Copper Electroplating for Build-up PCBs with Via-hole and Through-hole
Kimiko Oyamada, Shuhei Miura, Hiroshi Nishinakayama, Hideo Honma
Faculty of Engineering, Kanto Gakuin University
Mutsuurahigashi 1-50-1, Kanazawa-ku, Yokohama-shi,
Kanagawa 236-8501 Japan

Build-up process has become a key technology for the manufacturing of the printed circuit boards (PCBs) along with the miniaturization of the electronic devices. In this technology, via-holes are formed and filled with copper, or conductive paste to connect the each conductive layer.

In the previous research, we confirmed that void-free and bottom-up filling was accomplished by copper electroplating using a copper sulfate bath with polyethylene glycol (PEG), bis-(3-sulfopropyl) disulfidedisodium (SPS) and janus green (JGB). In this study, copper electroplating for via-hole and through-hole was examined by using a substrate with via-holes (diameter: 100-180 µm) and through-holes (diameter: 300-500 µm). The purpose of this study is conformal plating for through-holes and via-filling for copper electroplating. In addition, the influence of additives on copper deposition was studied by using Linear Sweep Voltammetry (LSV) and Quartz Crystal Microbalance (QCM).

Low copper concentration bath so-called high throwing bath, which has high throwing power, was used as the electroplating bath. PEG, SPS and JGB were used as additives. For LSV measurement, a copper rotating disk electrode and platinum were used as a working and counter electrode, respectively. Ag/AgCl electrode was used as a reference electrode.

Conformal plating for through-holes and via-filling could not achieved by using PEG-SPS-JGB at 1-3 A/dm². Fig.1 shows thickness of deposited copper with and without additives at 0.1-5 A/dm². Thickness of deposited copper at high current density was decreased when PEG added to the electroplating bath. It is considered that copper deposition at high current density area was suppressed by the adsorption of large amount of PEG molecular. From these results, PEG seemed to selectively absorb at the corner area of through-holes and via-holes, which concentrated the current lines, and copper deposition was inhibited at these area during electroplating. Accordingly, copper electroplating at high current density was employed for through-holes and via-holes. Conformal plating for through-holes and via-filling were achieved at plating at high current density in the first stage as shown in Fig.2. Behavior of PEG at high current density on copper deposition was examined by using LSV. For working electrodes, (1) blank copper electrode, (2) pre-deposition with PEG at 1 A/dm² on blank copper electrode, and (3) pre-deposition with PEG at 5 A/dm² on blank copper electrode were prepared. Fig. 3 shows LSV curves in the plating bath with PEG when electrode (1)-(3) was used as a working electrode, respectively. From these results, copper deposition on the electrode (3) was greatly inhibited compared with the case of (1) and (2), since large amounts of PEG were adsorbed on the electrode by deposition at high current density. In addition, the adsorption of PEG on substrates was observed by QCM during the cut off of the current (Fig.4).

In order to elucidate the mechanism of copper deposition, the effects of JGB and SPS on copper deposition were also examined by LSV and QCM.

---

Fig.1 Thickness of deposited copper with and without additive at 0.1-5 A·dm⁻²
PEG : 100 mg·dm⁻³, SPS : 1 mg·dm⁻³, JGB : 0.1 mg·dm⁻³

Fig.2 Cross-sectional images of via-holes and through-holes after electroplating.
Current density : 5 A·dm⁻² (First stage), 1 A·dm⁻² (Second stage), Additives : PEG-4000-SPS-JGB (0.01 g·dm⁻³), (a) 500 µm, (b) 300 µm, (c) 120 µm, (d) 150 µm, (e) 180 µm

Fig. 3 The effect of pre-deposition with PEG at 1 and 5 A·dm⁻² on LSV curves.
(1) Without pre-deposition, (2) Pre-deposition at 1 A·dm⁻², (3) Pre-deposition at 5 A·dm⁻²

Fig. 4 Relationship between ∆I and time when the addition of PEG in the copper sulfate solution.
(a) PEG-200, (b) PEG-4000, (c) PEG-20000 (d) PEG-200000 (Without CT)

References