Stress-Accelerating Defects with a Cu/porous low-k Structure: Possibility of SCC (Stress Corrosion Cracking) of Copper during CMP

Masako Kodera [1,2], Shin-ichiro Uekusa[2], Hidekazu Nagano[1], Katsuhiko Tokushige[1], Shohei Shima[1], Akira Fukunaga[1], Yoshihiro Mochizuki[3], Akira Fukuda[3], Hiroyuki Hiyama[3], Manabu Tsujimura[1],

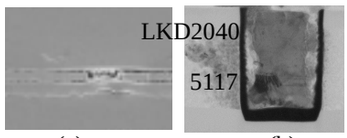
1 Ebara Corporation, 4-2-1 Honfujisawa, 251-8502, Japan
2 Meiji University, 1-1-1, Higashimita,214-8571, Japan
3 Ebara Research Co., Ltd. Honfujisawa, 251-8502, Japan

Porous low-k materials are required in the construction of 45nm-node LSI devices. However, the extremely low Young's modulus values of these materials result in a much higher number of previously unreported defects. Nagai et al. [1)] have reported that the LKD5117 porous low-k film (modulus = 7.0 GPa) stacked with the LKD2040 dense low-k film (15~20 GPa) showed pronounced cracking in its Cu wiring that might have been related to ILD mechanical strength. Figure 1 shows the cracking of Cu wiring with the LKD2040/5117 films in isolated lines 0.18um in width. On the other hand, denser lines showed less cracking and the LKD2040 single structure showed no cracking. It was also noted that observed cracking was accelerated with longer CMP times. We hypothesized that this cracking might be categorized as SCC. Accordingly, we investigated the relation between stress and corrosion in certain kinds of slurry. We have also researched the effects on corrosion of temperature, various metals, and friction during CMP.

Experiments were performed with the combined use of a potentiostat and a three-point bending tool. First we confirmed that our experimental tools were able to detect corrosion current. Figure 2 represents the relation between tensile stress and corrosion current in 99.9% pure Cu plates with 5 kinds of slurry. It was found that corrosion current increased according with increasing stress with all slurry. Figure 3 shows the relation between stress and corrosion. EP (electroplating) Cu films and sputtered seed-Cu films on Si substrates were tested with slurry A1 at 20°C and 35°C, as the temperature during CMP is approximately 35°C on a polishing pad. Slurry A1 was used for CMP of the sample shown in Fig.1. We found that corrosion current increased up to 5.6 times according with increasing temperature and up to 3 times according with increasing stress.

Figure 4 represents the simulation of vertical stress with a Cu/low-k structure, assuming that a uniform downward force of 2psi and horizontal friction 0.86psi was applied to the flat surface after Cu CMP. The maximum stress appeared at the edges of the isolated line, corresponding to the cracking sites of the Cu/LKD structure. In the actual CMP process, the Cu surface is not flat at the outset, and abrasives induce concentration of stress, which increases the actual stress applied to the line edges. Thus we concluded that stress enhances corrosion during CMP.

1) Nagai et.al., 2004 IITC, in press



(a) (b)

Fig.1 Cracking of Cu wiring with LKD 2040 / 5117: Line width is 0.18um. (a) Top view by SEM, (b) Cross sectional view by TEM.

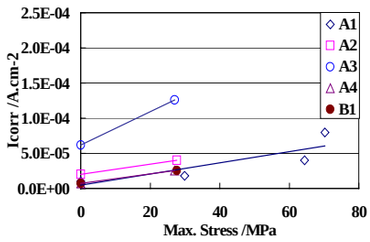


Fig.2 Relation between tensile stress and corrosion current of Cu plate with five kinds of slurry at 20°C.

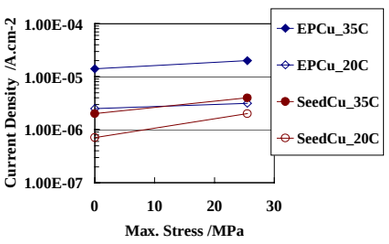
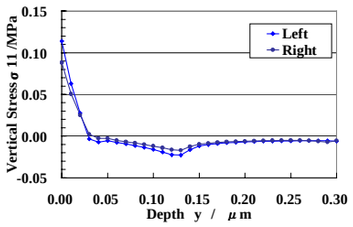


Fig.3 Relation between tensile stress and corrosion current: two kinds of metal films with slurry A1 at 20°C and 35°C.



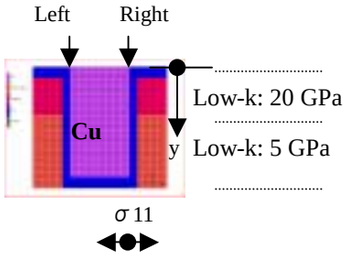


Fig.4 Simulation of vertical stress during CMP with LKD 2040/5117 and Cu structure.