Formation of a bilayer of low-temperature CVD-SiO_2 and sputtered Al_2O_3 films on polyethylene terephthalate substrates for an OLED encapsulation layer

Hyuk Jin Kim[1,2], Sang hyun Park[1], Yoon Jang Kim[1,2], Hong Woo Lee[1,2], Seungha Oh[1] and Hyeong Joon Kim[1]

[1]Department of Materials Science and Engineering, Inter-university Semiconductor Research Center, Seoul National University, Seoul 151-742, Republic of Korea
[2]Development Center (LCD), Samsung Display, Asan-city 336-741, Republic of Korea

Organic light-emitting diode (OLED) displays have promising potential for flat-panel display to replace liquid crystal displays (LCDs). The limited lifetime of OLED is a major drawback for its commercial applications such as TV and monitor. Since the organic materials and low work-function metals used in OLEDs are sensitive to moisture, OLED displays are easily degraded in humid environment. Encapsulation with organic or inorganic thin films has been actively investigated to fulfill a requirement of low water permeability ($< 10^{-6}$ $g/m^2 \cdot day$). Recently, multilayers of inorganic thin films have been proposed for the encapsulation of OLEDs using various deposition methods such as sputtering, atomic layer deposition (ALD), and chemical vapor deposition (CVD).[1-5].

In this study, we prepared a single-layer barrier of sputtered Al_2O_3 and a bilayer barrier consisting of CVD SiO_2 and sputtered Al_2O_3 as a potential moisture barrier for an OLED encapsulation. Sputtered Al_2O_3 films were prepared at room temperature using an RF magnetron sputtering system (CS5000, SNTek Co.). The process pressure and Ar flow rate were 5 mTorr and 10 sccm, respectively. The RF power of Al_2O_3 target was 150 W. For the bilayer barrier, the CVD SiO_2 thin films were formed at 100◦C using tris(ethyl-methyl-amino)silane (TEMS, $HSi[N(C_2H_5)(CH_3)]_3$) and O_3 as a Si precursor and oxidant gas, respectively.

Figure 1 shows the Fourier transform infrared spectroscopy (FTIR) spectra of CVD SiO_2 layer. Absorbance bands at 1070 cm^{-1} and 800 cm^{-1} are ascribed to the stretching and bending vibrations of Si-O-Si, respectively. The peak at 950 cm^{-1} has been reported to be associated with the stretching mode of Si–OH. The absorbance band at 880 cm^{-1} is assigned to the bending modes of $H\text{-}SiO_3$, indicating that CVD SiO_2 contains small amount of –OH radicals. Since CVD SiO_2 with –OH radicals exhibits a flowable behavior, the CVD-SiO_2 film exhibits a conformal gap-filling at the acute angle region between the silica particle and the substrate, as shown in Fig. 2. Because the conformal gap-filling behavior of CVD SiO_2 enhanced the blocking of the pin holes or cracks of sputtered Al_2O_3 layer, the bilayer barrier with CVD-SiO_2 layer and sputtered Al_2O_3 layer reduced the water permeation compared to the Al_2O_3 single-layer barrier, as shown in Fig. 3. The bilayer with the 100 nm thick Al_2O_3 and the 100 nm thick CVD-SiO_2 exhibits lower water vapor transmission rate (WVTR) (0.214 $g/m^2 \cdot day$) than the 200 nm thick sputtered Al_2O_3 single-layer (0.325 $g/m^2 \cdot day$), although both barriers have the same thickness.

In summary, the encapsulation bilayer with CVD SiO_2 and sputtered Al_2O_3 layers was studied to reduce the moisture permeation through PET film. Even though the WVTR (0.214 g/m^2-day) of the bilayer barrier is much lower than the target value (10^{-6} g/m^2-day) of the OLEDs, the inorganic bilayer barrier of OLEDs with different materials and different deposition methods makes it possible to reduce the water permeation to OLEDs. Especially the gap-filling property of flowable CVD-SiO_2 plays the key role in a surface planarization and blocking of surface defects.

References

[1] Y. M. Chung, M. J. Jung, K. H. Nam, J. G. Han, S. H. Baeg, and S. H. Yang, Surf. Coat. Tech., 171, 65 (2002).
[2] H. K. Kim and C. K. Cho, Nanoscale Res. Lett., 7, 69 (2012).
[3] M. C. Lin, C. H. Tseng, L. S. Chang, and D. S. Wuu, Thin Solid Films, 515, 4596 (2007).
[4] M. Groner, S. George, R. McLean, and P. Carcia, Appl. Phys. Lett., 88, 051907 (2006).
[5] P. Carcia, R. McLean, M. Reilly, M. Groner, and S. George, Appl. Phys. Lett., 89, 031915 (2006).

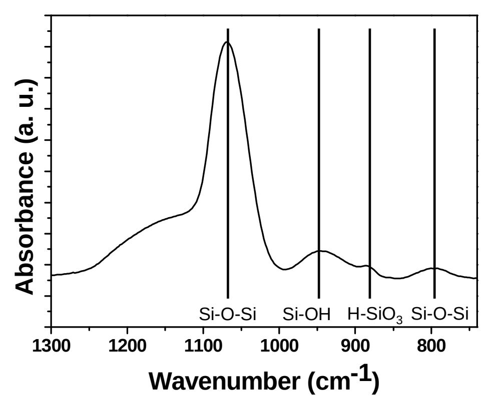

Fig. 1. The FTIR spectra of CVD-SiO_2 film.

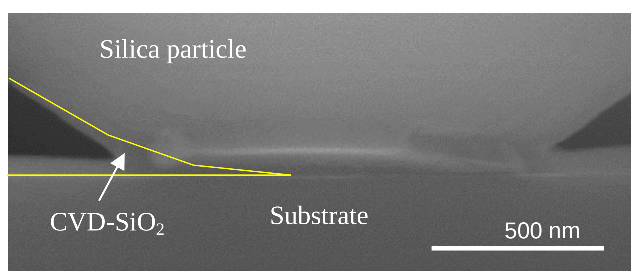

Fig. 2. Cross-sectional SEM image showing the coverage of CVD-SiO_2 film at the acute angle underneath a silica particle.

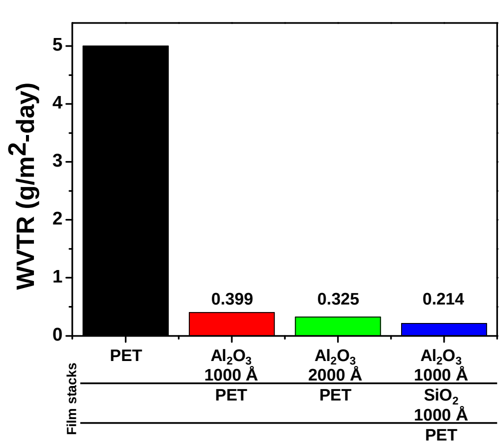

Fig. 3. The comparison of the WVTR of the single-layer and bilayer barriers.