NITROGEN-FREE Cu BARRIER SiOCH FILM WITH K=4.3

[1]Yuko Nishimoto, [1]Yoshimi Shioya, [1]Haruo Shimoda, [2]Toshiyuki Ohdaira, [2]Ryoichi Suzuki and [1]Kazuo Maeda

[1]Semiconductor Process Laboratory Co., Ltd.
2-13-29 Konan, Minato-ku, Tokyo 108-0075, Japan
[2]National Institute of Advanced Industrial Science and Technology
1-1-1, Umezono, Tukuba, Ibaraki 305-8568, Japan
Tel: 81-3-3740-4535
Fax: 81-3-3740-4537
yuko@spl.co.jp

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Recently, Cu interconnection and low-k dielectric film began to be used in high speed and high density logic devices to reduce RC delay time of signal. The Cu interconnection has several disadvantages compared with an Al interconnection. Copper atom is easily oxidized and diffuses to interlayer dielectric film. Therefore, it is necessary to use barrier film for preventing Cu diffusion into the dielectric film. PE-CVD silicon nitride (p-SiN) and silicon carbide (p-SiC) are known as barrier films to Cu diffusion. However, the films have relatively high k value around 7 and 5, respectively.

We have been developing the Cu barrier SiOCH film (1-2). However, the film contains nitrogen (N) that causes poisoned via-hole. We have developed N-free (NH_3-free) barrier SiOCH film to Cu diffusion with dielectric constant (k value) 4.3. The film deposited by parallel plate type PE-CVD using HMDSO and H_2O gases. The k value is 4.3 and the value is not changed with adding C_2H_4 gases as shown in Fig. 1. This fact shows that the etching selectivity to low-k film can be increased without increasing k value. The leakage current is very low. The value after annealing at 450 °C for 4 hours in N_2 is on the order of 10^{-10} to 10^{-9} A/cm at 1MV/cm as shown in Fig. 2. The Cu diffusion was measured with SIMS. The value is very small after the annealing as shown in Fig. 3. The Cu concentrations are on the order of 10^{16} atoms/cm^3. The diffusion depth is less than 4-nm. Ammonium (NH_3^+) ions were not detected by thermal desorption spectroscopy (TDS). The pore size was measured with positron annihilation loss spectroscopy (PALS) to investigate the origin of Cu barrier ability of nitrogen-free SiOCH film. The pore size is around 0.47 nm. The value is very small and as same as the value of SiO_2 film (average pore size: 0.46 nm). The density is almost constant. The value is in the range between 2.14 to 2.21 g/cm^3. The hardness and Young's modulus are almost constant but slightly increases with C_2H_4 flow rate. The values are very large and in the range between 1.78 and 2.13 Gpa, and 12.7 and 14.7 GPa, respectively. These values are also suitable for the barrier film. The origin of the barrier property to Cu thermal diffusion is caused by the very small pore size and large film density.

The film can prevent the generation of poisoned via-hole and reduce the effective k value of dielectric film. The film is superior candidate for Cu dual damacine process.

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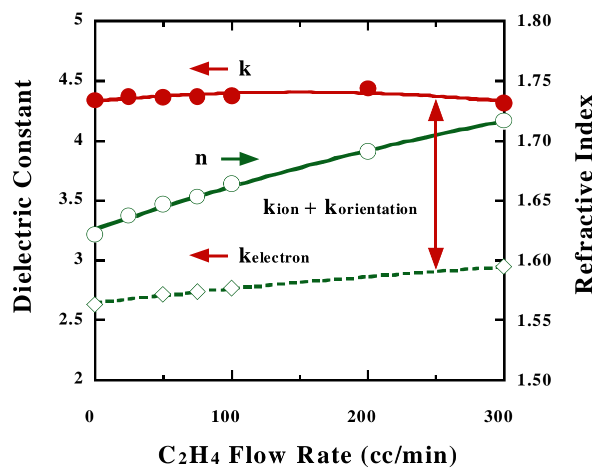

Fig. 1 K value of Cu barrier SiOCH film at 1MHz as a function of C_2H_4 flow rate.

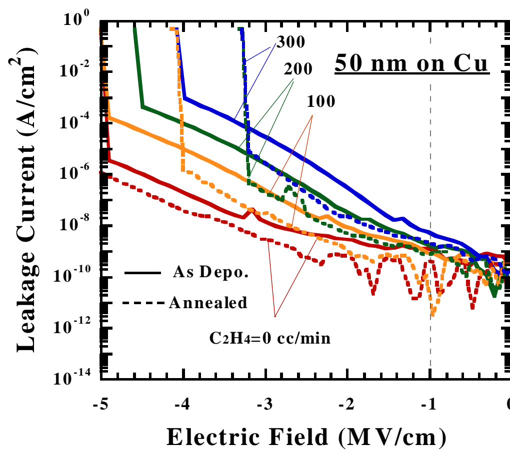

Fig. 2 Leakage current of Cu barrier SiOCH film before and after annealing.

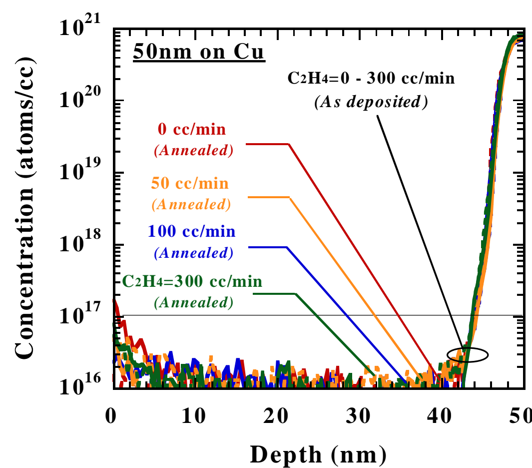

Fig. 3 Cu diffusion profiles in Cu barrier SiOCH film before and after annealing.