New Plastic Substrate for Flexible Display

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Abstract

A plastic substrate for flexible display is developed. The developed PES film has good resistance to heat, low intrinsic birefringence, and mechanical stability. The gas barrier property in the substrate is improved through depositing organic and inorganic multi layer on plastic film by PVD and CVD process.

1. Introduction

The research and development activities on plastic based flat panel displays have been widely advanced [1,2]. The customer driven factors into the flexible display market include reduced weight, reduced thickness, good resistance to breakage, compatibility to roll-to-roll process, and lower cost.

There are some serious issues in fabricating flat panel display using plastic substrates. First, the mechanical stability of plastic substrate must be ensured in panel fabrication process. The problems of mechanical stability include heat resistance, dimensional stability in each process. Second, the performance of plastic displays must be equivalent to that of conventional glass-based displays. The birefringence, transmission, and gas barrier property of plastic substrate should satisfy requirements of the glass substrate for flat panel displays.

The objective of this research is to enhance the gas barrier property of plastic substrate. The inorganic layer (Al_2O_3, SiOx) is deposited at the low thickness for effective gas barrier layer. But inorganic barrier coating has limitations for display substrate; inferior gas barrier property and curling after depositing on the base film. These result from weak adhesion and difference of thermal shrinkage between inorganic layer and the base film. Inserting polymer layer between the inorganic layer and base film not only stabilize mechanically for the barrier layer against thermal shock (expansion and shrinkage) but also enhances gas barrier property by leveling the surface of base film and improving the adhesion between inorganic layer and base film.

2. Results and Discussion

Compared with other plastic films, the glass transition temperature of the PES film is much higher (Tg: 223°C). We produced the PES film with a superior resistance to heat. The optical properties of PES film such as optical retardation, transmittance, haze, and yellow index are controlled by extrusion processing conditions. The optical retardation is determined by controlling line tension, roll speed, and roll gap pressure of the extrusion process. The transmittance and yellow index especially at low wavelength near 400 nm of the optical film depends on the processing temperature of resin and cooling temperature of polishing roll. The surface roughness mainly depends on the degree of polishing of the rolls and processing conditions. The transmittance of 88% at 550 nm, retardation below 8 nm, and haze below 0.3 % were obtained. Yellow index below 2.5, and surface roughness below 5 nm were observed for 200 micron PES film.

Hexamethyldisiloxane(HMDSO) was degassed by freezing-thawing process. The reactor is a bell-jar type chamber and 13.56 MHz RF power was applied to the upper electrode and includes the following components: RF power supply system, pumping system, mass flow control system, pressure gauge, monomer and gas delivery lines. Monomer and gas are delivered and regulated by mass flow controller (MFC).

The chemical structure of the coated layer was characterized using the X-ray photoelectron spectroscopy(XPS). SEM was used to obtain the microstructure of the plasma deposited films. Internal stress measurements were carried out with use of the method developed by Yasuda et al. The internal stress of the deposited films was calculated using the

Stoney's equation,

$$\sigma = \frac{ED^2}{6Rd}$$

where D and E are the thickness of the substrate and its Young's modulus and R is curvature of plasma deposited films and σ is internal stress(dyne/cm^2).

Figure 1 shows XPS results of plasma deposited film with O_2/HMDSO mixture with various RF powers.

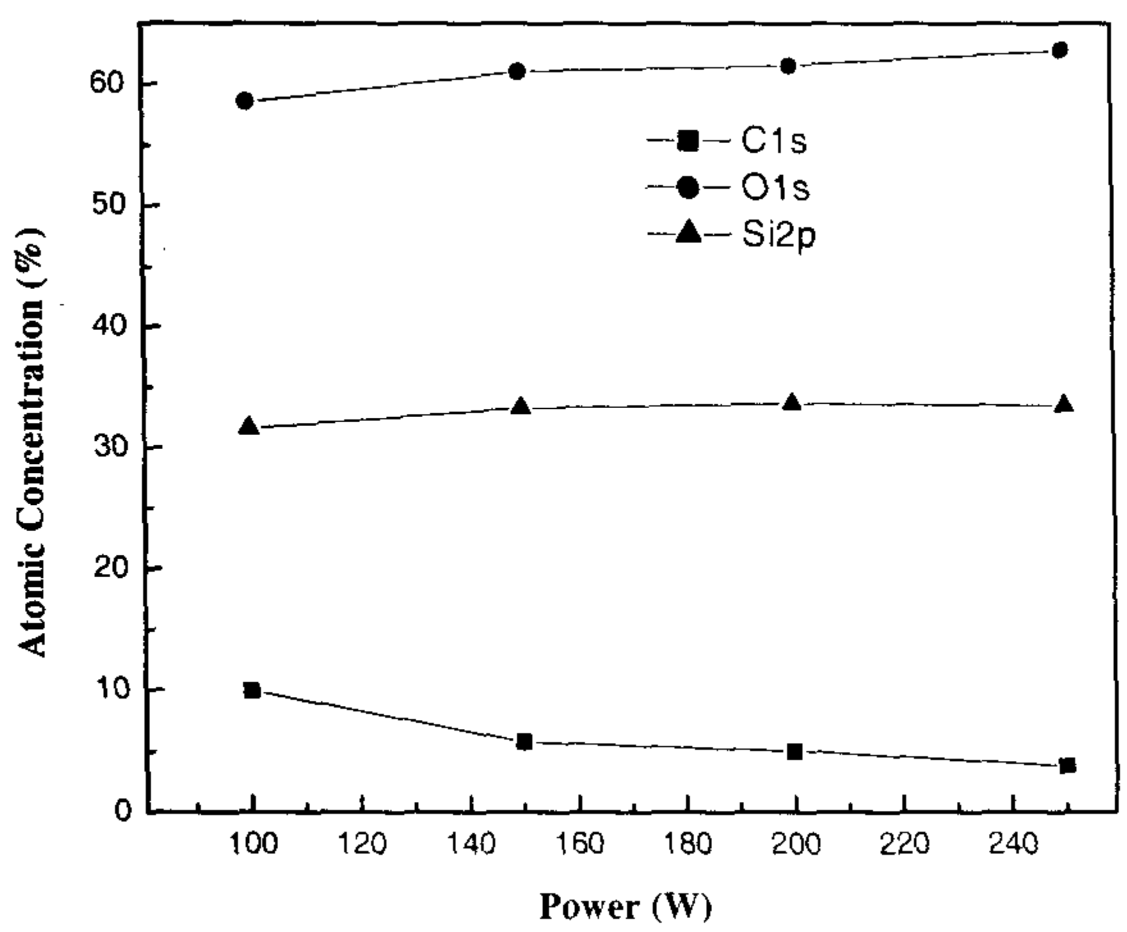


Figure 1. Atomic concentration of plasma polymers determined by XPS as a function of RF power.

The carbon content decreases with increasing deposition power and the oxygen content increases with RF power. Raising the power results in an increase in average electron energy, thus leading to a sufficient power for the overall oxidation of methyl groups bound to each silicon atom. The chemical structure of the plasma polymer at 250W is SiO_xC_y, where x is between 1.8 and 1.9 and y is less than 0.12.

Figure 2 shows the internal stress change of plasma deposited films with deposition power. It can be seen that the curling force in the films increased with increase in the deposition power. The carbon compounds in the plasma deposited film can reduce the internal stress from attack by energetic species during the plasma deposition process.

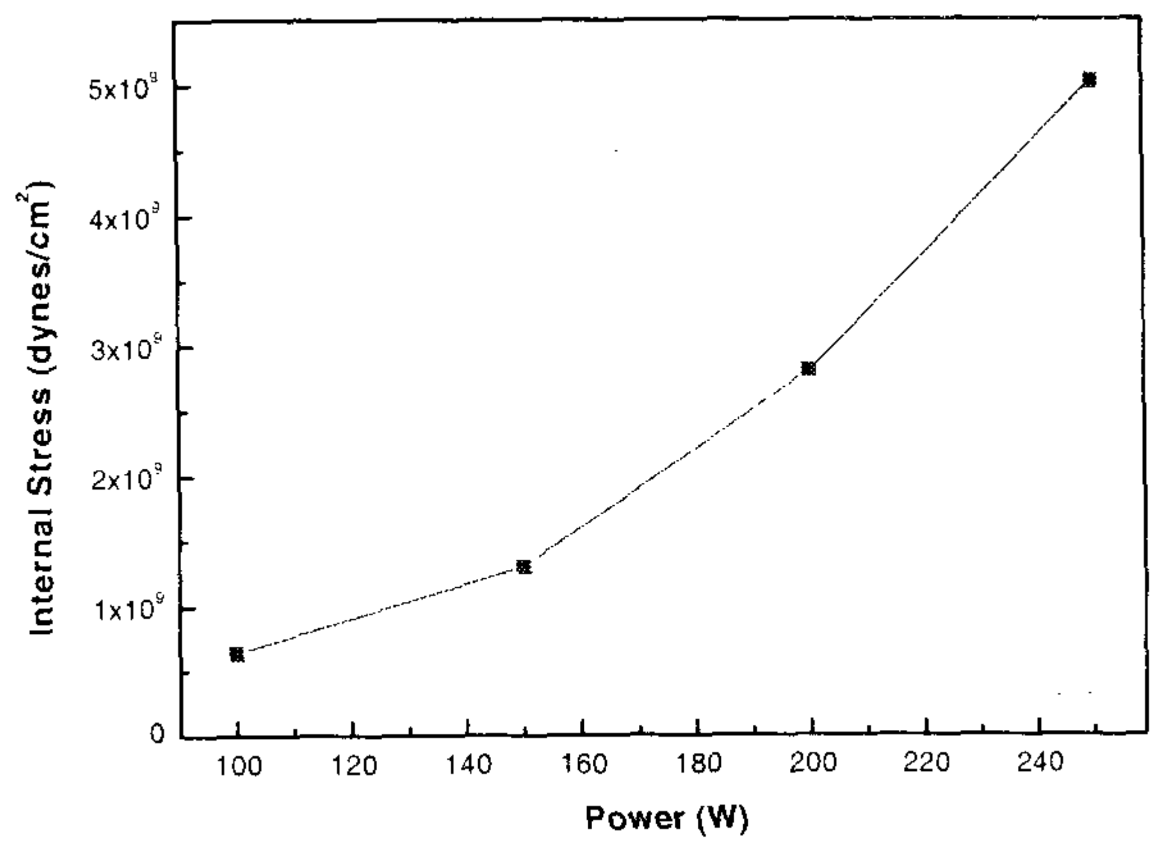
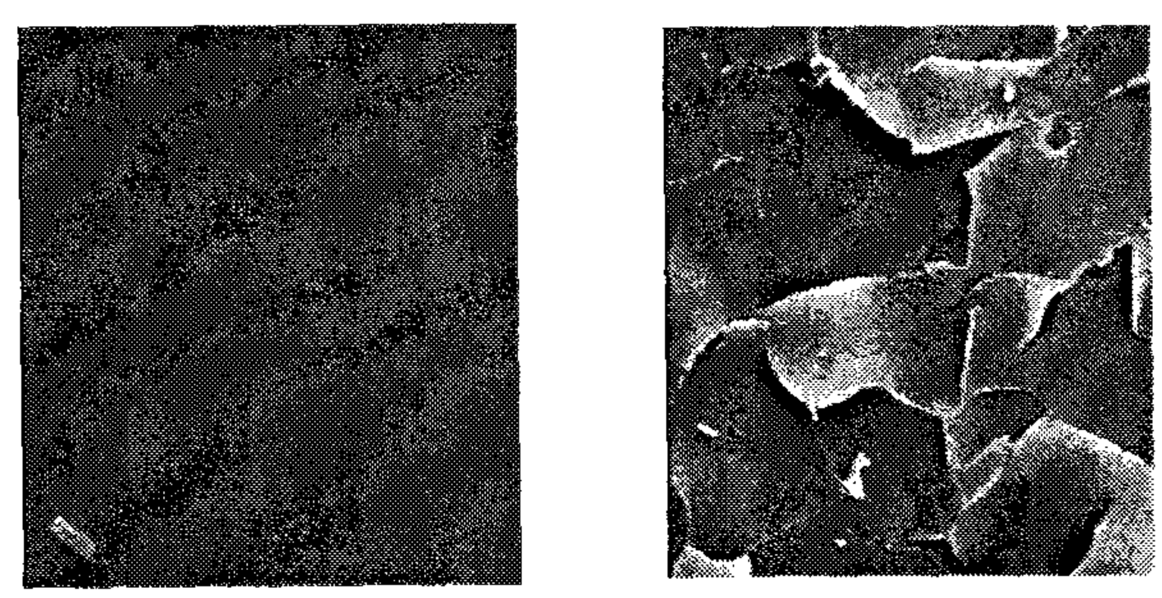


Figure 2. Internal stress of plasma-deposited films as a function of RF power. (thickness = 3500 □).

Figure 3 is SEM photos of the plasma deposited film. In case of (a), it shows very flat surface that is a characteristic of plasma deposited films. But, surface crack appeared in case of (b).



(a) (b)

Figure 3. Scanning electron micrographs of film cracking on substrate film caused by the internal stress: (a) 4000 Å; (b) 6000 Å

The inorganic layer is deposited at the lowest thickness for effective gas barrier layer. Thicker inorganic film is micro-cracked and is weak in gas permeability. The common thickness is in the range of 10-50nm. The barrier property of inorganic layer can be enhanced by densifying inorganic layer.

We tried that the polymer layer is coated by solution coating and cured by UV radiation. The thickness of polymer layer is 0.5-2.0 micron.

Table 1 shows the effect of polymer/inorganic trilayer in barrier film on gas permeability.

	Water vapor transmission rate ($g/m^2/day$)	Oxygen transmission rate ($cc/m^2/day$)
Bare PES	50	250
Inorganic deposited on PES	0.7	6
Inorganic/polymer /PES film	0.05	0.5

Table 1. Gas permeability of plastic substrates

3. Conclusion

We have shown improved properties of inorganic coated polymer film intended for flexible display substrate. We were able to show how to improve the performance of plastic substrate to satisfy the requirements of plastic substrate for LCD in many aspects (Table 2). But the performance of dimensional stability for mask alignment in TFT manufacturing needs to be improved.

New plastic substrate we developed shows strong possibility to commercialize various flexible displays such as electronic paper, plastic LCD, and flexible organic light emitting displays.

4. References

[1] Y. Okada et al, "A 4-inch Reflective Color TFT-LCD Using a Plastic substrate", SID'02 DIGEST, pp1204

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[4] T. Hanada et al, "Flexible Plastic Substrate for Flat Panel Displays", IDW'02, pp401

[5] M. Okamoto et al, "Development of a Color Reflective TFT-LCD Using Plastic Substrate", IDW'02, pp315

	Requirements of plastic substrate in LCD	New Plastic substrate
Heat resistance (°C)	>200	>200
Transmittance (% at 550nm)	>85	88
Retardation (nm)	<10	8
Water vapor transmission rate ($g/m^2/day$)	<0.05	0.05
Oxygen transmission rate ($cc/m^2/day$)	<0.5	0.5

Table 2. The requirements of plastic substrate for LCD and the performance of new plastic substrate