Effects of Leveler Concentration in High Aspect Ratio Via Filling in 3D SiP

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3D packaging field is actively being studied in order to obtain better characteristics, such as shorter interconnection, reduction in signal delay, etc. Electroplating copper via filling is the most important technology in 3D stacking interconnection of SiP. Copper is inexpensive electrode material that has excellent electrical properties and easily obtained. In this study, the effects of leveler concentration in high aspect ratio via filling was investigated without the addition of other additives such as inhibitor and accelerator. Tetronic 701 was used as leveler. The effects of leveler on copper deposition was investigated using galvanostatic, polarization and cyclic voltammetric techniques. High overpotential of copper deposition in tetronic 701 added solution was confirmed. Finally, the optimum conditions of copper via filling in high aspect ratio via filling was investigated without the addition of other additives such as inhibitor and accelerator. Tetronic 701 was used as leveler. The effects of leveler concentration to fill via without using accelerator and suppressor. In this study, accelerator and suppressor were not added to reduce the concentration of organic additives. Specifically, the effect of only leveler (tetronic 701) concentration in high aspect ratio via filling were investigated.

1. Introduction

Most portable devices require smaller part size, multifunction capability, and higher performance. Au wire bonding has been widely used for the interconnection between stacked chips. Although wire bonding can reduce footprint of packaged chip area, it cannot reduce RC-delay due to its long wiring length. 3D packaging is a fast growing field that encompasses different types of technologies. One of the most promising technologies in 3D packaging is through silicon via (TSV). 1,2) It can achieve high density of packaging and minimize signal delay. Low electric resistance is achieved by interconnecting through via holes due to its short wire length. It is also compatible with multilayer and back-end processes. 1–3) In this study, high aspect ratio via was filled by electroplating method. The inside of via hole should have no void or seams and it can be achieved by bottom-up deposition in fine trenches called ‘superfilling’. 4,5) For successful bottom-up superfilling, which is a prerequisite condition for defect-free copper via filling, organic additives such as inhibitor, accelerator and leveler are necessary in a copper plating bath. 6–10)

However, the decomposition of these organic additives process have been known to cause contamination of bath. 1,2) This contamination problem can cause reliability problems in the devices and reduce the life time of the solution. 11,12) Therefore, an alternative plating process employing a plating solution which has lower additive concentration has been studied. 11–17) The objective of this study is to find optimum leveler concentration to fill via without using accelerator and suppressor. In this study, accelerator and suppressor were not added to reduce the concentration of organic additives. Specifically, the effect of only leveler (tetronic 701) concentration in high aspect ratio via filling were investigated.

2. Experimental Procedure

Prior to copper via filling, electrochemical deposition behaviour of copper with various concentration of tetronic 701 was studied by electrochemical methods such as galvanostat-
cm² were analysed with time. The addition of tetronic 701 increased the copper deposition overpotential. The deposition potential of copper in stock solution was around 0.02 V (vs Ag/AgCl), on the other hand those in tetronic 701 added solution were lowered to −0.1 V and the overpotential difference with additive concentration was less than 0.02 V. Tetronic 701 showed very strong levelling power even at low concentration. In Fig. (b), the polarization plot also showed the levelling behaviour of tetronic 701. Tetronic 701 completely suppressed the copper deposition between OCV and −0.15 V regardless of tetronic 701 concentration. Cyclic voltammetric technique was used to analyse the levelling power of the additive and the results were shown in Fig. 2. Copper was deposited immediately and the current was increased from just below OCV in stock solution. However copper was not deposited and the current did not increased until −0.18 V (vs Ag/AgCl) in tetronic 701 added solutions regardless of their concentrations. Over10 ppm of tetronic 701, cyclic voltammograms showed almost identical hysteresis loops which proved the levelling effects of the tetronic 701 even at low concentration. Thus, copper deposition was suppressed as much as 200 mV due to high overvoltage in tetronic 701 added solution.

Copper filling behaviour in AR 5.5 via was investigated and the cross section of via was shown in Fig. 3. In stock solution, without additive, copper deposition rate at top of via was faster than that at bottom of via. However, the deposition of copper at top of via was completely suppressed in tetronic 701 added solutions. The concentration of tetronic 701 at bottom was lower than that at top and then the copper deposition at top of via was completely suppressed due to high overpotential in copper deposition. As tetronic concentration was increased, copper deposition rate at bottom was decreased.

Copper filling behaviour in AR 15 via was investigated and the cross section of via was shown in Fig. 4. The low concentration of tetronic 701 cannot prevent the early closure of via entrance. The bottom of via cannot be filled in 10 and 20 ppm tetronic 701 added solution. Since the copper deposition at middle wall cannot be completely suppressed, and then via was blocked eventually. Once via was blocked the plating solution cannot reach to the bottom of via. Superfilling behaviours were observed at 30 and 40 ppm, however the growth of copper at the top of via was also observed. When 100 ppm tetronic 701 was added, the growth of copper at the top of via was completely suppressed and then superfilling behaviour was observed. The same conditions were applied to the via filling and successful superfilling without defects was obtained. The cross section of copper filled high AR via was shown in Fig. 5.

4. Conclusions

In this study, the effects of leveler concentration in high
aspect ratio via filling was investigated to reduce the use of additives. Galvanostatic, polarization and cyclic voltammetric techniques were used to verify the levelling power of additive. Tetronic701 showed higher levelling effects and increase of overpotential in copper deposition was as much as 200 mV. The optimum concentration of tetronic701 was dependent on the aspect ratio. Filling morphologies changed with different tetronic701 concentrations. 10 or 20 ppm of tetronic 701 was enough to obtain defect free copper filling in AR5.5 via by controlling the plating time. However higher concentration of tetronic 701 was required for high aspect ratio via filling. In AR15 via, 100 ppm tetronic 701 was added to achieve defect free via filling.

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REFERENCES