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

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Three-dimensional Packaging will realize high-density packaging and high speed performance. Higher aspect ratios through chip electrodes offer shortest interconnection and reduce signal delay(Fig.1).

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. We will report on how to fill this high aspect ratio via of 70 μm in depth and 10 μm in square side within one hour.

This one hour is very critical time, since processing time of RIE, barrier and seed formation and also high speed CMP are order of several ten minutes. The copper via filling electrodepositing is the rate determining step. The cost estimation by ASET says that the three dimensional packaging process is commercialized if time shortening of one hour by copper via filling electrodepositing can be achieved.

Experiment

The bath consist of $CuSO_4 \cdot 5H_2O$ and H_2SO_4 for basic bath and Supressor(SPR), Leverer(LEV), SPS (Bis(3-sulfopropyl) disulfide) and HCl as additives.

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

Results

1. SUP and LEV concentrations were optimized initially by increasing the current density of 4 and 5mA/cm^2. 5mg/L of SUP and 0.2mg/L of LEV were the optimized concentrations and perfect via filling with 90min by 5mA/cm^2. The difference in Ar/Ar-value by CVS also showed maximum difference at SPR concentration of 5mg/L.

2. SPS, HCl and H_2SO_4 concentrations were optimized by increasing the current density of 6mA/cm^2. 2mg/L of SPS, 70mg/L of HCl and 25g/L of H_2SO_4 were the Irev/Ion=2.0(Ion=6mA/cm^2). With 6mA/cm^2, however voids were formed with every optimized conditions.

3. Next, the oxygen gas was bubbled into the above mentioned optimized bath by increasing the current density of 6mA/cm^2. We succeeded in perfect via filling with 75min by 6 mA/cm^2. The oxygen gas oxide the inhibitor of Cu^+ to Cu^{2+}. Therefore, the accelerator complex of Cu(I)thiolate accumulates at inside of the via and accelerates via inside preferentially(Fig.3).

4. Two steps current densities of initially lower current of 6mA/cm^2 at 50min and higher current of 15 mA/cm^2 at 10min were applied. With this two steps current densities method, we finally succeeded in perfect via filling of 60min(Fig.2). Time shortening was successful. We further observed the marked bottom up V-shaped with applying initial current of 6mA/cm^2 for 50min.

Acknowledgements

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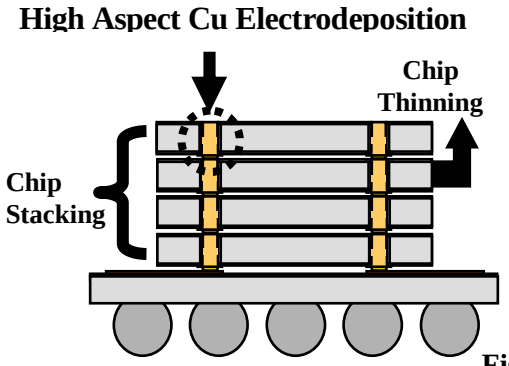

Fig.1 Three Dimensional Packaging

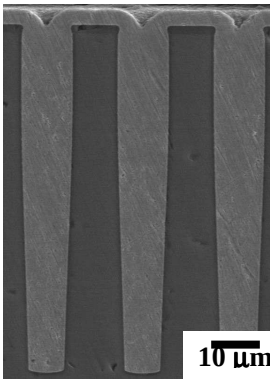

Fig. 2. Time shorting of 6 minute with 2 steps meth Cross sectional view of through electrodes.