# OXIDE BARRIER COATINGS ON ION-BEAM TREATED POLYMER SUBSTRATES

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## Introduction

Transparent thin oxide layers grown on flexible polymer substrates have been considered as appropriate barriers against gas and water vapor permeation. A water vapor transmission rate (WVTR) value in the range of $10^{-3}$ to $10^{-4}$ g/m$^2$/day is applicable to flexible flat panel displays and photovoltaic applications [1]. However, the low WVTR values have not been achieved by thin oxide barriers grown on polymer substrates using conventional plasma-enhanced chemical vapor deposition (PECVD) and sputtering methods. It is generally recognized that the water vapor impermeability of oxide barriers is degraded by the presence of microscopic pinholes and cracks in the barriers [2–4]. The formation of these defects is strongly affected by the surface status of polymer substrates.

In this study, we investigated the correlation between the characteristics of ion-beam pretreated polyethylene terephthalate (PET) substrates and the water vapor impermeability of $Al_2O_3$ layers sputtered on the PET surfaces. Effects of the ion-beam pretreatment on the PET properties—including wettability, morphology, and chemistry—were determined by contact angle and surface free energy measurements, field-emission scanning electron microscopy (FE-SEM), atomic force microscopy (AFM), and infrared (IR) absorption spectroscopy.

## Experimental

The surface of PET substrates (Kimoto Co., Ltd.) was pretreated by $Ar^+$ ion beams with the conditions as follows: working pressure of $3 \times 10^{-3}$ Torr, Ar flow rate of 45 sccm, pretreatment time of 0–9 min, surface temperature of 50–120 °C, and dc power of 200–280 W. The $Al_2O_3$ layer was grown by a rf magnetron sputtering system using a 4 in. $Al_2O_3$ target.

## Results and Discussion

It was found that the morphology and wettability of polymer surface were significantly improved by the Ar ion-beam treatment, as demonstrated in Fig. 1. The water contact angle

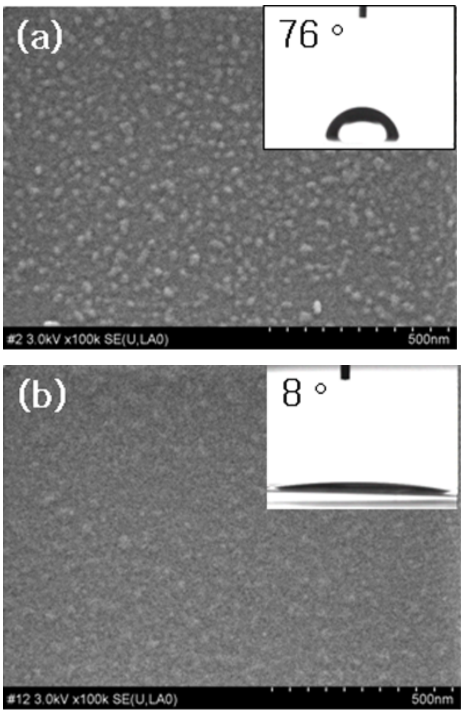


Fig. 1 Surface morphology of PET substrates (a) before $Ar^+$ ion-beam pretreatment and (b) after the pretreatment with conditions: time of 3 min, surface temperature of 120 °C and dc power of 224 W. The insets are the images of water contact angle measurements.

of an untreated PET surface was about 76°. Large amounts of defects such as dust, particle, and organic contaminant were observed on the PET surface. When the surface was modified by bombardments of $Ar^+$ ions during the pretreatment process, the wettability improved with increasing the pretreatment time, power, and surface temperature. The minimum contact angle was obtained at a surface temperature of 120 °C.

High-quality $Al_2O_3$ layers with low WVTR values close to the range of $10^{-3}$ $g/m^2/day$ were obtained on the PET substrates pretreated with the optimized ion-beam conditions. This result can be explained by the increase in the wettability of the PET surface without any apparent morphological deterioration after $Ar^+$ ion-beam pretreatment. The defect elimination and the wettability increase on the PET surface leaded to the adhesion improvement between the substrate and the $Al_2O_3$ layer. However, the failure of water vapor impermeability occurred with a significant roughening of the PET surface due to extended exposure to Ar ion beams. Large amounts of defects developed in an $Al_2O_3$ layer grown on a heavily reconstructed PET surface, as shown in Fig. 2.

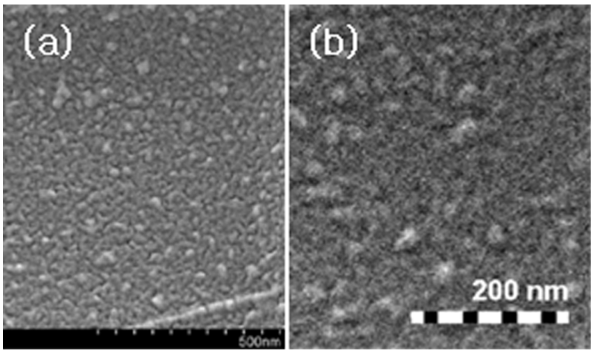


Fig. 2 Surface morphology of (a) a PET surface damaged by extended ion-beam pretreatment and (b) a 20-nm thick $Al_2O_3$ layer sputtered on the damaged PET surface.

## Conclusion

The water vapor impermeability of thin $Al_2O_3$ layers sputtered on PET substrates was improved by optimizing the conditions applied to PET surfaces during $Ar^+$ ion-beam pretreatment. The PET pretreatment at relatively high surface temperatures close to 120 °C was found to be a crucial factor for the improvement in the water vapor impermeability of $Al_2O_3$ layers.

## References

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