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GOLD WIRE BONDABILITY OF ELECTROLESS GOLD PLATING USING DISULFITEAURATE COMPLEX

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ABSTRACT

For the fabrication of the circuits, contact or terminal areas are usually coated with nickel and gold. Usually, diluted palladium solution is applied to initiate electroless nickel plating on the copper circuits. However, the trace amounts of palladium remains on the resin and it causes the extraneous deposition. We confirmed that selectivity was greatly improved by the treatment with the strong reducing agents such as SBH or DMAB. Bondability was greatly influenced by the contents of phosphorus in the deposited nickel. Stabilizers in the electroless gold plating were also influenced the bonding strength. The baths containing cupferron or potassium nickel cyanide as a stabilizer showed superior bondability. The gold deposits having strong orientation with Au(220) and Au(311) showed good bondability.

INTRODUCTION

With a downsizing of the electronics devices, LSI's (Large Scale Integrated Circuits) and PCB's (Printed Circuit Boards) are provided finer pitch terminals and circuits. Electrogold plating is applied for the improvement of the conductivity. Therefore development of an electroless gold plating is expected since the pitch intervals of circuits become narrow. Cyanide bath has been used as an electroless gold plating extensively.[1,2] Recently electroless gold plating of non-cyanide type such as thiosulfateaurate or disulfiteaurate complex as a metal salt has attracted a great deal of attention, since non-cyanide bath is not poisonous and solution does not penetrate to the resist.[3,4] The purpose of this paper is development of non-cyanide electroless gold plating using disulfiteaurate complex as a metal source and evaluation of wire bondability of deposited gold films.

EXPERIMENTAL PROCEDURE

PRETREATMENT PROCESS

A sample is pretreated as shown in Table I. Generally, electroless nickel plating on copper circuits is treated with low concentration of palladium solution since copper has not catalytic action to initiate nickel deposition. However, palladium ions adsorb on a resist and it causes an extraneous deposition.

Therefore, selectivity of catalytic action using DMAB as an activator was also investigated.

BATH COMPOSITION

Bath composition and conditions of electroless nickel and gold plating are shown in Table II, and III respectively.

Table. I Pretreatment process.

Alkaline degreasing.(40℃, 5min)

↓

Rinsing

↓

10% $-H_2SO_4$(40℃, 5min)

↓

Rinsing

↓

0.05M − DMAB(R.T., 30～40sec)

Table. II Plating bath compositions and operating conditions of electroless nickel plating

P-content : 10～12wt%(High)	
$NiSO_4 \cdot 6H_2O$	0.05M
Lictic acid	0.05M
$NaH_2PO_2 \cdot H_2O$	0.05M
pH	4.50
Temp.	90℃
P-content : 6～9wt%(Middle)	
$NiSO_4 \cdot 6H_2O$	0.05M
DL-Malic acid	0.05M
$NaH_2PO_2 \cdot H_2O$	0.05M
$Na_2S_2O_3$	1PPM
pH	4.50
Temp.	90℃
P-content : 3～5wt%(Low)	
$NiSO_4 \cdot H_2O$	0.05M
Propionic acid	0.25M
$NaH_2PO_2 \cdot H_2O$	0.15M
pH	6.00
Temp.	50℃

Table III Plating bath compositions and operating conditions of electroless gold plating.

Component	Value
$Na_3Au(SO_3)_2$	0.006M
Na_2SO_3	0.10M
$Na_2S_2O_2$	0.10M
NTA	0.10M
NH_4Cl	0.05M
Sodium L-ascorbate	0.25M
Stabilizer	10～100ppm
Agitation	Air
pH	6
Temp.	60℃

EVALUATION METHOD.

The film thickness of gold was measured by flüorescence X-ray (SFT7300 XRF SII). The contents of phosphorus were measured by plasma emission spectroscopy. Gold wire of 25μm (gold purity 99.99%) was used for bonding strength measurement. Gold wire was compressively adhered with heat and ultrasonic waves.

RESULT AND DISCUSSION

ACTIVATION FOR NICKEL PLATING.

Treatment with a strong reducing agent may be effective for prevention of extraneous deposition of nickel on the copper substrate. Appearances of the deposited nickel on the copper patterns were compared using palladium solution and 0.05M − DMAB solution as an activator. Result is shown in Fig. 1. When copper circuits were activated with diluted palladium solution, deposits of nickel on the epoxy layer occurred, and epoxy layer was covered with nickel particles after plated for 3min. Entiresurface was completely cov-

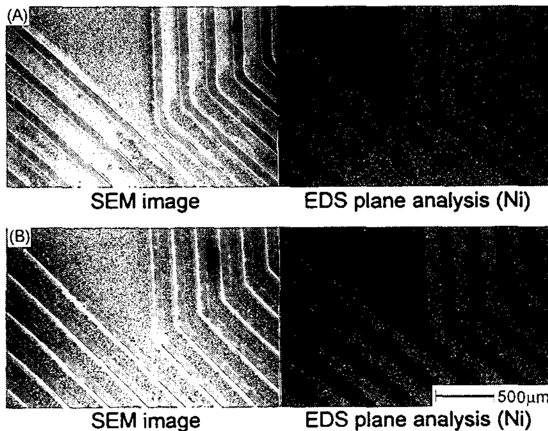


Fig. 1 Appearances of electroless nickel deposition on coppermicro circuit initiated by palladium or DMAB activator
(A) : Activated by diluted palladium solution.
(B) : Activated by DMAB solution.

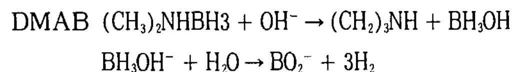
ered with nickel in 15min. (Fig. 1A) On the other hand, when copper circuits were activated with 0.05M−DMAB, deposition reaction was completely suppressed on the epoxy layer even after plating for 15min. (Fig. 1B) The adhesion strength between nickel and copper was superior, and the exfoliation at the copper-nickel interface was not recognized with tape test.

EVALUATION OF OTHER REDUCING AGENTS AS AN ACTIVATOR

If DMAB was used as an activator, nickel was deposited only on copper circuits. Reducing agents such as sodium borohydride (SBH), sodium hypophosphite, hydrazine and formaldehyde were also examined as the activator. Electroless nickel plating reaction occurred with SBH. On the other hand, reaction did not occur with formaldehyde, hypophosphite and hydrazine.

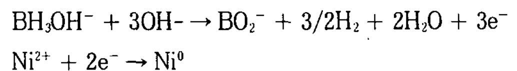
REACTION MECHANISM OF ACTIVATION BY REDUCING AGENT.

It was identified that electroless nickel plating reaction progressed on the copper substrates by the borohydride compound. Activation enhancement seems to be following.



$$\text{DMAB } (CH_3)_2NHBH3 + OH^- \rightarrow (CH_2)_3NH + BH_3OH$$
$$BH_3OH^- + H_2O \rightarrow BO_2^- + 3H_2$$

This reducing agent produces BH3OH-, and electrons are discharged at the copper surface by anodic reaction. Subsequently, Ni^0 forms on the copper surface by the cathodic reaction.



$$BH_3OH^- + 3OH- \rightarrow BO_2^- + 3/2H_2 + 2H_2O + 3e^-$$
$$Ni^{2+} + 2e^- \rightarrow Ni^0$$

Since deposited nickel on the copper surface shows catalytic function to the hypophosphite, accordingly electroless nickel plating is proceeded as auto catalytically. Activation power of DMAB depend on pH and increases with increasing pH. Following experiments were performed using DMAB at the concentration of 0.05M.

CONDITION OF ACTIVATOR.

Temperature dependency and effect of activation were investigated. Activation power of DMAB was decreased with increasing the temperature of DMAB activator above room temperature. Spotty deposits were observed on the circuits above 60℃. The efficiency as an activator is decreased due to the self decomposition by heat. Therefore, the activator was maintained at room temperature. Since DMAB was not possessed buffer action, pH was decreased with the progress of reaction and activation power

was decreased. Therefore, 0.06M of boric acid is added as a buffer in the solution, and operated at room temperature in the following experiments. Activation power was also increased by decreasing the quantities of dissolved oxygen (DO) in the activator.

RELATION BETWEEN BONDABILITY AND PHOSPHORUS CONTENTS IN THE DEPOSITED NICKEL.

Displacement reaction between nickel and gold take place in the early stages of reaction, and gold acts as the oxidation catalyst of ascorbic acid and autocatalytic reaction progresses as follows.[3)]

$$C_6H_7O_6Na \rightarrow Au\ C_6H_6O_6Na + 2H^+ + 2e^- \quad (1)$$

$$[Au(SO_3)_2]^{3-} + e^- \rightarrow Au + 2SO_3^{2-} \quad (2)$$

The physical properties of gold depends on the deposited nickel films. Phosphorus content in the electroless nickel plating coatings, effect of additives of gold plating bath and crystal orientation of gold coatings were investigated. Approximately 5mm was deposited as an underlayer using high, medium or low phosphorus content type of nickel plating. Gold of 0.5μm was deposited using autocatalytic type of electroless plating. Bonding strength was measured by auto bonding tester. The measurement points were selected approximately 100 points. Results are shown in Fig. 2. Mean bonding value of 7.9 g was obtained in high phosphorus type and 6.4g was obtained with medium phosphorus type of nickel as the underlayer. On the other hand, bonding strength was quite low and most of the measured points showed below 1g by using low phosphorus type of nickel deposits.

INFLUENCE OF ADDITIVES TO THE DEPOSITED GOLD.

The electroless gold plating without stabilizer was poor in stability, and self-decompo-

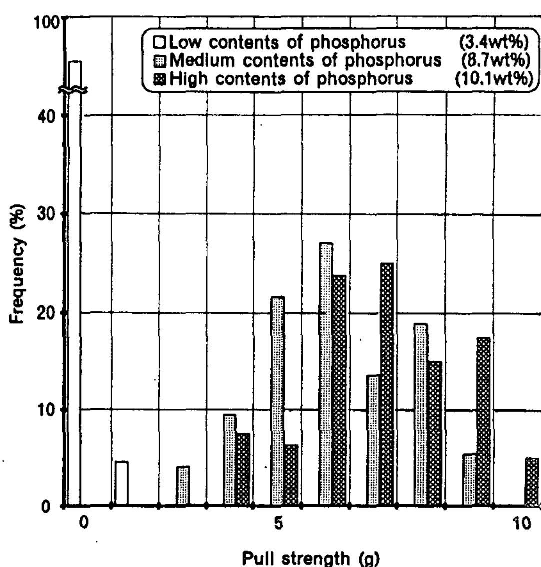


Fig. 2 Adhesion strength of gold wire bonding.

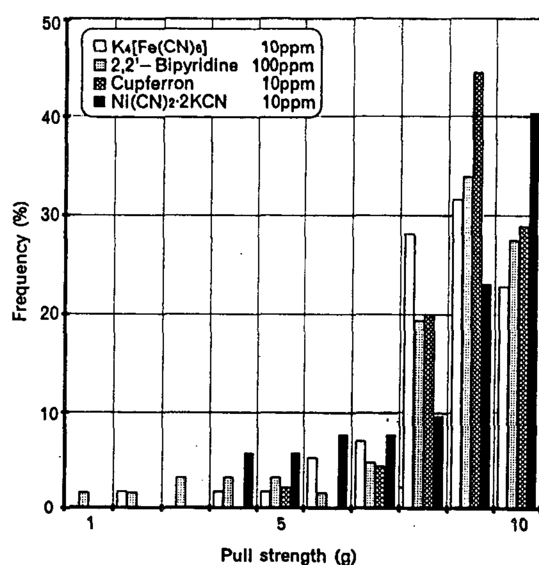


Fig. 3 Adhesion strength of gold wire bonding.

sition reaction progressed in several hours. Accordingly, gold was plated using potassium ferrocyanide, cupferron, potassium nickel cyanide and 2,2′-Bipyridyl as a stabilizer, and bondability was evaluated. The result is shown in Fig. 3. Bonding strength of coatings was less than 4g using the nickel deposits of medium phosphorus type as an underlayer. On the other hand, the nickel was coated using high phosphorus type bath as an underlayer and gold deposited with the addition of cupferron or potassium nickel cyanide as a stabilizer showed high bonding strength.

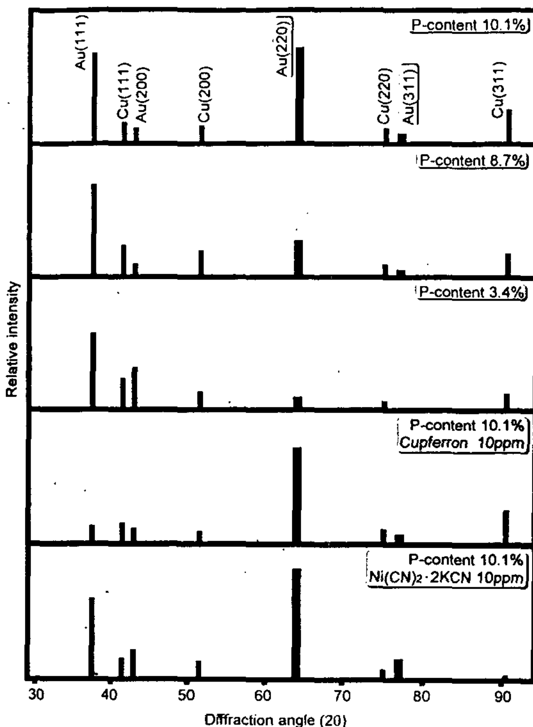


Fig. 4 X-ray diffraction patterns of electroless Au deposits.

CRYSTAL ORIENTATION AND BONDABILITY OF GOLD COATING.

X-ray diffraction of gold films using low, medium and high phosphorus type nickel deposits as an underlayer is evaluated. The coating of high phosphorus type was applied as an underlayer film showed high bonding strength, and gold was preferred oriented atAu(220), Au(311). Furthermore, X-ray diffraction of gold coatings with addition of stabilizer was also analyzed, and result is shown in Fig. 4. The coating having strong orientation in Au(220), Au(311) showed good bondability.

CONCLUSIONS

Bondability of electroless gold plating from disulfiteaurate complex and selectivity of nickel deposition as an underlayer was investigated and following results are obtained.

1) Low concentration of DMAB showed good selectivity than the palladium ion activator. When 0.05M-DMAB was used as the activator, electroless nickel coatings were deposited selectively.

2) With increase the phosphorus content in the nickel films (around 10-12%), good bondability was obtained. Stabilizers in the electroless gold plating were also influenced the bonding strength. The baths containing cupferron or potassium nickel cyanide as a stabilizer showed high bondability.

3) The gold deposits having strong orientation with Au(220) and Au(311) showed good bondability.

ACKNOWLEDGMENT

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