Development of 2.3" Plastic Film STN LCDs with uniform Cell Gap

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Abstract

STN LCDs on Plastic Film substrates for mobile communication devices have been researched and developed at KETI in KOREA. The Plastic Film substrate is so weak to heat and pressure that its fabrication process is limited to 110℃(Tg). In order to maintain uniform pressure on Plastic Film substrate we used newly designed jig and fabrication process. Electro-optical characteristics are better than or equivalent to those of typical glass LCD though it is thinner, lighter-weight, and more robust than glass LCD.

Introduction

There is an increasing demand for displays based on plastic film substrates instead of glass. The potential advantages of using plastic substrates include lighter weight, thinner displays, and reduced incidence of breakage. As well, the use of plastic substrates will enable a new product concept such as curved or flexible displays. The advantages of plastic substrates compared to glass substrate are greater flexibility and reduced sensitivity to flaws and defects. However, plastic substrates have considerably low thermal resistance and unreproducible shrinkage. Because of the difference between plastic and glass substrates it is recognized that modifications to the other materials used in LCD process, to substrate handling practices and to process conditions and methods will be necessary to produce Plastic Film LCDs.

Properties of plastic substrates

To use plastic substrates in STN LCD, optical properties, thermal properties and mechanical properties have to be considered.
Because STN LCD utilize optical birefringent phenomenon, the substrates are required to be optical isotropic or low optical retardation and high transmission. Thermal properties of plastic substrates are critical because high temperature is applied in several steps during a conventional LCD process. These process can cause considerable problems in plastic substrates such as substrate shrinkage and crack in ITO films due to the difference of thermal expansion between plastic material and ITO film. Table 1 below decribes general characteristics of plastic substrates used in our research. It is essential that substrates are resistant to the variety of chemical solutions used in LCD process. We routinely tested it for organic solvents and acids frequently used in LCD process. Table 2 shows chemical stability of plastic substrates.
The mechanical properties of plastic and glass substrates are different and these differences underlie the advantages of using plastic substrates in portable display devices. Plastic substrates are less brittle, more flexible and weigh less than glass. But flexibility causes some problems in maintaining cell gap, chip bonding process and others.

Table 1. General properties of plastic substrates

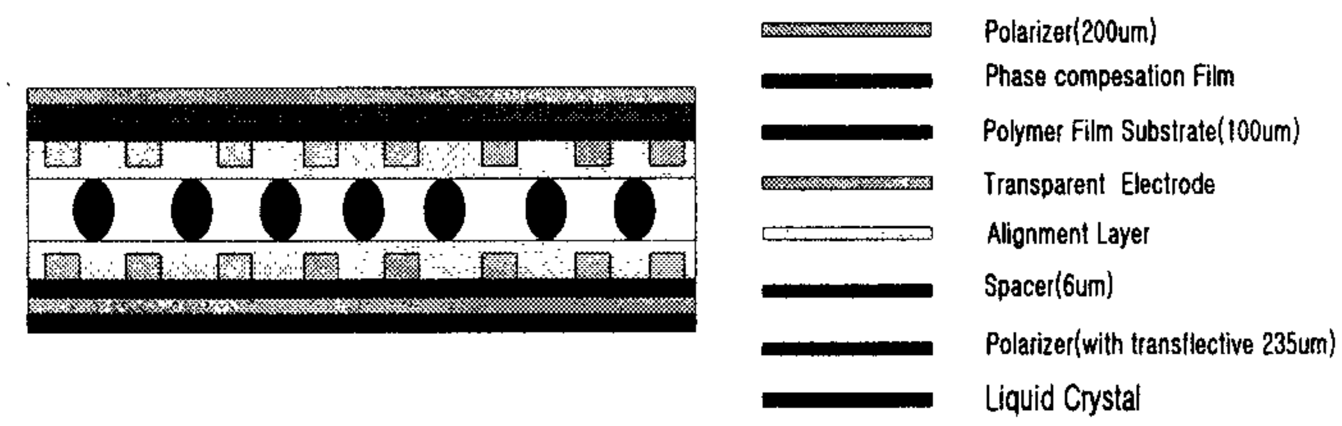
Electrical resistance	Optical Transmission	Thickness	Thermal resistance
45Ω/□	>80%(400-700nm)	100μm	120 °C

Table 2. Chemical stability of plastic substrates

5% HCL	Stable
5% NaOH	Stable
Isopropyl alcohol	Stable
Acetone	Stable
NMP	Stable
Distilled water	Stable
γ-Butyrolactone	Stable

Fabrication and Experimental Results

Figure 1 shows the cross-sectional view of a Plastic Film FSTN LCD developed by KETI. It is a transflective cell with a transmissive polarizer, a compensation film on a top substrate and a transflective polarizer on the bottom substrate. As substrate material we use 100μm thin PES coated with a 150-200nm ITO layer showing 30nm optical retardation at 550nm. As described above, the surface of plastic substrates is non-uniform and flexible. It is very important to maintain flatness of the substrate surface. Because almost fabrication process needs to fix the substrate on a stage with vacuum press, conventional vacuum zone line damages the flatness of the substrate surface. It can cause problems such as grooves on plastic substrate, so result in non-uniform coating, exposure and rubbing etc. In order to solve these problems, we devised a new vacuum chuck with many micro vacuum holes and used it in all the process.



.Fig 1. Cross-sectional view of Plastic Film FSTN LCD

The ITO electrode was patterned by photolithography process, alignment layer was printed by flexgraphic printing and the printed polyimide was cured in an oven below 110°C. Rubbing was done with a velvet coated roller. Due to the non-flatness and flexibility of plastic substrates, Plastic Film LCD required a high density of immobile spacers in order to maintain uniform cell gap and high mechanical stability. The spacers coated with resin was adopted in this process and cured at 100°C. Also the same characteristics of plastic substrates, it is difficult to fill displays having a uniform cell gap by a conventional vacuum filling method. Non-flatness and flexibility of plastic substrates form a vacant area in the cell and spacers lied in this area flow to the edge of cell after filling process. So, the areas without spacers have different cell gaps, and it results in considerable color difference. To overcome this problem, we have developed a filling method which uses two flat and transparent substrates as a support. These two supports fix plastic substrates using surface tension power of water or glycerin lied in between a support and plastic substrate. We used a glass substrate as a support and this method was adopted to measure the pretilt angle and others. Fig 3 shows the overview of cell fabricated by conventional methods.

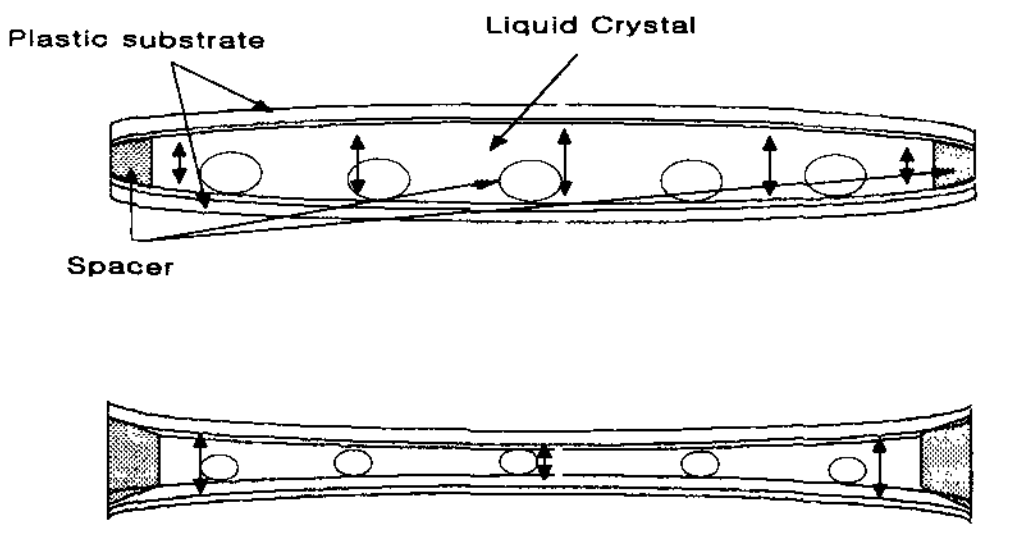


Fig.3 The problems caused by flexibility of plastic substrate

We have measured a difference of cell gap by capacitance of a cell. In glass substrates, the diffenence of cell gap was about 0.1-0.3μm. It .was 1.5 –2 μm for plastic substrates without a support and 0.2 – 0.4μm for plastic substrates with a support.

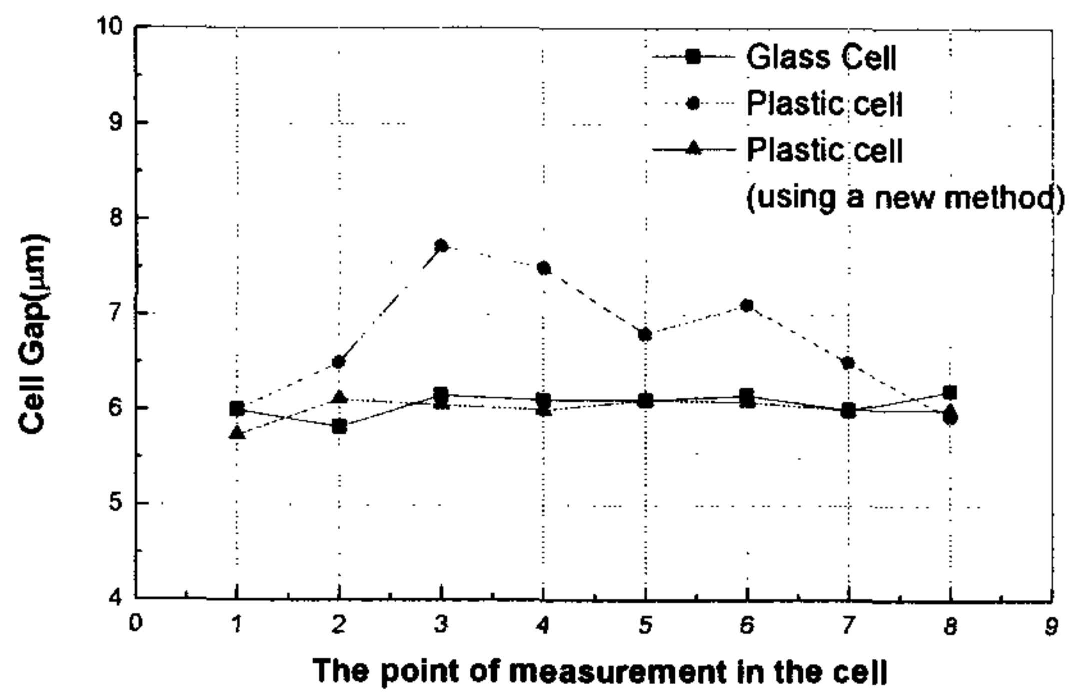


Fig 4. Experimental result of cell gap measurement

As described above, another main problem of plastic substrates is low thermal resistance. This flaw is critical in the process of main sealing and curing of a alignment layer. So, we used the material have low temperature curing state and optimized curing time.
To minimize the shrinkage caused by abrupt heating temperature increased through many steps. The last process of a Plastic Film LCD Module is interconnection of a Plastic Film LCD to driving circuit. Our Plastic Film LCD connected with driving circuit board by thermally activated ACF that developed for Plastic Film LCD.
Fig 5 demonstrates that transflective type Plastic Film STN LCD developed in this work operates successfully with optical and electrical properties similar to those of glass LCD. Tables 3 summarize the specification of Plastic Film LCD.
Through these process and newly developed methods, we successfully achieved 2.3" Plastic Film STN LCD. Electro-optical characteristics of this Plastic Film LCD

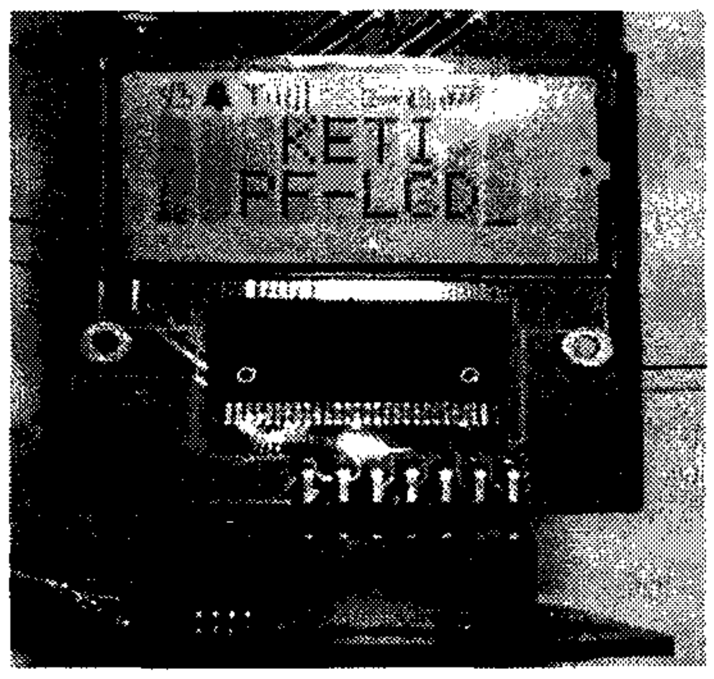


Fig 5. Operation of Plastic Film FSTN LCD

Table 3. Specification of Plastic Film FSTN LCD

Item	Feature	Item	Feature
Size	39 x 23.8mm	ViewingArea	35 x 17.1mm
Duty Ratio	1/18 Duty 1/5 Bias	Dot Size	0.53 x 0.64mm
Active Area	T.B.D	Maximum Process Temp.	110°C
Dot Pitch	0.53 X 0.64 mm	Operation Voltage	2.4 –3.6V
Thickness	0.6 – 0.7mm	Type	Transflective
Weight	0.6g	Contrast Ratio	> 8:1
Mode	NW	Response Time	< 200ms

Conclusion

We have demonstrated Plastic Film STN LCD technology which includes a new process method, and newly developed vacuum chuck and jig. The key issues of this process are low temperature process and new methods to overcome flexibility and non flatness of plastic substrates. The electro-optical characteristics of Plastic Film LCD were better than or very close to those of glass LCD though its thickness was about one third and its weight is about one fifth. Considering its unique characteristics, Plastic Film LCD is expected to be a strong candidate in display applications for hand held electronic devices in terms of weight and thickness.

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