

## Moisture-Barrier Properties of Carbon-coated Silicon Oxide Films

Wen-Ray Chen<sup>1</sup>, Hsiung-Ming Guo<sup>2</sup>, Teen-Hang Meen<sup>1</sup>,  
Kuen-Hsien Wu<sup>2</sup>, Fuh-Shyang Juang<sup>3</sup>, and Chien-Jung Huang<sup>4</sup>.

<sup>1</sup>Department of Electronic Engineering, National Formosa University, Yun-Lin, Taiwan 632, R.O.C.  
Phone:+886-5-6315648 E-mail:chenwr@nfu.edu.tw

<sup>2</sup>Department of Electrical Engineering, Southern Taiwan University of Technology,  
Tainan, Taiwan 710, R.O.C.

<sup>3</sup>Department of Electro-Optics Engineering, National Formosa University  
Yun-Lin, Taiwan 632, R.O.C.

<sup>4</sup>Department of Applied Physics, National University of Kaohsiung,  
Nan-Tzu 811, Kaohsiung, R.O.C.

### 1. Introduction

Although a portable and light OLED display has great competition in the future, however, how to prevent the moisture attack is a key issue for the device with a long lifetime [1]. Compared with the conventional glass-sealed package technique, it gets more attractive by using the dielectric/organic mixed multi layers as the passivation barrier. For the choice of the dielectric layers, the silicon nitride or the silicon oxide layers are widely used [2,3]. In this work, we proposed that the carbon-coated silicon oxide films might be used as the effective passivation layers. The silicon oxide films were deposited onto the plastic substrate by the electron-gun evaporation and then treated in a RIE chamber by injecting the CH<sub>4</sub> plasma. The water vapor transmission rate was measured and discussed in detail.

### 2. Experiment and Results

In this study, the SiO<sub>x</sub> films were all deposited onto the 0.2mm-thick PET substrates by using the electron-gun evaporation. The deposition rate was controlled at 2nm/sec. After the silicon oxide deposition process, the samples were then treated in a RIE chamber by injecting the CH<sub>4</sub> gas driving with a low power of 50W. In addition, the effect of other reactant gas such as oxygen or hydrogen was also incorporated and discussed. For the testing of the water vapor transmission rate (WVTR), the sample was tightly sealed over a glass bottle filled with the CaCl<sub>2</sub> (2g) by using the UV glue and then put into an controlled environment of 60°C and 95% relative humidity (RH). Typically, the weight gain as a function of time was recorded.

Fig.1 shows the typical weight gain as a function of time at various RIE treating time. Fig.2 shows the corresponding water vapor transmission rate as a function of time. From Fig.2, it was found that the minimum WVTR value was obtained as low as 11.9 g/day/cm<sup>2</sup> at the processing time of 4 minutes, which is 8 times lower than the untreated silicon oxide films as shown in Fig.3. It is easily found that the average WVTR value of various silicon oxide films was about 90 g/day/cm<sup>2</sup> which is similar to that of the PET substrate (95 g/day/cm<sup>2</sup>). The reason can be explained when we performed the contact angle of water

drops measurement. Fig.4 shows the contact angle of water drops on (a) the PET substrate and on (b) the silicon oxide films. The contact angles were 94° and 19° for the PET and the silicon oxide films, respectively. If the CH<sub>4</sub> plasma treatment was further performed on the silicon oxide films, the contact angle of water drops increase up to 77° as shown in Fig.4(c). However, it is worth to point out that the surface roughness were 0.34 nm and 0.52 nm for the untreated SiO<sub>x</sub> films and after the CH<sub>4</sub> plasma treatment, respectively. It can be concluded that the most important key issue was not depended on the surface morphology; the surface dangle bonds or surface states play the important roles.

Fig.5 shows the AES depth profile of the CH<sub>4</sub> plasma treated silicon oxide films. After the RIE treatment of CH<sub>4</sub> plasma, the carbon was obviously coated on top of the SiO<sub>x</sub> films and the contact angle of water drops shows a significant increase up to 77° as shown in Fig.4(c). From the interface between the carbon and silicon oxide layer, the silicon and oxygen atoms seem to slightly out diffuse into the carbon layer during the CH<sub>4</sub> plasma treatment. Therefore, in order to pre-compensate the dangling bonds on the surface of the silicon oxide layers, the treatment using hydrogen plasma was carried out before the CH<sub>4</sub> plasma treatment. In order to avoid the etching process during the H<sub>2</sub> plasma treatment, the treating time is short and the power is also kept at a low value. Fig.5(b) indicates that the AES depth profile shows almost no diffusion phenomenon between the interface of the carbon and the silicon oxide layer. The WVTR values (5~6 g/day/cm<sup>2</sup>) were about two times lower than the minimum value (11.9 g/day/cm<sup>2</sup>) of pure CH<sub>4</sub> RIE treatment as shown in Fig.6.

### 3. Conclusions

In summary, the silicon oxide films were successfully deposited on the PET substrates, and then the samples were treated in the CH<sub>4</sub> plasma. It was found that the WVTR values of the SiO<sub>x</sub> films were almost the same as that of the PET substrate due to the contact angle of water drops was obtained as low as 19° on top of the SiO<sub>x</sub> films. However, after the CH<sub>4</sub> plasma treatment, the contact angle of water drops shows a significant increase up to 77°. This

increasing in contact angle of water drops results in a minimum WVTR value of 11.9 g/day/cm<sup>2</sup> at a CH<sub>4</sub> treatment of 4 minutes. If a time-limited H<sub>2</sub> plasma treatment was performed before the CH<sub>4</sub> plasma treatment, the WVTR values can be further reduced to about 56 g/day/cm<sup>2</sup>.

### Acknowledgements

This work was partially supported by National Science Council of R.O.C. under contract no: NSC-94-2212-E-150-048.

### References

- [1] H. Kubota, S. Miyaguchi, S. Ishizuka, T. Walimoto, J. Fukuda, T. Watanabe, H. Ochi, T. Sakamoto, T. Miyake, M Tsuchida, I. Ohshita, and T. Tohma, "Organic LED full color passive-matrix display", *Journal of Luminescence*, **87-89** pp.56-60 (2000).
- [2] H. Lin, L. Xu, X. Chen, X. Wang, M. Sheng, F. Stubhan, K. H. Merkel, and J. Wilde, "Moisture-resistant properties of Si<sub>n</sub>x films prepared by PECVD", *Thin Solid Films*, **333**, pp.71-76 (1998).
- [3] R. S. Kumar, M. Such, E. Ou, G. Ewald, C. S. Jin, "Low moisture permeation measurement through polymer substrates for organic light emitting devices", *Thin Solid Films*, **417**, pp.120-126 (2002)

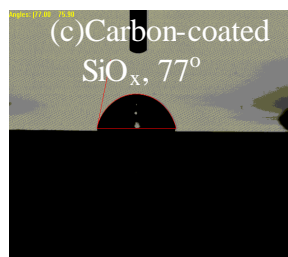
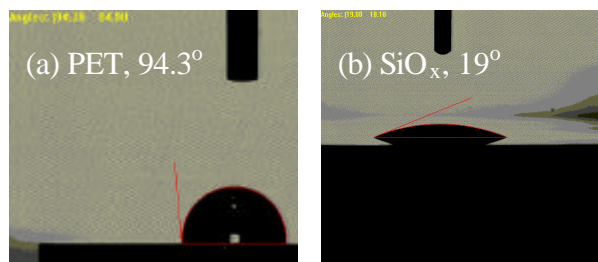


Fig.4 The contact angle of water drops on (a) the PET substrate, (b) the SiO<sub>x</sub> films, and (c) the carbon-coated SiO<sub>x</sub> films

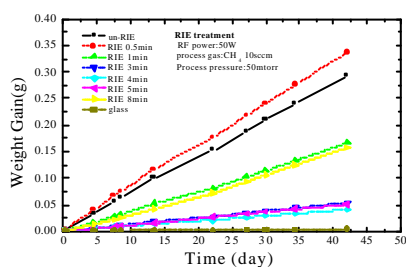


Fig.1 Weight gain of the SiO<sub>x</sub> films measured at various RIE treating time.

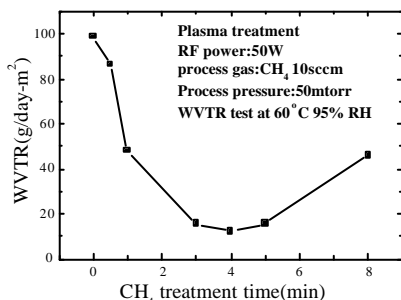


Fig.2 WVTR values as a function of the treating time.

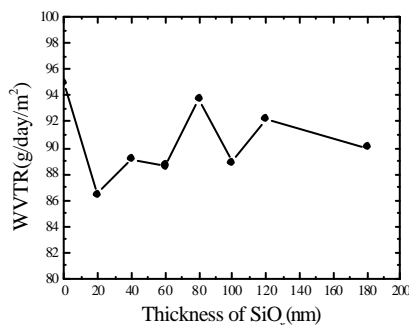


Fig.3 WVTR values as a function of the thickness of SiO<sub>x</sub>.

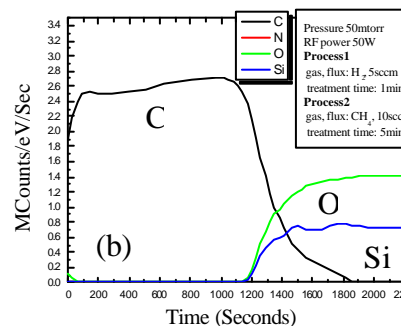
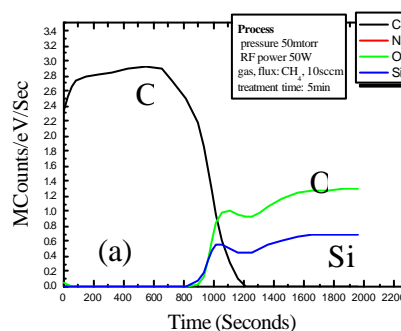


Fig.5 The AES depth profile of the SiO<sub>x</sub> films treated by (a) the CH<sub>4</sub> plasma, and (b) the H<sub>2</sub> plasma before the CH<sub>4</sub> plasma.

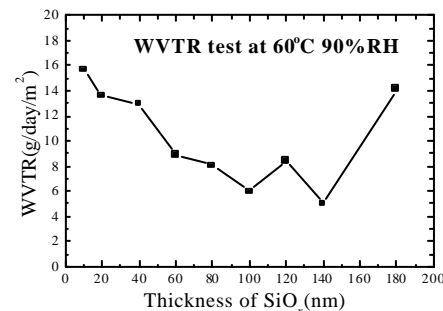


Fig.6 WVTR values as a function of the thickness of SiO<sub>x</sub> films through the H<sub>2</sub> plasma treatment one minute and the CH<sub>4</sub> plasma treatment 4 minutes.