Investigation of the Plasma Etching-Induced Pore Structure Transformation and Diffusion of Fluorine in Porous Low-k Thin Films

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There have been extensive efforts to develop porous thin films with ultra low-dielectric constant. Such materials can be used as interlayer dielectrics (ILD), allowing one to reduce the RC delay. However the presence of accessible pores in ILD often generates problems in functioning of electronic devices. These problems may become considerable, when the fluorine species penetrate into pores of the low-k film in the course of the etching process. It was reported that the fluorine species diffused into the pores react with hydrogen species in an electrolyte solution in the course of the Cu electroplating process and form HF molecules. The latter eventually make larger void in the film[1]. In our experiments, the porous SiOxCy films made by means of the porogen-templating method were exposed to etching. The film's pore connectivity can be easily controlled by varying the content of porogen[2]. Some basic physical properties of the films, having the dielectric constant value of 2.2, are summarized in Table 1. The previously exposed to the fluorocarbon plasma, low-k thin films with partially interconnected pores were characterized using scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS), see Fig.1 and Fig.2, respectively. The obtained results indicate that the surface region is oxidized simultaneously with the diffusion of the fluorine species. The diffusion depth is restricted to approximately to 930Å. We have also observed that the diffusion of the fluorine species is more significant for the films with fully interconnected pores. This implies that the low-k film pore-connectivity has to be tuned at some minimal critical level, in order to prevent the etching-caused damage of electronic devices. At the same time, the film dielectric constant must have the lowest possible value.

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Table 1. Some basic properties of porous low-k films with dielectric constant of 2.2.

Item	Analysis	Property
Dielectric Constant	HP4284, MIM	2.1 ~ 2.3
Pore size (nm)	PALS	1.7
Modulus (GPa)	Nanoindentor	3.38
Hardness (GPa)	Nanoindentor	0.49
Density (g/cm^3)	RBS	1.114
Adhesion intensity with SiC(MPa-m$^{1/2}$)	m-ELT	0.145

Figure 1. SEM images of the surface transformation after plasma treatment.

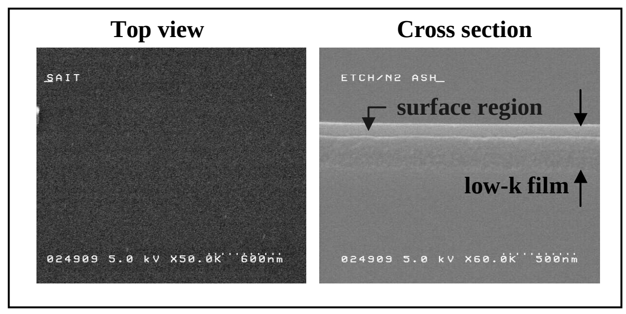

Figure 2. The analysis of low-k films after plasma etching /ashing process by XPS.