Extended Abstracts of the 2003 International Conference on Solid State Devices and Materials, Tokyo, 2003, pp. 380-381

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Copper Electrodeposition of High-Aspect-Ratio Vias for Three Dimensional Packaging

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1. Introduction

Three-dimensional chip stacking will realize high-density packaging and high speed performance. Higher aspect ratios through chip electrodes offer shortest interconnection and reduce signal delay.

For the ASET three dimensional packaging, the interconnection pitch is 20μm. The minimum polished silicon thickness is 50μm and 20μm is necessary for margin. Hence the via size of though chip electrode is 10μm in square and 70μm in depth. In this proceeding, we will report on how to fill this high aspect ratio via of 70 μm in depth and 10 μm in square side in a much shorter time.

2. Experimental

We adopted two kinds of baths. The commercially-available bath includes $CuSO_4 \cdot 5H_2O$ and H_2SO_4 for basic bath and PEG (polyethylen glycol), JGB (Janus Green B), SPS (Bis(3-sulfopropyl) disulfide) and HCl as additives: 130 g/L $CuSO_4 \cdot 5H_2O$, 200 g/L H_2SO_4, 600 mg/L PEG, 100 mg/L HCl, 10 mg/L JGB and 5 mg/L SPS. For specially-designed bath, SPS, SPR B and LEV A as additives to the basic bath

A chip with 70 μm in depth and 10μm in square vias was mounted on rotating disk electrode(R.D.E.). Rotating speed of the R.D.E. was 1000rpm. Pulse reverse current was applied. This pulse reverse current consists of on, reverse and off current. Their cross sections were observed by FESEM. A CVS (cycling voltammetric stripping) method was used to evaluate the inhibition effect of JGB.

3. Results

Commercially-available bath

At our middle stage of research project, the vias were completely filled with JGB concentration of 20mg/L and on current of $1mA/cm^2$. It should be noted that the electrodeposition time was 12 hrs.

With CVS, the electrodeposited copper during cathodic scan is accurately evaluated by the stripping area. The larger the striping areas are, the greater the acceleration effects.

Figure 1 shows the dependence of normalized stripping area of JGB bath concentration at two different rotating speeds of R.D.E.. At two different rotating speeds of 100 and 2500 rpm, the largest difference in Ar-value at JGB concentration of 30mg/L. R. D. E. was rotated at 1000 rpm in the case of via filling experiment. Nonetheless, the convection of electrolyte is much lower inside the via.

The 100r.p.m. rotating speed corresponds to the convection of electrolyte inside the via and the 2500r.p.m. rotating speed corresponds to that outside the via. Since the normalized Ar-value at 100r.p.m. is larger than that at 2500r.p.m., bottom-up filling is obtained at JGB concentration ranges from 20 mg/L to 40 mg/L.

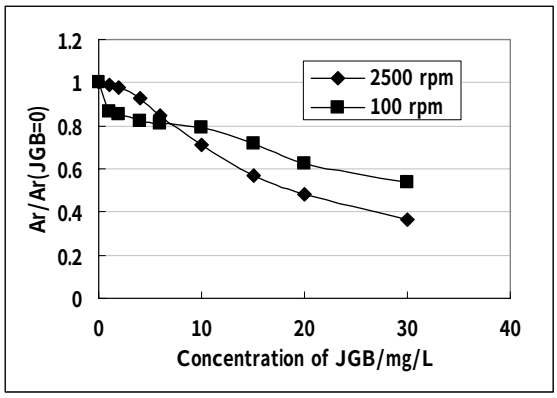

Fig. 1. The dependence of normalized stripping area on JGB concentration at different rotating speeds in the electrolyte containing 130g/L $CuSO_4 \cdot 5H_2O$, 200g/L H_2SO_4, 600mg/L PEG, 100 mg/L HCl and 5 mg/L SPS.

At next step, we increased the JGB concentration from 20 mg/L to 30 mg/L and on current of 2mA/cm^2. We succeed in shorter deposition time of 6 hours which is caused by stronger levelling effect of JGB. No voids or seams were found and perfect filling was achieved.

With 30mg/L of JGB concentration and on current of 3 mA/cm^2 for 3 hrs, voids were formed at the via bottoms. In order to avoid these voids, we adopted a two-step electrodeposition method, i.e. application of initial lower on current of 2 mA/cm^2 for 2 hr and final higher on current of 3 mA/cm^2 for 1.5 hr. No voids or seams and perfect filling was achieved within 3.5 hrs (Fig. 2).

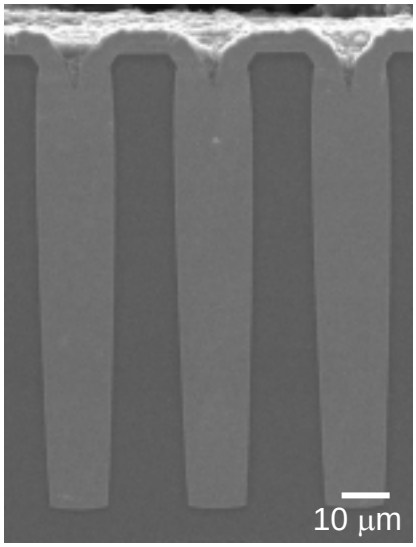

Fig. 2. Perfect filling within 3.5 hr by applying 2 mA/cm^2 for 2 hr and 3 mA/cm^2 for 1.5 hr.

Specially designed bath

The additives consist of Cl, suppresser B, leveler A and SPS as accelerator for the specially designed bath. Now 3mA/cm^2 of on current was applied. Voids has always been existed at via bottom for every runs. However, for this time, void moves upwards up to the middle height of via for specially-designed bath of (SPS, SPR B, LEV A) = (2 ppm, 2 ppm, 0.5 ppm).

Figure 3 shows the result of this perfect filling. No void nor seam is existing. This is our best time shorting data at hand.

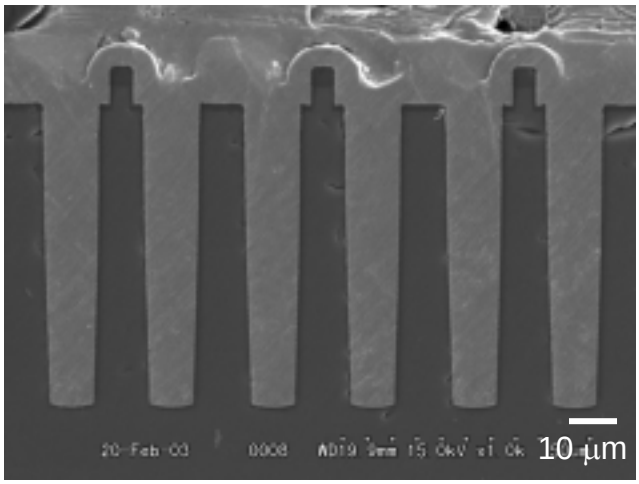

Fig. 3. Perfect filling accomplished within 2.5 hr with the use of the specailly-designed bath: (SPS, SPR B, LEV A) = (2 ppm, 2 ppm, 0.5ppm).

4. Conclusions

1.Via filling without void was obtained by using the pulse reverse current and by increasing JGB concentration from 10 mg/L to 20 mg/L and 30mg/L.

2.From the analysis of CVS, the bottom-up filling is obtained at JGB concentration from 30 mg/L.

3.With commercially-available bath, electrodeposition time was shortened to 3.5 hr by adopting two-step electrodeposition method.

4.Electrodeposition time was further shortened to 2.5hr by the use of specially-designed bath. The additive composition was (SPS, SPR B, LEV A) = (2 ppm, 2 ppm, 0.5 ppm).

5.1hr short time shorting results will be presented at the meeting.

Acknowledgements

Additives used for the specially designed bath was from EEJA (Electroplating Engineers of Japan Ltd.).

Refrences

[1]K.Kondo etal.,ICEP2002,Tokyo April

[2]K.Kondo etal.,ICEP2003, Tokyo April