Structural Analysis of SiCOH Low-k Thin Films Prepared by Chemical Vapor Deposition of Organosilane Precursors

K. Heo[1], J. Yoon[1], K. S. Jin[1], S. Jin[1], S.-G. Park[2], S.-W. Rhee[2,*], M. Ree[1,*]

[1]*Department of Chemistry, National Research Lab for Polymer Synthesis & Physics, Pohang Accelerator Laboratory, Center for Integrated Molecular Systems, Polymer Research Institute, and BK School of Molecular Science;* [2]*Department of Chemical Engineering, Pohang University of Science and Technology, Pohang 790-784, Republic of Korea*

Introduction

As integrated circuit feature sizes in high performance microelectronics continue to shrink, the signal propagation delay, power consumption, noise, and crosstalk between metal interconnections become acute. Since these issues critically depend on the dielectric constant (*k*) of the separating insulator. To solve these issues, the lower line-to-line capacitance and RC delay afforded by combining low-*k* dielectrics with high speed copper interconnects. In recent years, spin-on-dielectrics and chemical vapor deposition (CVD) based SiCOH dielectrics were intensively investigated because of their low dielectric constant along with good thermal and mechanical stability. In particular, dielectric films prepared by plasma enhanced chemical vapor deposition (PECVD) have several advantages over the spin-on-dielectrics: good thermal, mechanical, and adhesion strength as well as high resistance to humidity, while the *k* value is as low as 2.4 to 3.0. However, the structures of PECVD-based dielectrics have not been characterized in detail. [1.2]

In the present study, porous SiOC(-H) dielectric films were prepared vinyltrimethylsilane (VTMS), divinyldimethylsilane (DVDMS), and tetravinylsilane (TVS) precursors and oxygen by PECVD process in various conditions. The obtained dielectric films were in detail characterized their structures and properties by synchrotron grazing Incidence small-angle X-ray scattering (GISAXS) and specular X-ray reflectivity (SXR), and will be discussed in detail with considering the precursor chemistry and chemical reactions associated with PECVD process.

Methods and Materials

A capacitively coupled plasma reactor was used where both O_2 and precursors [vinyltrimethylsilane (VTMS), divinyldimethylsilane (DVDMS), and tetravinylsilane (TVS)] and the films were deposited on (100) oriented p-type silicon substrates. Precursor flow rate was fixed at 10 sccm and O_2 flow rate was varied with total flow rate adjusted at 210 sccm with helium. The chamber pressure remained constant at 1 Torr. GISAXS and XR measurements were carried out at the 4C2 and 3C2 beam lines at the Pohang Light Source (PLS), respectively. A monochromatized X-ray radiation source of λ = 0.154 nm.

Results and Discussion

Figure 1 shows 1D GISAXS profiles of SiCOH films, which were annealed at 450°C. The average radius of pores within the VTMS film is 1.22 nm and its width of pore size distribution is 0.2. The DVDMS and TVS films show featureless scattering profiles. Table 1 shows the electron density of the film, which were determined by XR measurements.

It was shown that vinyl silanes were quite effective to deposit SiCOH/C_xH_y dual phase films. In this research we tried 3 vinyl silanes with one, two and four vinyl groups attached on silicon. Through annealing, volatile phase was evaporated to make nano pores in the film. It was confirmed that VTMS was the most effective precursor to lower the dielectric constant of the film. Thermal annealing requires relatively long time and more effective annealing technique is required.

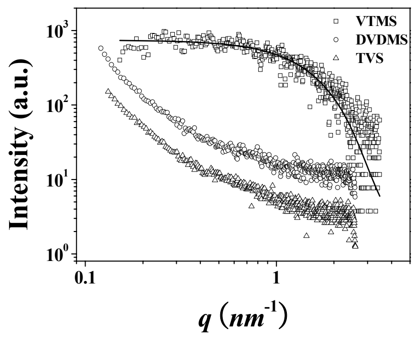

Fig. 1. 1D GISAXS profiles of SiCOH films.

Sample	Annealing Temp (˚C)	Annealing Time (hr)	Electron density (nm-3)
VTMS 1	RT	0	362
VTMS 2	400	0.5	353
VTMS 3	450	0.5	339
VTMS 4	450	4	339
DVDMS 1	RT	0	385
DVDMS 2	400	0.5	379
DVDMS 3	450	0.5	369
DVDMS 4	450	4	367
TVS1	RT	0	428
TVS2	400	0.5	418
TVS3	450	0.5	418
TVS4	450	4	404

Table. 1. Electron densities of the SiCOH film.

REFERENCES

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