1546
doi:10.1017/S1431927610059118

Microsc. Microanal. 16 (Suppl 2), 2010

EELS Characterization of Patterned Low-k Materials

Yuji Otsuka,* Yumiko Shimizu,* Naohiko Kawasaki,* Kosuke Kurushima,* and Shinichi Ogawa**

* Toray Research Center, Inc., 3-3-7, Sonoyama, Otsu, Shiga 520-8567, Japan
** Semiconductor Leading Edge Technologies, Inc., 16-1, Onogawa, Tsukuba, Ibaraki 305-8569, Japan

1. Introduction

For a rapid development of low-k materials in copper metallization for Ultra Large Scale Integrated (ULSI) devices, nm-order characterization methods of low-k materials after several processes such as dry etching, metal sputter deposition are required to optimize materials and processes quickly. In this study, relative thickness measurement by log-ratio method [1] and dielectric constant measurement by Kramers-Kronig analysis (KKA)[1,2] have been applied to obtain process damage information of low-k materials at higher spatial resolution by VEELS combined with conventional compositional analysis by core-EELS (CEELS).

2. Experimental

A porous SiOC (p-SiOC) of k=2.4 patterned structure on a SiO_2 layer with Cu interconnect (Ta/TaN barrier) was used for characterization. A TEM cross sectional specimen was prepared by a FIB method. The TEM, STEM, EELS analysis were performed with JEOL JEM-2100F at 200keV, equipped with GATAN Imaging Filter (Tridiem). Typical energy resolution was 0.8eV FMHM.

Compositional analysis was carried out by CEELS. Relative thickness (t/λ) was determined from the low-loss region of the EELS by the log-ratio method [1]. Dielectric constant (k) was determined from VEEL spectra by KKA. In KKA we checked the retardation effect such as Cérenkov radiation loss might have changed the profile of low-loss region at 0-5 eV [2, 3]. To check the result of elimination of Cérenkov radiation we compared two spectra recorded at 3 mrad collection semi-angle (β) and for 30 mrad.

3. Results and Discussion

Figure 1 shows a STEM image of the patterned structure, and Figure 2 shows composition profiles analyzed along an arrow in Fig.1. Carbon composition gradually decreased close to the side wall in the area of 40nm. Such composition analysis by CEELS is often used for low-k films [4] however we could know only the change of composition such as carbon depletion and this approach is not so sensitive for structural changes which might affect electrical and mechanical properties. Figure 3 shows a relative thickness (t/λ) profile derived from VEELS at the same line in Fig.1. In composition profiles (Fig.2), the slope of carbon decrease was simple in the range of 40nm however the relative thickness was firstly decreased at 40-20nm from side wall then increased from 20nm towards the side wall. Suppose that the inelastic mean free path (λ) of p-SiOC at each position is constant, the changes of t/λ value might indicate that the density or porosity of the p-SiOC has been changed at the adjacent area of the side wall. Carbon depletion from the p-SiOC during patterning processes such as dry etch might have caused shrinkage of the p-SiOC to increase of density at 0-20nm from the side wall (region A in Fig.3). This shrinkage has secondarily setoff the fracture at outside of the dense region (20-40nm from the side wall; region B in Fig.3). As regards Cérenkov radiation loss there were no significant changes at low energy loss region (0–5 eV) even in the loss function for 3 mrad collection semi-angle so that in our study for SiO_2 and low-k materials that have lower refractive index than SiO_2, we convinced that we could ignore Cérenkov radiation. In our study the intensity of Cérenkov radiation from insulator such as SiO_2 is too small to detect so we did not make any special treatment before KKA.

Figure 4 shows a plot of the dielectric constant (k) profile derived from VEELS at the interconnect layer. In the region of about 20nm from the side wall k-values were inclined to increase to about 4.0, which is similar value of SiO_2. The increase of the k-value might have been occurred because of carbon depletion and densification of p-SiOC to generate SiO_2-like structure.

References

[1] R. F. Egerton : *Electron Energy Loss Spectroscopy in the Electron Microscope*, section 4, (Plenum Press, New York), (1996)
[2] M. Stöger-Pollach : *Micron*, **39**, (2008) 1092.
[3] M. Stöger-Pollach et al.: *Micron*, **37**, (2006) 396.
[4] O. Richard et al.: *Microelectronic Engineering*, **84**, (2007) 517.

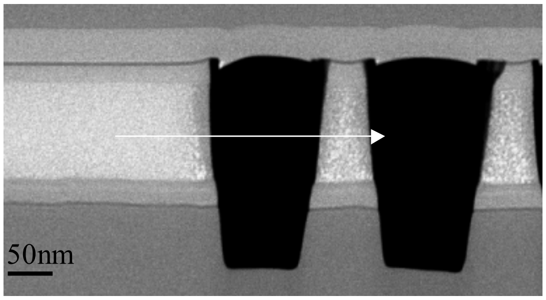

Fig. 1. Bright field STEM image of the patterned p-SiOC film.

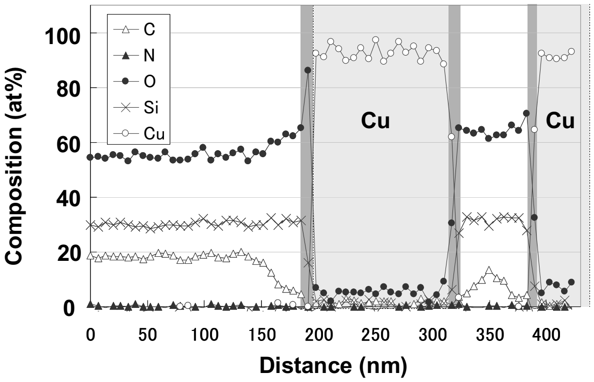

Fig. 2. Compositional line profile of the patterned p-SiOC film. Line is corresponding to the arrow in Fig.1.

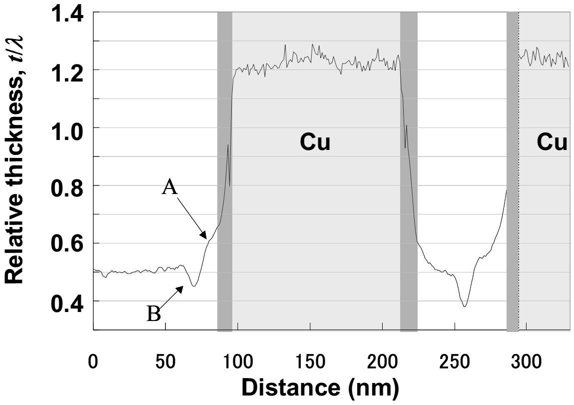

Fig. 3. Relative thickness line profile of the patterned p-SiOC film. Line is corresponding to the arrow in Fig.1.

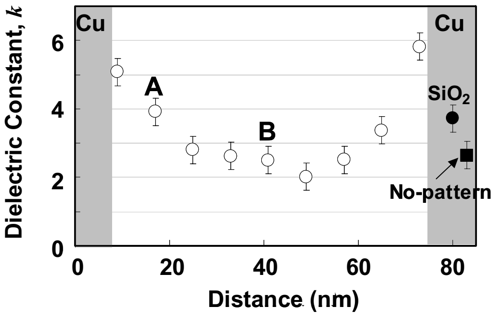

Fig. 4. The plot of the dielectric constant (k) at interconnect layer by VEELS-KKA.