

## Roll-to-Roll Barrier Coatings on PET Film by Using a Closed Drift Magnetron Plasma Enhanced Chemical Vapor Deposition

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**Abstract:** Korea institute of materials science (KIMS) use a linear deposition source called as a closed drift linear plasma source (CDLPS) as well as dual magnetron sputtering (DMS) to deposit  $\text{SiO}_x\text{C}_y\text{H}_z$  films in HMDSO/ $\text{O}_2$  plasma. The CDLPS generates linear plasma using closed drifting electrons and can reduce device degradations due to energetic ion bombardments on organic devices such as organic photovoltaic and organic light emission diode by controlling an ion energy. The deposited films are investigated by Fourier transform infrared (FT-IR) spectroscopy, X-ray photoelectron spectroscopy (XPS), and atomic force microscopy (AFM). Optical emission spectroscopy (OES) is used to measure relative radical populations of dissociation and recombination products such as H, CH, and CO in plasma. And  $\text{SiO}_x$  film is applied to a barrier film on organic photovoltaic devices.

### 1. Closed Drift Linear Plasma Source Process

$\text{SiO}_x\text{C}_y\text{H}_z$  film is deposited using CDLPS equipped in vacuum chamber as shown in Fig. 1. Pumping system consisted of turbo molecular pump and backing rotary pump. The chamber pressure was measured by Baratron capacitance manometer (MKS) and ion gauge (Granville Phillips). Deposition precursors were introduced by a mass flow controller (MKS) into the chamber. Oxygen flow was fixed as 200 sccm and the partial pressure of HMDSO (Aldrich, 99 %) was changed from 6.6 to 30 %. The HMDSO was injected by a home-made liquid vaporizer. The total pressure was maintained at  $4 \pm 0.5$  mTorr. The CDLPS generated 20 kHz frequency discharge to dissociate the precursors, HMDSO, and oxidant,  $\text{O}_2$ . The input power density was fixed to  $4.7 \text{ W/cm}^2$  at 500 mm width. The distance between CDLPS and substrate was 70 mm.

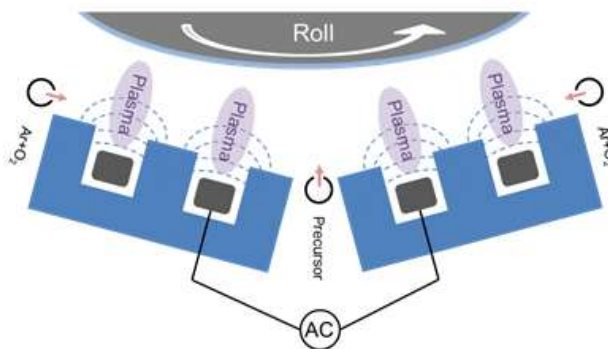


Fig. 1. Schematic of closed drift linear plasma source process

### 2. Result and discussion

Figure 2 is a deposition rate as a function of the ratio of  $\text{HMDSO}/(\text{HMDSO}+\text{O}_2)$  at  $6 \text{ W/mm}$ . As the ratio increases from 6.6 to 30 % a dynamic deposition rate is in range of  $50\sim 270 \text{ nm} \cdot \text{m/min}$ . It is well known that the high deposition rate at the high HMDSO composition is due to polymeric  $\text{SiO}_x\text{C}_y\text{H}_z$  depositions, which attributed to insufficient oxidations of organosilane precursors [1]. The polymeric growth results in the deposition with rough surface and the formation of grain boundary. It degrades a gas barrier performance. Gas permeations are accelerated

through a grain boundary and a nano-size pore in SiO<sub>x</sub>CyHz molecules. Especially the sizes of nano pores are bigger than the transmission gas [2].

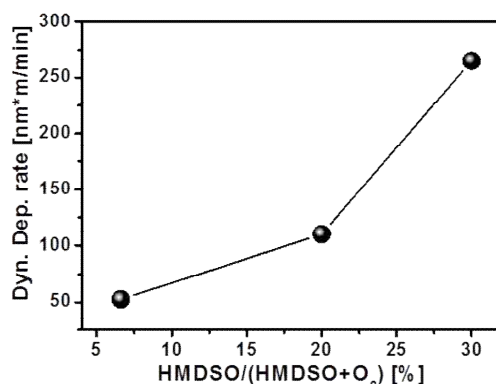


Figure 2. Dynamic deposition rate as a function of HMDSO fraction

Figure 3 shows the FT-IR spectra of the films deposited with the different HMDSO ratios from 6.6 to 30 %. Table 1 represents main absorption bands in SiO<sub>x</sub>CyHz films. One can observe the peak at 1027 cm<sup>-1</sup> (Si-O-Si symmetric stretches) corresponding to the formation of SiO<sub>x</sub> film. However, this peak has also been assigned to Si-O-C asymmetric stretches due to insufficient oxidations of carbon and hydrogen as H<sub>2</sub>O and CO in HMDSO [3]. The remaining polymeric CH<sub>3</sub> chains are incorporated during the deposition, resulting in polymer-like film synthesis. For example, the peaks at 1254 cm<sup>-1</sup> (CH<sub>3</sub> symmetric bending in Si(CH<sub>3</sub>)<sub>x</sub>), 795 cm<sup>-1</sup> (CH<sub>3</sub> rocking in Si(CH<sub>3</sub>)<sub>3</sub>), and 839 cm<sup>-1</sup> (CH<sub>3</sub> rocking in Si(CH<sub>3</sub>)<sub>2</sub>) are also revealed at the HMDSO fraction of 30 %. Effective oxidation of HMDSO has been observed when the HMDSO fraction is decreased up to 6.6 % as shown in Fig. 4. The absorptions at 795, 839, and 1254 cm<sup>-1</sup> corresponding to the CH<sub>x</sub> bonds are disappeared for the sample prepared at 6.6 %. The reduction of carbon and hydrogen means that one can obtain a stoichiometric SiO<sub>2</sub> film.

SiO<sub>x</sub> film deposited at 6.6 % of HMDSO was adapted to the encapsulation of organic photovoltaic device, having a conventional structure. The power conversion efficiency was maintained continuously after the SiO<sub>2</sub> encapsulation. When one uses conventional PECVD to encapsulate the OPV devices ion bombardment and plasma heating easily degrade the OPV device, which is represented as the decreases of the PCE. On the other hand, the CDLPS adapted SiO<sub>2</sub> encapsulation showed stable encapsulation results. The encapsulation effect to prolong the PCE at atmospheric environment was maintained during 2 days. For more excellent encapsulation function, the design of barrier structure should be improved.

### 3. Concluding Remark

CDLPS deposited SiO<sub>x</sub>-like films without plasma damages on organic device, OPV. This result gives an insight that the CDLPS deposition processes with metal-organic precursors can be successfully adapted to in-line OPV and OLED fabrication processes. The deposition rate of SiO<sub>x</sub>-like film was in range of 100 nm • m/min, which should be increased to realize high speed roll-to-roll or in-line processes.

### Reference

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