

Possibility of thin film glass

1. Prologue

What is your image of sheet-like thin glass? Some substrates for Liquid Crystal (LC) have a thickness of 0.7mm. One of the thinnest substrates for mobile devices use is 0.4mm thick. There is also cover glass for touch panels with a thickness of 0.2mm. Even plate glass of 0.15mm thick is actually in the market. You were familiar with para-plate cover glass for micro scope in your school days which has the same thickness of 0.15mm. That is enough to imagine how thin the plates are. We guess these are the general image of such thin glass. In reality, thanks to the stable development of thin glass utilization, much thinner plate glass so-called "thin film glass" is produced on a mass production basis. Let's have a look of such plate glass in its history, current status, and prospect.

2. Glass fusion and basic component

Any kind of glass contains large amount of anhydrous silicic acid, SiO_2 . Such an anhydrous substance (SiO_2 , or B_2O_3 , P_2O_5 etc.) called "net-work former" composes net-like glass structure. Na_2O , K_2O , CaO , and etc. do not change into glass by themselves but come into the mesh of the net of oxide mentioned above to bring some change in the characteristics of glass. In addition, Al_2O_3 or AnO has intermediate characteristics between the net-work former and the non net-work former. These substances are fused together to create necessary characteristics.

3. Journey to thin film glass production

(1) Aroud 30 to 20B.C. in Phoenicia, people made glass vessels by blowing heated glass with an iron pipe. In 7th century, Syrians invented "crown process", one of the blowing processes. A glass hemisphere made by blowing process was rotated and flattered with centrifugal force. And then the flattered glass with a diameter of 30 to 40 inches was cut and divided in four-sided plates. Around 10th century, a new process was invented. This time the blown glass had a shape of cylinder before cutting (cylinder-blowing process). But flattening warped plates required high techniques to put into production line. So it was not 18th or at the beginning of 19th century until that the cylinder process was replaced with crown process.

(2) The next stage of glass processing history was a mechanical blowing process called "Mechanical cylinder blowing process of Lubbers style" which was invented in 1902. The cylinder was enlarged to 0.9m in diameter and 12m in length. The blown glass was cut and divided in specific size. Heat treatment was provided again to flatten the glass. This mechanical process became widespread soon after the invention but still had some limitations in mass productivity and output rate of acceptable products. In spite of such difficulties the Lubbers techniques have been developed in Japan for peculiar cases. Currently this techniques are specially applied to produce thin glass with a thickness of 1.5~50 μ . (Temporarily we call it MATSUNAMI STYLE MECHANICAL BLOWING PROCESS) The important and difficult point of this specialized process is to make a plate by securing the cylindrical from and blowing air into thin film glass at the same time.

(3) There have been drastic development in the production process of general window glass.

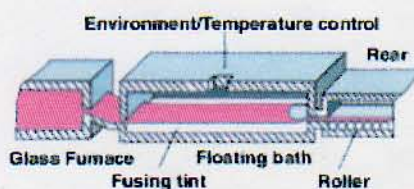


Fig.1 Float process

In 1901, Fourcault invented "up-draw process" in which plate glass was directly up-drawn out of a fire-resistant slit called "debiteuse". This process was named "Fourcault style up-draw process". Next, Colburn invented new process so called "Colburn process" in 1910. Molten glass was up-drawn out of a pit up to about 60cm

high. The top edge was gassed and softened to bend at a right angle and then moved horizontally.

Later these processes had some changes and improvements in their procedure, meanwhile a rollout style process, which was generally adopted for sheet metal processing, was introduced to glass production. And finally the float process, invented by Sir A. Pilkington, made a debut into the plate market with a big impact. (fig.1) The Float process seemed to have occupied the general plate glass industry. However, in the electronic industry, this process requires special surface treatment on each side due to tin-plating. When glass made by float process is used for TFT LC substrates, surface polishing is needed. Although this process will improve to some extent in the future, production of thin glass of 0.2mm thick or thinner in this process doesn't seem to be.

(4) Another process called "Fusion process" was developed by Corning Inc.

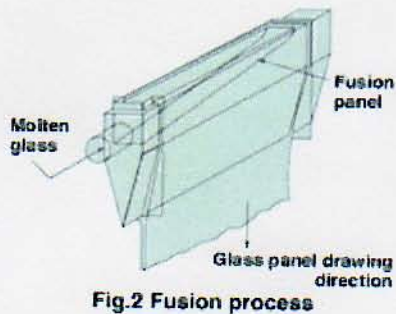


Fig.2 Fusion process

Glass panels with excellent flatness even without polishing became available. In that process, molten glass is poured into a receptacle, which has a shape of heart, to be overflowed. The overflowed glass slumps down out of the receptacle and becomes a glass panel while flowing. Contact with only air allows the surface tension to create substantial flatness. Later "Down-draw process" was invented in 20th century based on the same theory mentioned above.

In this process, molten glass slumps through a slit. But contrary to the Fourcault process or Colburn process in which glass is up-draw, the down-draw process can avoid troubles such as breaks caused by alien substances or falls. In addition, tension and gravity tempered the glass in its high quality, especially in its precision.

After a long journey of history, finally here we got to the stage of the main subject "Thin Film Glass". There is also another process called "Re-draw" in which heat treatment is provided to rollout the panel glass. However, from the practical viewpoint in mass production and the size of products, down-draw process is more advantageous. 4.Characteristics of thin film glass.

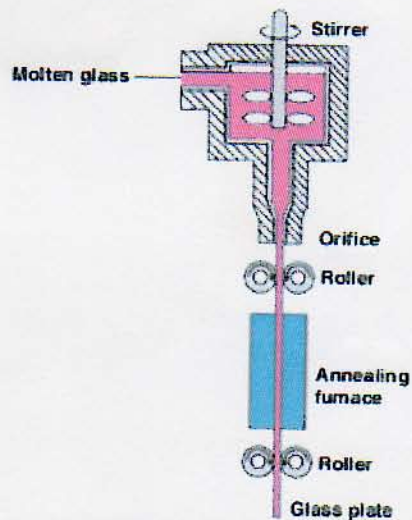


Fig.3 Down-draw process

4. Characteristics of thin film glass

Assuming that the definition of thin film glass is the thickness of 0.2mm or thinner, there are three options for processing : MATSUNAMI-style mechanical blowing process, re-draw process, and down-draw process. (This time polishing process should be excluded because of the limitation in the size.) "Down-draw process" is enough capable for mass production and is showing various results. The following are specific characteristics of standard products made by down-draw process.

(1) Standard plate glass with a thickness of 50 μ (wt%)

	SiO ₂	Al ₂ O ₃	B ₂ O ₃	B ₂ O ₅	Na ₂ O	K ₂ O	ZnO
Borosilicate glass A	50.4	12.1	23.7	13.2			
Borosilicate glass B	64.2	3.0	3.1	8.9	7.2	6.4	7.1

(2) Property data of plate glass with a thickness of 50 μ (borosilicate glass A and B)

Mechanical properties 1

	Borosilicate glass A	Borosilicate glass B
Density at 20°C (68 °F)	2.72g/cm ³	2.51g/cm ³
Stress-optic coefficient C	3.2 · 1.02 · 10 ⁻¹² m ² /N	3.44 · 1.02 · 10 ⁻¹² m ² /N

Mechanical properties 2

	Borosilicate glass A	Borosilicate glass B
Young's modulus E	66.0kN/mm ²	72.9kN/mm ²
Tension modulus G	26.7kN/mm ²	30.1kN/mm ²
Poisson's ratio μ	0.235	0.208
Knoop hardness HK ₁₀₀	555	590

Electric properties

	Borosilicate glass A	Borosilicate glass B
Dielectric constant (1MHz) ϵ'	6.2	6.7
Dielectric loss factor (1MHz) $\tan \delta$	9 · 10 ⁻⁴	61 · 10 ⁻⁴
Electric resistivity at A.C. 50Hz ρ_D ($\theta=250^\circ\text{C}$) ρ_D ($\theta=350^\circ\text{C}$)	6.0 · 10 ¹³ Ωcm 3.2 · 10 ¹¹ Ωcm	1.6 · 10 ⁹ Ωcm 3.5 · 10 ⁹ Ωcm

Thermal properties

Viscosity and corresponding temperature

Viscosity log η (d Pas)	Temperature °C		Property
	Borosilicate Glass A	Borosilicate Glass B	
14.5	627	529	Strain point
13.0	663	567	Annealing point
7.6	883	736	Softening point

Coefficient of mean linear thermal expansion α 20~300°C

45 × 10⁻⁷/°C (Borosilicate glass A)

72 × 10⁻⁷/°C (Borosilicate glass B)

Optical properties

	Borosilicate glass A	Borosilicate glass B
Refraction rate at 20°C		
n_d ($\lambda=588\text{nm}$)	1.5255	1.5230
n_e ($\lambda=546\text{nm}$)	1.5275	1.5255
Abbe number ν_d	62.2	55.0

5. Various applications of thin film glass

(1) Insulating film for Plasma Addressed Liquid Crystal

People have been envisioning wall-hanging type large-sized TV for decades. And now the dream is coming true thanks to the technological development of Liquid Crystal and PDP (Plasma Display Panel). New type of indication device to replace with a conventional TV tube should be provided in order to make such thin and flat TV fit for practical use. So TFT LC panels, used for LC TV or lap top computer, are attracting attention. Currently flat displays in Plasma

Address Liquid Crystal Style as a super-sized panel is under development.

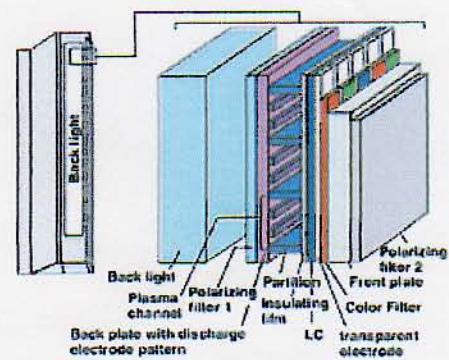


Fig.4 Structure of PALC

Each pixel is connected to one transistor on a TFT LC Panel to control picture creation. The characteristics of this style are availability of quality vision because of free control of each pixel, not to mention the possibility for thinness and flatness of display. A new way to control LC, instead of transistors, is necessary when you produce a super-sized LC panel keeping its picture quality. In the PALC system, only one discharge tube works as much as 1000 transistors using electric effect of plasma discharge function. It is the plasma that carries out the function of electronic switches performed by transistors in TFT LC. The structure is shown in fig.4. The front side of LC has a color filter that contacts with transparent electrode as in the same structure of LC display. Generally each side of the LC layer has an electrode. But the other side of PALC has not electrode, instead of that, plasma channels function as switch elements. Each plasma channels partitioned by baffles has an equivalent function of a scanning line. Thin film glass with a thickness of 50 μ is used for the insulating layer. The size of a glass panel for 42-inch display is 1000mm X 600mm. Who could predict such an application? On a practical level, there have been no problem in the output rate of accessible products regarding the process of washing and frit sealing of t50 μ glass, according to manufactures information sources. It's amazing.

(2) Spacers for Field Emission Display (FED)

One of the technologies attracting attention recently is FED. In a cathode-ray tube, a electron gun is used to emit a ray as luminescent source. The characteristic function of FED is to make every pixel luminant with a fined electron gun. As the theory of luminescence is the same as that of cathode-ray tube, each pixel secure quality luminance brightness. This is also the most economical system for power consumption. How to form a perfect vacuum inside the glass structure, like in a cathode-ray tube, is one of the points to consider for an electron gun's light emission. If two big glass panels are put together to form a perfect vacuum, they stick to each other because of air pressure. To avoid such a phenomenon, spacers should be put between the panels. Spherical spacers are generally used, but if the height of a spacer is 1mm or more, the display will become too wide. So putting glass columns that have a diameter of 50 μ was considered. But still there was a problem. The number of columns would be enormous. Finally an idea came out: cutting thin film glass with a thickness of 50 μ into four-sided plates precisely to use them as columns. The technique to finish spacers with a width of 300mm and a height of 1mm has already established.

(3) Micro lens covers for LC projector

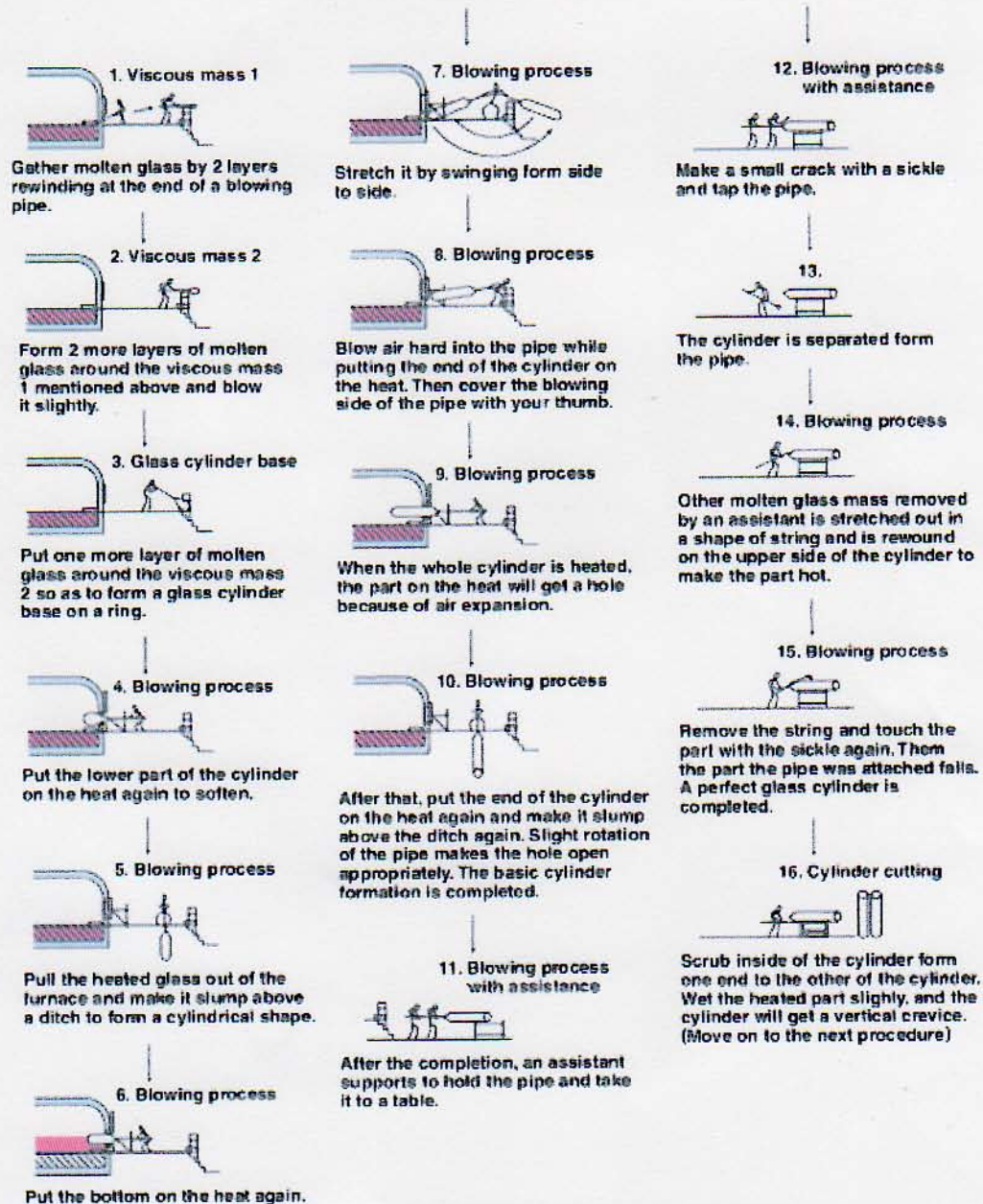
LC projectors are now widely used for presentation/demonstration. There is a possibility of development to be used for 50~60-inch rear projection TV in the future. Regarding LC devices, miniature projectors with a size of 1.3 to 0.9 inches or even 0.7 inches are in the market. One the other hand, high contrast with high brightness is required for the quality. Thanks to the progress of TFT fine processing, aperture efficiency has become high enough to upgrade the resolution. In reality, however, micro lens array should be arranged around pixels in order to improve the brightness without changing optical scale, because some shading is still caused by panel apertures. Currently high temperature silicon type is mainly used for LC device. Therefore, for covers of micro lens array, silica glass or other materials tha have close expansion rate to silica glass is generally applied after polishing. However, borosilicate glass panels with t50 are being applied recently by upgrading low temperature poly-silicon type for cost reduction. This trend will be accelerated in the future.

(4) Others

Heat bonding process with magnetic materials and ceramics is also applicable for thin film glass. Taking advantage of the characteristics, t50u to t30u glass is used as a spacer for magnetic heads to form cell gap or for contact type image sensor other than the applications mentioned above.

6. Conclusion

There have been various approaches to use thin film materials. Film of organic materials, metallic materials, printing process, sealing, sputtering etc. Among them, variety of merits including heat resistance, non-conductance, and simple processibility have been discovered in thin glass characteristics. Thin film glass materials have a bright future to be used widely not only for many types of display but for various electronic devices. Currently each process of thin film glass production from fusion to formation is increasingly automated and computerized. So the productivity is greatly improving. In conclusion, we would like to present the flow chart of blowing process performed in old times. And here we would like to pay our respects to our predecessors' endeavor.



Blowing process of glass manufacturing

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