[Short Note]

Development of High Reliability Process for Fine Cu Wiring for 2.1D Packaging

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Abstract

The electrochemical migration resistance was improved by plating Ni-P on the surface of $L/S = 2/2 \mu\text{m}$ Cu wiring. Ni-P plating film became more uniform by increasing dissolved oxygen in the Pd catalyst solution. This is because oxidation of the Pd-substituted film increased a catalytic activity of Pd.

Keywords: Semi-Additive Process, Chip to Chip Connection, High Reliability, Electroless Ni-P Plating, Catalyst Activity

I. Introduction

Heterogeneous integration such as 2.5D and 2.1D system in package, Multi-chip Fan-Out Wafer Level Package (FOWLP) and Fan-Out Panel Level Package (FOPLP) require fine wiring technology that connects multiple IC chips at high density.[1] However, electrochemical migration (ECM) occurs in $L/S = 2/2 \mu\text{m}$ or less wiring fabricated using a semi-additive process. Therefore, technical development for improving reliability is demanded.[2, 3]

In this study, we performed improvement of the reliability of fine wiring by electroless nickel-phosphorus (Ni-P) plating on the Cu wiring surface using substituted Pd as catalyst. In the field of catalytic chemistry, Pd-O chemical-bonding state enhances catalytic activity of Pd has been reported.[4] Therefore, we considered that dissolved oxy-

gen (DO) in the Pd treatment solution affects Pd oxidation and catalytic activity. In particular, we focused on the DO in Pd catalyst solution, which evaluated the some properties of the Pd-substituted film and ECM resistance of the Ni-P plating film.

2. Experiment Procedures

Figure 1 shows the preparing process of sample for High Temperature Accelerated Humidity Test (HAST). In the first, Cu wiring of $L/S = 2/2 \mu\text{m}$ was formed on thermal oxidized silicon wafers. In the next, electroless Ni-P was plated on the Cu wiring. As a pretreatment, the catalyzing step was in 0.19 mmol/L Pd solution at 32°C for 2 min. DO in the Pd catalyst solution was controlled by purging O_2 or N_2 gas. After that, electroless Ni-P was plated at

Fig. 1 Process for HAST sample preparation.

60°C for 1 min using sodium hypophosphite as a reducing agent (Ni-P film thickness: 25 nm). Phosphorus content in the Ni-P film was obtained to around 9 mass% as measured using X-ray fluorescence measurement. An organic insulating film was laminated on the wiring, and electrodes were opened by UV laser ablation. Finally, Ni/Au plating was formed on the electrodes.

Prepared samples were carried out pre-conditioned step and HAST step according to JEDEC standards.[5, 6] First, the samples were dried at 125°C for 24 hours. Then, these were exposed to 60°C/60%RH for 40 hours and reflowed for three cycles at 260°C peak temperature. After pre-conditioned, a migration tester measured insulation resistance of the samples in a chamber at 130°C/85%RH at an applied voltage of 7.0 V for 200 hours. In addition, the threshold amount for migration detection was determined at 6 MΩ.

X-ray Photoelectron Spectroscopy (XPS) evaluated Pd coverage and chemical-bonding state of Pd-substituted surface when the DO was changed.

Anodic polarization measured catalytic activity of the substituted Pd. Working electrode (electrode area: 1 cm²) was Cu substrate after Pd-substituted. Electrolyte was 0.1 mol/L sodium hypophosphite solution, sweep rate was 10 mV/sec, and sweep range was -0.5 to 0.1 V (vs. Ag/AgCl). Ag/AgCl electrode was used as reference electrode, and Pt coated Ti plate was used as counter electrode.

3. Result and Discussion

Figure 2 shows the result of the HAST. The time until occurrence of migration was longer with higher DO in the Pd catalyst solution.

Figure 3 shows the surface SEM images after Pd catalyzing and electroless Ni-P plating with different DO. After the Pd catalyst treatment, higher DO accelerated the oxidation and formed to a refined roughness on the Cu sur-

face. The Ni-P plated film surface at DO 22 mg/L deposited more densely than that at 2 mg/L. Therefore, it can be said the deposited density of Ni-P film effected on ECM resistance.

Surface Pd coverage as measured by XPS was 14 at% at DO 2 mg/L, 6 at% at 22 mg/L respectively. Cu 2p and Pd 3d spectra after Pd catalysis showed the same peak position regardless of DO. On the other hand, O 1s spectrum showed a clear difference depending on DO. Figure 4

Fig. 2 HAST at Ni-P thickness 25 nm.

Fig. 3 Surface SEM images after Pd catalyzing and electroless Ni-P plating at DO (a) 2 mg/L and (b) 22 mg/L.

Fig. 4 O 1s spectrum of after Pd catalyst-treated at DO (a) 2 mg/L, (b) 22 mg/L.

Fig. 5 Anodic polarization of catalyzed Cu substrate.

shows O 1s spectrum after Pd catalyst treatment. Pd 3p_{3/2} peak appeared at 533 eV, and O 1s peak appeared at 531 eV. At DO 22 mg/L, a peak area of the O 1s increased compared to 2 mg/L. Hence, it can be considered that the catalyzed Cu surface in higher DO was susceptible to oxidation of Pd.

Figure 5 shows the results of anodic polarization of the Cu substrate after Pd catalyst treatment. Anodic current at DO 22 mg/L was higher than at 2 mg/L. This current is due to the oxidation of sodium hypophosphite in the solution. Therefore, we have concluded the catalytic activity of Pd when treated at DO 22 mg/L may have been improved.

4. Conclusion

The catalytic activity of Pd and the deposition behavior of electroless Ni-P were affected by the concentration of DO in the Pd catalyst solution. The higher DO also improved some properties of the plating film. Pd-substituted surface catalyzed in higher DO solution was more oxidized than lower DO. Accordingly, the catalytic activity

of Pd was increased, and electroless Ni-P film was able to be obtained denser. As a result, ECM resistance in HAST was improved excellently.

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