

TRANSPARENT CONDUCTIVE OXIDE AND PERMEATION BARRIER OXIDE MULTILAYERS ON FLEXIBLE POLYMERS

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Introduction

Potential applications of flexible polymers have been continuously discovered in displays and in solar cells because of excellent properties such as mechanical flexibility, optical transparency, lightweight, and cost-competitiveness [1,2]. The economic impact of the polymers on liquid crystal displays (LCD), organic-emitting diode (OLED) displays, and photovoltaic modules will be comparable to that of conventional panel glasses.

In a general structure of engineered polymer substrates, a single or multilayer of optically transparent oxides provides excellent functional properties such as high electronic conductance and low permeability. Impermeability against water vapor and/or oxygen is achieved by a thin barrier film coated on polymers, while the conductance is achieved by a transparent conductive oxide (TCO) that is often coated on the barrier. However, the formation of cracks and debondings in these films coated on polymers is a serious issue in situations in which bend geometries are applied due to the large difference between the elastic properties of oxides and polymers [3,4]. The failure behavior of the oxide multilayer coatings in the bend geometries has not been well understood.

In this study, the excellent water vapor impermeability was obtained by optimizing the pretreatment process of polyethylene terephthalate (PET) surfaces. The performance of SiO_x water vapor permeation barrier and indium-zinc-oxide (IZO) conductive layer was investigated in bend geometries.

The water vapor impermeability and electrical conductance of the films were measured in different bending radii and bending cycles.

Experimental

The multilayer system was composed of (i) a 10-nm-thick Al₂O₃ interlayer sputtered on polymers, (ii) a thicker SiO_x barrier subsequently grown on the interlayer using a plasma-enhanced chemical vapor deposition (PECVD), and (iii) an IZO film sputtered on the barrier. A 188-μm-thick PET substrate (Kimoto Co., Ltd) was initially pretreated with Ar ion beams with the conditions: pressure of 1×10^{-4} Torr, dc power of 220 W, Ar flow rate of 15 sccm, and pretreatment time of 3 min. The Al₂O₃ interlayer was sputtered by a reactive magnetron sputtering system using a 4-in. Al target (Applied Science Corp) with the conditions: pressure of 3×10^{-3} Torr, dc power of 300 W, and Ar:O₂ flow rate of 45:5 sccm. The SiO_x barrier was coated by a PECVD system using a radio frequency of 13.56 MHz with the conditions: pressure of 0.18 Torr, r.f. power of 200 W, and hexamethyldisiloxane (HMDSO):O₂:Ar flow rate of 2.7:10:100 sccm. The growth process and film properties of the barrier system, SiO_x/Al₂O₃/PET, are demonstrated in detail elsewhere [5]. The IZO film was sputtered on the barrier system by a r.f. (13.56 MHz) magnetron sputtering using an IZO target (Samsung Corning CO., Ltd.) with the conditions: pressure of 2.6×10^{-3} Torr, r.f. power of 200 W, and Ar flow rate of 32 sccm.

Results and Discussion

Advanced water vapor impermeability was achieved when a two-step pretreatment process—comprising (i) PET treatment with Ar^+ ion beams and (ii) subsequent sputtering of a 10-nm-thick Al_2O_3 interlayer on the PET—was carried out prior to a SiO_x PECVD process. This process brought about an improvement in both the morphology of the SiO_x barrier and the adhesion of the barrier with a polymer substrate, resulting in significant barrier enhancement. A low water vapor transmission rate (WVTR) value in the range of 10^{-4} $\text{g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ was obtained from a $\text{SiO}_x/\text{Al}_2\text{O}_3/\text{PET}$ system with a 150-nm-thick SiO_x barrier, as shown in Fig. 1. We previously reported a WVTR value of about 2.5×10^{-2} $\text{g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ at the same SiO_x thickness when the Al_2O_3 interlayer was grown on PET substrates without a pretreatment process [5]. The significant reduction of WVTR can be understood as a result of the elimination of surface defects on the polymers and the adhesion improvement of the Al_2O_3 interlayer with ion-beam treated PET surfaces.

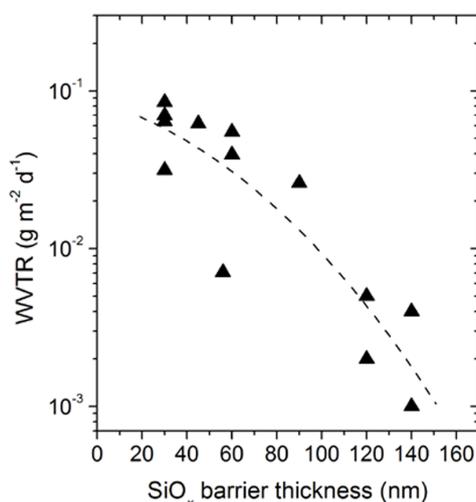


Fig. 1 Water vapor transmission rate (WVTR) of $\text{SiO}_x/\text{Al}_2\text{O}_3/\text{PET}$ system as a function of SiO_x barrier thickness.

The IZO film sputtered on the $\text{SiO}_x/\text{Al}_2\text{O}_3/\text{PET}$ system exhibited excellent mechanical stabilities in bend geometries when compared to the films grown directly on PET substrates. The resistance and WVTR of IZO/ $\text{SiO}_x/\text{Al}_2\text{O}_3/\text{PET}$ systems remained low and

invariable even in severe bent states. The IZO (135nm) / SiO_x (90nm) / Al_2O_3 (10nm) / PET system maintained a resistance of 3.2×10^{-4} $\Omega\cdot\text{cm}$ and a WVTR of $< 5 \times 10^{-3}$ $\text{g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ after 1000 bending cycles at a bending radius of 35 mm. The system satisfies the water vapor impermeability requirements for organic thin film transistors (TFTs), liquid crystal displays (LCDs), and inorganic photovoltaics.

Conclusion

Water vapor impermeability of SiO_x barriers and electrical conductance of IZO films were significantly improved by applying Ar^+ ion beam PET pretreatment and a subsequent Al_2O_3 interlayer sputtering. The IZO/ $\text{SiO}_x/\text{Al}_2\text{O}_3/\text{PET}$ system provided excellent structural stabilities in severe bend geometries.

References

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