Low thermal shrinkage glass substrate for high definition display

Masahiro Hayashi, **Shinkichi Miwa, and Masahiko Ohji**

Nippon Electric Glass, Co., Ltd. 2-7-1 Seiran, Otsu, Shiga 520-8639, Japan

Abstract

Low thermal shrinkage glass substrate, OA-12, has been developed. Since OA-12 shows 1/3 lower shrinkage than our conventional glass substrate, OA-10G for LCD, this glass is suitable for the high temperature manufacturing process for high definition display with low temperature poly-silicon (LTPS) or oxide TFTs.

1. Introduction

High resolution displays have been widely used for mobile phones. LTPS is the most suitable TFT for the displays due to its high electron mobility. Since the LTPS process requires high temperature process, conventional glasses may cause patterning mismatch because of their high thermal shrinkage. The high resolution displays are also used for Tablet PCs and smartphones. Since the display size of tablet PCs is larger than that of the mobile phones, thinner and lighter devices are required. However, decreasing thickness occasionally causes breakage of glass substrate in the processes due to its larger gravity sag, which would be a critical issue of lowering the productivity of the devices.

2. Properties of OA-12

The properties of OA-12 are shown in Table1, compared with our conventional LCD glass substrate OA-10G[1]. The environmental and typical characteristics are described as follows.

2.1. Thermal shrinkage

Figure 1 shows a schematic illustration of the measurement method for thermal shrinkage[2]. Marking lines were made by patterning Cr film. Glass sample which has marking lines was separated along the longer edges into two pieces with laser. One piece was subject to heat-treatment. After the heat-treatment, the treated piece was placed in touch with the untreated one. The displacements of each marking lines, Δl_1 and Δl_2, were measured and then shrinkage was calculated. Shrinkage was calculated using the following equation:

Shrinkage [ppm] = (Δl_1 [μm]+ Δl_2 [μm]) / l_0 [m] .

Here, l_0 is length between marking lines before heat-treatment. The precision of the measurement is ±0.5 ppm .

Figure 2 shows thermal shrinkage of OA-12 and OA-10G after heat-treatment at 400-600˚C for 60 min. The profile of heat-treatment is shown in Figure 3.

Table 1. Properties of OA-12 and OA-10G.

Properties / glass code		unit	OA-12	OA-10G
Density		g/cm^3	2.47	2.46
Thermal expansion coefficient (30-380 °C)		×10^{-7}/K	35	38
Strain point		°C	705	650
Thermal shrinkage	500°C 60min	ppm	20	60
	600°C 60min		105	360
Young's modulus		GPa	77	73
Specific modulus		GPa/g/cm^3	31.2	29.7
Poisson's ratio			0.2	0.2
Volume resistivity (350°C)		Ω·cm	12.0	12.0
Dielectric constant (1MHz, RT)			5.4	5.3
tanδ (1MHz, RT)			0.001	0.001
Refractive index (nd:587.6nm)			1.52	1.52
Alkali contents		wt %	<0.1	<0.1
As, Sb contents			<0.1	<0.1

The thermal shrinkage of OA-12 is less than 1/3 of OA-10G, which is obtained by higher strain point of OA-12. OA-12 is suitable for the high temperature manufacturing process for high definition display with LTPS or oxide TFTs. Moreover, it is possible that thermal shrinkage could be reduced more by using an NEG originally-developed thermal-treatment technology. In this instance, thermal shrinkage is expected to reduce to less than 5ppm at 500˚C for 60min or less than 40ppm at 600˚C for 60min.

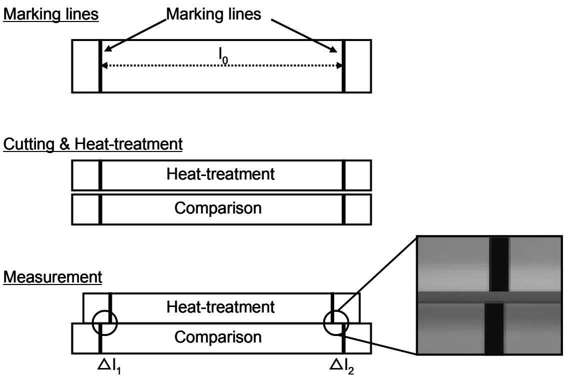


Figure 1. Schematic illustration of the measurement method for thermal shrinkage.

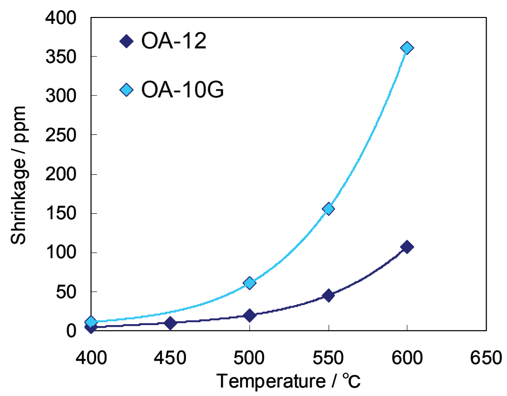


Figure 2. Thermal shrinkage of OA-12 and OA-10G heat-treated at 400-600˚C for 60 min.

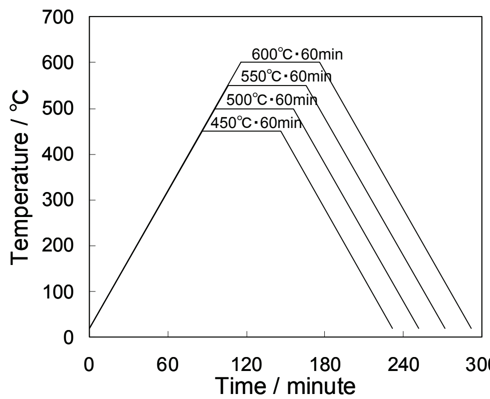


Figure 3. Profile of heat treatment for measurement of thermal shrinkage.

2.2. Gravity sag

Figure 4 shows difference of calculated gravity sag of OA-12 and OA-10G along the thickness. The gravity sag of the glass substrate is calculated using the equation in Figure 5, which indicates that the sag decreases with increasing specific modulus, that is, the ratio of Young's modulus to density (Young's modulus / density). The sag of OA-12 is lower than that of OA-10G. The lower sag is achieved by high specific modulus of OA-12. OA-12 exhibits small gravity sag. When glass size is increased or thickness is decreased to meet the demand of LCD panels, the gravity sag of the glass substrate increases. If the gravity sag is too large, the risk of fracture of glass substrate increases during the transportation. So OA-12 is expected to increase productivity of the device by reducing the risk of the glass breakage.

2.3. Transmittance

Figure 6 shows transmittance curves of OA-12 and OA-10G. Thickness of the glass substrate is 0.5mm. OA-12 has very high transmittance, the same as OA-10G. OA-12 is appropriate for high-brightness display.

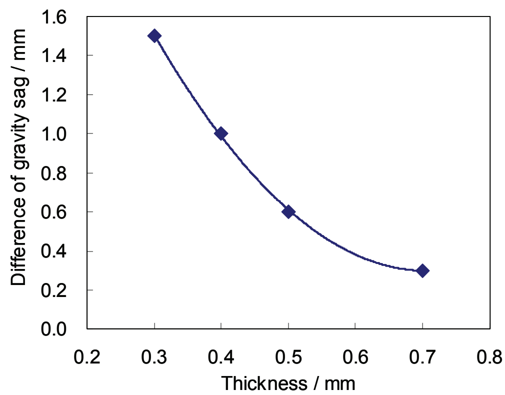
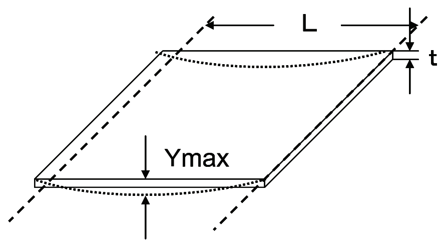


Figure 4. Difference of calculated gravity sags between OA-12 and OA-10G along thickness of glass substrate. The supporting span is 500mm.



$$\text{Max. Sag (Ymax) [mm]} = \frac{5g}{32} \cdot \frac{d(1-\nu^2)}{E\times 10^9} \cdot \frac{L^4}{t^2}$$

g : Gravity acceleration (m/s²), d : Density (g/cm³)
E : Young's modulus(GPa), ν : Poisson's ratio
L : Supporting span (mm), t : Glass thickness (mm)

Figure 5. Gravity sag for glass substrate.

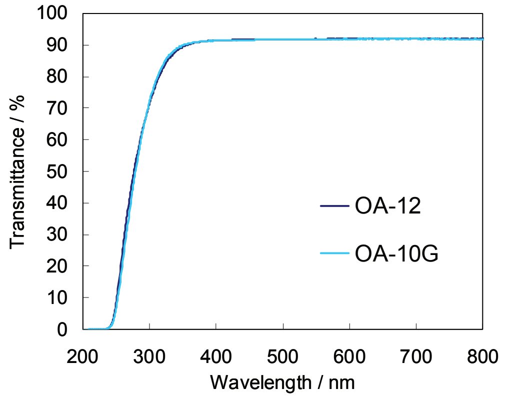


Figure 6. Transmittance curves of OA-12 and OA-10G. Thickness of the glass substrate is 0.5mm.

2.4. Chemical durability

Figure 7 shows chemical durability of OA-12 and OA-10G. Chemical durability of OA-12 for 63BHF solution at 20˚C for 30min is most of the same as OA-10G. Generally, the glass substrate with high strain point and high productivity of melting tends to show low chemical durability for BHF. Low chemical durability raises corrosion of surface of glass substrate. Owing to optimizing glass composition, this glass achieved both high strain point and high chemical durability for BHF with keeping high productivity. Chemical durability of OA-12 for 10wt% HCl solution at 80˚C for 180min is also most of the same as OA-10G. Therefore, OA-12 can be used stably in the etching process, similar to OA-10G.

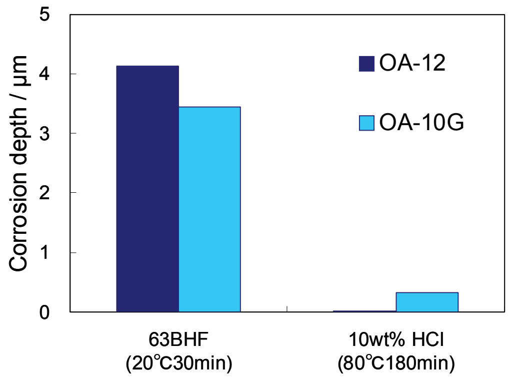


Figure 7. Chemical durability of OA-12 and OA-10G for 63BHF and 10wt% HCl solutions.

2.5. Environmentally-friendliness

OA-12 and OA-10G are environmentally-friendly Green glass. They do not contain the following six substances restricted by the RoHS Directive: Pb, Cd, Cr^{6+}, Hg, PBB, and PBDE. In addition, they do not use arsenic nor antimony. The contents of these components are less than 0.1wt%.

3. Summary

Higher strain point of OA-12 provides higher thermal dimensional stability, which will be quite important properties for obtaining the high resolution displays. And low density of the glass enables light weight device for Tablet PC. Moreover, higher specific modulus reduces the gravity sag, which contribute to the increase of the yield.

4. Reference

[1]Tomoki Yanase et. al., IDW ’08, pp.1837-1840.
[2]Takahiro Kawaguchi et. al., IDW ’09, pp.827-830.