# Study on Resistivity Characteristics of Plastic ITO Film with the Multi-barrier Film by the Bending Process

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## Abstract

*Transmittance and resistivity is investigated according to bending of ITO (indium tin oxide) film with four other multi-barrier film. Transmission data of ITO film with four ITO films showed there was about large 90% transmission above 550 nm wavelength at three multi-barrier structures. But, both-side hard coated structure showed relatively low 75% transmission above 550 nm wavelength. Also, resistivity change of four other multi-barrier film showed there was the lowest change at one-side hardcoated structure. Subsequently, with result of resistivity change according to position, it was known the resistivity change of the center increased rapidly than that of the edge.*

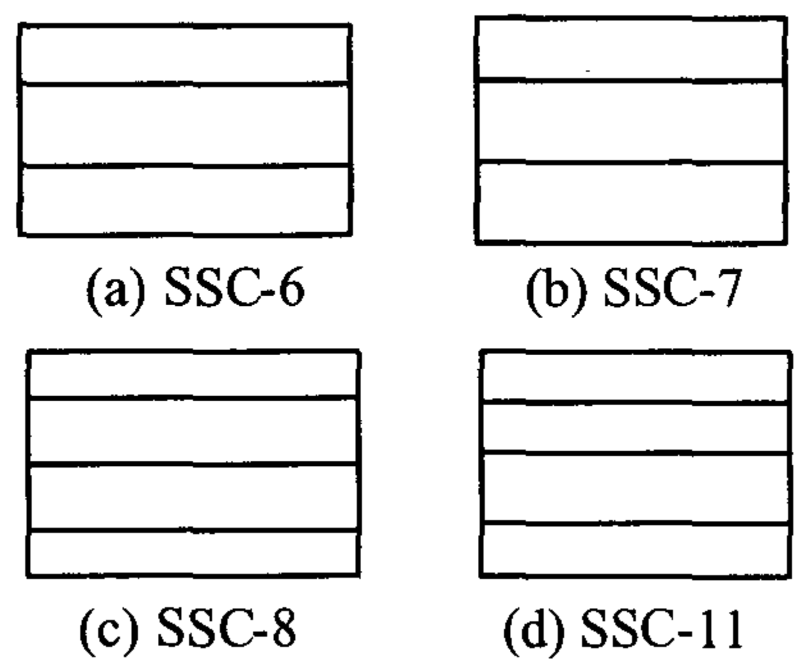
## 1. Introduction

At flat panel display, ITO (one of transparent thin-film conductive film) coated glass substrate is used for transparent electrode. Recently, the studies about using polymer substrate replaced by glass substrate continue. Using polymer substrate, it is applicable for portable display because of the significant volume and weight savings compared to a glass substrate, for curved display with large flexibility. Presently, this polymer substrate is frequently used for cholesteric reflective liquid crystal display and organic light emitting diode. But, practically polymer substrate is coated with very thin glass film, referred to as a permeation barrier film. The role of this film is to protect against transmission of oxygen and water vapor, transparency. In flexible display, as polymer substrate is bent, stress proportional bending curvature is applied and at the critical stress crack occurs. This barrier film has an effect on stress applied to film in flexible display. Until, investigations about crack occurring on the polymer substrate have been reported by several investigators[1-6]. Darran R. Cairns et al. reported electrical property of mechanically deformed ITO coated polymer substrate[6]. But, it has not been reported about electrical property of patterned ITO on polymer substrate. In this study, it is investigated about transmission, stress characteristics of four other multi-layered permeation barrier film with patterned ITO film.

## 2. Experiment and Results

Four ITO film's structures are shown as Fig. 1. The thickness of ITO is about 20~30 nm and polymer substrate used is polyetyleneterephthalate (PET). In this structure, permeation barrier film referred previously is called as hardcoat. Hardcoat 2 is used for non-glare property by doping silica particles within hardcoat. Also, it is used ITO film pattern showed in Fig. 2 to compare & evaluate properties of four other multi-layered permeation barrier film. From this experiment, the effect of position-dependent stress with bending is investigated. A pixel size is 1000 µm*2050 ?m, a density is 5 pixel/cm², bending curvature is 0.834. A & D position and B & C position is marked to investigate affect of center-position and edge-position stress. The reason of patterning is to investigate the influence of applied stress to each position's pixel such as practical pixels for display application. According to applying stress with constant bending curvature and increasing the time of applied stress, the damage of ITO film occurs. Because resistivity increasing of conducting film is related to crack density dependent on bending curvature and thickness of film, we can know how much the ITO film is damaged from resistivity change[4-8]. The resistivity measurement was achieved from two-probe method. Finally, in flexible display when the stress is applied, we can attain minimum damaged ITO film structure.

To evaluate the properties of four other multi-layered permeation barrier film, we measured ITO film's transmittance using spectrophotometer.




**(a) ITO/PET/Hardcoat**
**(b) ITO/PET/Hardcoat**
**(c) ITO/Hardcoat2/PET/Hardcoat**
**(d) ITO/Hardcoat2/PET/Hardcoat2**

**Figure 1 The structure of four other ITO film pixels.**

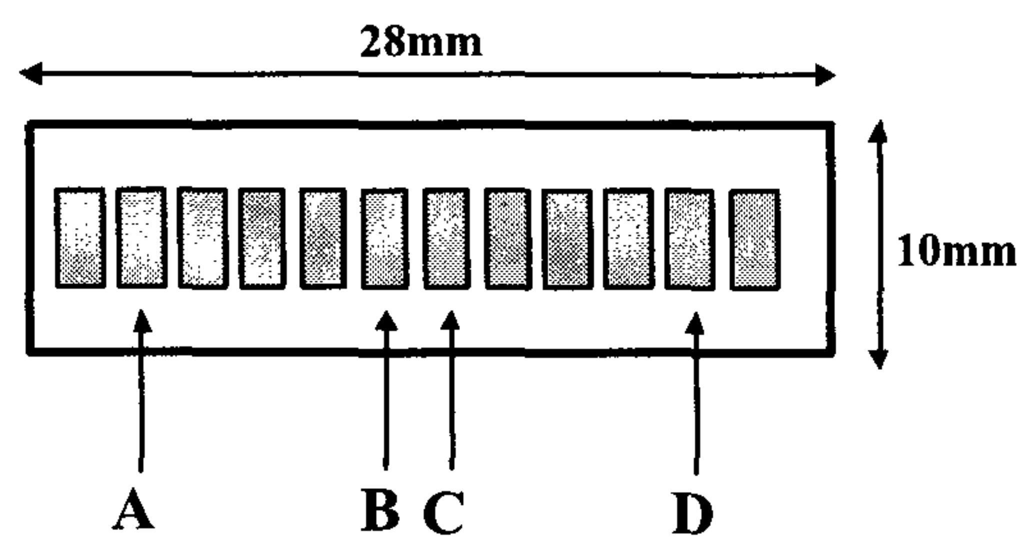



**Figure 2 The pattern structure of ITO film.**

We showed the transmittance of four other ITO film measured from Spectrophotometer in Fig. 3. Figure 3 (a), (b), (c) showed that there was about large 90% transmittance above 550nm wavelength corresponding to visible-light region, but Fig. 3 (d) showed relatively low 75% transmittance above 550nm wavelength. It should be constantly maintained for visible-light region (the most eye-sensitive 550nm wavelength) with minimum light transmittance of 78% to make natural color. Figure 3 (a), (b), (c) show about constant 90% transmittance above 550nm wavelength. This fact shows almost equivalent transmittance compared to transmittance 90 ~92% of glass substrate. But, both-side hardcoated Fig. 3 (d) shows it is not suitable for display application due to about lowered 75% transmittance than minimum transmittance of 78%.

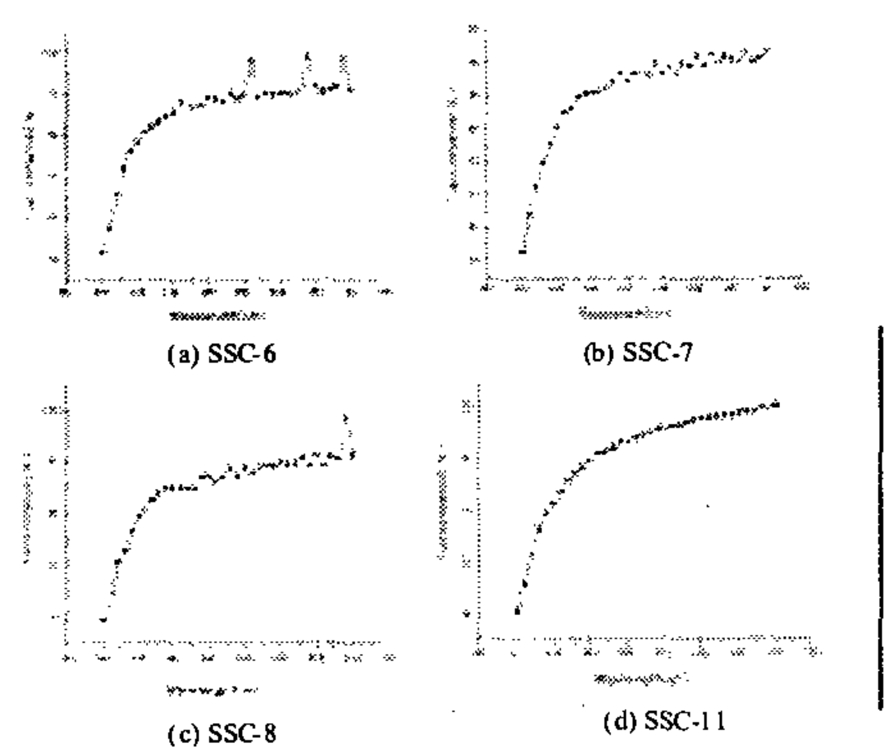
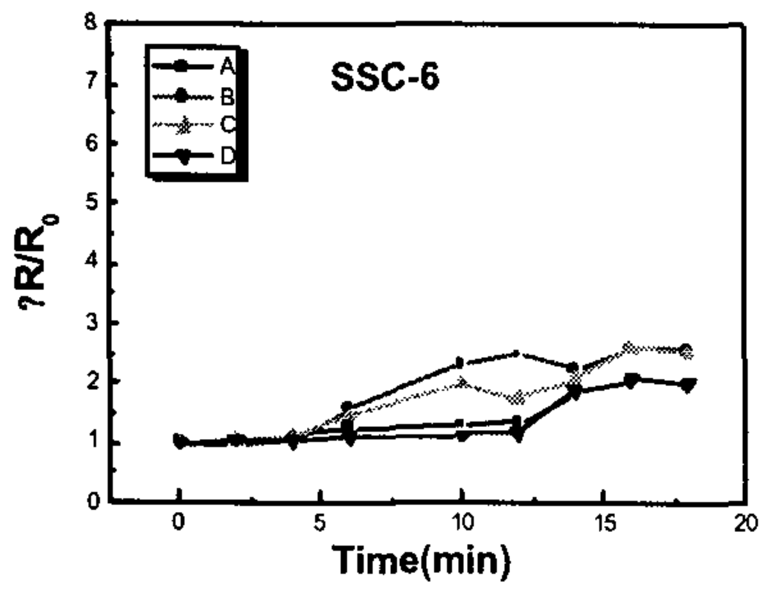
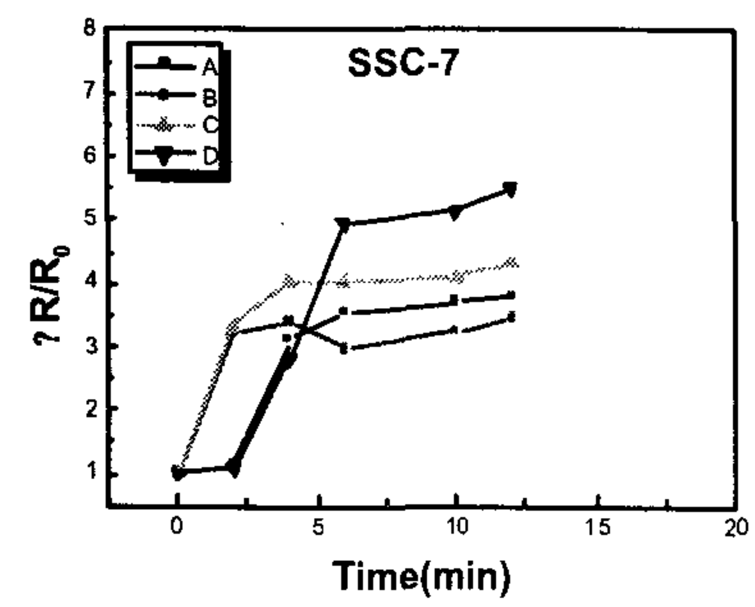



**Figure 3 The transmittance of four other ITO film with Spectrophoto meter.**

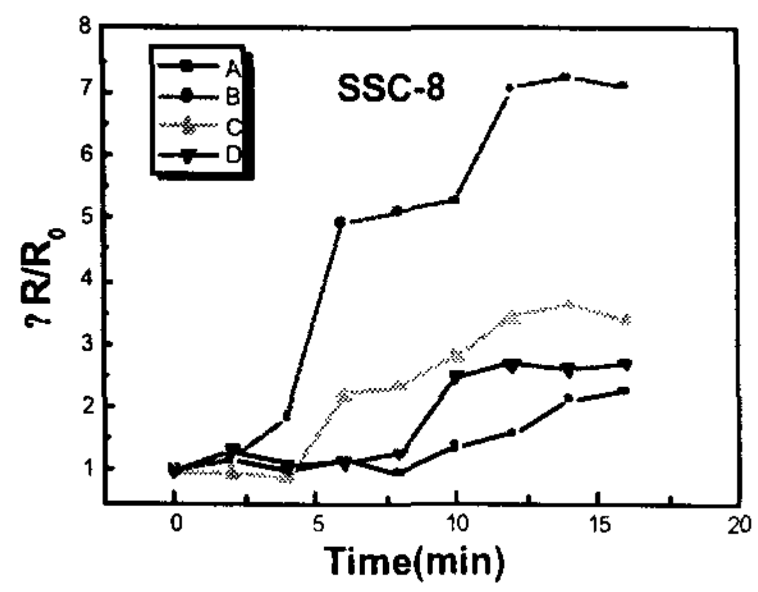
Figure 4 shows bending time dependency of four other ITO film's resistivity. This figures show measured each pixel resistivity's change from initial resistivity before bending after measuring each different position's resistivity with increasing bending time with four other patterned ITO film of constant bending curvature. From Fig. 4 (a), we can know that resistivity have a little increasing tendency and resistivity change due to bending is significantly small. And, as expected we can know that ITO film is relatively stable and film's edge region A and D & center region B and C curve coincidence almost each other. Figure 4 (b) showed resistivity change due to bending was not uniform all over the film as previous and had largely increasing tendency above bending time of 2 minutes. Therefore, we can investigate that ITO film is very unstable and position C&D resistivity increase rapidly due to relatively large applied stress. Figure 4 (c) shows rapid resistivity change at center region of film and not relatively large resistivity change at edge region as Fig. 4 (b). Figure 4 (d) shows uniform resistivity change as Fig. 4 (a), but that resistivity change due to bending is relatively large compared to Fig. 4 (a). We can know that ITO film is relatively stable as Fig. 4 (a).



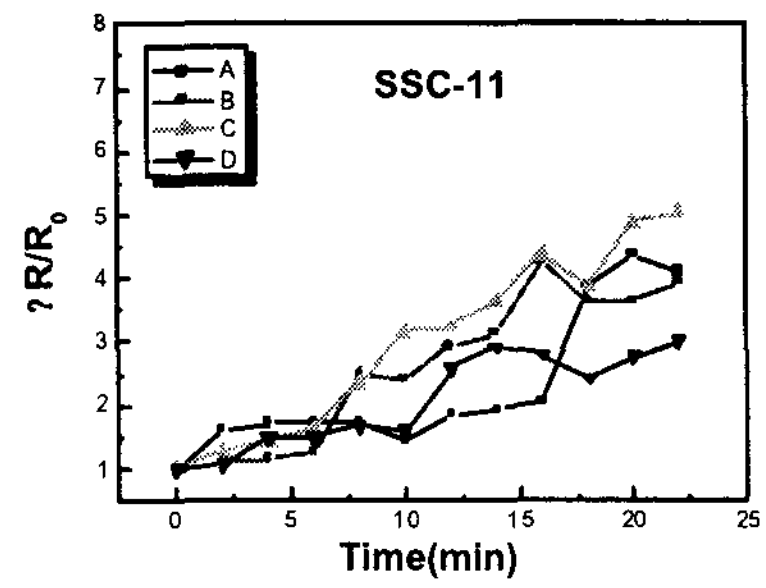

(a) SSC-6




(b)SSC-7



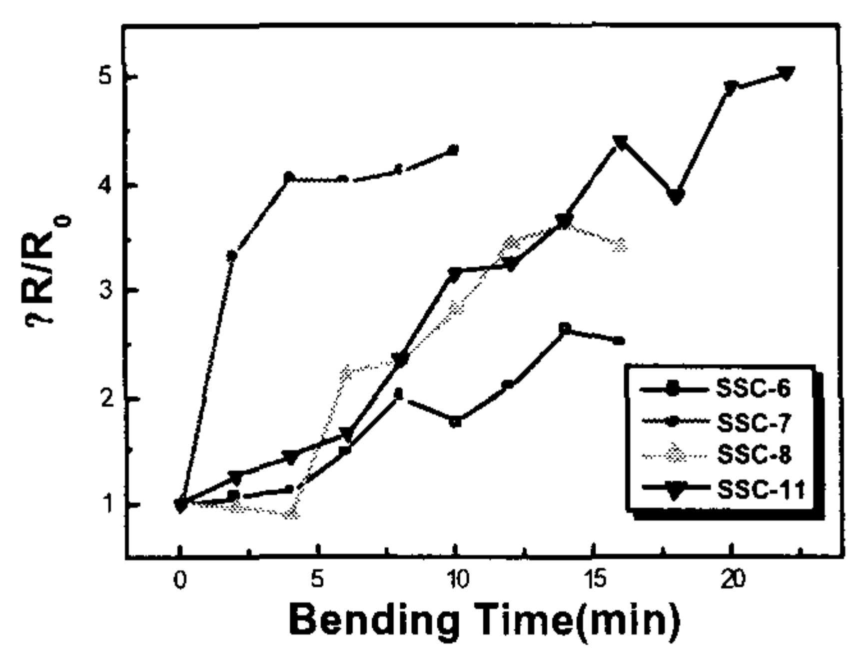

(c) SSC-8



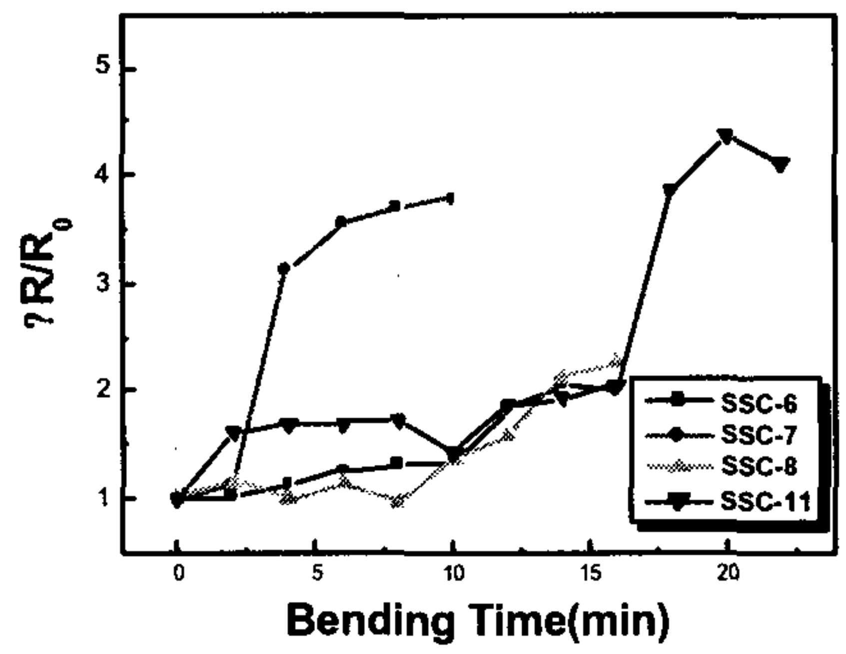

(d)SSC-11

**Figure 4 The bending-time dependence of four other ITO films resistivity.**

Figure 5 showed bending time dependency of resistivity corresponding to position of four other ITO film. As Fig. 5 (a) showed, center region of all four ITO film structures have largely increasing resistivity corresponding bending time. Particularly, resistivity change of one-side hardcoated structure (SSC-7) was very rapidly increasing. But, resistivity change of SSC-6 structure was not so large as that of SSC-7. Therefore, even if same one-side hardcoated structure exists, resistivity corresponding to bending time makes significant difference dependent on property of hardcoat. So, as showed in Fig. 5 (b), at edge region of ITO film three structures except SSC-7 showed a little change of resistivity until bending time of 15 min. From this result, we can know that resistivity change of center region C has rapidly increasing tendency corresponding to bending time than that of edge region A.




(a) C-position




(b) A-position

**Figure 5 The bending-time dependence of four other ITO films resistivity according to the position.**

## 3. Conclusion

The transmittance results of four other other multi-layered permeation barrier film represents three of four other structures show about large 90% transmission above 550nm wavelength. But, both-side hard coated structure shows relatively low 75% transmission above 550nm wavelength. Also, it is known about apparently bending effect according to ITO film structure from the measurements of four other ITO film's resistivity change. From this result, it is known one-side hardcoated structure showed relatively low resistivity change by bending compared to that of both-side hardcoated structure. Subsequently, from the result of position-dependent resistivity change, it is known the resistivity change of the center increased rapidly than that of the edge with bending time increased.

## 4. Acknowledgement

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## 5. References

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