractions X_i , according to

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

Table 5: Glass Compositions

Oxide	Miwa ‘535 Embodiment 15 (mol%)	Experiment Sample #5 (mol%)	‘491 Patent Limitation 1[a] (mol%)
SiO ₂	67.2	67.1	64.0 - 71.0
Al ₂ O ₃	10.2	10.2	9.0 - 12.0
B ₂ O ₃	10.3	10.3	7.0 - 12.0
MgO	2.1	2.1	1.0 - 3.0
CaO	9.3	9.4	6.0 - 11.5
SrO	0.63	0.94	0 - 2.0
BaO	0.21	0.00	0 - 0.1

100. According to Table 6, the composition of Sample #5 is very similar to the glass

described in Miwa '535's Embodiment 15. Differences in the mole fractions, if any, are in the sub-percent range and will, therefore, not significantly impact the viscosity. Regarding viscosity, the glass composition of Sample #5 is *identical* to that of Miwa '535's Embodiment 15 except a) BaO in Embodiment 15 is replaced by SrO and b) Sb₂O₃, as a controlled substance, is not included in sample 5# but it has little impact on the liquidus viscosity.

101. The liquidus viscosity of the glass denoted as Sample #5 can be obtained as follows: During cooling from high temperature, the viscosity was experimentally determined for an array of closely spaced temperature within a high-temperature interval, from 1620 down to 1270 °C.
102. From such high-temperature viscosity data, the liquidus viscosity, i.e. the viscosity at the liquidus temperature, can be estimated by the Fulcher equation (James E. Shelby: Introduction to Glass Science and Technology, Royal Society of Chemistry, 2005, Section 6.5), EX1009.
103. EX1010, "Foshan Ceramics Research Institute Testing Co., Ltd, Test Report: Sample #5," provides experimental data on the liquidus temperature of Sample #5. Accordingly, the liquidus temperature of Sample #5 equals 1075 °C.
104. EX1010 presents a graph showing the results of viscosity measurements over temperatures within an interval [1270, 1620] °C of temperatures, above the liquidus temperature of 1075 °C. The document also presents the results of fitting the Fulcher equation to the experimental high-temperature data in order to obtain the viscosity at the liquidus temperature. The analysis performed uses the Fulcher equation in the form

$$P := \text{Log}_{10} \left[\frac{\eta}{\eta_0} \right] = A + \frac{B}{T + C},$$

where η is the viscosity, $\eta_0 = 1 \text{ dPa}\cdot\text{s}$, T is the temperature, and A , B , and C are fitting parameters (temperatures).

105. For Sample #5, the following Fig 1 shows the decadic logarithm of the viscosity (normalized by $\eta_0 = 1 \text{ dPa}\cdot\text{s}$) versus temperature, indicated in $^{\circ}\text{C}$. Bold symbols: Experimental data, obtained at high temperature. The thin line represents the fitting function based on the above form of the Fulcher equation with all temperatures in $^{\circ}\text{C}$. The fitting routine obtained the coefficient values for A , B , C shown in the text box.

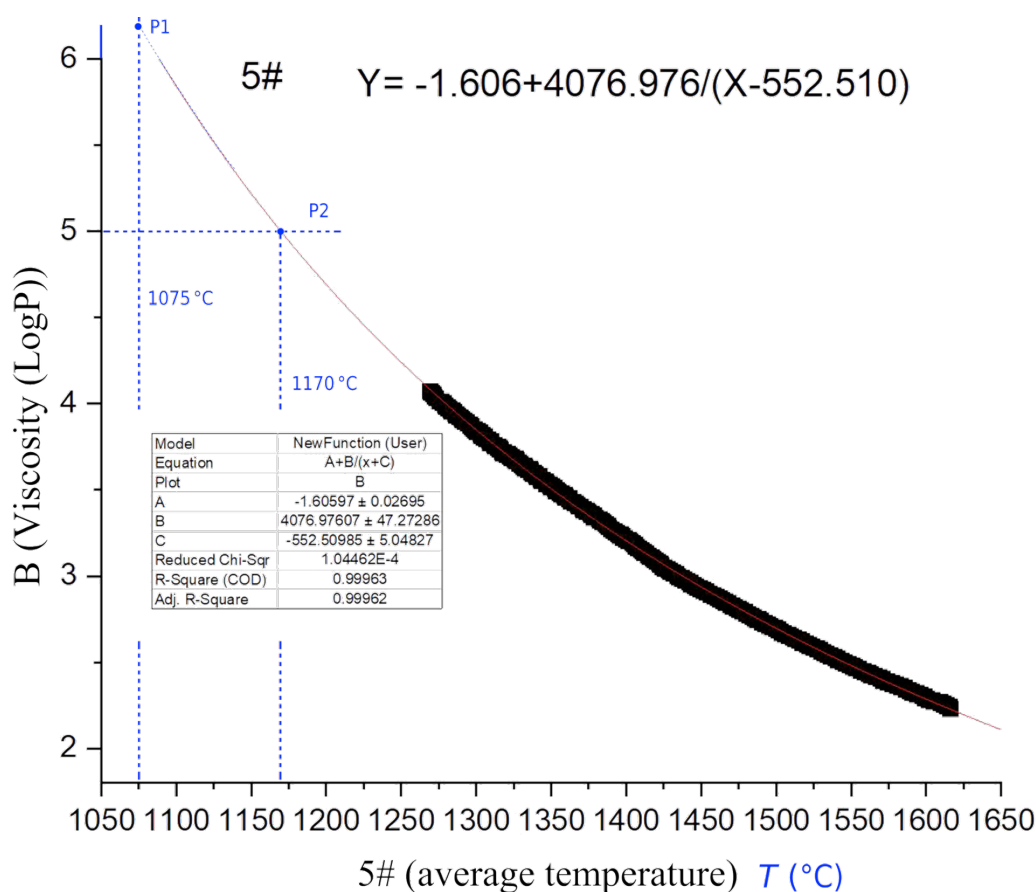


Fig 1: Decadic logarithm of the viscosity of Sample #5 versus temperature. Bold symbols: Experimental data, obtained at high temperature. Thin line: fitting function based on the Fulcher equation and extrapolation to the liquidus temperature of 1114°C . Blue markup added..

106. Extrapolating the fitting line to the liquidus temperature of 1075 °C indicates a liquidus viscosity of $10^{6.2}$ dPa. While the reliability of the low temperature extrapolation may not be quite as good as the thinness of the fitting line may suggest, the quality of the fit is high, with an “ R^2 ” value of 0.9996. Accordingly, the liquidus viscosity of Sample #5 is significantly larger than the minimum liquidus viscosity of $10^{5.0}$ dPa specified in limitation 1[m]. In fact, this minimum liquidus viscosity of $10^{5.0}$ dPa is already obtained at ≈ 1170 °C, significantly above the liquidus temperature of 1075 °C. The added (blue) markup intends to visualize these conclusions: The viscosity of point P1 is significantly higher than $10^{5.0}$ dPa, and the temperature of point P2 is significantly higher than the liquidus temperature of 1075 °C.
107. In conclusion, glasses with the composition specified in Miwa ‘535’s Embodiment 15 meet the requirement of Limitation 1[m].
108. As all of the limitations of Claim 1 are described and/or suggested by Miwa ‘535 and Peuchert ‘469, Claim 1 is obvious.

B. Dependent Claim 2

109. *The glass of claim 1 wherein: $\Sigma[RO]/[Al_2O_3] \leq 1.25$.*

110. For the glass composition disclosed in Miwa ‘535’s Embodiment 15 (EX1004, Table 4), $\sum_{i \in R} X_i / X_{Al_2O_3} = 1.20$. This value is ≤ 1.25 , as specified in Claim 2. Therefore, “ $1.00 \leq \Sigma[RO]/[Al_2O_3] \leq 1.25$, where $[Al_2O_3]$ is the mole percent of Al_2O_3 and $\Sigma[RO]$ equals the sum of the mole percents of MgO, CaO, SrO, and BaO” required in Claim 2 is disclosed by Miwa ‘535. EX1004, Table 4.
111. Thus, Claim 2 is disclosed by Miwa ‘535 and is obvious.

C. Dependent Claim 3

112. *The glass of claim 1 wherein, on an oxide basis, SrO is at most 1.0 mole percent.*

113. Replacing the mass of BaO with SrO (see paragraph 87), Embodiment 15 of Miwa (EX1004, Table 4) describes an SrO mole fraction of $X_{\text{SrO}} = 0.94 \text{ mol\%}$, which within the range in Claim 3.

114. Thus, Claim 3 is disclosed by Miwa '535 and is obvious.

D. Dependent Claim 4

115. *The glass of claim 1 wherein the glass has at least one of the following properties:*

116. *(a) a density that is less than or equal to 2.41 g/cm³;*

117. Embodiment 15 of Miwa '535 describes a glass density of 2.39 g/cm³, which within “a density that is less than or equal to 2.41 g/cm³” as in dependent Claim 4. EX1004, Table 4.

118. Thus, Claim 4(a) is disclosed by Miwa '535 and is obvious.

119. *(b) a linear coefficient of thermal expansion (CTE) over the temperature range 0-300° C, which satisfies the relationship: $28 \times 10^{-7}/^{\circ} \text{C} \leq \text{CTE} \leq 34 \times 10^{-7}/^{\circ} \text{C}$;*

120. Miwa '535 describes (emphasis added) “As can be seen from the table, the transmittance of all of the test samples (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 $30\text{-}34 \times 10^{-7}/^{\circ}\text{C}$. 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 102.5 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.”

121. Embodiment 15 of Miwa ‘535 reports a coefficient of thermal expansion (CTE) of $34 \times 10^{-7} \text{K}^{-1}$ when measured over a temperature range of $(30..380)^{\circ}\text{C}$, which is in the range of $28 \times 10^{-7} \text{K}^{-1} \leq \text{CTE} \leq 34 \times 10^{-7} \text{K}^{-1}$ of limitation 7[c]. EX1004, Table 4.
122. While the CTE in Claim 4 refers to the temperature range $(0..300)^{\circ}\text{C}$, Miwa ‘535’s CTE refers to $(30..380)^{\circ}\text{C}$. The following paragraphs (123-143) show that the CTE within $(0..300)^{\circ}\text{C}$ is *lower* than within $(30..380)^{\circ}\text{C}$.
123. 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 and makes the atom sample more of these non-Hookean regions of restoring

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

² This is understood to be liquidus temperature.

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.

124. 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.

125. 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 .

126. 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: $\partial L / \partial T > 0$. However, certain glasses may show an anomalous behavior, where $\alpha[T]$ does not increase or even decreases over certain intervals of temperature T .

127. Integrating $\alpha[T]$ over a temperature interval $[T_1, T_2]$ yields the “true strain” caused by thermal expansion over this temperature interval:

$$\epsilon = \int_{T_1}^{T_2} \alpha[T] dT$$

128. 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”

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

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

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

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

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

where the symbol “:=” defines the quantity next to the colon. 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 $[T_1, T_2]$.

129. 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 $2/3$. Figure 2 shows that for pure SiO_2 , $\alpha[T]$ does not monotonously increase, but exhibits a maximum at $\approx 500 \text{ K} \approx 200^\circ \text{C}$.
130. However, it is also apparent 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 $[T_1, T_2] = [0, 300]^\circ \text{C}$.

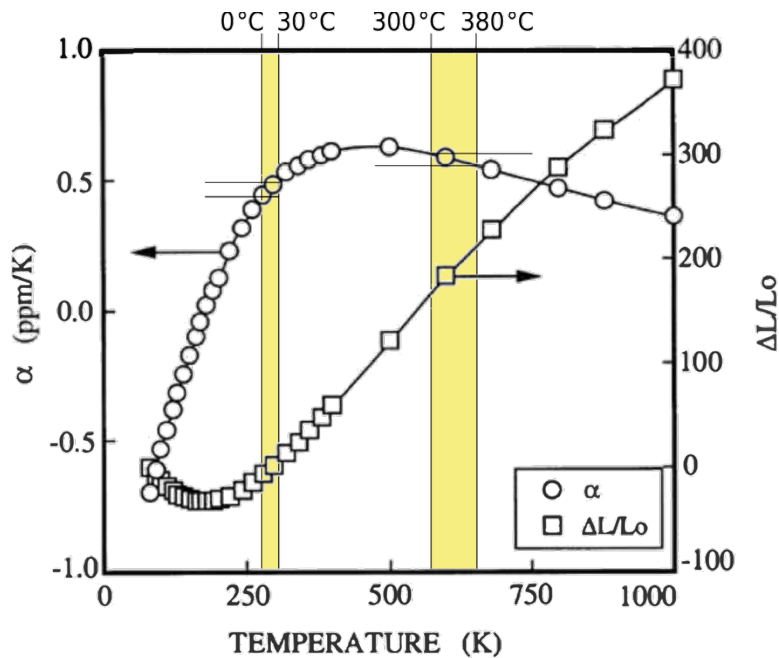


Figure 7.9 Effect of temperature on the thermal expansion coefficient and specimen length of vitreous silica.

FIG. 2: Data from EX1009.

131. Consequently, the CTE reported in Miwa '535, measured for $[T_3, T_4] = [30, 380]^\circ\text{C}$, is *greater* than it would have been found when measured for $[T_1, T_2] = [0, 300]^\circ\text{C}$, the temperature interval used in the '491 Patent. Conversely: Had the CTE measurements in Miwa '535 been performed in the temperature interval $[T_1, T_2] = [0, 300]^\circ\text{C}$ of the '491 Patent, the CTE would have been found *smaller* than $34 \cdot 10^{-7} \text{ K}^{-1}$, the value reported for the $[T_3, T_4] = [30, 380]^\circ\text{C}$.
132. Similar conclusions can be drawn from independent experimental measurements described in EX1011, "Foshan Ceramics Research Institute Testing Co., Ltd, Test Report: Sample #6." The composition is shown in Table 7 below.

Table 6

Oxide	Experiment Specimen #6 (mol%)
SiO ₂	67.4
Al ₂ O ₃	10.9
B ₂ O ₃	11.2
MgO	1.7
CaO	8.2
SrO	0.3
BaO	0.2

133. Figure 3 shows experimental data on the relative thermal expansion (engineering strain) Δ/l_0 of the glass with the composition described in Table 7, measured over the temperature interval $[T_1, T_2] = [0, 300]^\circ\text{C}$.

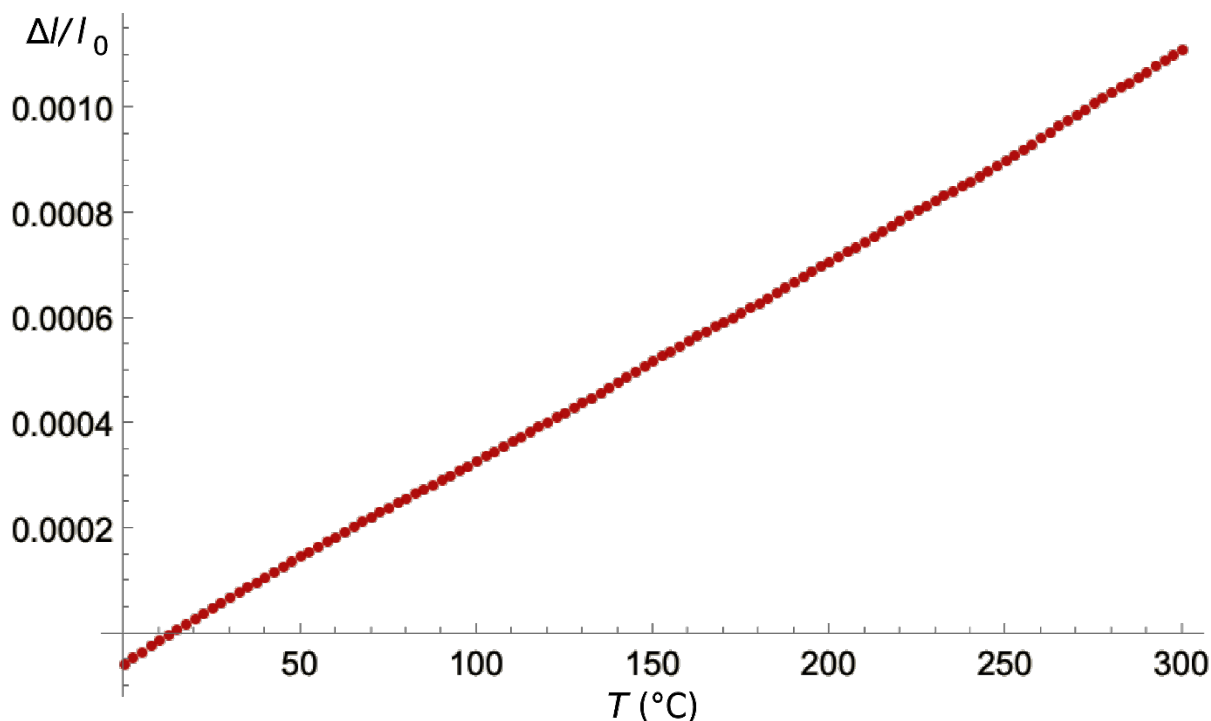


Fig 3: Experimental data on the relative thermal expansion (engineering strain) $\frac{\Delta l}{l_0}$ of the glass with the composition described in the table over the temperature interval $[T_1, T_2] = [0, 300]$ °C.

134. To determine $\alpha[T]$ and the CTE, $(\Delta l/l)[T]$ in Fig 3 needs to be differentiated with regard to the temperature T . It is a common problem with experimental data that (i) it contains noise and (ii) differentiation largely amplifies the noise. Therefore, the better approach is to fit a steady, smooth function to the data and perform the differentiation “analytically,” i.e. applying the known rules of differentiation to the fitting function. Fig 4 shows the result of fitting the experimental data of Fig 3 by a polynomial of 3rd order. The graph of the fitting function is laid over the experimental data points. As the figure shows, the fit is close to perfect.

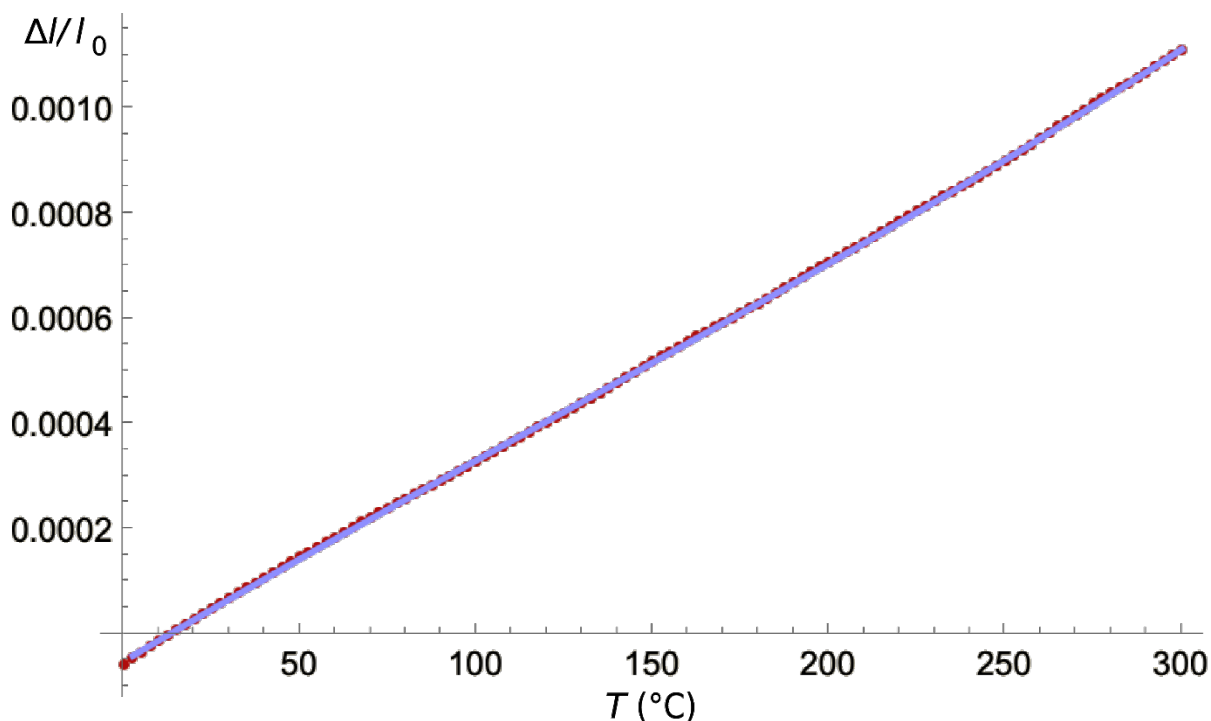


Fig 4: Graph of a 3rd-order polynomial fitting function $f[T]$ laid over the experimental data of Fig 3.

135. Quantitative numerical analysis confirms high-quality of the polynomial fit: A common measure of “goodness of fit” is the R^2 (read "R-squared") parameter, which measures the proportion of variance explained by the model. The closer R^2 to 1, the better the fit. For the polynomial fit in Fig 4, the R-squared goodness-of-fit value is

$$R^2 = 0.999987,$$

meaning that the fit is excellent.

136. The fitting polynomial of third order is a steady function that can be differentiated analytically to obtain $\alpha[T]$. Figure 5 $\alpha[T]$ for the experimental data of Fig 2, obtained as the first derivative, $f'[T] := d/dT f[T]$, of the 3rd-order polynomial fitting function $f[T]$. To better see the behavior of the graph, the y-axis starts at $37 \cdot 10^{-7} \text{ K}^{-1}$, not $0 \cdot 10^{-7} \text{ K}^{-1}$.

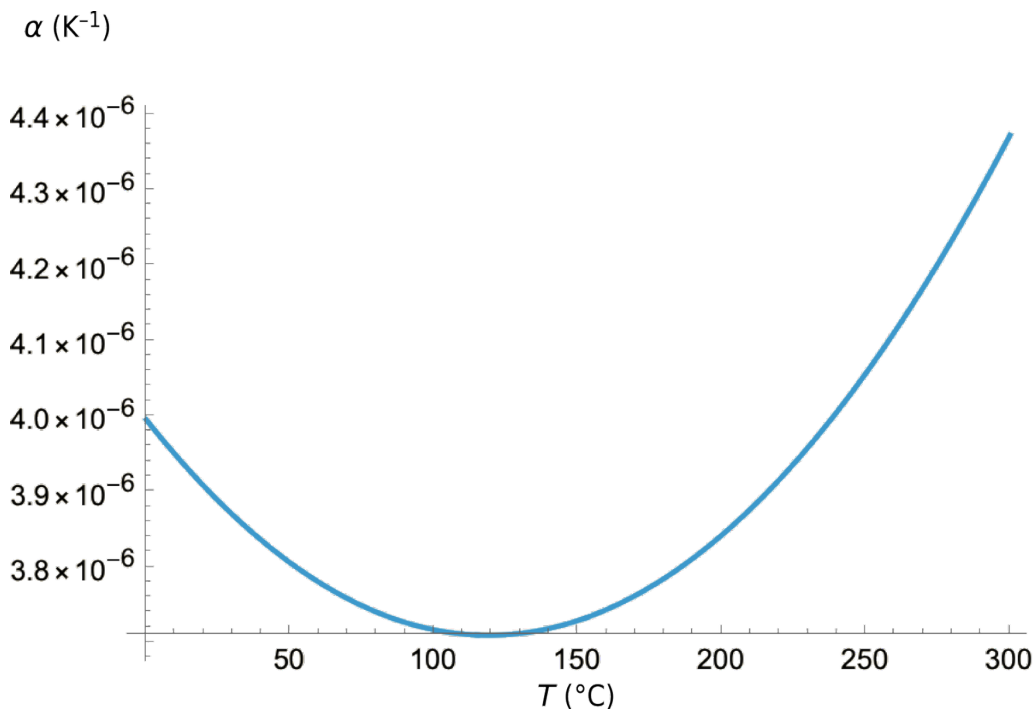


Fig 5: $\alpha[T]$ for the experimental data of Fig 3, obtained as the first derivative of the 3rd-order polynomial fitting function $f[T]$. To better see the behavior of the graph, the y-axis starts at $37 \cdot 10^{-7} K^{-1}$, not $0 \cdot 10^{-7} K^{-1}$.

137. Fig 5 exhibits an anomalous behavior of $\alpha[T]$. In this case, it is a local minimum, which occurs at around 120 °C. Equivalent to Fig 2, however, Fig 5 also shows significantly higher values of $\alpha[T]$ near the upper end (right side) of the temperature interval than near the lower end (left side). Similar to Fig 2, therefore, Fig 5 implies that measuring the CTE over $[T_3, T_4] = [30, 380] ^\circ C$ will yield higher values than measuring over $[T_1, T_2] = [0, 300] ^\circ C$.
138. This can be visualized even more clearly by extrapolating the derivative of the fitting function $f'[T]$ over the temperature interval $[T_2, T_4] = [300, 380] ^\circ C$. The result is displayed in Fig 6.

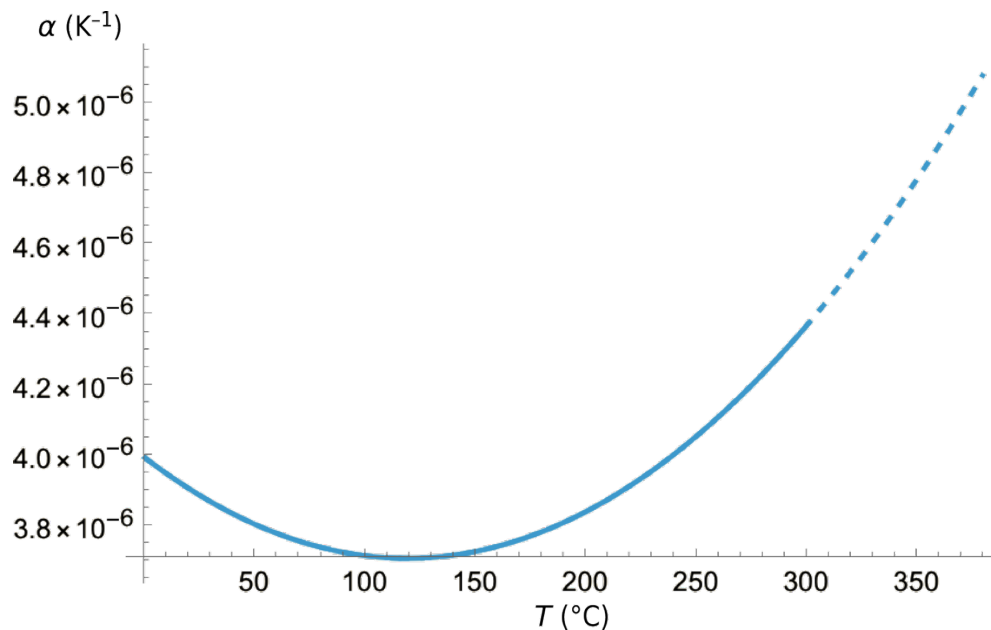


Fig 6: Extrapolation of the derivative $f'[T]$ of the 3rd-order polynomial fitting function $f[T]$ to higher temperatures T . The extrapolated section of the graph is shown as a dashed line.

139. Figure 7 shows the same graph as Fig 6, but highlighting the two subintervals of temperature T in which the intervals $[T_1, T_2] = [0, 300]^{\circ}\text{C}$ and $[T_3, T_4] = [30, 380]^{\circ}\text{C}$ do not overlap. In the right highlighted subinterval, $[30, 380]^{\circ}\text{C}$, the thermal expansion coefficient α is consistently higher than in the left highlighted subinterval, $[0, 30]^{\circ}\text{C}$.

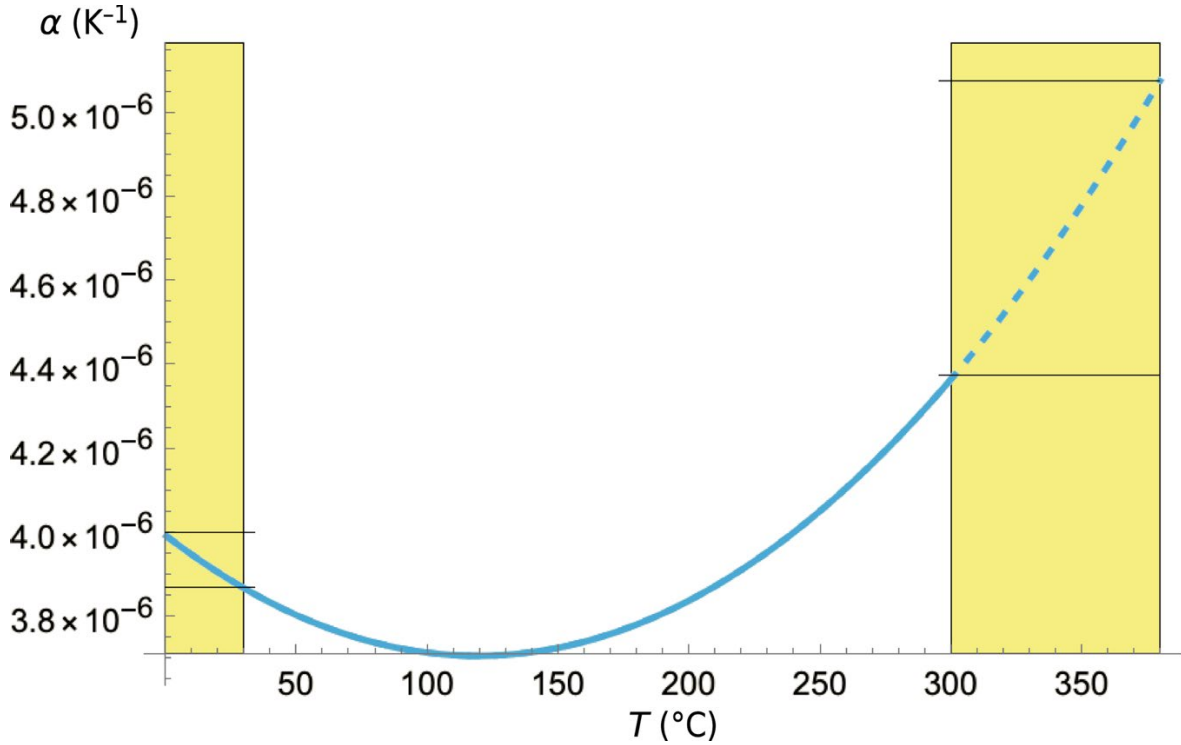


Fig 7: Same as Fig 6, but with highlighted intervals of temperature. The effective thermal expansion coefficient, $\bar{\alpha}$ or CTE, will be found larger in $[T_3, T_4] = [30, 380]$ °C than in $[T_1, T_2] = [0, 300]$ °C because α is higher in the right highlighted interval $[300, 380]$ °C than in the left highlighted interval $[0, 30]$ °C.

140. Therefore, evaluating the *effective* (average) thermal expansion coefficient, denoted as $\bar{\alpha}$ or CTE, from measurements over $[T_3, T_4] = [30, 380]$ °C will yield *larger* values than when measuring over $[T_1, T_2] = [0, 300]$ °C.
141. Conversely, when measuring the *same* glass over $[T_1, T_2] = [0, 300]$ °C, the *effective* (average) thermal expansion coefficient, denoted as $\bar{\alpha}$ or CTE, will be found *smaller* than when measuring over $[T_3, T_4] = [30, 380]$ °C.
142. For Sample #6, this can be verified by replacing $\alpha[T]$ by the derivative $f'[T]$ of the fitting function $f[T]$ in

$$\bar{\alpha} \equiv \varepsilon \approx \epsilon = \int_{T_1}^{T_2} \alpha[T] dT$$

yields a CTE of $\bar{\alpha} = 35.5 \cdot 10^{-7} \text{ K}^{-1}$ for $[T_3, T_4] = [30, 380]^\circ\text{C}$, but only $\bar{\alpha} = 34.0 \cdot 10^{-7} \text{ K}^{-1}$ for $[T_1, T_2] = [0, 300]^\circ\text{C}$ – significantly smaller.

143. Consequently, if the glass described in Miwa ‘535’s Embodiment 15 had been measured over $[T_1, T_2] = [0, 300]^\circ\text{C}$, the temperature interval used in the ‘491 Patent, the *effective* (average) thermal expansion coefficient, denoted as $\bar{\alpha}$ or CTE, would have been found *smaller* than the value of $34 \times 10^{-7} \text{ K}^{-1}$ that was found by measuring over $[T_3, T_4] = [30, 380]^\circ\text{C}$. Since $34 \times 10^{-7} \text{ K}^{-1}$ coincides with the upper limit of the range specified in limitation 4[b], the CTE that would have been found when measuring over $[T_1, T_2] = [0, 300]^\circ\text{C}$ would safely be *within* that interval. Thus, Miwa ‘535 describes the same CTE as in Claim 4(b).

144. (c) *a liquidus temperature less than or equal to 1170° C;*

145. Embodiment 15 of Miwa ‘535 describes a liquidus temperature at 1120 °C, which is within the range of Claim 4(c). EX1004, Table 4.

146. EX1010, “Attachment 3.4 Liquidus temperature_EN,” provides experimental data on the liquidus temperature of Sample #5, a glass with a composition corresponding to Miwa ‘535’s Embodiment 15. Accordingly, the liquidus temperature of Sample #5 equals 1075 °C. This value is less than or equal to 1170 °C, as specified in Claim 4(c).

147. (d) *a strain point that is greater than or equal to 650° C.*

148. Embodiment 15 of Miwa ‘535 describes a strain point at 673 °C, which is within the range of “a strain point that is greater than or equal to 650°C” as in limitation 4[d]. EX1004, Table 4.

149. Thus, Miwa discloses limitation 4[d].

150. All the limitations in Claim 4 are disclosed by Miwa '535 and as such Claim 4 is obvious.

E. Dependent Claim 5

151. *The glass of claim 4 wherein the glass has at least properties (a) through (c).*

152. As is evident from Claim 4, Embodiment 15 of Miwa '535 describes (a) through (c) as in Claim 5. Thus, Claim 5 is obvious.

F. Dependent Claim 6

153. *The glass of claim 4 wherein the glass has properties (a) through (d).*

154. As is evident from Claim 4, Embodiment 15 of Miwa '535 describes (a) through (d) as in Claim 6. Thus, Claim 6 is obvious.

G. Dependent Claim 7

155. *The glass of claim 1 wherein the glass has a liquidus viscosity greater than or equal to 200,000 poise.*

156. 200,000 poise corresponds to $10^{5.30}$ dPa·s.

157. EX1010, "Attachment 2.5 Fitting based on Fulcher equation_EN," presents a graph showing the results of viscosity measurements over temperatures within an interval [1270, 1620] °C of temperatures, above the liquidus temperature of 1075 °C. Fitting the data to the Fulcher equation and extrapolating the fitting line to the liquidus temperature of 1075 °C indicates a liquidus viscosity of

$10^{6.2}$ dPa. While the reliability of the low temperature extrapolation may not be quite as good as the thinness of the fitting line may suggest, the quality of the fit is high, with an “ R^2 ” value of 0.9996. Accordingly, the liquidus viscosity of Sample #5 is significantly larger than the liquidus viscosity of $10^{5.30}$ dPa specified in Claim 7. In fact, Fig 8 shows that a liquidus viscosity of $10^{5.30}$ dPa is already obtained at ≈ 1145 °C, significantly above the liquidus temperature of 1075 °C. The added (blue) markup intends to visualize these conclusions: The viscosity of point P1 is significantly higher than $10^{5.3}$ dPa, and the temperature of point P3, where the viscosity equals $10^{5.30}$ dPa·s, is significantly higher than the liquidus temperature of 1075 °C.

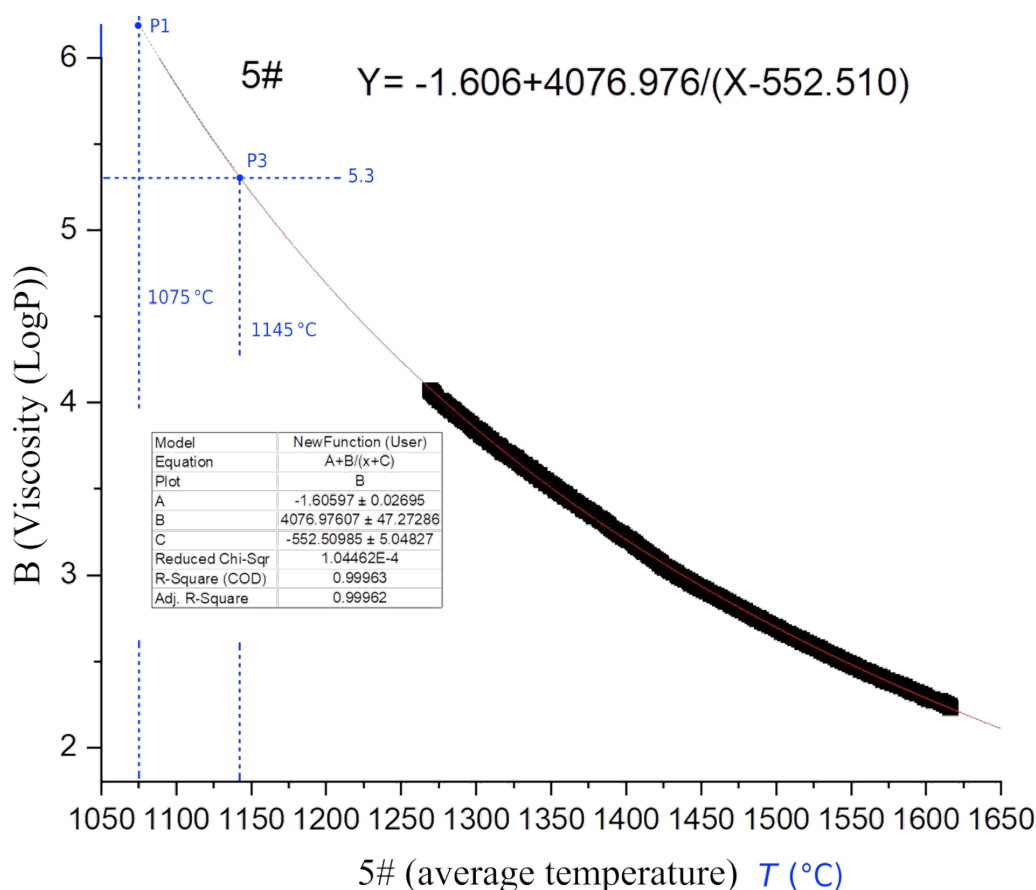


Fig 8: Decadic logarithm of the viscosity of Sample #5 versus temperature. Bold symbols: Experimental data, obtained at high temperature. Thin line: fitting function based on the Fulcher equation and extrapolation to the liquidus temperature of

1114 °C. , blue markup added.

158. In conclusion, glasses with the composition specified in Miwa ‘535’s Embodiment 15 meet the requirement of Claim 7. Thus, Claim 7 is obvious.

H. Dependent Claim 8

159. *The glass of claim 1 wherein, on an oxide basis, the glass comprises at most 0.15 mole percent SnO₂.*

160. Embodiment 15 of Miwa ‘535 includes 0.04 mol% of SnO₂ (Table 1, paragraph 53). Therefore, Claim 8 is also obvious.

I. Dependent Claim 9

161. *The glass of claim 1 wherein the glass has a MgO content between 1.2 and 2.8 mole percent.*

162. Embodiment 15 of Miwa ‘535 includes 2.1 mol% of MgO. Therefore, Claim 9 is also obvious.

J. Dependent Claim 10

163. *The glass of claim 1 wherein the glass is substantially free of BaO*

164. Miwa ‘535 discloses that the glass composition can comprise a mass fraction of “BaO 0-10%,” Ex1004, ¶ [0022]. Further, again referring to mass fractions, Miwa ‘535 discloses that “BaO, like SrO, is an ingredient that improves the chemical resistance and impermeability of glass.” However, Miwa ‘535 also teaches the adverse effects that too much BaO can have on glass properties:

“The foregoing effects can be obtained when the content is 10% or less. The preferred range is 0-5%. As the BaO increases, the density of the glass and the coefficient of thermal expansion tend to increase, and its fusibility tends to deteriorate significantly.” EX1004, ¶ [0030].

165. Actually, with regard to some important properties, BaO can be replaced by SrO. Both SrO and BaO play a network-modifying role in these glasses and their combined mass fraction ($W_{\text{SrO}} + W_{\text{BaO}}$) or, equivalently, combined mole fraction ($X_{\text{SrO}} + X_{\text{BaO}}$), can be optimized to obtain glasses with desired mass density, coefficient of thermal expansion, and refractive index. In other words, to obtain low-density glasses without compromising important properties, the BaO fraction may be set to 0 by replacing it with SrO. For example, the mole fraction X_{SrO} of SrO in Miwa’s Embodiment 15 may be increased to $X_{\text{SrO}} = 0.84$ mol% with $X_{\text{BaO}} = 0.00$ mol%, while the other components remain unchanged. Completely replacing BaO with SrO is one of a finite number of identified ways to obtain non-alkali glasses with low mass density and would have had a reasonable expectation of success of their combination.
166. With SrO and BaO playing equivalent roles in the glass compositions, as discussed, it would have been obvious to adjust the mole fraction of BaO from $X_{\text{BaO}} = 0.21$ mol% to 0.00 mol% and adjust the mole fraction of SrO from $X_{\text{SrO}} = 0.63$ to 0.84 mol% to keep their combined mole fraction ($X_{\text{SrO}} + X_{\text{BaO}}$) constant.
167. A zero mole fraction of BaO also overlaps the BaO mole fraction of $X_{\text{BaO}} = (0..0.1)$ mol% in Claim 10.
168. Additionally, Peuchert ‘469 describes (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.”

EX1006, ¶¶ 0024, 0025, 0026.

169. Thus, it would be reasonable for a POSITA to optimize and/or optimize the amount of BaO, including having a zero mole fraction of BaO when Miwa ‘535 and Peuchert ‘469 are properly understood.

K. Dependent Claim 11

170. The glass of claim 1 wherein the glass comprises at most 0.005 mole percent As_2O_3 and at most 0.005 mole percent Sb_2O_3 .

171. Miwa ‘535 describes (emphasis added): “The alkali-free glass substrate of this invention does not contain alkali metal oxides, and is characterized by the following: **SnO_2 0.01-0.3%, As_2O_3 0-0.1%, Sb_2O_3 0-1.0%**, and the Fe content in the glass is 0.005-0.03% by mass, when converted to Fe_2O_3 .” EX1004, cover page.

172. Further, JP '741 describes (emphasis added): “However, **As₂O₃ is highly toxic** and has the potential to pollute the environment during the glass manufacturing process or the disposal of waste glass. As a result, **its use is increasingly being restricted.**”

“Therefore, it is an objective of the present invention is to provide an alkali-free glass that does **not use As₂O₃** as a fining agent and is free from bubbles that cause display defects, as well as a method for manufacturing such glass.”

“As a result of various experiments, the present applicant found that the object of the present invention could be realized by using **SnO₂ instead of As₂O₃** as a clarifying agent, and thus proposes this finding as the present invention.”

“In this way, an alkali-free glass of the present invention can be obtained, **which has a composition in weight percent of 40–70% SiO₂, 6–25% Al₂O₃, 5–20% B₂O₃, 0–10% MgO, 0–15% CaO, 0–30% BaO, 0–10% SrO, 0–10% ZnO, and 0.05–2% SnO₂, and essentially contains no alkali metal oxides.**”

“Next, **SnO₂ is added to the glass raw material mixture. The amount of SnO₂ added is 0.05 to 2.0 weight% relative to 100 weight% of the glass raw material mixture. The reason for this is that if the amount is less than 0.05%, there will be no fining effect, and if it exceeds 2.0%, the volatilization amount increases, making the glass more prone to alteration.**”

EX1005, ¶¶ 0005, 0006, 0007, 0022, 0019.

173. Thus, JP '741 considered with Miwa '535 provides the motivation for avoiding the use of toxic fining agents and, instead, using only SnO₂ as a fining agent. Additionally, the composition of Example 5 in Miwa '535 falls within the compositional range described in JP '741, making it applicable to use the same type and content of fining agent. JP '741 discloses that the mass percentage of the

SnO₂ fining agent is 0.05–2 mass%. When replacing the fining agent in Miwa ‘535 with SnO₂, the mass percentages of the other components are scaled to 100% minus the mass ratio of SnO₂. That is, when SnO₂ takes the endpoint values of 0.05 and 2 mass%, the mass percentages of the other components become 99.5 and 98 mass%, respectively. Based on this, the corresponding mass percentages and molar percentages for the endpoint values are calculated as follows.

174. The converted values for each component and $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$ fall within the scope of claim 1. The calculated molar percentage range of SnO₂ is 0.02–0.87 mol%, as shown in the following table:

	BaO substituted by SrO	0.05 wt% SnO ₂		2 wt% SnO ₂	
	wt%	wt%	mol%	wt%	mol%
SiO ₂	62	62	67.16	62	66.60
Al ₂ O ₃	16	16	10.21	16	10.13
B ₂ O ₃	11	11	10.28	11	10.20
MgO	1.3	1.3	2.10	1.3	2.08
CaO	8	8	9.28	8	9.21
SrO	1.5	1.5	0.94	1.5	0.93
BaO	0	0	0.00	0	0.00
Fe ₂ O ₃	0.01	0.01	0.00	0.01	0.00
ZrO	0	0.00	0.00	0.00	0.00
Sb ₂ O ₃	0.1	0.00	0.00	0.00	0.00
SnO ₂	0.1	0.05	0.02	2.00	0.85

175. Thus, Claim 11 is obvious when considering the combination of Miwa ‘535 and JP ‘741.

L. Dependent Claim 12

176. *The glass of claim 1 wherein the downdraw process is a fusion process.*

177. Miwa '535 describes glass compositions suitable for manufacturing glass sheets by a downdraw process and overlapping with all limitations of Claim 1. EX1004, 0001 and 0036.

178. Miwa '535 teaches (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." EX1004, ¶ 0036.

179. Among the methods listed, the overflow-die draw method is a fusion process. It is also called the "fusion" or "overflow" downdraw method. Molten glass overflows from a trough, flows down both sides, fuses at the bottom, and is drawn downward as a continuous sheet.

180. Overflow-die draw methods are fusion processes. Therefore, Miwa '535 describes Claim 12 and is obvious.

M. Independent Claim 13

181. **Limitation 13[p]:** *An alkali-free glass sheet produced by a downdraw process comprising a glass that comprises SiO₂, Al₂O₃, B₂O₃, MgO, and CaO, and, on*

an oxide basis, has:

182. Miwa ‘535 discloses a continuous range of alkali-free glass compositions, specified as *mass* fractions on an oxide basis. EX1004, 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 Claim 1.” EX1004, at [Claim 3]. Table 4 of Miwa illustrates various embodiments, including Embodiment 15 of alkali-free glass defined by mass fractions (in percent) of each listed oxide.

183. The composition of Embodiment 15 of Miwa ‘535 was converted from mass fractions W_i to mole fractions X_i , according to

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

184. The resulting mole fractions X_i are shown in the following Table 1 – as percentages (mol%).

Table 7: Glass Composition

Oxide	Miwa ‘535 Embodiment 15 (mol%)	
SiO ₂	67.2	
Al ₂ O ₃	10.2	
B ₂ O ₃	10.3	
MgO	2.1	

CaO	9.3	
SrO	0.63	
BaO	0.21	

185. Miwa ‘535 teaches (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.” EX1004, ¶ [0036].
186. Among the methods listed, the following are “downdraw” methods: (1) The Slot-die draw method: In this method, molten glass is delivered through a slot-shaped die and drawn downward to form a thin glass sheet. (2) The overflow-die draw (fusion) method: This is also called the “fusion” or “overflow” downdraw method. Molten glass overflows from a trough, flows down both sides, fuses at the bottom, and is drawn downward as a continuous sheet. Thus, Miwa ‘535 describes alkali-free glass sheet produced by a **downdraw** process comprising a glass that comprises SiO₂, Al₂O₃, B₂O₃, MgO, and CaO.
187. **Limitation 13[a]:** *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*
188. For the glass composition disclosed in Miwa ‘535’s Embodiment 15,

$\sum_{i \in R} X_i / X_{\text{Al}_2\text{O}_3}$. EX1004, Table 4. This is in the range of 1.00 to 1.25, as in limitation 13[a]. Therefore, the limitation “ $1.00 \leq \sum[\text{RO}]/[\text{Al}_2\text{O}_3] \leq 1.25$, where $[\text{Al}_2\text{O}_3]$ is the mole percent of Al_2O_3 and $\sum[\text{RO}]$ equals the sum of the mole percents of MgO , CaO , SrO , and BaO ” is disclosed by Miwa ‘535.

189. **Limitations 13[d]-[f]:** *(ii) a MgO content greater than or equal to 1.0 mole percent; wherein*

(a) on an oxide basis, the glass comprises at most 0.005 mole percent As_2O_3 ;

(b) on an oxide basis, the glass comprises at most 0.005 mole percent Sb_2O_3 ;

(c) on an oxide basis, the glass comprises at least 0.01 mole percent SnO_2 ;

190. In JP ‘741, the passage “Next, SnO_2 is *added* to the glass raw material mixture. The amount of SnO_2 added is 0.05 to 2.0 wt% *of* the glass raw material mixture.” describes *adding* the fining agent SnO_2 as an amount that corresponds to a *mass* fraction of 0.05 to 2.0 % of the total mass of all other components, considered as exactly 100 %. So, after adding e.g. 2.0% SnO_2 , the total mass will be 102.0% of what it was before. In the following, I investigate the *mole* fraction of SnO_2 obtained by adding it to the composition of Embodiment 15 of Miwa ‘535 in this way, after replacing BaO with SrO “mass-wise” and setting the mass fraction of Sb_2O_3 and the *initial* mass fraction of SnO_2 to 0: $W_{\text{Sb}_2\text{O}_3}=0$, $W_{\text{SnO}_2}=0$.

191. The glass compositions shown in JP ‘741 are free of both As_2O_3 or Sb_2O_3 . This is confirmed by the observation that the glass compositions shown in the examples in Table 2 in JP ‘741 do neither list As_2O_3 , nor Sb_2O_3 , and add up to exactly 1 (100 ms%).

192. The following shows that combining Miwa ‘535’s Embodiment 15 (EX1004, Table 4) with the teachings of JP ‘741 discloses Limitations 1[j-l]. This includes the following steps to be applied to the composition described in

Miwa '535's Embodiment 15:

(i) Remove (i.e. reset to zero) the mass fraction $W_{\text{Sb}_2\text{O}_3}=0.1 \text{ ms}\%=0.001$ of Sb_2O_3 and the *initial* mass fraction $W_{\text{SnO}_2}=0.1 \text{ ms}\%=0.001$ of SnO_2 . Then, renormalize all other mass fractions with a factor $k_1:=1/(1-W_{\text{Sb}_2\text{O}_3}-W_{\text{SnO}_2})$. Let these renormalized mass fractions be denoted as V_i .

(ii) Add the resulting renormalized value V_{BaO} of the BaO mass fraction to the renormalized value V_{SrO} of the SrO mass fraction and set the BaO mass fraction to zero:

$$\begin{array}{ccc} V_{\text{SrO}} = k_1 \cdot 0.010 & \xrightarrow{\text{Replace}} & V_{\text{SrO}} = k_1 \cdot 0.015 \\ V_{\text{BaO}} = k_1 \cdot 0.005 & & V_{\text{BaO}} = 0 \end{array}$$

(iii) Considering the resulting $\sum V_i$ as exactly 100ms%, as JP '741 suggests, *add* a mass of SnO_2 as fraction $Q_{\text{SnO}_2}=(0.0005..0.0200)$ (i.e. 0.05 to 2.00 ms%) of that glass mass without SnO_2 . Now, the sum of all mass fractions will be $(1+Q_{\text{SnO}_2})\sum V_i$. So, renormalize the mass fractions V_i by multiplying them with the factor $k_2=1/(1+Q_{\text{SnO}_2})$. Let these renormalized mass fractions be denoted as U_i .

(iv) Convert the mass fractions U_i to mole fractions X_i to obtain the glass composition $\{X_i\}$, $i=1, \dots, N$, including the added SnO_2 , removed Sb_2O_3 and initial SnO_2 , and additional SrO from “mass-wise” replacement of BaO. As usual, the mole fractions X_i can be obtained from mass fractions U_i according to

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

(v) 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.

193. Result: Adding SnO_2 as a mass corresponding to $Q_{\text{SnO}_2} = 0.05\%$ of the mass without SnO_2 to Miwa ‘535’s Embodiment 15 glass composition after removing Sb_2O_3 and initial SnO_2 and replacing BaO “mass-wise” with SrO yields the results shown in the following Table. Columns 2 and 3 refer to the minimum and maximum SnO_2 addition specified in JP ‘741, namely $Q_{\text{SnO}_2} = 0.05\text{ ms}\%$ and $Q_{\text{SnO}_2} = 2.00\text{ ms}\%$. Already for the minimum addition of SnO_2 specified in JP ‘741, $Q_{\text{SnO}_2} = 0.05\text{ ms}\%$, the resulting SnO_2 mole fraction of $X_{\text{SnO}_2} = 0.02\text{ mol}\%$ is in agreement with the requirement of “at least 0.01 mole percent SnO_2 ” specified in Limitation 1[1].

Table 8

Component	X (mol%) $Q_{\text{SnO}_2} = 0.05\text{ ms}\%$	X (mol%) $Q_{\text{SnO}_2} = 2.00\text{ ms}\%$
SiO_2	67.2	66.6
Al_2O_3	10.2	10.1
B_2O_3	10.3	10.2
MgO	2.1	2.1
CaO	9.3	9.2
SrO	0.94	0.93
BaO	0.00	0.00
Fe_2O_3	0.00	0.00
As_2O_3	0	0
Sb_2O_3	0.00	0.00
SnO_2	0.02	0.85

194. As shown in the table of mass fractions converted to mole fractions in Table 1 (paragraph 53), Embodiment 15 of Miwa ‘535 includes an As_2O_3 mole fraction

of $X_{\text{As}_2\text{O}_3} = 0 \text{ mol}\%$. With that, a mass fraction of $W_{\text{Sb}_2\text{O}_3} = 0$ implying a mole fraction of $X_{\text{Sb}_2\text{O}_3} = 0 \text{ mol}\%$ and the mole fraction of $X_{\text{SnO}_2} = 0.02 \text{ mol}\%$ (at least), Miwa '535 in view of JP '741 overlaps with each of limitations 13[d]-[f].

195. Thus, each of Limitations 13[d]-[f] is obvious in view of these collective disclosures.

196. **Limitation 13[g]:**

(d) the glass has a liquidus viscosity that is greater than or equal to 100,000 poise.

197. 100,000 P corresponds to $10^{5.00} \text{ dPa}\cdot\text{s}$ (decipascal-second). EX1010, "Attachment 2.3 High-temperature viscosity (5#-LJJ)_EN," provides experimental data on the liquidus viscosity of a glass with a composition corresponding to Miwa '535's Embodiment 15. The composition is shown in **EX1010, "Attachment 2.2 ICP TEST_EN,"** and summarized in the following Table – in comparison with that in Miwa '535's Embodiment 15 and the composition range specified in Limitation 1[a]. The compositions of Miwa '535'- Embodiment 15 and EX1010, "Attachment 2.2 ICP TEST_EN," were converted from mass fractions W_i to mole fractions X_i , according to

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

Table : Glass Compositions

Oxide	Miwa '535 Embodiment 15 (mol%)	Experiment Sample #5 (mol%)
SiO ₂	67.2	67.1

Al ₂ O ₃	10.2	10.2
B ₂ O ₃	10.3	10.3
MgO	2.1	2.1
CaO	9.3	9.4
SrO	0.63	0.94
BaO	0.21	0.00

198. According to Table above , the composition of Sample #5 is very similar to the glass described in Miwa '535's Embodiment 15. Differences in the mole fractions, if any, are in the sub-percent range and will, therefore, not significantly impact the viscosity. Regarding viscosity, the glass composition of Sample #5 is *identical* to that of Miwa '535's Embodiment 15 except a) BaO in Embodiment 15 is replaced by SrO and b) Sb₂O₃, as a controlled substance, is not included in sample 5# but it has little impact on the liquidus viscosity..
199. From the high-temperature data in EX1010, "Attachment 2.3 High-temperature viscosity (5#-LJJ)_EN," the viscosity at the liquidus temperature can be obtained by extrapolating a function fitted to the high-temperature data based on the Fulcher equation. EX1010, "Foshan Ceramics Research Institute Testing Co., Ltd, Test Report: Sample #5," presents measurements of the liquidus temperature of Sample #5. Accordingly, the liquidus temperature equals 1075 °C.
200. For Sample #5, the following Fig 1 shows the decadic logarithm of the viscosity (normalized by $\eta_0 = 1 \text{ dPa}\cdot\text{s}$) versus temperature, indicated in °C. Bold symbols: Experimental data, obtained at high temperature. The thin line represents the fitting function based on the above form Fulcher equation with all temperatures in °C.

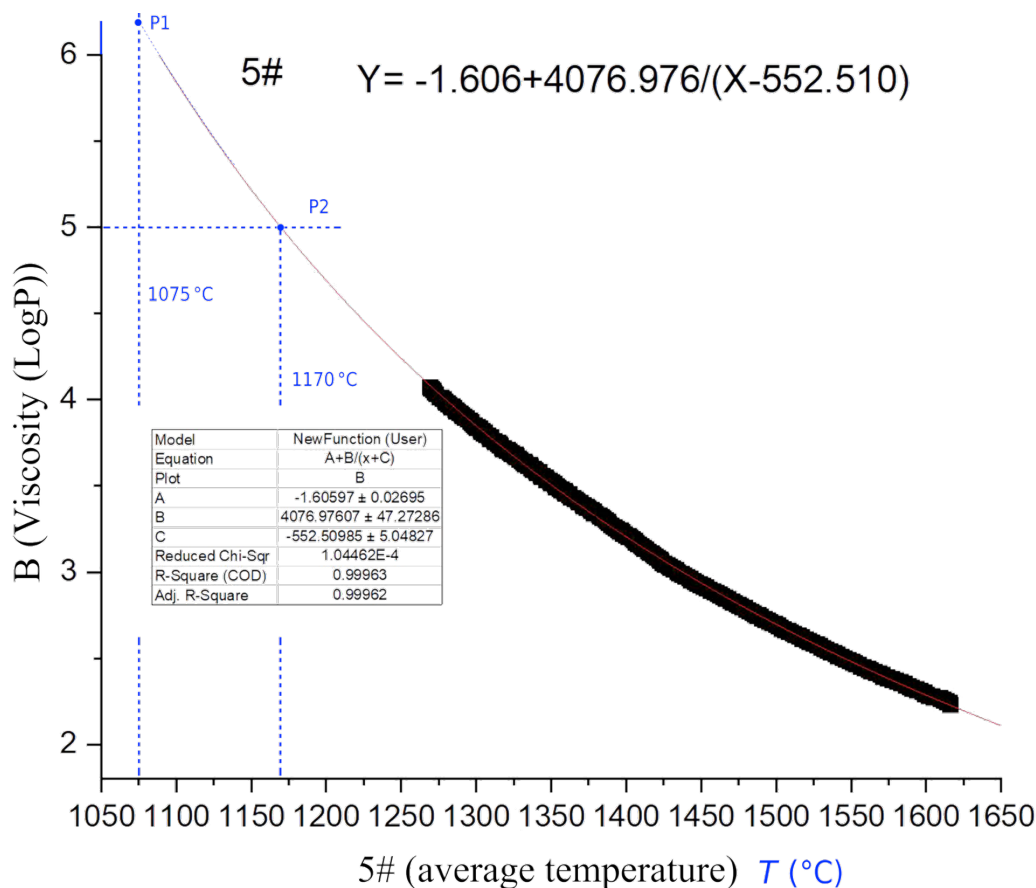


Fig 1: Decadic logarithm of the viscosity of Sample #5 versus temperature. Bold symbols: Experimental data, obtained at high temperature. Thin line: fitting function based on the Fulcher equation and extrapolation to the liquidus temperature of 1114 °C. Blue markup added.

201. According to Fig 1, the liquidus viscosity of the glass of Sample #5 is $10^{6.2}$ dPa. As, concerning viscosity, the glass composition described in Miwa '535's Embodiment 15 is identical to that of Sample #5 except a) BaO in Embodiment 15 is replaced by SrO and b) Sb_2O_3 , as a controlled substance, is not included in sample 5# but it has little impact on the liquidus viscosity, this means that the glass of Miwa '535's Embodiment 15 has a viscosity greater than $10^{5.0}$ dPa·s (100,000 P), as required by Limitation 13[g].
202. As all of the limitations of Claim 13 are described by Miwa '535, Claim 13 is obvious in view of Miwa '535.

N. Dependent Claim 14

203. The glass sheet of claim 13 wherein on an oxide basis, the glass comprises at most 0.15 mole percent SnO_2 .

204. JP '741 teaches: "Next, SnO_2 is added to the glass raw material mixture. The amount of SnO_2 added is 0.05 to 2.0 wt% of the glass raw material mixture. The reason for this range is that an amount less than 0.05% has no clarifying effect, and an amount more than 2.0% increases the amount of volatiles, making the glass more susceptible to deterioration." EX1005, 0019.

205. Embodiment 15 of Miwa '535 describes a glass composition with an SnO_2 mole fraction of $X_{\text{SnO}_2}=0.04$ mol%. Miwa '535 also describes that the glass can comprise a mass (or weight) fraction of $W_{\text{SnO}_2}=0.01$ to 0.3 ms%. EX1004, 0017.

206. Accordingly, the glass described in Miwa '535's Embodiment 15 when considered with JP '741 would reasonably result in no more than 0.15 mol% of SnO_2 , as required by Claim 14 as this value is optimizing known variables conventionally used in these types of glass compositions. As a result, Claim 14 is obvious.

O. Dependent Claim 15

207. The glass sheet of claim 13 wherein the glass has a MgO content between 1.2 and 2.8 mole percent.

208. Embodiment 15 of Miwa '535 includes an MgO mole fraction of $X_{\text{MgO}}=2.1$, which is within the range of Claim 15 and is thus obvious.

P. Dependent Claim 16

209. The glass sheet of claim 13 wherein the glass is substantially free of BaO.

210. Peuchert '469 describes (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 light-weight 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.”

EX1006, ¶¶ 0024, 0025, 0026.

211. Miwa '535 discloses that the glass composition can comprise a mass fraction of “BaO 0-10%,” Ex1004, ¶[0022] and further, again referring to mass fractions, discloses “BaO, like SrO, is an ingredient that improves the chemical resistance and impermeability of glass. The foregoing effects can be obtained when the content is 10% or less. The preferred range is 0-5%. As the BaO increases, the density of the glass and the coefficient of thermal expansion tend to increase, and its fusibility tends to deteriorate significantly.” EX1004, [0030].

212. According to paragraphs 72-75,, SrO and BaO play equivalent roles in modifying the network in these glasses. Their combined mass fraction ($W_{\text{SrO}} + W_{\text{BaO}}$)

or, equivalently, combined mole fraction ($X_{\text{SrO}} + X_{\text{BaO}}$), can be optimized to obtain glasses with desired density, coefficient of thermal expansion and refractive index, without compromising the fundamental glass properties. In other words, to obtain low-density glasses, BaO may be set to 0 and the corresponding fraction of BaO may be replaced by SrO. For example, the concentration of SrO in Miwa '535's Embodiment 15 may be increased to $X_{\text{SrO}} = 0.84$ mol% with $X_{\text{BaO}} = 0.00$ mol%, while the other components remain unchanged. The reason for this replacement could be to reduce the mass density without compromising other important glass properties.

213. With SrO and BaO being mutually replaceable without compromising fundamental glass properties related to the network of chemical bonds, as discussed, it would have been obvious to replace BaO entirely with SrO. Replacing the mass of BaO with SrO (see paragraph 87), Embodiment 15 of Miwa (EX1004, Table 4) describes an SrO mole fraction of $X_{\text{SrO}} = 0.94$ mol% and a BaO mole fraction of $X_{\text{BaO}} = 0.00$ mol%,
214. The resulting mole fraction $X_{\text{BaO}} = 0.00$ mol% of BaO overlaps the BaO mole fraction of $X_{\text{BaO}} = 0-0.1$ mol% in Claim 16 and thus is obvious in view of Miwa '535 and Peuchert '469.

Q. Dependent Claim 17

215. *The glass sheet of claim 13 wherein the glass has a density that is less than or equal to 2.41 grams/cm³.*
216. Embodiment 15 of Miwa '535 describes a glass density of 2.39 g/cm³, which is within this range in dependent Claim 17. EX1004, Table 4.

217. Thus, Claim 15 is disclosed by and obvious in view of Miwa '535

R. Dependent Claim 18

218. *The glass sheet of claim 13 wherein the glass has a linear coefficient of thermal expansion (CTE) over the temperature range 0-300° C. which satisfies the relationship: $28 \times 10^{-7}/^{\circ}\text{C} \leq \text{CTE} \leq 34 \times 10^{-7}/^{\circ}\text{C}$.*

219. Miwa '535 describes (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** $\times 10^{-7}/^{\circ}\text{C}$. 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 102.5 poise³ is 1610°C or less, and the liquid phase temperature⁴ is 1120°C or less, so it also has excellent fusibility and formability. In addition, it showed excellent in acid resistance and BHF resistance."

220. Embodiment 15 of Miwa '535 reports a coefficient of thermal expansion (CTE) of $34 \times 10^{-7} \text{K}^{-1}$ when measured over a temperature range of (30..380) °C, which is in the range of $28 \times 10^{-7} \text{K}^{-1} \leq \text{CTE} \leq 34 \times 10^{-7} \text{K}^{-1}$ of limitation 7[c]. EX1004, Table 4.

221. While the CTE of Claim 18 refers to the temperature range (0..300) °C, Miwa '535's CTE refers to (30..380) °C. Paragraphs (123-143) herein show in

³ This is understood to be 10^{2.5} poise.

⁴ This is understood to be liquidus temperature.

great detail that the CTE within (0..300) °C is actually *lower* than within (30..380) °C.

222. Summarizing, this is shown in the following way: (i) Regarding thermal expansion, the glass composition of Miwa ‘535’s Embodiment 15 is equivalent to the composition of Sample #5 described in EX1010, “Attachment 2.2 ICP TEST_EN,”. (ii) provides experimental CTE data for Sample #6 is provided. (iii) Figure 7 shows that when measuring the *same* glass over $[T_1, T_2] = [0, 300]$ °C, the *effective* (average) thermal expansion coefficient, denoted as $\bar{\alpha}$ or CTE, will be found *smaller* than when measuring over $[T_3, T_4] = [30, 380]$ °C. (iv) For Sample #6, replacing $\alpha[T]$ by the derivative $f'[T]$ of the fitting function $f[T]$ yields a CTE of $\bar{\alpha} = 35.5 \cdot 10^{-7} \text{ K}^{-1}$ for $[T_3, T_4] = [30, 380]$ °C, but only $\bar{\alpha} = 34.0 \cdot 10^{-7} \text{ K}^{-1}$ $[T_1, T_2] = [0, 300]$ °C – significantly smaller. (v) Consequently, if the glass described in Miwa ‘535’s Embodiment 15 had been measured over $[T_1, T_2] = [0, 300]$ °C, the temperature interval used in the ‘491 Patent, the *effective* (average) thermal expansion coefficient, denoted as $\bar{\alpha}$ or CTE, would have been found *smaller* than the value of $34 \times 10^{-7} \text{ K}^{-1}$ that was found by measuring over $[T_3, T_4] = [30, 380]$ °C. Since $34 \times 10^{-7} \text{ K}^{-1}$ coincides with the upper limit of the range specified in limitation 4[b], the CTE that would have been found when measuring over $[T_1, T_2] = [0, 300]$ °C would safely be *within* that interval.
223. Therefore, for the temperature interval $[T_1, T_2] = [0, 300]$ °C referenced in the ‘491 Patent, the CTE of Miwa ‘535’s glass will overlap with the interval of $[28, 34] \cdot 10^{-7} \text{ K}^{-1}$ reported in the in Claim 18 and is obvious.

S. Dependent Claim 19

224. *The glass sheet of claim 13 wherein the glass has a liquidus temperature less than or equal to 1170° C.*

225. As described above, Miwa '535 describes glass compositions suitable for manufacturing glass sheets by a downdraw process and overlapping with all limitations of Claim 13.

226. The composition of Sample #5, EX1010, "Attachment 2.2 ICP TEST_EN," has a composition very similar to the glass described in Miwa '535's Embodiment 15. Differences in the mole fractions, if any, are in the sub-percent range and will, therefore, not significantly impact the liquidus temperature. Regarding the liquidus temperature, the glass composition of Sample #5 is *identical* to that of Miwa '535's Embodiment 15 except a) BaO in Embodiment 15 is replaced by SrO and b) Sb₂O₃, as a controlled substance, is not included in sample 5# but it has little impact on the liquidus viscosity. EX1010, "Foshan Ceramics Research Institute Testing Co., Ltd, Test Report: Sample #5," provides experimental data for the liquidus temperature of Sample #5. Accordingly, the liquidus temperature equals 1075 °C.

227. In conclusion, Miwa '535's Embodiment 15 teaches a glass that overlaps with Claim 19 and has a liquidus temperature less than or equal to 1170° C. Thus, I consider Claim obvious in view of these analyses.

T. Dependent Claim 20

228. *The glass sheet of claim 13 wherein the glass has a strain point that is greater than or equal to 650° C.*

229. Embodiment 15 of Miwa ‘535 describes a strain point at 673 °C, which is within the range of in Claim 20. EX1004, Table 4.

230. Thus, Claim 20 is described by and obvious in view of Miwa ‘535.

U. Dependent Claim 21

231. The glass sheet of claim 13 wherein the downdraw process is a fusion process.

232. As described above, Miwa ‘535 describes glass compositions suitable for manufacturing glass sheets by a downdraw process and overlapping with all limitations of Claim 13.

233. Miwa ‘535 teaches (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.” EX1004, [0036].

234. Among the methods listed, the overflow-die draw method is a fusion process. It is also called the “fusion” or “overflow” downdraw method. Molten glass overflows from a trough, flows down both sides, fuses at the bottom, and is drawn downward as a continuous sheet.

235. Overflow-die draw methods are fusion process. Therefore, Claim 21 is described by and obvious in view of Miwa '535.

V. Dependent Claim 22

236. *The glass sheet of claim 13 wherein: (i) the glass sheet has a volume of at least 500 cubic centimeters; and (ii) a population of 50 of the glass sheets sequentially produced by the drawdown process has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter.*

237. The 491 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 '491 Patent, the results may not be comparable for the following reasons:

238. The specification of Claim 22 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 22. 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.

239. Claim 22 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 ‘491 Patent.

240. Moreover, the specification in Claim 22 relies on processing parameters that are not are not part of the claims of the ‘491 Patent, nor part of the invention background described in the ‘491 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.
241. While Miwa ‘535 does not provide experimental data on glass quality under the – insufficient and arbitrary – conditions of Claim 22, Miwa ‘535 meets all relevant specifications given in the ‘491 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 ‘491 Patent does not specify any further process parameters required to obtain the specified limit for defects in Claim 22, 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 .”

242. Thus, Claim 22 is included in what is disclosed by Miwa ‘535 and I consider it obvious as reducing the number density and total volume of defects to a minimum is well-within the knowledge and abilities of a POSITA. This would have motivated obtaining a glass with an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter, as recited in Claim 22.

W. Dependent Claim 23

243. *The glass sheet of claim 13 wherein the glass has a liquidus viscosity greater than or equal to 200,000 poise.*

244. As shown above, the glass described in Miwa ‘535’s Embodiment 15 overlaps with Claim 13, including all limitations.

245. Regarding viscosity, the glass composition of Miwa ‘535’s Embodiment 15 is identical to the composition of Sample #5 described in EX1010 except a) BaO in Embodiment 15 is replaced by SrO and b) Sb_2O_3 , as a controlled substance, is not included in sample 5# but it has little impact on the liquidus viscosity,

“Attachment 2.2 ICP TEST_EN,”. EX1010, “Attachment 2.3 High-temperature viscosity (5#-LJJ)_EN,” provides experimental data for the viscosity of Sample #5.

246. According to Fig 1, the liquidus viscosity of the glass of Sample #5 is $10^{6.2}$ dPa. As, concerning viscosity, the glass composition described in Miwa ‘535’s Embodiment 15 is identical to that of Sample #5 except a) BaO in Embodiment 15 is replaced by SrO and b) Sb_2O_3 , as a controlled substance, is not included in sample 5# but it has little impact on the liquidus viscosity, this means that the glass of Miwa ‘535’s Embodiment 15 has a viscosity as recited in Claim 23. Thus, Claim 23 is obvious in view of Miwa ‘535.

X. Dependent Claim 24

247. The glass of claim 1 wherein the glass has a density that is less than or equal to 2.41 grams/cm³.

248. Embodiment 15 of Miwa ‘535 describes a glass density of 2.39 g/cm³, which is within the range of “a density that is less than or equal to 2.41 g/cm³” as in Claim 24. EX1004, Table 4.

249. Thus, Claim 24 is disclosed by and obvious in view of Miwa ‘535.

VII. GROUND 2: CLAIMS 1-12 AND 16 WOULD HAVE BEEN OBVIOUS OVER JP ‘643 IN VIEW OF JP ‘741 AND PEUCHERT ‘469, CLAIMS 13-15 AND 17-24 WOULD HAVE BEEN OBVIOUS OVER JP ‘643 IN VIEW OF JP ‘741

A. Independent Claim 1

250. **Limitation 1[p]:** *An alkali-free glass for a downdraw process comprising in mole percent on an oxide basis:*

251. JP ‘643 describes: “Additionally, the alkali-free glass of the present invention has a liquidus temperature of 1,150°C or lower (preferably 1,130°C or lower, more preferably 1,100°C or lower) and a viscosity at the liquidus temperature of 10^{5.4} dPa·s or higher (preferably 10^{6.0} dPa·s or higher), enabling formation into sheets by the downdraw method without devitrification and allowing the omission of polishing processes to reduce production costs.” EX1007, ¶ 0030.

252. JP ‘741 describes: “The molten glass is then molded into the desired shape. For display applications, the fusion method, down-draw method, float method, or roll-out method, etc. is used to mold the glass into thin sheets.” EX1005, ¶0021

253. Peuchert ‘469 describes: “The invention relates to an alkali-free aluminoboro-silicate glass. The invention also relates to uses of this glass. High requirements are placed on glasses for applications as substrates in flat-panel liquid-crystal display technology . . .” EX1006, ¶¶0001, 0002

254. Thus, all of JP ‘643, JP ‘741, and Peuchert ‘469 describe limitation 1[p] in Claim 1.

255. **Limitations 1[a]-1[f]:** *SiO₂: 64.0-71.0; Al₂O₃: 9.0-12.0; B₂O₃: 7.0-12.0; MgO: 1.0-3.0; CaO: 6.0-11.5; SrO: 0-2.0*

256. JP '643 describes several examples, including Sample 5:

		Sample No. 4		Sample No. 5		Sample No. 6	
		Mass %	mol%	Mass %	mol%	Mass %	mol%
SiO ₂		61.2	67.4	61.2	67.2	61.7	68.2
Al ₂ O ₃		16.8	10.9	16.8	10.9	17.0	11.1
B ₂ O ₃		11.8	11.3	11.8	11.2	10.5	10.0
MgO		0.5	0.8	1.0	1.6	-	-
CaO		7.4	8.7	6.9	9.3	8.0	9.5
SrO		0.5	0.3	0.5	0.3	1.0	0.6
BaO		0.5	0.2	0.5	0.2	0.5	0.2
ZnO		-	-	-	-	-	-
P ₂ O ₅		-	-	-	-	-	-
As ₂ O ₃		-	-	-	-	-	-
SnO ₂		-	-	-	-	-	-
Sb ₂ O ₃		1.0	0.2	1.0	0.2	1.0	0.2
ZrO ₂		0.3	0.2	0.3	0.2	0.3	0.2
Cl		-	-	-	-	-	-
(BaO + SrO)/BaO		2		2		3	
Density (g/cm ³)		2.382		2.379		2.400	
Thermal expansion coefficient [30-380°C] (x10 ⁻⁷ /°C)		33		32		34	
Viscosity	Strain point (°C)	669		670		674	
	Annealing point (°C)	724		724		731	
	Softening point (°C)	973		973		984	
	10 ^{4.0} (°C)	1301		1301		1322	
	10 ^{3.0} (°C)	1467		1467		1488	
	10 ^{2.5} (°C)	1573		1573		1597	
Young's modulus		70		70		71	
Specific Young's modulus		29.3		29.5		29.4	
BHF resistance	Corrosion (μm)	0.6		0.6		0.6	
	Visual appearance evaluation	○		○		○	
HC resistance	Corrosion (μm)	7.3		7.3		4.6	
	Visual appearance evaluation	○		○		○	

Liquidus temperature (°C)	1128	1146	1094
Liquidus viscosity	10 ^{5.6}	10 ^{5.4}	10 ^{6.1}

EX1007, Table 3.

257. As shown in Table 10 below, the composition of Sample 5 in JP ‘643 overlaps with each of limitations 1[a]-1[f].

Table 9: Glass Composition

Oxide	JP ‘643 Sample 5 (mol%)	‘491 Patent Limitation 1[a] (mol%)
SiO ₂	67.2	64.0 - 71.0
Al ₂ O ₃	10.9	9.0 - 12.0
B ₂ O ₃	11.2	7.0 - 12.0
MgO	1.6	1.0 - 3.0
CaO	9.3	6.0 - 11.5
SrO	0.3	0 - 2.0

258. **Limitation 1[g]:** *BaO: 0-0.1*

259. JP ‘643 describes: “BaO and SrO are components that improve the chemical resistance and devitrification resistance of the glass, but if contained in large amounts, they increase the glass’s density and thermal expansion coefficient. Therefore, their respective contents must be restricted to 0.1–5% for BaO and 0–4% for SrO. Particularly when reducing BaO and SrO to achieve lower density, if the contents of these two components become extremely imbalanced, the effect of improving BHF resistance diminishes.” EX1007, ¶ 0039.

260. Peuchert ‘469 describes: “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.”

EX1006, ¶¶ 0024, 0025, 0026.

261. JP ‘643 considered with Peuchert ‘469 provides motivation for not using BaO and that the roles of SrO BaO are similar with regard to the atomistic network structure of the glass. This is consistent with the analysis detailed in paragraph 72-75, according to which Sr and Ba play a similar role of network modifiers in the silicate glass structure. Thus, it is obvious that the properties of a relevant glass can be optimized by substituting part or all of its BaO fraction (mass- or mole fraction) by a corresponding (mass- or mole-) fraction of SrO. This can result in BaO mole fractions X_{BaO} overlapping with Limitation 1[g] as well as SrO mole fractions X_{SrO} within the ranges of Claim 1[g].
262. In JP ‘643’s Sample 5, for example, the mass fractions of SrO and BaO are $W_{\text{SrO}}=0.5 \text{ ms\%}$ and $W_{\text{BaO}}=0.5 \text{ ms\%}$, respectively. Referring to paragraph 85, consider replacing BaO “mass-wise” by SrO, i.e. replacing the mass fraction $W_{\text{BaO}}=0.5 \text{ ms\%}$ entirely by a corresponding additional mass fraction $\Delta W_{\text{SrO}}=0.5 \text{ ms\%}$ of SrO, so that the total SrO mass fraction becomes

$W_{\text{SrO}} = 1.0 \text{ mol\%}$. Then, the *mole* fractions of SrO and BaO become $X_{\text{SrO}} = 0.64 \text{ mol\%}$ and $X_{\text{BaO}} = 0 \text{ mol\%}$, respectively. This agrees with Limitations 1[g-f].

263. From JP '643 considered with Peuchert '469, as well as from textbook knowledge (paragraph 72-75), such substitution would have been obvious.

264. **Limitation 1[h]:** *wherein: (a) $1.00 \leq \Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$, where $[\text{Al}_2\text{O}_3]$ is the mole percent of Al_2O_3 and $\Sigma[\text{RO}]$ equals the sum of the mole percents of MgO, CaO, SrO, and BaO;*

265. Sample 5 of JP '643 includes a $\Sigma_{i \in R} X_i / X_{\text{Al}_2\text{O}_3} = 1.05$, where summing is performed over the alkaline earth metal oxides of the set $R = \{\text{MgO}, \text{CaO}, \text{SrO}, \text{BaO}\}$. This value is within the range of Limitation 1[h] and as such would have been obvious.

266. **Limitations 1[i]-[l]:** *(b) the glass has the following compositional characteristics:*

(i) on an oxide basis, the glass comprises at most 0.05 mole percent As_2O_3 ;

(ii) on an oxide basis, the glass comprises at most 0.05 mole percent Sb_2O_3 ;

and

(iii) on an oxide basis, the glass comprises at least 0.01 mole percent SnO_2 ;

and

267. JP '741 describes: "However, because 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.”

“Next, SnO_2 is added to the glass raw material mixture. The amount of SnO_2 added is 0.05 to 2.0 wt% of the glass raw material mixture. The reason for this range is that an amount less than 0.05% has no clarifying effect, and an amount more than 2.0% increases the amount of volatiles, making the glass more susceptible to deterioration.”

EX1005, ¶¶ 0005, 0006, 0022, 0025.

268. JP ‘741 considered jointly with JP ‘643 provides a motivation to avoid the use of toxic fining agents and instead using only SnO_2 as a fining agent. Additionally, the composition of Sample 5 in JP ‘643 falls within the compositional range described in JP ‘741, making it applicable to use the same types and contents of fining agents.
269. In JP ‘741, the passage “Next, SnO_2 is *added* to the glass raw material mixture. The amount of SnO_2 added is 0.05 to 2.0 wt% *of* the glass raw material mixture.” describes *adding* the fining agent SnO_2 as an amount that corresponds to a *mass* fraction of 0.05 to 2.0 % of the total mass of all other components, considered as exactly 100 %. So, after adding e.g. 2.0 % SnO_2 , the total mass will be 102.0 % of what it was before. In the following, I investigate the *mole* fraction of SnO_2 obtained by adding it to the composition of Embodiment 15 of Miwa ‘535 in

this way, after replacing BaO with SrO “mass-wise” and setting the mass fraction of Sb_2O_3 to 0: $W_{\text{Sb}_2\text{O}_3}=0$.

270. The following shows that combining the example of JP ‘643’s Sample 5 with the teachings of JP ‘741 discloses Limitations 1[j-1]. This includes the following steps to be applied to the composition of Sample 5 in JP ‘741 (EX1007, Table 3):

- (i) Remove the mass fraction $W_{\text{Sb}_2\text{O}_3}=1 \text{ ms}\%=0.01$ of Sb_2O_3 and renormalize all other mass fractions with a factor $k_1=1/(1-W_{\text{Sb}_2\text{O}_3})$. Let these renormalized mass fractions be denoted as V_i .
- (ii) Add the resulting renormalized value V_{BaO} of the BaO mass fraction to the renormalized value V_{SrO} of the SrO mass fraction and set the BaO mass fraction to zero:

$$\begin{array}{ccc} V_{\text{SrO}} = k_1 \cdot 0.005 & \xrightarrow{\text{Replace}} & V_{\text{SrO}} = k_1 \cdot 0.010 \\ V_{\text{BaO}} = k_1 \cdot 0.005 & & V_{\text{BaO}} = 0 \end{array}$$

- (iii) Considering the resulting $\sum V_i$ as exactly 100ms%, as JP ‘741 suggests, *add* a mass of SnO_2 as fraction $Q_{\text{SnO}_2}=(0.0005 \text{ .. } 0.0200)$ (i.e. 0.05 to 2.00 ms%) of that glass mass without SnO_2 . Now, the sum of all mass fractions will be $(1 + Q_{\text{SnO}_2})\sum V_i$. So, renormalize the mass fractions V_i by multiplying them with the factor $k_2 = 1/(1 + Q_{\text{SnO}_2})$. Let these renormalized mass fractions be denoted as U_i .
- (iv) Convert the mass fractions U_i to mole fractions X_i to obtain the glass composition $\{X_i\}$, $i = 1, \dots, N$, including the added SnO_2 , removed Sb_2O_3 , and additional SrO from “mass-wise” replacement of BaO. As usual, the mole fractions X_i can be obtained from mass fractions U_i according to

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

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.

271. Result: Adding SnO_2 as a mass corresponding to $Q_{\text{SnO}_2} = 0.05\%$ of the mass without SnO_2 to the composition of Sample 5 in JP ‘643 after removing Sb_2O_3 and replacing BaO “mass-wise” with SrO yields the results shown in the following Table 11. Already for the smallest addition of SnO_2 specified in JP ‘741, $Q_{\text{SnO}_2} = 0.05 \text{ ms}\%$, the resulting SnO_2 mole fraction of $X_{\text{SnO}_2} = 0.02 \text{ mol}\%$ is in agreement with “at least 0.01 mole percent SnO_2 ,” as specified in Limitation 1[l].

Table 10

Component	$X \text{ (mol\%)}$ $Q_{\text{SnO}_2} = 0.05 \text{ ms}\%$	$X \text{ (mol\%)}$ $Q_{\text{SnO}_2} = 2.00 \text{ ms}\%$
SiO_2	67.3	66.8
Al_2O_3	10.9	10.8
B_2O_3	11.2	11.1
MgO	1.6	1.6
CaO	8.1	8.1
SrO	0.64	0.63
BaO	0.00	0.00
ZrO_2	0.16	0.16
As_2O_3	0	0
Sb_2O_3	0.00	0.00
SnO_2	0.02	0.86

272. The glass compositions shown in JP ‘741 are free of both As_2O_3 or Sb_2O_3 . This is confirmed by the observation that the glass compositions shown in the examples in Table 2 in JP ‘741 do neither list As_2O_3 , nor Sb_2O_3 , and add up to exactly 1 (100mol%). JP ‘643’s Sample 5 is free of As_2O_3 . With that, a mass fraction of $W_{\text{Sb}_2\text{O}_3}=0$ implying a mole fraction of $X_{\text{Sb}_2\text{O}_3}=0\text{ mol}\%$ and the mole fraction of $X_{\text{SnO}_2}=0.02\text{ mol}\%$ (at least), JP ‘643 in view of JP ‘741 overlaps with each of limitations 1[j]-[l].

273. Thus, each of Limitations 1[i]-[l] is obvious in view of these collective disclosures.

274. **Limitation 1[m]:** *(c) the glass has a liquidus viscosity that is greater than or equal to 100,000 poise*

275. Sample 5 of JP ‘643 reports a liquidus viscosity of $10^{5.4}\text{ dPa}\cdot\text{s}$ ($250,000 \pm 60,000$)P. This value, including its lower uncertainty boundary, falls within the range of Limitation 1[m].

276. As JP ‘643 considered with JP ‘741 and Peuchert ‘469 discloses substantially the same composition and properties, a skilled person would have found Claim 1 obvious when these citations are properly understood.

B. Dependent Claim 2

277. *The glass of claim 1 wherein: $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3] \leq 1.25$.*

278. Sample 5 in JP ‘643 meets this ratio. The data shown in Table 3 of JP ‘643 yields $\sum_{i \in R} X_i / X_{\text{Al}_2\text{O}_3} = 1.05$.

279. Thus, Claim 2 is disclosed by Miwa and is obvious in view of this Sample 5.

C. Dependent Claim 3

280. *The glass of claim 1 wherein, on an oxide basis, SrO is at most 1.0 mole percent.*

281. In JP ‘643’s Sample 5, for example, the mass fractions of SrO and BaO are $W_{\text{SrO}}=0.5 \text{ ms\%}$ and $W_{\text{BaO}}=0.5 \text{ ms\%}$, respectively. Combining the example of JP ‘643’s Sample 5 with the teachings of JP ‘741, as described under Limitations 1[i]-[l] of Claim 1, consider replacing BaO with SrO “mass-wise,” i.e. replacing the mass fraction $W_{\text{BaO}}=0.5 \text{ ms\%}$ entirely by a corresponding additional mass fraction $\Delta W_{\text{SrO}}=0.5 \text{ ms\%}$ of SrO, so that the total SrO mass fraction becomes $W_{\text{SrO}}=1.0 \text{ ms\%}$. Then, the *mole* fractions of SrO and BaO become $X_{\text{SrO}}=0.64 \text{ mol\%}$ and $X_{\text{BaO}}=0 \text{ mol\%}$, respectively (Table 11, paragraph 271). An SrO mole fraction of $X_{\text{SrO}} = 0.64 \text{ mol\%}$ is within the range of at most 1.0 mol% in Claim 3.

282. Thus, Claim 3 is disclosed by JP ‘643 and is obvious in view of this Sample 5.

D. Dependent Claim 4

283. *The glass of claim 1 wherein the glass has at least one of the following properties: (a) a density that is less than or equal to 2.41 grams/cm³; (b) a linear coefficient of thermal expansion (CTE) over the temperature range 0-300° C. which satisfies the relationship: $28 \times 10^{-7}/^{\circ} \text{C.} \leq \text{CTE} \leq 34 \times 10^{-7}/^{\circ} \text{C.}$; (c) a liquidus temperature less than or equal to 1170° C.; (d) a strain point that is greater than or equal to 650° C.*

284. (a) Sample 5 of JP ‘643 has a density of 2.379 g/cm³ and is thus within the range of Claim 4.

285. (b) Within the temperature interval $[T_3, T_4] = [30, 380] ^{\circ}\text{C}$, Sample 5 of JP ‘643

has an effective thermal expansion coefficient of $\bar{\alpha} = 32 \cdot 10^{-7} \text{ K}^{-1}$. This is within the range specified in Claim 4. In paragraphs 123-143, it is shown that within $[T_1, T_2] = [0, 300] \text{ }^\circ\text{C}$, the temperature interval to which Claim 4 refers, glasses with this composition have a somewhat *lower* effective thermal expansion coefficient $\bar{\alpha}$. According to the calculations shown in paragraphs 123-143, $\bar{\alpha}$ will be lower by $(1..2) \cdot 10^{-7} \text{ K}^{-1}$ over that temperature interval, i.e. $\bar{\alpha} = (30..31) \cdot 10^{-7} \text{ K}^{-1}$. This value is still safely within the range specified in Claim 4.

286. (c) Sample 5 of JP ‘643 has a liquidus temperature of 1146 °C. This is within the range of Claim 4.

287. (d) Sample 5 of JP ‘643 has a strain point of 670 °C and is thus within the range of Claim 4.

288. Thus, Claim 4 is disclosed by Miwa and is obvious in view of this Sample 5.

E. Dependent Claim 5

289. *The glass of claim 4 wherein the glass has at least properties (a) through (c).*

290. As is clear from the analysis of Claim 4 above, JP ‘643 includes properties (a), (b) and (c) and are obvious in view of JP ‘643.

F. Dependent Claim 6

291. *The glass of claim 4 wherein the glass has properties (a) through (d).*

292. As is clear from the analysis of Claim 4 above, JP ‘643 includes properties (a)-(d) and are obvious in view of JP ‘643.

G. Dependent Claim 7

293. *The glass of claim 1 wherein the glass has a liquidus viscosity greater than or equal to 200,000 poise.*

294. Sample 5 of JP '643 reports a liquidus viscosity of $10^{5.4}$ dPa·s ($250,000 \pm 60,000$) P. This value, including its lower uncertainty boundary, is greater than 200,000 P, as in Claim 7 and is obvious in view of JP '643.

H. Dependent Claim 8

295. *The glass of claim 1 wherein, on an oxide basis, the glass comprises at most 0.15 mole percent SnO₂*

296. Embodiment No. 5 of JP '643 has 0 mol% SnO₂. EX1007, Table 3. Additionally, JP '741 teaches an amount of SnO₂ added is 0.05 to 2.0 wt% of the glass raw material mixture. EX1005, ¶ [0019]. Therefore, it would have been obvious to adjust the mole fraction of SnO₂ through JP '741 to achieve optimal glass performance such as for example to facilitate clarification and attenuate deterioration.

I. Dependent Claim 9

297. *The glass of claim 1 wherein the glass has a MgO content between 1.2 and 2.8 mole percent.*

298. Embodiment No. 5 of JP '643 has 1.6 mol% MgO and as this falls within the range of 1.2 and 2.8 mole percent in Claim 9, Claim 9 would have been obvious.

J. Dependent Claim 10

299. *The glass of claim 1 wherein the glass is substantially free of BaO.*

300. As is evident from limitation 1[g], JP '643 considered with Peuchert '469 provides motivation for not using BaO and as such Claim 10 would have been obvious.

K. Dependent Claim 11

301. *The glass of claim 1 wherein the glass comprises at most 0.005 mole percent As₂O₃ and at most 0.005 mole percent Sb₂O₃.*

302. Sample 5 of JP '643 includes As₂O₃: 0 mol%, Sb₂O₃ 0.2 mol%.

303. The glass compositions shown in JP '741 are free of both As₂O₃ or Sb₂O₃. This is confirmed by the observation that the glass compositions shown in the examples in Table 2 in JP '741 do neither list As₂O₃, nor Sb₂O₃, and add up to exactly 1 (100 mass%). EX1005, Table 2.

304. As is discussed in the context of Claim 1, limitations [i]-[l], JP '741 considered with JP '643 provides a motivation to avoid the use of toxic fining agents and instead using only SnO₂ as a fining agent. Additionally, the composition of Sample 5 in JP '643 falls within the compositional range described in JP '741, making it applicable to use the same types and contents of fining agents.

305. JP '741 discloses that the mass percentage of the SnO₂ fining agent is 0.05–2 mass%. When replacing the fining agent in JP '643 with SnO₂, the mass percentages of the other components are scaled to 100% minus the mass ratio of SnO₂. That is, when SnO₂ takes the endpoint values of 0.05 and 2 mass%, the

mass percentages of the other components are 99.5 and 98 mass%, respectively. Thus, the corresponding mass percentages and molar percentages for the end-point values are calculated as follows. The converted values for each component and $\Sigma[\text{RO}]/[\text{Al}_2\text{O}_3]$ still remains within the scope of Claim 1 of the '491 patent. The calculated molar percentage range of SnO_2 is 0.02–0.88 mol% as shown in the following Table:

	BaO substituted by SrO	0.05 wt% SnO_2		2 wt% SnO_2	
	wt%	wt%	mol%	wt%	mol%
SiO_2	61.2	61.2	67.32	61.2	66.75
Al_2O_3	16.8	16.8	10.89	16.8	10.80
B_2O_3	11.8	11.8	11.20	11.8	11.11
MgO	1	1	1.64	1	1.63
CaO	6.9	6.9	8.13	6.9	8.06
SrO	1	1	0.64	1	0.63
BaO	0	0	0.00	0	0.00
Fe_2O_3	0	0	0.00	0	0.00
ZrO	0.3	0.3	0.16	0.3	0.16
Sb_2O_3	1	0.00	0.00	0.00	0.00
SnO_2	0	0.05	0.02	1.98	0.86

306. Thus, Claim 11 is obvious when the combination of JP '643 and JP '741 is considered.

L. Dependent Claim 12

307. *The glass of claim 1 wherein the downdraw process is a fusion process.*

308. JP '741 describes: "For display applications, the fusion method, down-draw method, float method, or roll-out method, etc. is used to mold the glass into thin

sheets.” EX1005, ¶ [0021].

309. JP ‘643 describes (emphasis added): “Furthermore, glass substrates for TFT-LCDs are primarily formed using the **downdraw method or the float method**. Examples of the downdraw method include the slot downdraw method and the overflow downdraw method. Glass substrates formed by the **downdraw method** do not require polishing, offering the advantage of cost reduction. However, when forming glass substrates using the **downdraw method**, the glass is prone to devitrification, necessitating glass with excellent devitrification resistance.” EX1007, ¶ [0021].

“Additionally, the alkali-free glass of the present invention has a liquidus temperature of 1,150°C or lower (preferably 1,130°C or lower, more preferably 1,100°C or lower) and a viscosity at the liquidus temperature of $10^{5.4}$ dPa·s or higher (preferably $10^{6.0}$ dPa·s or higher), enabling formation into sheets by **the downdraw method** without devitrification and allowing the omission of polishing processes to reduce production costs.” EX1007, ¶ [0030].

“Additionally, the glass of Sample 36 from the examples was melted in a test melting furnace and formed using the **overflow downdraw method** to produce a display glass substrate with a thickness of 0.5 mm.” EX1007, ¶ [0084].

Furthermore, the alkali-free glass of the present invention has a low liquidus temperature and high liquidus viscosity, making it suitable for forming into sheets using **the downdraw method**.” EX1007, ¶ [0086].

310. The third paragraph, EX1007, ¶ [0084], clarifies that “the downdraw method” mentioned in the other paragraphs refers to the *overflow* downdraw method, which implies “fusion.”

311. In summary, JP ‘643 and JP ‘741 (EX1005, ¶ 0021) describe that it was well-

known to make glass articles by a downdraw process that is a fusion process. Samples studied in JP ‘643 were actually made by a downdraw process that is fusion process. Thus, JP ‘643 and JP ‘741 disclose Claim 12 and is obvious.

M. Independent Claim 13

312. **Limitation 13[p]:** *An alkali-free glass sheet produced by a downdraw process comprising a glass that comprises SiO₂, Al₂O₃, B₂O₃, MgO, and CaO, and, on an oxide basis, has:*

313. JP ‘643 describes (emphasis added): “Additionally, the alkali-free glass of the present invention has a liquidus temperature of 1,150°C or lower (preferably 1,130°C or lower, more preferably 1,100°C or lower) and a viscosity at the liquidus temperature of 10^{5.4} dPa·s or higher (preferably 10^{6.0} dPa·s or higher), enabling formation into sheets by the **downdraw** method without devitrification and allowing the omission of polishing processes to reduce production costs. EX1007, ¶ 0030.

314. JP ‘741 describes (emphasis added): “The molten glass is then molded into the desired shape. For display applications, the **fusion** method, **down-draw method**, float method, or roll-out method, etc. is used to mold the glass into thin sheets.” EX1005, ¶ 0021.

315. Peuchert ‘469 describes (emphasis added): “The invention relates to an **alkali-free** aluminoborosilicate glass. The invention also relates to uses of this glass. High requirements are placed on glasses for applications as substrates in flat-panel liquid-crystal display technology . . .” EX1006, ¶¶ 0001, 0002.

316. Thus, all of JP ‘643, JP ‘741 and Peuchert ‘469 describe limitation 1[p] in

Claim 13.

317. **Limitation 13[a]:** *(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*

318. For the composition of Sample 5 in JP '643, $\sum_{i \in R} X_i / X_{Al_2O_3} = 1.05$. This value is within the range of Limitation 13[a].

319. **Limitation 13[b]:** *(ii) MgO content greater than or equal to 1.0 mole percent*

320. Sample 5 of JP '643 includes 1.6 mol% of MgO , which is within the range of Limitation 13(ii).

321. **Limitations 13[c]-[f]:** *wherein*

(a) on an oxide basis, the glass comprises at most 0.005 mole percent As_2O_3 ;

(b) on an oxide basis, the glass comprises at most 0.005 mole percent Sb_2O_3 ;

(c) on an oxide basis, the glass comprises at least 0.01 mole percent SnO_2 ; and

322. JP '741 describes: "However, because 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."

“Next, SnO₂ is added to the glass raw material mixture. The amount of SnO₂ added is 0.05 to 2.0 wt% of the glass raw material mixture. The reason for this range is that an amount less than 0.05% has no clarifying effect, and an amount more than 2.0% increases the amount of volatiles, making the glass more susceptible to deterioration.”

EX1005, ¶¶ 0005, 0006, 0022, 0025.

323. JP ‘741 considered jointly with JP ‘643 provides a motivation to avoid the use of toxic fining agents and instead using only SnO₂ as a fining agent. Additionally, the composition of Sample 5 in JP ‘643 falls within the compositional range described in JP ‘741, making it applicable to use the same types and contents of fining agents.
324. In JP ‘741, the passage “Next, SnO₂ is *added* to the glass raw material mixture. The amount of SnO₂ added is 0.05 to 2.0 wt% *of* the glass raw material mixture.” describes *adding* the fining agent SnO₂ as an amount that corresponds to a *mass* fraction of 0.05 to 2.0 % of the total mass of all other components, considered as exactly 100 %. So, after adding e.g. 2.0 % SnO₂, the total mass will be 102.0 % of what it was before. In the following, I investigate the *mole* fraction of SnO₂ obtained by adding it to the composition of Embodiment 15 of Miwa ‘535 in this way, after replacing BaO with SrO “mass-wise” and setting the mass fraction of Sb₂O₃ to 0: $W_{\text{Sb}_2\text{O}_3}=0$.
325. The following shows that combining the example of JP ‘643’s Sample 5 with the teachings of JP ‘741 discloses Limitations 113[c-f]. This includes the following steps to be applied to the composition of Sample 5 in JP ‘741 (EX1007, Table 3):
- (v) Remove the mass fraction $W_{\text{Sb}_2\text{O}_3}=1 \text{ ms}\%=0.01$ of Sb₂O₃ and renormalize

all other mass fractions with a factor $k_1 = 1/(1 - W_{\text{Sb}_2\text{O}_3})$. Let these renormalized mass fractions be denoted as V_i .

- (vi) Add the resulting renormalized value V_{BaO} of the BaO mass fraction to the renormalized value V_{SrO} of the SrO mass fraction and set the BaO mass fraction to zero:

$$\begin{array}{ccc} V_{\text{SrO}} = k_1 \cdot 0.005 & \xrightarrow{\text{Replace}} & V_{\text{SrO}} = k_1 \cdot 0.010 \\ V_{\text{BaO}} = k_1 \cdot 0.005 & & V_{\text{BaO}} = 0 \end{array}$$

- (vii) Considering the resulting $\sum V_i$ as exactly 100ms%, as JP '741 suggests, *add* a mass of SnO_2 as fraction $Q_{\text{SnO}_2} = (0.0005 \text{ .. } 0.0200)$ (i.e. 0.05 to 2.00 ms%) of that glass mass without SnO_2 . Now, the sum of all mass fractions will be $(1 + Q_{\text{SnO}_2})\sum V_i$. So, renormalize the mass fractions V_i by multiplying them with the factor $k_2 = 1/(1 + Q_{\text{SnO}_2})$. Let these renormalized mass fractions be denoted as U_i .

- (viii) Convert the mass fractions U_i to mole fractions X_i to obtain the glass composition $\{X_i\}$, $i = 1, \dots, N$, including the added SnO_2 , removed Sb_2O_3 , and additional SrO from “mass-wise” replacement of BaO. As usual, the mole fractions X_i can be obtained from mass fractions U_i according to

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

- (ix) 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.

326. Result: Adding SnO_2 as a mass corresponding to $Q_{\text{SnO}_2} = 0.05\%$ of the mass without SnO_2 to the composition of Sample 5 in JP '643 after removing Sb_2O_3

and replacing BaO “mass-wise” with SrO yields the results shown in the following Table 12. Already for the smallest addition of SnO₂ specified in JP ‘741, $Q_{\text{SnO}_2} = 0.05 \text{ ms\%}$, the resulting SnO₂ mole fraction of $X_{\text{SnO}_2} = 0.02 \text{ mol\%}$ is in agreement with “at least 0.01 mole percent SnO₂,” as specified in Limitation 1[l].

Table 11

Component	X (mol%) $Q_{\text{SnO}_2} = 0.05 \text{ ms\%}$	X (mol%) $Q_{\text{SnO}_2} = 2.00 \text{ ms\%}$
SiO ₂	67.3	66.8
Al ₂ O ₃	10.9	10.8
B ₂ O ₃	11.2	11.1
MgO	1.6	1.6
CaO	8.1	8.1
SrO	0.64	0.63
BaO	0.00	0.00
ZrO ₂	0.16	0.16
As ₂ O ₃	0	0
Sb ₂ O ₃	0.00	0.00
SnO ₂	0.02	0.86

327. The glass compositions shown in JP ‘741 are free of both As₂O₃ or Sb₂O₃. This is confirmed by the observation that the glass compositions shown in the examples in Table 2 in JP ‘741 do neither list As₂O₃, nor Sb₂O₃, and add up to exactly 1 (100ms%). JP ‘643’s Sample 5 is free of As₂O₃. With that, a mass fraction of $W_{\text{Sb}_2\text{O}_3} = 0$ implying a mole fraction of $X_{\text{Sb}_2\text{O}_3} = 0 \text{ mol\%}$ and the mole fraction of $X_{\text{SnO}_2} = 0.02 \text{ mol\%}$ (at least), JP ‘643 in view of JP ‘741 overlaps with each of limitations 13[d]-[f].

328. Thus, each of Limitations 13[d]-[f] is obvious in view of these collective disclosures.

329. **Limitation 13[g]:** *(d) the glass has a liquidus viscosity that is greater than or equal to 100,000 poise.*

330. Sample 5 of JP '643 reports a liquidus viscosity of $10^{5.4}$ dPa·s ($250,000 \pm 60,000$) P. This value, including its lower uncertainty boundary, is greater than 200,000 P, as formulated in Claim 13[g].

331. As JP '643 considered with JP '741 discloses substantially the same composition and properties, a skilled person would have found Claim 13 obvious when these citations are properly understood.

N. Dependent Claim 14

332. *The glass sheet of claim 13 wherein on an oxide basis, the glass comprises at most 0.15 mole percent SnO₂.*

333. As discussed in regards to Limitation 13[f], JP '741 considered with JP '643 provides a motivation to avoid the use of toxic fining agents and instead using only SnO₂ as a fining agent.

334. Repeating the above calculation for the maximum fraction of SnO₂ specified in JP '741, i.e. adding a mass of SnO₂ corresponding to $Y_1 = 0.0020 = 0.2\%$ of the mass without SnO₂ to the glass composition of Sample 5 of JP '643, yields a glass with an SnO₂ mole fraction of $X_1 = X_{\text{SnO}_2} = 0.00088$ – or 0.088 mol%.

335. The upper limit of $X_{\text{SnO}_2} = 0.088$ mol% obtained in this way is within the range of Claim 14 and as such Claim 14 is obvious.

O. Dependent Claim 15

336. *The glass sheet of claim 13 wherein the glass has a MgO content between 1.2 and 2.8 mole percent.*

337. Embodiment 5 of JP '643 has 1.6 mol% **MgO**, *hence falls within the range of 1.2 and 2.8 mole percent in Claim 15.*

338. Thus, Claim 15 is disclosed by JP '643 and is obvious.

P. Dependent Claim 16

339. *The glass sheet of claim 13 wherein the glass is substantially free of BaO.*

340. JP '643 describes: "BaO and SrO are components that improve the chemical resistance and devitrification resistance of the glass, but if contained in large amounts, they increase the glass's density and thermal expansion coefficient. Therefore, their respective contents must be restricted to 0.1–5% for BaO and 0–4% for SrO. Particularly when reducing BaO and SrO to achieve lower density, if the contents of these two components become extremely imbalanced, the effect of improving BHF resistance diminishes." EX1007, ¶ 0039.

341. Peuchert '469 describes: "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 re-

stricted 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.”

EX1006, ¶¶ 0024, 0025, 0026.

342. As shown above, a skilled person would have found Claim 16 obvious from JP ‘643 considered with JP ‘741 and Peuchert ‘469. JP ‘643 considered with Peuchert ‘469 provides motivation for not using BaO, and that the roles of BaO are similar to that of SrO. Thus, the corresponding BaO fraction can be substituted by SrO and optimized to result in SrO mole fractions X_{SrO} within the ranges of Claim 1 and BaO mole fractions X_{BaO} overlapping with Claim 16. Thus, Claim 16 is also obvious when JP ‘643 considered with JP ‘741 and Peuchert ‘469 are properly understood.

Q. Dependent Claim 17

343. *The glass sheet of claim 13 wherein the glass has a density that is less than or equal to 2.41 grams/cm³.*

344. Sample 5 of JP ‘643 has a density of 2.379 g/cm³. This value falls within the range of Claim 17 and as such Claim 17 is obvious.

R. Dependent Claim 18

345. *The glass sheet of claim 13 wherein the glass has a linear coefficient of thermal*

expansion (CTE) over the temperature range 0-300° C. which satisfies the relationship: $28 \times 10^{-7}/^{\circ}\text{C.} \leq \text{CTE} \leq 34 \times 10^{-7}/^{\circ}\text{C.}$

346. Within the temperature interval $[T_3, T_4] = [30, 380]^{\circ}\text{C}$, Sample 5 of JP ‘643 has an effective thermal expansion coefficient of $\bar{\alpha} = 32 \cdot 10^{-7} \text{ K}^{-1}$. This is within the range specified in Claim 18. In paragraphs 123-143, it is shown that within $[T_1, T_2] = [0, 300]^{\circ}\text{C}$, the temperature interval to which Claim 18 refers, glasses with this composition have a somewhat *lower* effective thermal expansion coefficient $\bar{\alpha}$. According to the calculations shown in paragraphs 123-143, $\bar{\alpha}$ will be lower by $(1..2) \cdot 10^{-7} \text{ K}^{-1}$ over that temperature interval, i.e. $\bar{\alpha} = (30..31) \cdot 10^{-7} \text{ K}^{-1}$. This value is still safely within the range specified in Claim 18.
347. As shown above, a skilled person would have found Claim 13 obvious from JP ‘643 considered with JP ‘741 and Peuchert ‘469. Since Sample 5 of JP ‘643 has a CTE within the specified range, JP ‘643 overlaps with Claim 18 and is also obvious.

S. Dependent Claim 19

348. *The glass sheet of claim 13 wherein the glass has a liquidus temperature less than or equal to 1170° C.*
349. Sample 5 of JP ‘643 has a liquidus temperature of 1146 °C. As this is within the range, Claim 19 is obvious.

T. Dependent Claim 20

350. *The glass sheet of claim 13 wherein the glass has a strain point that is greater*

than or equal to 650° C.

351. Sample 5 of JP ‘643 has a strain point of 670 °C. As this is within the range, Claim 20 is obvious.

U. Dependent Claim 21

352. **The glass sheet of claim 13 wherein the downdraw process is a fusion process.**

353. JP ‘741 describes: “For display applications, the fusion method, down-draw method, float method, or roll-out method, etc. is used to mold the glass into thin sheets.” EX1005, ¶ [0021].

JP ‘643 describes (emphasis added): “Furthermore, glass substrates for TFT-LCDs are primarily formed using the **downdraw method or the float method**. Examples of the downdraw method include the slot downdraw method and the overflow downdraw method. Glass substrates formed by the **downdraw method** do not require polishing, offering the advantage of cost reduction. However, when forming glass substrates using the **downdraw method**, the glass is prone to devitrification, necessitating glass with excellent devitrification resistance.” EX1007, [0021]

“Additionally, the alkali-free glass of the present invention has a liquidus temperature of 1,150°C or lower (preferably 1,130°C or lower, more preferably 1,100°C or lower) and a viscosity at the liquidus temperature of $10^{5.4}$ dPa·s or higher (preferably $10^{6.0}$ dPa·s or higher), enabling formation into sheets by **the downdraw method** without devitrification and allowing the omission of polishing processes to reduce production costs.” EX1007, [0030].

“Additionally, the glass of Sample 36 from the examples was melted in a

test melting furnace and formed using the **overflow downdraw method** to produce a display glass substrate with a thickness of 0.5 mm.” EX1007, [0084].

Furthermore, the alkali-free glass of the present invention has a low liquidus temperature and high liquidus viscosity, making it suitable for forming into sheets using **the downdraw method.**” EX1007, [0086].

354. The third paragraph, EX1007, [0084], clarifies that “the downdraw method” mentioned in the other paragraphs refers to the *overflow* downdraw method, which implies “fusion.”

355. In summary, JP ‘643 and JP ‘741 (EX1005, ¶0021) describe that it was well-known to make glass articles by a downdraw process that is a fusion process. Samples studied in JP ‘643 were actually made by a downdraw process that is fusion process. As JP ‘643 and JP ‘741 disclose Claim 21, it is obvious.

V. Dependent Claim 22

356. *The glass sheet of claim 13 wherein: (i) the glass sheet has a volume of at least 500 cubic centimeters; and (ii) a population of 50 of the glass sheets sequentially produced by the downdraw process has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter.*

357. The 491 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 ‘491 Patent, the results may not be comparable for the following

reasons:

358. The specification of Claim 22 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 22. 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 defects.
359. Claim 22 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 ‘491 Patent.
360. Moreover, the specification in Claim 22 relies on processing parameters that are not are not part of the claims of the ‘491 Patent, nor part of the invention background described in the ‘491 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.

361. While JP ‘643, JP ‘741 and Peuchert ‘469 do not provide experimental data on glass quality under the – insufficient and arbitrary – conditions of Claim 22, JP ‘643, JP ‘741 and Peuchert ‘469 meet all relevant specifications given in the ‘491 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, JP ‘643, JP ‘741 and Peuchert ‘469 describe the same manner of making the glass sheets. Since the ‘491 Patent does not specify any further process parameters required to obtain the specified limit for defects in Claim 22, I expect that what JP ‘643, JP ‘741 and Peuchert ‘469 describe 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 cm³, where each glass sheet in the population has a volume of at least 500 cm³.

362. Thus, Claim 22 would have been obvious based on JP ‘643, and JP ‘741.

W. Dependent Claim 23

363. *The glass sheet of claim 13 wherein the glass has a liquidus viscosity greater than or equal to 200,000 poise.*

364. Sample 5 of JP '643 reports a liquidus viscosity of $10^{5.4}$ dPa·s ($250,000 \pm 60,000$) P. This value, including its lower uncertainty boundary, is greater than 200,000 P, as formulated in Claim 23. Thus, Claim 23 is obvious.

X. Dependent Claim 24

365. *The glass of claim 1 wherein the glass has a density that is less than or equal to 2.41 grams/cm³.*

366. Sample 5 of JP '643 has a density of 2.379. As this is within the range of Claim 24, Claim 24 is obvious.

VIII. GROUND 3: CLAIMS 13-14 AND 19-21 ARE ANTICIPATED BY MIWA '377, CLAIM 16 ARE OBVIOUS OVER MIWA '377 IN VIEW OF PEUCHERT '469, CLAIMS 22-23 ARE OBVIOUS OVER MIWA '377

A. Independent Claim 13

367. **Limitation 13[p]:** *An alkali-free glass sheet produced by a downdraw process comprising a glass that comprises SiO₂, Al₂O₃, B₂O₃, MgO, and CaO, and, on an oxide basis, has:*

368. Miwa '377 describes (emphasis added): "As a result of repeated experiments, the present inventor discovered that in SiO₂-Al₂O₃-B₂O₃-RO alkali-free glass, the presence of SnO₂ is essential to sufficiently reduce gas bubbles in the glass without the inclusion of arsenic oxide, and discovered that the amount of

SnO₂ that can be incorporated into glass without crystallizing occurring is limited by the amount of alkaline earth metal oxides (MgO, CaO, SrO, BaO) in the glass. The present invention has been proposed on the basis of these discoveries.”

“As described above, the glass in the present invention has (1) a density of 2.50 g/cm³ or less, (2) a coefficient of thermal expansion of 25 to 40 x 10⁻⁷/°C, (3) a strain point of 630°C or more, (4) a temperature of 10^{2.5} dPa·s of 1650°C or less, (5) a liquid phase temperature of 1200°C or less, (6) no SnO₂ crystal precipitation, (7) little change in the amount of erosion and appearance due to treatment with a specified BHF solution, and (8) little change in the amount of erosion and appearance due to treatment with a specified HCl solution. 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.”

EX1008, ¶¶ 0028, 0073.

369. Miwa ‘377 includes a number of examples, including Sample 8 in Table 3:

Sample	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	○		○		○	

EX1008, page 10.

370. Thus, Miwa '377 describes Limitation 13[p].

371. **Limitation 13[a]:** *(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*

372. For the composition of Sample 8 in Miwa '377, $\sum_{i \in R} X_i/X_{Al_2O_3} = 1.20$, where summing is performed over the alkaline earth metal oxides of the set $R = \{MgO, CaO, SrO, BaO\}$. This value is within the range of Limitation 13[a].

373. **Limitation 13[b]-[f]:** *(ii) a MgO content greater than or equal to 1.0 mole percent; 13[d] (a) on an oxide basis, the glass comprises at most 0.005 mole percent As₂O₃; 13[e] (b) on an oxide basis, the glass comprises at most 0.005 mole percent Sb₂O₃; 13[f] (c) on an oxide basis, the glass comprises at least 0.01 mole percent SnO₂; and*

374. Sample 8 of Miwa '377 includes 3.24 mol% MgO; 0 mol% As₂O₃, 0 mol% Sb₂O₃, and 0.07 mol% SnO₂.

375. Thus, Sample 8 of Miwa '377 is within the range of each of Limitations [b]-[f].

376. **Limitation 13[g]:** *(d) the glass has a liquidus viscosity that is greater than or equal to 100,000 poise.*

377. Miwa '377 describes (emphasis added): "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 no less than 10⁵ dPa·s, and more preferably no less than 10^{5.5} dPa·s.**" EX1008, ¶ 0012.

378. 100,000 P corresponds to 10^{5.00} dPa·s. Thus, "10⁵ dPa·s, and more preferably 10^{5.5} dPa·s" overlaps with Limitation 13[g] and as such Limitation 13[g] is described by Miwa '377.

379. As all of the limitations are disclosed in the same manner in Sample No. 8 in Miwa '377, Claim 13 is anticipated.

B. Dependent Claim 14

380. *The glass sheet of claim 13 wherein on an oxide basis, the glass comprises at most 0.15 mole percent SnO₂.*

381. Sample 8 of Miwa '377 includes 0.07 mol% of SnO₂.

382. Thus, Sample 8 of Miwa '377 is within the range of Claim 14 and is anticipated by this Sample.

C. Dependent Claim 16

383. The glass sheet of claim 13 wherein the glass is substantially free of BaO.

384. Sample 8 of Miwa '377 includes 0.2 mol% of BaO.

385. Peuchert '469 describes: "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."

EX1006, ¶¶¶ 0024, 0025, 0026.

386. Miwa '377 considered with Peuchert '469 provides motivation for not using BaO, and shows that the roles of BaO and SrO are similar regarding devitrification stability. A small fraction of BaO can be substituted by a corresponding fraction SrO, yielding a glass with a SrO fraction within the range specified in Claim 1 and substantially free of BaO, as in Claim 16. Thus, Claim 16 is obvious.

D. Dependent Claim 19

387. The glass sheet of claim 13 wherein the glass has a liquidus temperature less than or equal to 1170° C.

388. Miwa '377 teaches (emphasis added): “Specifically, in consideration of the temperature at which glass is formed using the downdraw method, the liquid phase⁵ temperature of the glass is preferably less than 1200°C, and more preferably less than 1150°C, and the liquid phase⁶ viscosity is preferably no less than 10⁵ dPa·s, and more preferably no less than 10^{5.5} dPa·s.” EX1008, ¶ [0012].

389. Sample 8 of Miwa '377 has a liquidus temperature of 1089 °C. This liquidus temperature overlaps with the range in Claim 19. Thus, Claim 19 is anticipated by Miwa '377.

E. Dependent Claim 20

390. The glass sheet of claim 13 wherein the glass has a strain point that is greater than or equal to 650° C.

391. Table 1 in Miwa '377 (EX1008, [0055]) shows a row labeled “Stress Point.” This is an error in the translation. A glass does not have a “stress point,” as any level of stress can be applied to a glass. A glass only has a *strain point*, which is the temperature at which applied stress results in plastic flow, i.e. strain.

392. With the above correction, Table 1 in Miwa '377 indicates that Sample 8 has a strain point, of 693 °C, which is greater than or equal to 650°C as in Claim 20. Thus, Claim 20 is anticipated by Miwa '377.

⁵ “liquid phase” should be “liquidus.”

⁶ “liquid phase” should be “liquidus.”

F. Dependent Claim 21

393. *The glass sheet of claim 13 wherein the downdraw process is a fusion process.*

394. Miwa '377 describes (emphasis added): “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 liquid phase viscosity is preferably no less than 10⁵ dPa·s, and more preferably no less than 10^{5.5} dPa·s, and more preferably 10^{5.5} dPa·s.**” EX1008, ¶ 0012.

395. Miwa '377 describes an *overflow* downdraw method, which is the same as a *fusion* downdraw process – as in Claim 21. Thus, Claim 21 is anticipated.

G. Dependent Claim 22

396. *The glass sheet of claim 13 wherein: (i) the glass sheet has a volume of at least 500 cubic centimeters; and (ii) a population of 50 of the glass sheets sequentially produced by the downdraw process has an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter.*

397. The 491 Patent describes the quality of the resulting glass sheets in a non-stand-

ardized, 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 '491 Patent, the results may not be comparable for the following reasons:

398. The specification of Claim 22 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 22. 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.
399. Claim 22 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 '491 Patent.
400. Moreover, the specification in Claim 22 relies on processing parameters that

are not are not part of the claims of the '491 Patent, nor part of the invention background described in the '491 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.

401. While Miwa '377 do not provide experimental data on glass quality under the – insufficient and arbitrary – conditions of Claim 22, Miwa '377 meets all relevant specifications given in the '491 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 describe the same manner of making the glass sheets. Since the '491 Patent does not specify any further process parameters required to obtain the specified limit for defects in Claim 22, I expect that what Miwa '377 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 .”
402. Miwa '377 reports: “The number of bubbles was measured by counting the number of bubbles (0.1 mm or longer) in a glass sample, and assigning “X” to

samples with more than 100 bubbles per 100 g of glass, “Δ” to samples with 10 to 100 bubbles, and “□” to samples with fewer than 10 bubbles. [0072] Sample 1, which is an example of the present invention, was melted in a test melting furnace and molded using the overflow down-draw method to produce a 0.5 mm thick display glass substrate. The substrate met the specifications for bubble quality and did not exhibit any loss of transparency. The warping of the glass substrate was 0.075% or less, the waviness (WCA) was 0.15 μm or less (cut-off fh: 0.8 mm, fl: 8 mm), and the surface roughness (Ry) was 100 Å or less (cut-off λc: 9 μm). The glass substrate exhibited excellent surface precision and was suitable for use as a glass substrate for liquid crystal displays.”

403. Sample 1 is marked as “fewer than 10 bubbles” per 100 g of glass. Given the mass density of 2.45 g/cm³, 100 g of this glass correspond to 41 cm³. “Fewer than 10 bubbles” per 41 cm³ corresponds to less than 0.25 bubbles per cm³. However, this specification suffers from similar mathematical insufficiencies as the specification in the ‘491 Patent. Regardless of these deficiencies, what is clear is that Miwa '377 teaches the desire and manner of reducing defects in the glass. Even if the defect density in Sample 1 appears to be slightly higher than the maximum of Claim 22, this does not necessarily mean that the quality of the glass is lower. For example, if Glass A has spherical bubbles with a number density of twice as high as Glass B, but the diameter of the bubbles in Glass A is only half of what it is in Glass B, then the total bubble volume per cm³ in Glass A is only 1/4 of what it is in Glass B. This is because the volume of a spherical bubble increases with a third power of its diameter. While the specifics of bubble size distribution and statistics are not disclosed in either one patent, reducing the number density and total volume of defects to a minimum is well-within the knowledge and abilities of a POSITA. This would have motivated

obtaining a glass with an average gaseous inclusion level of less than 0.05 gaseous inclusions/cubic centimeter, as recited in Claim 22. Thus, Claim 22 is obvious.

H. Dependent Claim 23

404. *The glass sheet of claim 13 wherein the glass has a liquidus viscosity greater than or equal to 200,000 poise.*

405. Miwa '377 describes (emphasis added): “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 no less than 10⁵ dPa·s, and more preferably no less than 10^{5.5} dPa·s.**” EX1008, ¶ 0012.

406. 100,000 P equals 10^{5.00} dPa·s. 10^{5.5} dPa·s equals (316,000 ± 73,000) P. These figures overlap with those in Claim 23. Thus, Claim 23 is obvious.

I. CONCLUSION

407. For the reasons set forth above, claims 1-24 of the '491 Patent are unpatentable in view of the prior art.
408. In signing this declaration, I recognize that it will be filed as evidence in a 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.
409. 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.
410. 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: 25-05-19