New Method of Gas Barrier Coating on Plastic Substrate for Flexible Display

Hee Nam Hwang, Jae-Moon Choi, Insun Kim, Jong Rak Park*
R & D Institute, i-Components co. Ltd, Choopal Industrial Zone, Pyungtaek, Kyonggi, Korea
*Department of Photonic Engineering, Chosun University 375 Seosuk-dong, Dong-gu, Gwangju, Korea

Abstracts

A plastic substrate for flexible display is developed. The gas barrier property in the substrate is improved through depositing metal and metal oxide multi layer on plastic film by PVD process. The metal/metal-oxide multiplayer on plastic film shows excellent gas barrier property and optical property.

Introduction

The researches and developments about plastic based flat panel display 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 of roll to roll process, lower cost.

There are some serious issues in fabricating flat panel display using the plastic substrate. 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 display must be equivalent to that of conventional display. The birefringence, transmission, and gas barrier property of plastic substrate should satisfy requirements of substrate for flat panel display[3,4,5].

We focused gas barrier property and optical transmittance in this work. For gas barrier property, metal layer shows effective results. But metal layer on plastic film cannot be used alone because of low optical transmittance. To increase optical transmittance, Metal oxide layer is deposited on metal layer in anti-reflection condition. We should select carefully the kinds of metal and metal oxide to meet anti-reflection condition.

Results & Discussion

In this work we present admittance diagram analysis[6] for the anti-reflection coatings in the following two structures: Metal-Oxide/Metal/Substrate structure and Metal-Oxide/Metal/Metal-Oxide/Substrate structure.

Figure 1 shows the admittance diagram for the Metal-Oxide/Metal/Substrate structure. The locus starts from the position of $(n_{sub}, 0)$ and approaches the position of $(n, -k)$, where n_{sub} and $n - ik$ represent the refractive indices of the substrate film and the metal layer, respectively. In order to realize the anti-reflection condition, the admittance locus caused by the metal oxide layer should stop at the position of $(1, 0)$. The refractive index n_f and the thickness d_f of the metal oxide layer, with which the anti-reflection condition is met, can be derived as follows:

$$n_f = \sqrt{x_0 + \frac{y_0^2}{x_0 - 1}}, \tag{1}$$

$$d_f = \frac{\lambda}{2\pi n_f} \tan^{-1}\left(\frac{n_f(1 - x_0)}{y_0}\right), \tag{2}$$

where x_0 and y_0 can be obtained using following equations.

$$Y_0 = x_0 + iy_0 = \frac{C}{B} \tag{3}$$

$$\begin{bmatrix} B \\ C \end{bmatrix} = \begin{bmatrix} \cos\alpha\cosh\beta + i\sin\alpha\sinh\beta & i\dfrac{\sin\alpha\cosh\beta - i\cos\alpha\sinh\beta}{n - ik} \\ i(n - ik)(\sin\alpha\cosh\beta - i\cos\alpha\sinh\beta) & \cos\alpha\cosh\beta + i\sin\alpha\sinh\beta \end{bmatrix} \begin{bmatrix} 1 \\ n_{sub} \end{bmatrix} \tag{4}$$

$$\alpha = \frac{2\pi}{\lambda} nd, \beta = \frac{2\pi}{\lambda} kd \tag{5}$$

In Eq. (5), d represents the thickness of the metal layer.

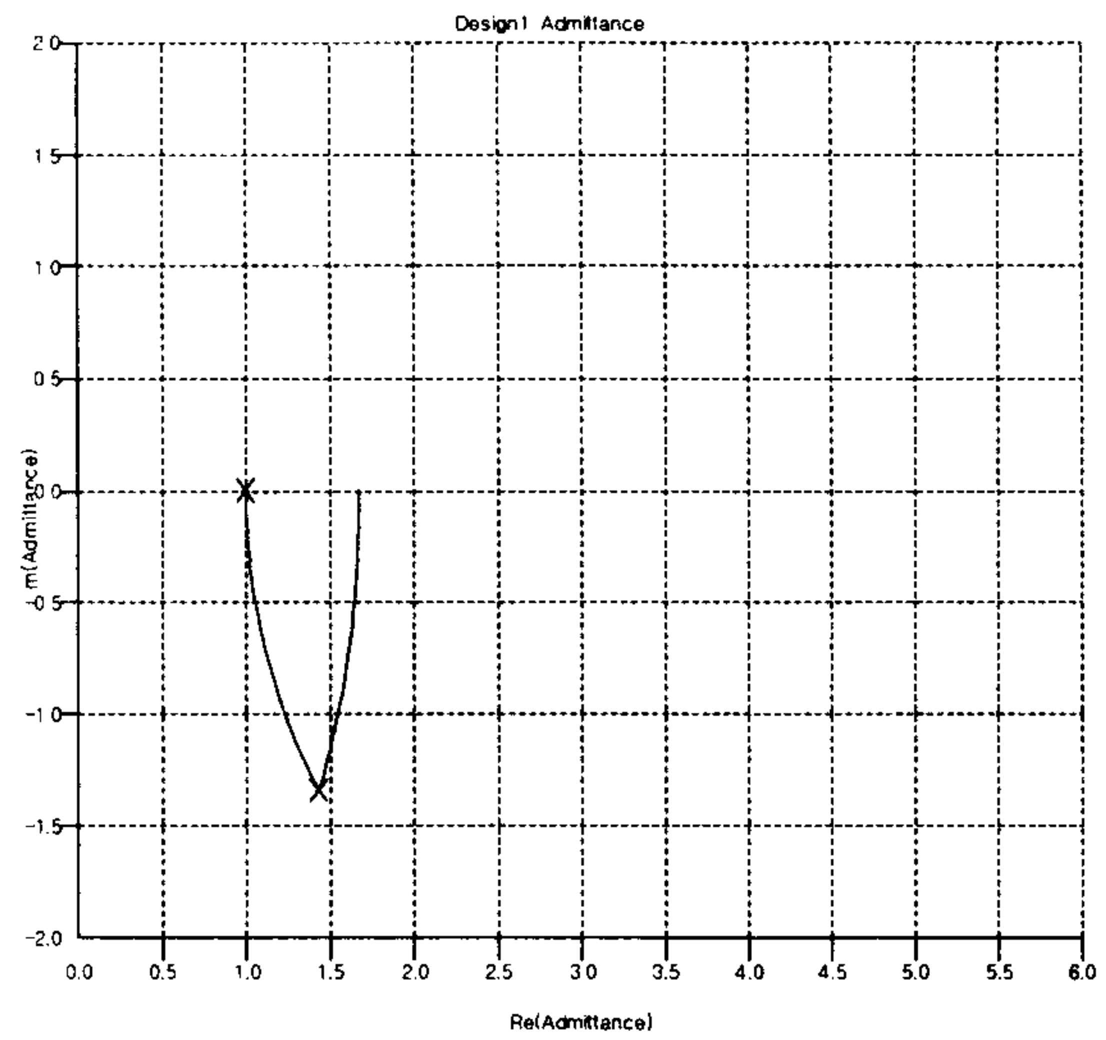

Fig. 1. Admittance diagram for Metal-Oxide/Metal/Substrate structure.

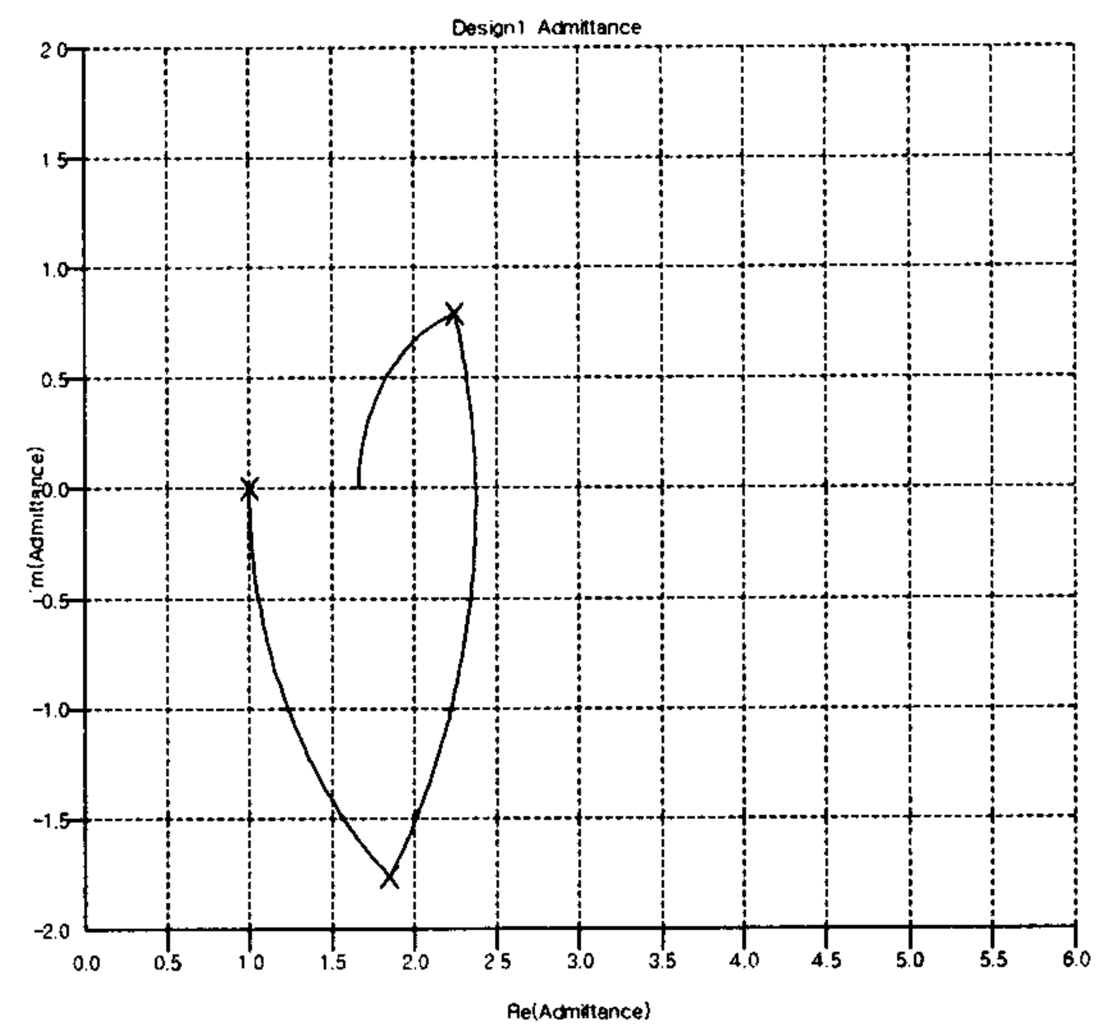

Fig. 2. Admittance diagram for Metal-Oxide/Metal/Metal-Oxide/Substrate structure.

The admittance diagram for the Metal-Oxide/Metal/Metal-Oxide/Substrate structure is depicted in Fig. 2. The locus starting from the position of $(n_{sub}, 0)$ follows a circular track leading to the position of $(n_f^2 / n_{sub}, 0)$. Similarly as the Metal-Oxide/Metal/Substrate structure, the locus caused by the upper metal oxide layer, which also follows a circular track passing through the position of $(n_f^2, 0)$, should stop at the position of $(1, 0)$ in order to accomplish the anti-reflection condition. The locus made by the metal layer should connect the above two circular arc loci. There do not exist unique conditions among the optical and physical parameters of the constituent layers for achieving the anti-reflection conditions. Here, numerical approach should be extensively employed and optical and physical parameters of the metal and metal oxide layers with which more wider transmitting bandwidth can be attained should be selected. Since the anti-reflection effects occur at the both sides of the metal layer, the transmitting bandwidth achievable in this configuration is generally wider than the Metal-Oxide/Metal/Substrate structure.

We produced the PES film having a superior resistance to heat and the excellent optical properties of PES film such as retardation, transmittance, haze, and yellow index. The transmittance was 88% at 550 nm, retardation below 8 nm, haze below 0.3 %, Yellow index below 2.5, and surface roughness below 5 nm of 200 um PES film.

The metal was deposited for effective gas barrier layer. The common thickness is 5-50nm for Al or Ag. As increase metal thickness, gas barrier property was improved but optical transmittance of plastic substrate dropped suddenly. The optimum thickness of metal layer was controlled carefully.

Figures 3 shows performance of TiO2/Al/TiO2/PES triple layer. The experimental transmittance spectrum of Al & TiO2 deposited layer PES is lower than theoretical data, but higher than Al deposited PES. The gas barrier property of triple layer is similar to that of Al layer (Fig. 4).

The metal/metal-oxide multiplayer on plastic film shows excellent gas barrier property and optical property.

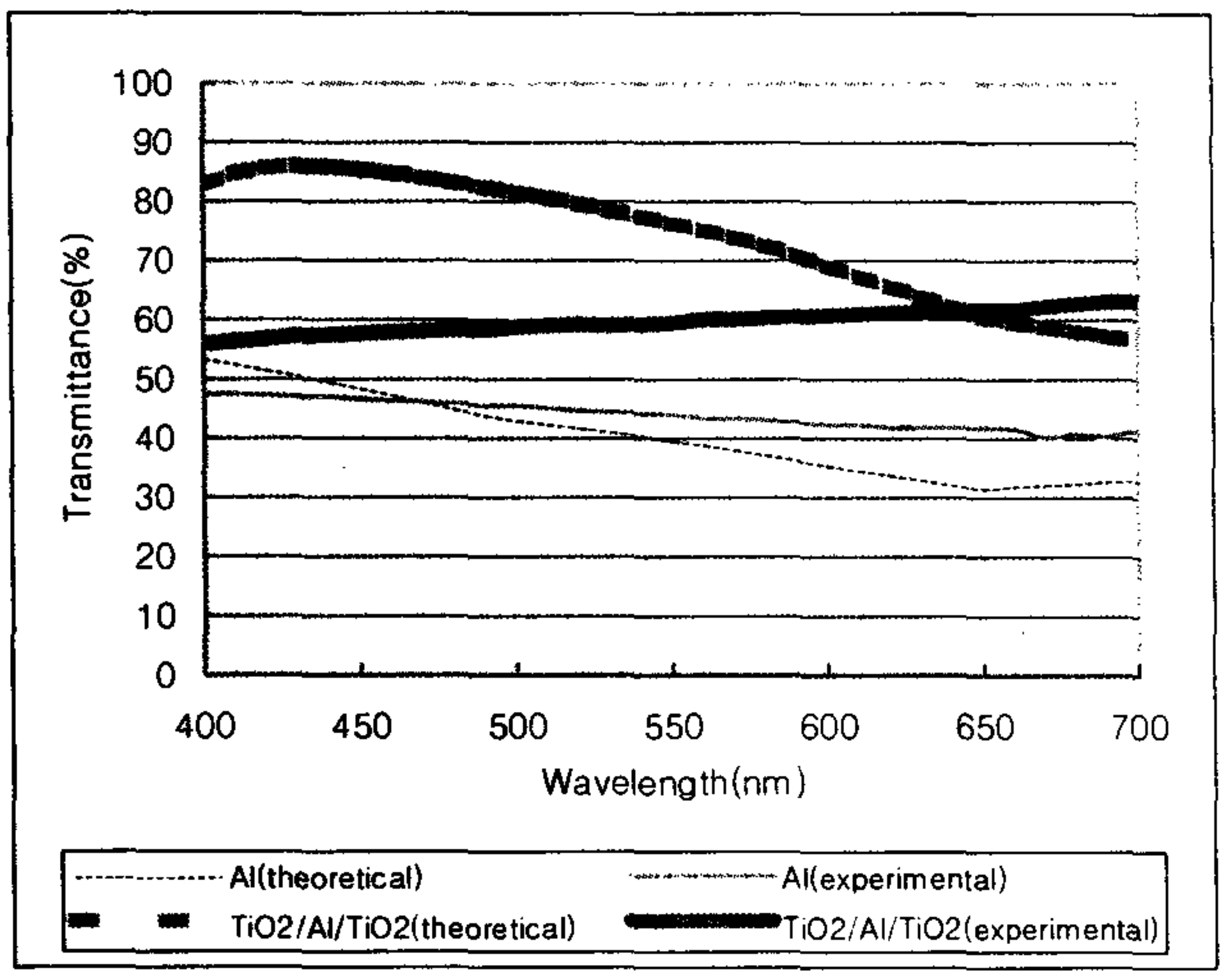

Fig. 3. Transmittance spectrum of Al deposited PES film & TiO2/Al/TiO2 deposited PES film.

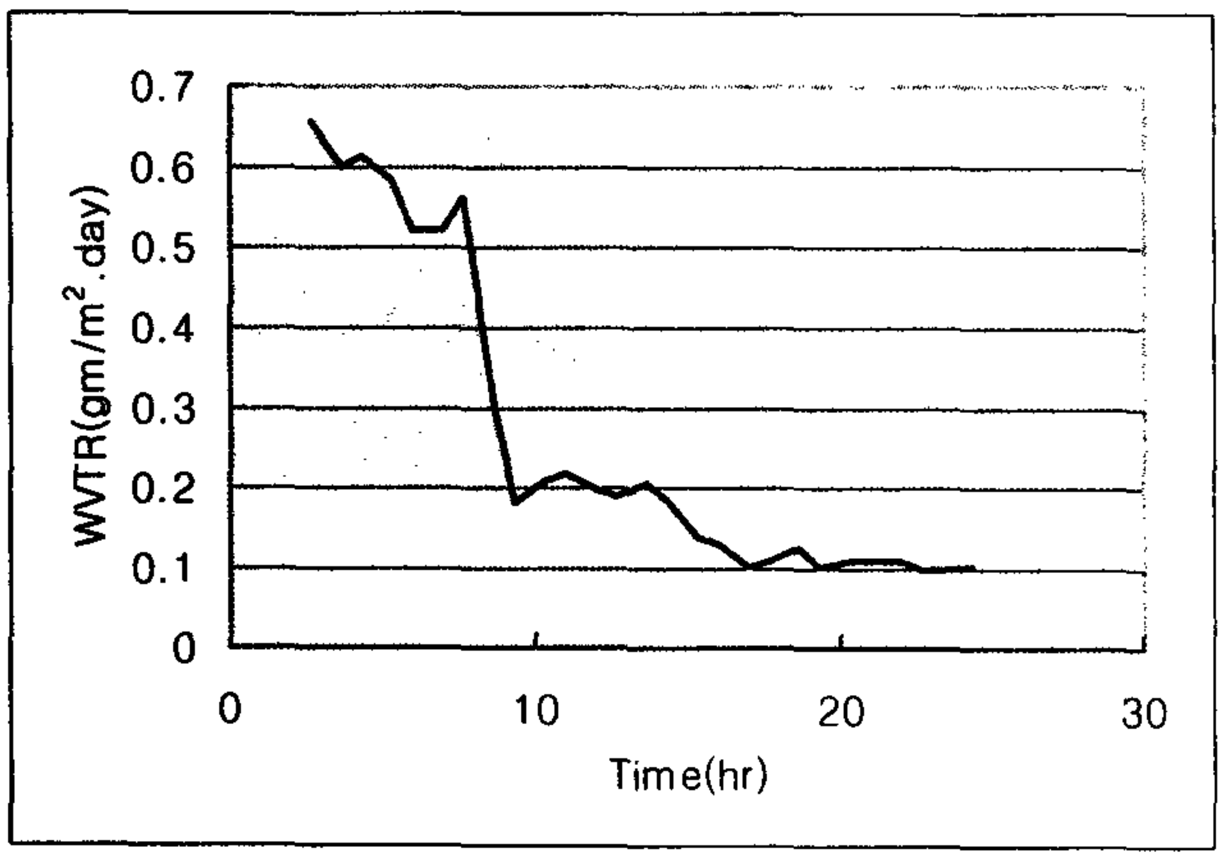

Fig. 4. The gas barrier property of TiO2/Al/TiO2 deposited PES film

Conclusion

Developing plastic substrate has allowed us to approach commercialization of flexible plastic display. We improved the performance of plastic substrate to satisfy the requirements of plastic substrate for TFT-LCD in many sides.

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

References

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