Control of Adhesion Strength and TSV Filling
Morphology of Electroless Barrier Layer

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Cu-filled TSV (through silicon via) is important technology for 3-D LSIs in order to obtain higher packing density, faster signal transmission, and lower power consumption. Diameter of TSV is expected to be smaller than 2 μm, and its aspect ratio to be larger than 10 in near future [1]. For realizing a high aspect ratio Cu-filled TSV, it is essentially important to form the barrier and seed layers by electroless plating which enables highly conformal deposition profile at low temperature. We reported the all-wet Cu filling process using electroless plating of both barrier and seed layers [2, 3].

In this study, we studied to control adhesion property of the electroless plated barrier layer on SiO2 and its deposition profile in a high aspect ratio TSV. The samples are plane substrates (SiO2/Si) and TSVs with 2-4 μm diameter and 30 μm in depth. Prior to electroless plating of barrier layer (CoWB), mono layer of APTES (3-aminopropyl-triethoxysiliane) was formed by dipping the sample in the solution of APTES with toluene as a solvent at 60 °C for 1h. Then the catalyst of Pd nano particles with 4 nm diameter were densely adsorbed on APTES who were bound on SiO2 [4].

The electroless Co-W-B plating bath contained cobalt sulfate, tungsten acid, dimethylamineborane (DMAB) and citric acid as reducing and complexing agents, respectively. The temperature was 60 °C and the pH was adjusted to 9.5.

We evaluated adhesion strength of the CoWB barrier layer by the stud-pull test (Romulus, Quad Group Inc.). Thickness dependence of adhesion strength is shown in Fig.1. Adhesion strength was highest at 20 nm thickness, and it decreased with increasing film thickness. The degradation of adhesion strength is considered to be due to an increase in film stress with increasing thickness. In order to obtain good barrier property against Cu diffusion, higher adhesion strength for thicker CoWB layer would be important. Then we considered effect of adding saccharin, which is well known additive to reduce film stress of Ni-alloy [5, 6], to improve adhesion property.

Figure 2 shows adhesion strength of CoWB (80nm thickness) as a function of saccharin concentration. It turned out that adhesion strength between CoWB layer and the SiO2 substrate increased with addition of saccharin until 4 g/L of saccharin, and it decreased with further increase in saccharin. There is a proper amount of saccharin concentration in the plating bath to obtain good adhesion strength.

As for TSV deposition profile of CoWB with saccharin addition, there is a big difference of film thicknesses between top and bottom. Then we studied control of CoWB deposition profile with addition of inhibitors besides saccharin. Figure 3 shows TSV sidewall coverage ratio (ratio of CoWB thickness at the bottom of TSV to that at the top of TSV) as a function of inhibitor concentration. With addition of adequate amount of inhibitors, coverage ratio of 1 was attained. These results strongly suggests that formation of highly conformal CoWB electroless barrier layer with a high adhesion strength is possible for a high aspect ratio TSV with addition of adequate amount of inhibitors and saccharin. Furthermore, electroless Cu can deposit directly on the Co-W-B film without seed layer. The proposed highly adhesive and conformal electroless barrier layer formation would provides a highly reliable all-wet TSV filling process.

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References