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Effects of pore on dielectric constants of films deposited by PECVD

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1. Introduction

Low-k interlayer dielectric materials are being developed to replace the traditional silica. Recently, ultra low-k CVD films demonstrate the potential of porous CVD films for implementation in the interconnect structure of future chips. If one can vary the porosity in a controlled manner, it should be possible to control the dielectric constant. Therefore, it is critical to characterize the structure of porous thin films to understand, interpret and control the correlations between the processing conditions and the resulting physical properties[1-4]. In this study, we investigated that the pore in ultra low-k film effects on dielectric constants of film deposited as a function of porogen ratio.

2. General Instructions

Ultra low-k films were deposited with MAHA^{SP} (Atto Co. Ltd., 300 mm PECVD system), and DEMS (Diethoxymethylsilane) and ATRP (Alpha-Terpinene) used as Si-source and porogen, respectively. To control the pore density or size, we tested that ultra low-k films were deposited with ratio of ATRP and DEMS flow rate at 225 ^{o}C, 8.5 torr.

All as-deposited ultra low-k films employing porogen precursor were treated by exposure to a UV Curing chamber in order to render them porous. Exposure were performed with the Fusion lamp system (wavelength 365 nm) retrofitted onto an ATTO. Co,.Ltd. MAHA SP in a 300mm single chamber. The bulb was across the surface of the film at a rate of approximately 180sec with the wafer held at approximately 400℃ and vacuum ambient. All films were treated with essentially identical cure process conditions. We could confirm that UV curing process was possible to generate pore in films as removed porogen.

Refractive index and thickness were determined using a NANOMETRICS i3000 spectroscopic. Specula X-ray reflectivity (XRR) data were measured on a GISAXS (Grazing Incidence SAXS). The FT-IR measurements were carried out in the absorbance mode with wave numbers ranging from 400 to 4000cm^{-1}. To calculate the atomic ratio of films, X-ray photoelectron spectroscopy (XPS) was analyzed in high resolution mode. To measure the C-V, MIS structure was fabricated. MIS was fabricated that circular type aluminum (Al) electrode using a shadow mask was evaporated on the surface of ultra low-k films. The C-V characteristics were measured at frequency of 1MHz, and then dielectric constant was calculated.

3. Results

From FT-IR spectra of porous films, the peak intensity of Si-O-Si cage structure at 1050 cm^{-1} increased with ATRP flow rate. It could be pore density to increase with increasing ATRP flow rate (see Fig. 1).

In the results of XPS, composition of films didn't change by ATRP flow rate, and there was not peak shift of bonding energy of silicon, oxygen, and carbon (not figure).

Fig. 2 is shown that the average pore size of low-k films analyzed by SAXS (small angle x-ray scattering) increased from 3.2 to 3.6 nm with ATRP flow rate. But it could be to nearly not change pore size by ATRP flow rate.

From nano-indentor data of hardness and modulus are decreased with ATRP flow rate. Hardness decreased from 4.5Gpa to 2.0Gpa with increasing ATRP flow rate. And modulus decreased from 111.0Gpa to 84.5Gpa with increasing ATRP flow rate. It could be pore density to increase with ATRP flow rate and Si-O-Si cage structure (see Fig. 3).

Dielectric constants decreased from 2.5 to 1.6 with increasing ATRP flow rate, and C-V curve shifted toward positive gate voltage by negative charge in films (Fig. 4).

Leakage currents of the SiCOH films are shown in Fig. 5. Leakage current increased from 5E-12 to 7E-09 at 10MV/cm. A decreasing trend for leakage current as the porogen ratio decreased can be seen. This is contrary to the fact that the leakage current increases at the case of more porosity. As DEMS: ATRP ratio increased, Si-O-Si cage structure peak intensity increased. In other word, it means that porosity was increased.

Fig. 6 is shown the SEM photography after patterning that conditions of dry etching were 2200W, 9mTorr, C_4F_8 35sccm, O_2 10sccm, and time 50sec.

3. Conclusion

we could explain that ultra low-k films had same pore size from results of SAXS analysis, and pore density increased with ATRP flow rate from results of FT-IR. So, it seems that dielectric constant decrease as pore density increased with the flow rate of ATRP.

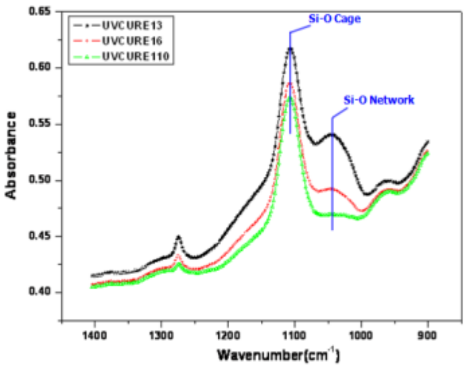

Fig 1. Porogen ratio to DEMS Si-O bonding peak from FTIR spectrum of the ULK film

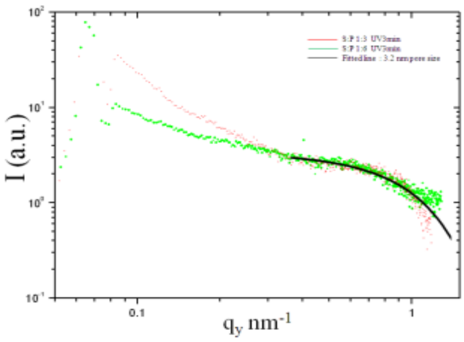

Fig 2. SAXS spectra of ultra low-k deposited with porogen ratio.

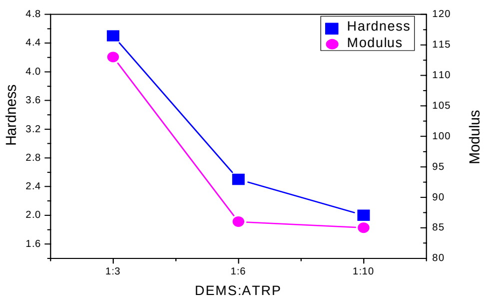

Fig 3. Hardness and Modulus with increasing ATRP flow rate by nano-indentor

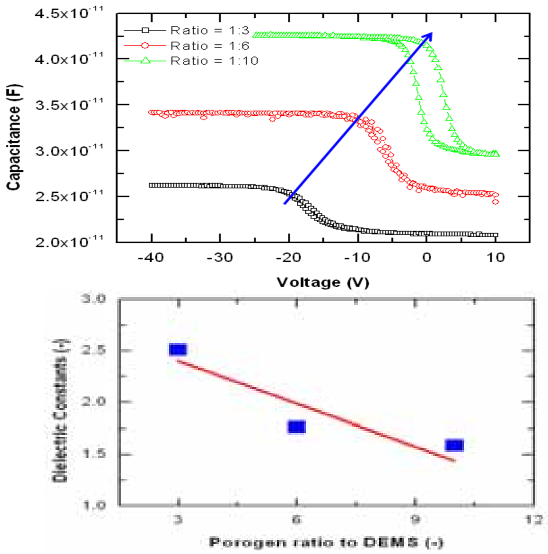

Fig 4. C-V curve, porogen ratio to DEMS dielectric constant graph of ULK films

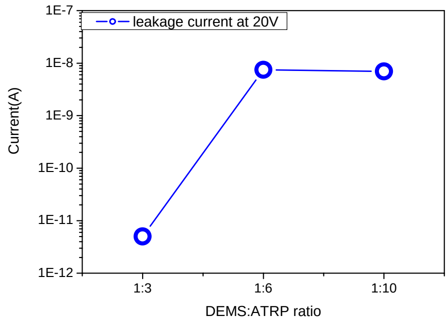

Fig 5. Leakage current vs. porogen ratio for the SiCOH films

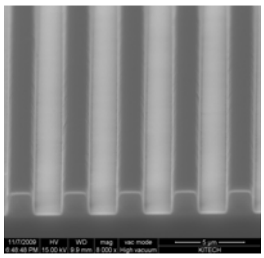

Fig.6. Porogen ratio to DEMS Si-O bonding peak from FTIR spectrum of the ULK film

Reference

[1] A. Grill et al., Appl. Phts. Lett. **79**, 803 (2001).
[2] D. W. Gidley *et al.*, *Appl. Phys. Lett.* **76**, 1282 (2000).
[3] F. N. Dultsev *et al.*, *Elect. Solid State Lett.* **2**, 192 (1999).
[4] W. L. Wu *et al.*, *J. Appl. Phys.* **87**, 1193 (2000).