



Flat panel display glass: Current status and future



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ABSTRACT

Since the appearance of the Active Matrix Liquid Crystal Display (AM-LCD) in 1995, flat panel display has been the fast growing industry during two decades [1]. Now LCD became the most dominant display technology world-wide. The flat panel display glass also has walked together along with the LCD industry. Great difficulties for manufacturing the flat panel display glass have given high entry barriers for the leading 3 companies: Corning, Asahi and NEG. These 3 companies occupy about 95% share of the flat panel display glass market [2]. However, these days, new players struggle to take significant part in the market. In this paper the detailed technological difficulties are analyzed.

Display industry, however, these days in the turmoil of the big change. Plasma display panel (PDP) has not been displayed in the exhibitions or showcases. LCD is going through the mature stage of the industrial life cycle. Lots of ownership change and M&A have reported in the news. After that OLED and lots of touch application gadget appeared in the market. Even though these new devices also use flat glasses, the required attributes are different from those of LCD. The differentiation is important topic in the display industry. Flexible display is interesting theme in both glass and display field. Even though final product appears as a thin plastic display [3], all the manufacturing process happens on the glass substrates.

In spite of the drastic change of the display industry, the glass production shows continuous growth. The need of larger screen does not show the saturation. The popularity of touchable hand held devices could continue in near future [4]. However all these situations are not the gospel for the glass industry. The display companies in the red ocean, push down the price of the glass with tremendous pressure. So in near future flat panel display glass also needs breakthrough for survival.

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1. Introduction

The present society can be defined as highly developed information era, and the flat panel display (FPD) industry has achieved radical development. The progress of the FPD has heavily focused on larger size and picture quality. From now on, it is expected that the display industry will concentrate more on meeting a variety of customer needs.

In order to find a new way of survival under new market environment, display makers are making huge efforts to preoccupy the market trend. These efforts are focused on newer technological keywords, “flexible”, “ambient”, “unbreakable”, “wearable”, and “reality”. However, the technological problems for display makers do not seem to be solved easily, as these technological keywords require new innovative materials and production methods, much more than simple reformations or integration of the existing technologies.

These fierce moves towards new display products are not only for the display panel makers. Glass has been recognized as one of the most significant component in the display panel which affects function,

price and durability of the product as a substrate. Thus, it is natural that the required features of display substrate will evolve subsequently in accordance with the changes of customers' needs. This report will discuss the values which the display substrate is required to satisfy from the point of view of the display makers.

2. Display technology trend

In this chapter, the trend of the display panels will be discussed for two main product lines, TV and IT/Mobile. At first, since digital TV has been introduced in 2010, there has been continuous intense competition for a larger screen and higher image quality. This trend is expected to be accelerated when UHD contents are released in mass around 2015. Meanwhile, while the makers have satisfactory response from the market, due to the lack of contents and the technical limitations. It means that TV makers have to find a new approach to the market.

Design is an indispensable attributes of the display market. Current approach, almost focused to reduced bezel and thickness, is near its limit. In the TV market, breakthrough is being sought for in the change of physical shape, such as the curved TV. In the long run, a display will evolve to find a way to harmonize with the surroundings. The TV is an interesting screen for information and entertainment while people

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Fig. 1. GOG (glass on glass).

enjoying. However, it is just a bulky and strange object when turned off, and it could have given aesthetical discomfort. Display makers recognized these problems, and tried to find some possible alternatives, such as wallpaper display, window display and roll-up display.

Secondly, the development of IT displays is expected to emphasize personalization of contents, connectivity activation and, improvement of the contents, both in quality and quantity. Since the first iPhone released, the people have seen the potentiality of the mobile gadgets to access the wider world in their hands. Since then, the market trend has been evolved into the wearable devices, with growing demands for differentiated design which emphasizes the user's individuality and connectivity between devices and maximized portability, as now people carries multiple portable devices. Moreover, in near future, not only flexible or foldable display for better visualization of augmented reality but even transparent display and holography are expected to reach the market.

3. Glass requirements

As the display products develop, glass substrates are required to have more advanced features. Now we discuss technical topics for the development of the glass, from the aspects of performance, manufacturing, and cost.

The performance part contains items to be prepared for long-term development in accordance with new market trend. Manufacturing part contains short-term items for guarantee of stable quality of the display production. Lastly, cost part deals with technologies for cost reduction, in order to survive continuous price down trend.

3.1. Performance

When we find the most important mega trends in current display industry, features such as slimness, flexibility and strength must be on the top of the list. "Slim & flexible" has its necessity to overcome the limit of design, and enhance appearance and portability. Especially the concept of "flexible" display is expected to develop gradually, from current state of flat panel, to curved (or bendable), rollable, and ultimately to foldable display.

The most essential property of the glass that should precede this trend is its thickness. The thickness is expected to be reduced down to 0.2 mm for curved displays, and further to 50–100 μm the minimum thickness by current glass manufacturing, for rollable display. For foldable displays, plastic substrates will replace the glass, due to the brittleness that limits the application.

For curved display, development of thin glass substrate, not thicker than the 0.2 mm, is necessary in order to improve light leakage and color mixture of the bended display, as well as flexibility itself.

Now conventional display process cannot handle 0.2 mm thickness glass substrate due to sagging and breakage. A new glass-on-glass (GOG) method, to attach thin substrate (0.2 mm) on the carrier glass of 0.5 to 0.7 mm thickness for manufacturing process, is under the development as shown in Fig. 1. There are mainly three types of attaching method, which are 1) direct attaching between glasses without additional treatment, anodic bonding to make use of electrostatic adhesion, and intermediate layer adhesion bonding to bond with adhesives [5]. Each method has pros and cons for the production. The most important technical matters are to maximize the span of carrier glass utilization, and control adhesion defects such as particles and bubbles [6].

Another property which gains its importance is the strength of the display substrate. Up to 10 years ago, most display products have been used in static condition, on the table or against the wall. However, the display found increasing application or mobile devices such as smartphones and tablet PCs nowadays.

According to the smartphone consumer service data in 2013, the display breakage was the top item of consumer complaint with the proportion of 22%, followed by the bad reception of 11% as shown in Fig. 2. This result means that consumers are more sensitive to

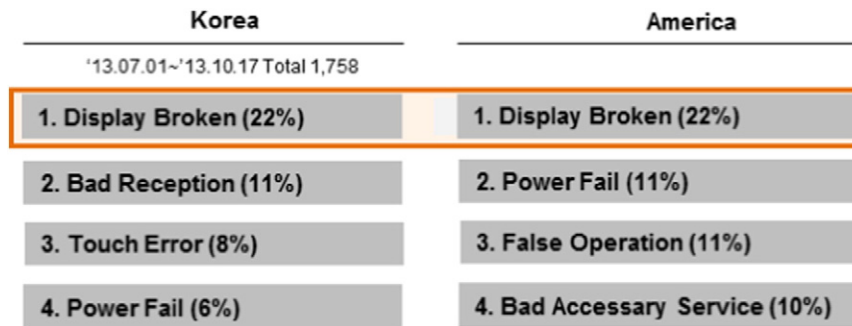


Fig. 2. Top complaint reasons of smartphone customer service.

Table 1
Comparison of alternative materials. PI stands for poly imide.

	Plastic	Stainless steel	Soluble PI
Advantage	<ul style="list-style-type: none"> – Transparent – Lighter – Rollable 	<ul style="list-style-type: none"> – Thermal stability – Rugged – Moisture barrier 	<ul style="list-style-type: none"> – Thermal stability – Lighter – Rollable
Disadvantage	<ul style="list-style-type: none"> – Thermal instability – Moisture permeation 	<ul style="list-style-type: none"> – Opaque 	<ul style="list-style-type: none"> – Yellowish – Transmittance (~80%)
Tech issue	<ul style="list-style-type: none"> – Process temp. – Substrate release – Flexible material 	<ul style="list-style-type: none"> – Opaque 	<ul style="list-style-type: none"> – Debonding damage – Moisture barrier – Yield

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