Investigation of Copper Permeability into Interlayer Dielectrics by Copper CMP Process

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During the implementation of copper (Cu) dual damascene process, the permeability or the contamination of Cu caused by Cu CMP process into interlayer dielectrics could be one of the key issues. Especially, when it comes to low-k dielectrics, it is said that the permeability or the contamination of Cu caused by Cu CMP process into these low-k dielectrics could increase because of their porous nature. In this paper, we investigated the relationship between the permeability of Cu into them and their properties. From our investigation, it was suggested that CVD-type SiOC low-k film and SOG-type porous organic polymer low-k film were easy to be Cu-contaminated by Cu CMP process.

Multilevel interconnection technologies have been increasingly important for ultra large scale integration (ULSI) devices and some extensive literature has existed on the advantages of Cu and low-k dielectrics over aluminum and silicon oxide as dielectrics and on the optimization of the interconnect RC delay. Regarding the correlation between polishing shear force in Cu CMP process and low-k dielectric film delamination, a lot of investigation has been carried out and has been reported. But the relationship between the permeability of Cu into low-k dielectric film and their properties has not been discussed enough.
In this report, we would like to discuss the effects of properties of low-k dielectric film on the permeability or the contamination of Cu into them.

Interlayer dielectric materials which were used in this investigation were, A) TEOS (k-value = 3.5 - 4.0), B) SOG-type organic polymer low-k (k-value = 2.6 - 2.8), C) SOG-type MSQ low-k (k-value = 2.6 - 2.8), D) CVD-type SiOC low-k (k-value = 2.6 - 2.8), E) SOG-type porous organic polymer low-k (k-value = 2.0 - 2.5).
Cu layer was prepared on the above dielectric films under the following condition, A) RF target power of Cu : 300 W, B) deposition pressure : 0.5 Pa, C) film thickness of Cu : 30 nm.
The procedures of Cu CMP process were, A) slurry : Al_2O_3 based slurry (grain size 0.1 μm, pH 4.5), B) process machine : ring polishing machine, C) pad : Suba 600 (poly Si), D) dress tool : dress of diamond layer, E) rotation speed : 30 rpm, F) polishing pressure : 100 g/cm^2, G) polishing time : 30 sec. After this Cu CMP process, the treated dielectrics were rinsed with DIW.
Each Cu concentration at the surface of the Cu contaminated film was measured with TXRF. The Cu contaminated dielectric film was etched with Ar gas at 2 kV, 20 mA and wasmeasured the Cu concentration inside the film with XRF, respectively.

Figure 1 shows Cu concentration at the surface of five kinds of dielectric films. From this figure, it was suggested that Cu contamination at the surface of CVD-type SiOC low-k whose k-value is 2.6 - 2.8 was about 10^{16} (atoms/cm^2) and this low-k film could be the most sensitive one. And SOG-type organic polymer low-k whose k-value is 2.0 - 2.5 also showed high Cu contamination due to its high porosity and its large pour size.

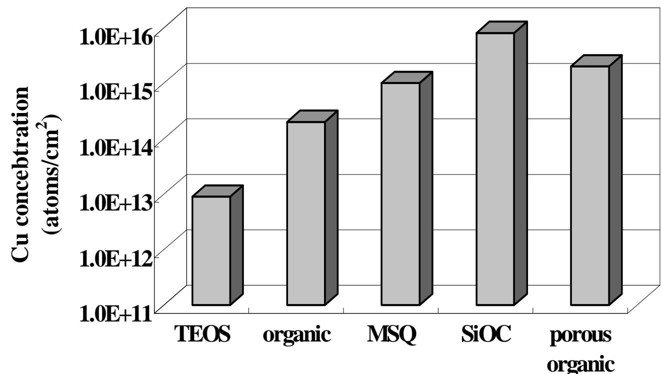

Figure 1: Cu concentration at the surface of dielectric films after Cu CMP process

Concerning the cleaning of this Cu contamination, 5 wt% of oxalic acid could remove almost all Cu contamination. Figure 2 shows Cu concentration after 5 nm Ar etching of the Cu-contaminated dielectric films. As for CVD-type SiOC low-k and SOG-type porous organic polymer low-k, we also observed Cu contamination after 5 nm Ar etching. But we did not observe any Cu contamination after 10 nm Ar etching of them.

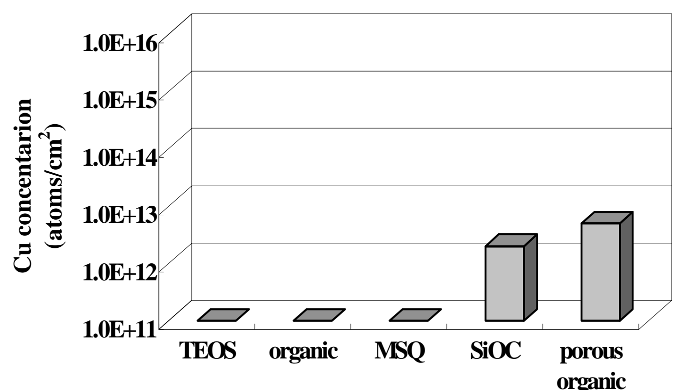

Figure 2: Cu concentration after 5 nm etching of dielectric films after Cu CMP process

From these results, the following issues were concluded.
1) CVD-type SiOC low-k film could be the most sensitive one in terms of Cu permeability or Cu contamination by Cu CMP process.
2) SOG-type porous organic polymer low-k film was also sensitive in terms of Cu permeability or Cu contamination by Cu CMP process owing to its high porosity and its large pour size.

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