Study of Cu Micro-via by TOF-SIMS and STEM

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Abstract—**The micro-via is a sandwiched structure with Cu electrolyte plating/electroless Cu plating/Cu electrolyte plating Pad, and the quality of the electroless Cu layer significantly affects the reliability of micro-via. In this work, we investigated the elemental ingredient of micro-vias which were prepared by a traditional electroless Cu plating method and a newly developed electroless Cu plating method by time of flight secondary ion mass spectrometry (TOF-SIMS) and scanning transmission electron microscopy (STEM). It is found that the concentration of hydrogen, oxygen and several elements exist in the electroless Cu layer prepared by traditional method compared to the new one. These can be a potential risk of nanovoids formation in the electroless Cu layer and decrease the reliability of HDI substrate.**

Keywords— Cu micro-via, electroless Cu, STEM, TOF-SIMS.

I. Introduction

Lately, the advanced high-density packaging requires reliable interconnection such as micro-vias or PTH in substrate. The packaging of electronic components have to possess superior stability as they usually are used in a tough environment such as high temperature, high humidity or longtime vibration in vehicles. In contrast to meet the requirement of downsizing and high functionality, the high-density interconnect (HDI) substrates suffer from "Weak-Micro-Via" issue. Micro-vias which are used as superior electrical interconnections between circuit built-up layers, which need a different preparation process that leads to a good reliability. The micro-via is a sandwiched structure with Cu electrolyte plating/electroless Cu plating/Cu electrolyte plating Pad, and the quality of the electroless Cu layer significantly affects the reliability of micro-via[1]. For this purpose, a new electroless Cu plating method named as "OPC-FLET" developed by Okuno Chemical Industries Co., Ltd recently. This method can effectively reduce a quantity of the nanovoids, which appears around the electroless Cu plating layer and the interface layer of electrolyte Cu plating and electroless Cu plating layer, might cause the weak micro-via issues recently.

In this study, we investigated and compared the elemental ingredient of micro-vias which were prepared by a traditional electroless Cu plating method and newly OPC-FLET method. The main difference between the two methods is the addition of Ni element, which has been widely used for stress releasing purpose in the electroless Cu layer. Traditional method uses Ni element but OPC-FLET does not. We carried out the elemental characterization for these two Cu plating by TOF-SIMS mainly and STEM.

II. Method

We used a typical sandwich structure with Cu electrolyte plating/ electroless Cu plating/Cu electrolyte plating pad prepared by the two different electroless Cu depositions as shown in Fig. 1. One is Ni-added traditional method and the other is Ni-free OPC-FLET method, respectively. The electroless Cu plating and electrolyte Cu plating was conducted on a PCB resin coated copper (RCC) substrate that was cleaned by an etching process. The surface is pre-dipped and palladium ions were adsorbed by using an ion catalyst. The electroless Cu processes adopted in a reaction bath that consists of Cu resource (Ni is added in traditional process), complexing agent and reductant.

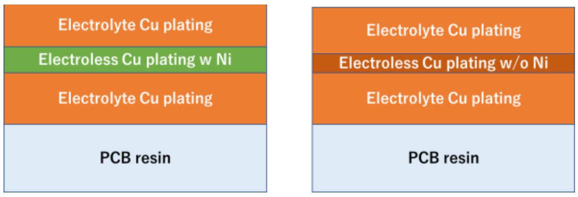

Fig. 1. The sandwiched structure designed to imitate the micro-via

The prepared samples were cut （15×15 mm plates） then applied to time of flight (TOF) -SIMS (M6, ION-TOF) for elemental depth analysis of the sandwich structure. Depth profiles were examined for the area (The analyzed area size is about 0.1 mm× 0.1 mm and its depth is around 18-20 μm). Bi_3^{2+} pulsed ion gun (1st Ion gun: 30 keV) as probe and O_2^+ ion gun (2 keV) for positive polarity and Cs^+ ion gun (2 keV) for negative polarity as spattering gun for acquiring the elemental depth profile. The cross-sectional samples for TEM were prepared by ion-milling (IM4000, Hitachi High-Tech Corporation) and then fabricated by using a focused ion beam system (FB-2000, Hitachi High-Tech Corporation) and dual beam FIB-SEM (Scios 2, Thermo Fisher Scientific). The prepared TEM specimens were observed by the spherical aberration corrected TEM/STEM (JEM-ARM200F, JEOL Ltd), equipped with X-ray energy dispersive spectrometer (X-EDS).

III. Results and Discussions

Fig. 2 shows the depth profile of sandwiched structure with electrolyte Cu plating/electroless Cu/ electrolyte Cu plating pad by the traditional method (a) and OPC-FLET(b), respectively by TOF-SIMS for negative ions. Several element concentrations (H, O, Cl and S) are obviously increased around the electroless layer and Ni element is for sure detected in traditional method sample. The thickness of electroless Cu with different Ni content was calculated via the weight measurement and the thickness. Taking Cu element intensity as a standard index for comparison, on the other hand, intensities of O, Cl and S in OPC-FLET method sample are weaker than that of traditional method sample and H concentration is remarkably weak in FLET sample.

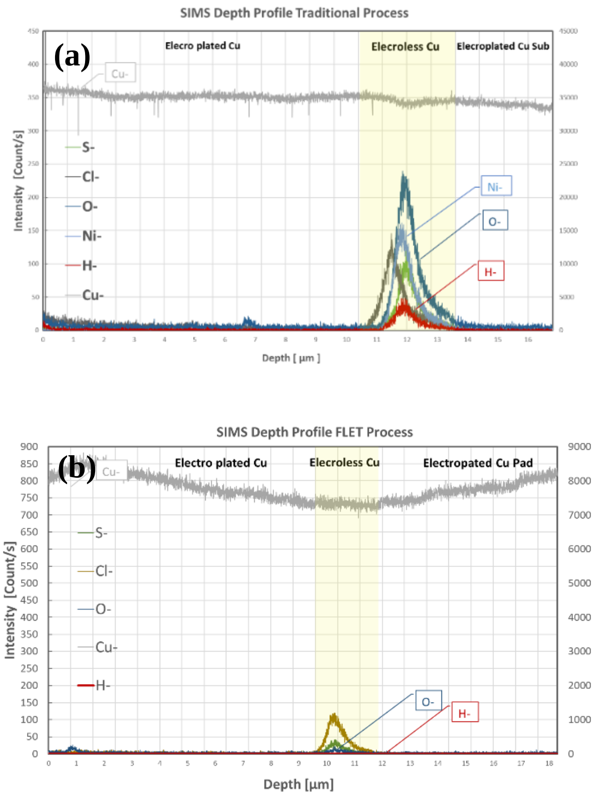

Fig. 2. The depth profile for traditional and OPC-FLET process.

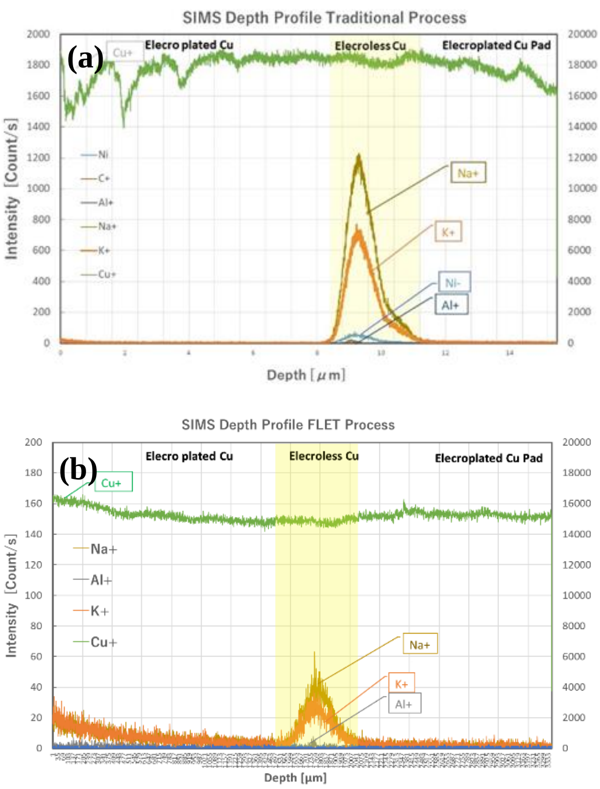

Fig. 3. The depth profile for traditional and OPC-FLET process.

But it should be noted that the thickness of the electroless layer is different in both sample. The thickness is about 200 nm for traditional process and 40 nm for FLET process. Although we could not prepare the standard sample for quantitative evaluation this time, we still can find that H and O contents are abundant in electroless Cu layer in traditional and O ions can enter and involve into the whole traditional beginning of traditional electroless Cu plating process, H ions method sample by relative comparison. Not only around the electroless Cu plating layer. Furthermore these results implies the possibility of nano-void formation from H and O (or another gas elements) aggregation after heat treatment in the process of micro-via manufacturing. The electroless Cu layer contains a large amount of hydrogen (H) and might form and grow nanovoids after heat treatments or production uses, it also become the potential hydrogen embrittlement.

Fig. 3 shows the depth profile of the samples by the traditional method (a) and OPC-FLET (b), respectively by TOF-SIMS for positive ions. Some element concentrations (Na, K and Al) are obviously increased around the electroless layer in both samples, indicating a similar tendency of the measurement of negative ions, i.e. abundant in the traditional ones. These cations come from the additive agents which are used in electroless process, however, the concentrations might be very low. As shown in Fig. 4 of STEM-EDX measurements, Na, K and Al could not be detected effectively, their concentration values show less than 0.1 at%. For sure, Carbon elements enter and involve into both electroless Cu plating layer but their existence form is very complicated and difficult to assign this time.

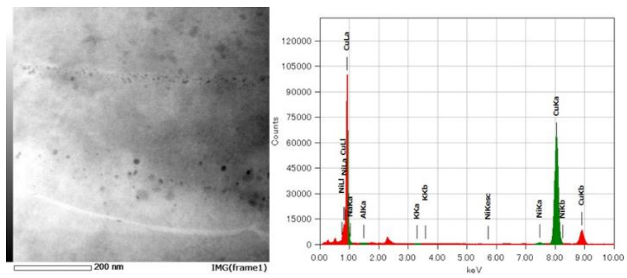

Fig. 4. HAADF-STEM image for traditional and EDS spectrum from the electroless Cu layer.

IV. Conclusions

In this work, we carried out the elemental characterization of the electroless Cu layer by TOF-SIMS and STEM-EDS. It is found that the higher concentration of hydrogen, oxygen and several elements exist in the electroless Cu layer prepared by traditional method compared to the OPC-FLET one. These can be a potential risk of nanovoids formation in the electroless Cu layer and decrease the reliability of HDI substrate. In other words, OPC-FLET method might effectively reduce the formation of nano-voids in the electroless Cu layer and enhance micro-via reliability.

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References

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