Neutral type Auto-Catalytic Electroless Gold Plating Process

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Abstract

In order to understand the reaction mechanism of an auto-catalytic type gold plating bath, it is necessary to recognize the following reactions: oxidation of reducing agent, gold deposition and dissolution of the underlying nickel deposit. Therefore, we have been studying the rest potential of the reducing agent, the rest potential of gold deposition and the rest potential of nickel dissolution, regarding two different types of auto-catalytic gold plating solutions. One is a neutral pH type non-cyanide auto-catalytic gold plating bath that has been newly developed for PCBs, and the other is an alkaline type auto-catalytic gold plating bath that is currently being used in the ceramic PKG industry. From our evaluation results, we discovered that a neutral type gold plating bath is apt to dissolve the nickel layer compared to an alkaline type. We also discovered that this dissolving character depends on the reducing agent type, which is contained in the neutral type auto-catalytic gold plating solution. Furthermore, observation results showed that the characteristics of the immersion gold bath, which is utilized as a strike gold bath for auto-catalytic gold plating, affect the characteristics of the total deposit. In this study, we were able to confirm that it is possible to obtain an electroless Ni/Au plating film with excellent wire bondability and solder joint characteristics by utilizing a newly developed neutral pH auto-catalytic gold plating process.

1. Introduction

Wire bonding and solder ball joint applications are used as a means for mounting ICs. Although a solder ball joint process is suited for high-density assembling, the cost for this process is higher than wire bonding processes. Moreover, recent improvements of bonding machines have enabled wire-bonding process applications to be adopted as an assembling method for high-density parts. Currently, PC-package (PKG) applications are wire bonding (W/B) or solder joint to the IC side, and socket joint (ex. PGA) or solder joint on the board side. This final plating process for PKG is shifting from an electrolytic plating process to an electroless plating process due to more complex circuit designs, which have independent patterns. However, an electrolytic heavy gold plating process is still common in this market because a reliable electroless plating process that inhibits acceptable wire bondability and solder joint reliability without attacking organic materials are only recently being developed. Therefore, in this study we investigated a neutral pH non-cyanide autocatalytic type electroless gold process, (referred to as Bath A) that is a non-cyanide neutral type bath and an alkaline cyanide type bath (referred to as Bath B).

2. Experiment and Results

2.1 Gold deposition potential and dissolution potential of EN film in electroless gold bath

In order to measure the rest potential of gold deposition and electroless nickel deposit dissolution into Bath A and Bath B, we utilized a Ag/AgCl working electrode under the following conditions.

Each electroless plating solution was made up according to standard catalogue procedure. Also, electroless nickel test coupons were prepared by using our commercially available process

a) Measuring condition of gold deposition rest potential

Working electrode: gold plate

Electrolytic solution:

Bath A (50^0 C, pH 7.0) and

Bath B (60^0 C, pH 12)

b) Measuring condition of electroless nickel (EN) film dissolution rest potential

Working electrode: 5 um EN deposit on copper coupon.

Electrolytic solution:

Bath A without gold & reducing agent and

Bath B without gold & reducing agent

From the results of each measurement, as shown in Fig.1, we consider that the EN deposit does not dissolve during plating in alkaline-cyanide Bath B. This is because the measured rest potential of the EN film electrode is a noble potential compared to the rest potential (plating potential) of the gold electrode. On the other hand, in the neutral non-cyanide Bath A, the dissolving potential of EN deposit is a base potential compared to the gold plating potential. This indicates that there is a possibility that EN deposit dissolution may occur during plating in Bath A.

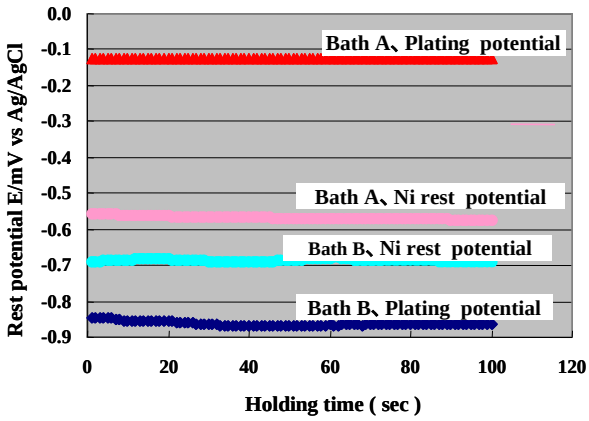


Fig.1 Comparison of Bath A and Bath B concerning plating potential and EN film dissolving potential

	Solution	Electrode
Plating potential	Bath A or bath B plating solution	Au
Ni rest potential	Plating solution withour Au & reducer	EN film

For the next comparison, we used thiourea and hydrazine as the reducer, which are typical reducing agents commonly mentioned, instead of the actual reducer for Bath A to see how oxidation potentials differ. Measurement solutions were prepared by adding 5g/L of each reducer into Bath A not containing gold. Bath temp was 50^0 C, which is the standard working condition. A gold plate was used as the working electrode. Measurement results are shown in Fig.2.

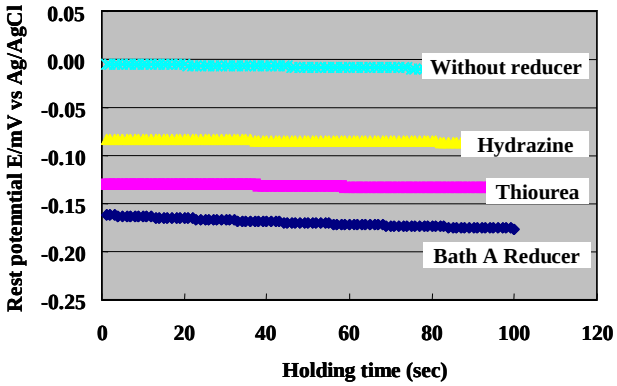


Fig.2 Comparison of reducer rest potential.
Temp.: 50 deg C
Working electrode: Gold plate vs Ag/AgCl

The results show the comparison of oxidation potentials between each reducer. From these results, we confirmed reducing power in the order of, Bath A reducer > Thiourea > Hydrazine in a neutral pH solution. Also, Fig.2 shows that the reducer of Bath A has the smallest difference in potential between EN deposit dissolution and gold plating. This indicates that the EN deposit dissolution power of Bath A is the weakest during plating.

2.2 Effect of immersion gold bath in the neutral pH type electroless heavy gold plating process

Previously in this study, we confirmed that a neutral pH autocatalytic type electroless gold plating bath has a possibility of dissolving the EN deposit during plating due to the plating potential being less noble than the EN deposit dissolution potential. Therefore, we checked the effect of the immersion gold bath that is normally used as a strike gold bath for autocatalytic gold plating. In this study, we used a semi-auto catalytic type immersion gold plating bath (commercial bath by C.Uyemura & Co., Ltd., referred as Bath C) and a conventional displacement type immersion gold plating bath (commercial bath by C.Uyemura & Co., Ltd., referred as Bath D). These plating solutions were prepared under standard catalogue procedures. Plating time conditions were 3 and 10min (Au thickness: approximately 0.03um and 0.06um) to check the effect of immersion gold coverage, and then, plated 30min in Bath A (Au thickness: approximately 0.5um). The plating process is shown in Fig.3, and the test coupon condition is stated in Table 1. Two test coupon types were used. One is 20um copper plated on FR-4 board, the other is solder mask coated in order to form a 0.75 mm diameter BGA's on the copper plated board.

Table 1 Test coupon type

Bath D	3 min.	------
	10 min.	
Bath C	3 min.	
	10 min.	
Bath D	3 min.	Bath A 30 min.
	10 min.	
Bath C	3 min.	
	10 min.	

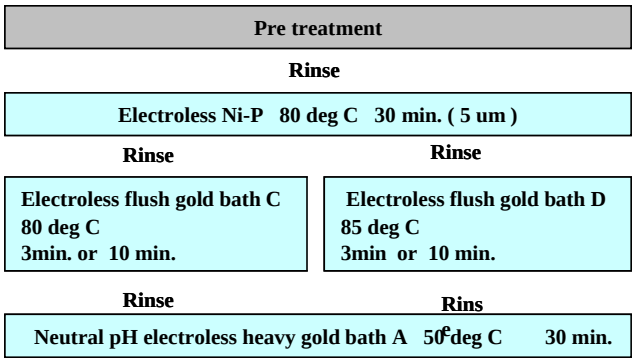


Fig.3. Plating process

a) Coverage measurement of flash gold film

We measured immersion gold coverage of the 4 test coupon types stated in Table 1 utilizing an anodic polarization method. Measuring condition and method are shown in Fig.4.

Coverage depends on plating time and bath type. As shown in Fig.5, 10min plating using the Bath C had an excellent result.

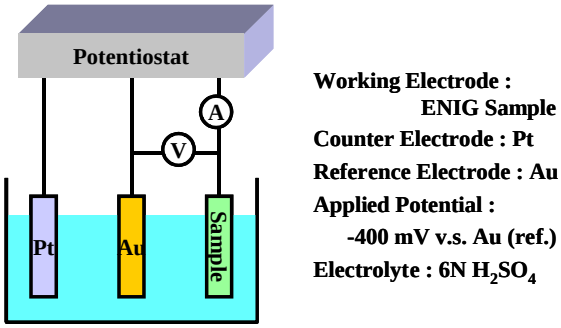


Fig.4. Test method of gold film coverage for ENIG film.

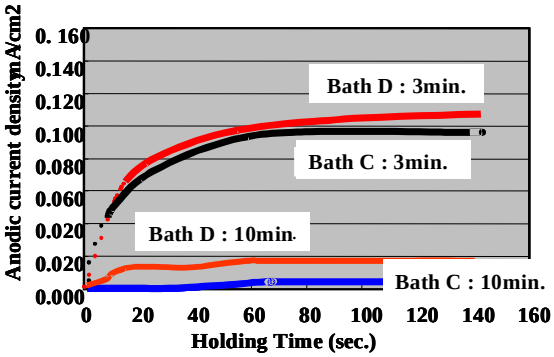
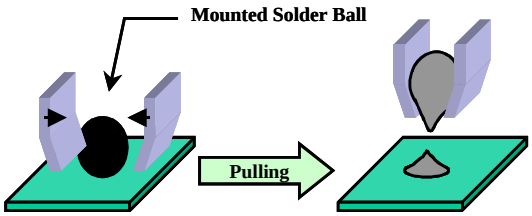


Fig.5. Compare covering in immersion gold.

b) Solder ball pull and wire bonding test on TMX films

Solder ball pull test and wire bonding test were conducted on the 4 Bath A test coupon types stated in Table 1. Furthermore, Bath A plated test coupons that underwent heat treatment for 175^0 C for 16hrs were also prepared and tested. As a comparison, solder ball pull tests were conducted on the immersion gold plated coupons also. Solder ball pull test conditions and test methods are shown in Fig.6. The results shown in Fig.7 indicate that the Bath A coupon with 10 min.- Bath D (displacement bath) plating had average solder pull test results, however the Bath A plated film with a Bath C plated film and 3min.-Bath D plated film had better results in this test. Wire bonding test conditions are shown in Table 2. The results in Fig.8 show excellent results in all coupons, and therefore, influence of flash gold plating conditions on the wire bondability of Bath A film could not be confirmed.



Solder ball pull Test conditions
Equipment : Dage #4000 / Tool Rate : 170um/sec
Flux : RMA-type / Alpha metal R5003
Reflow Condition : Hot plate 230/40sec (Sn-Pb)

Fig.6. Solder ball pull test conditions

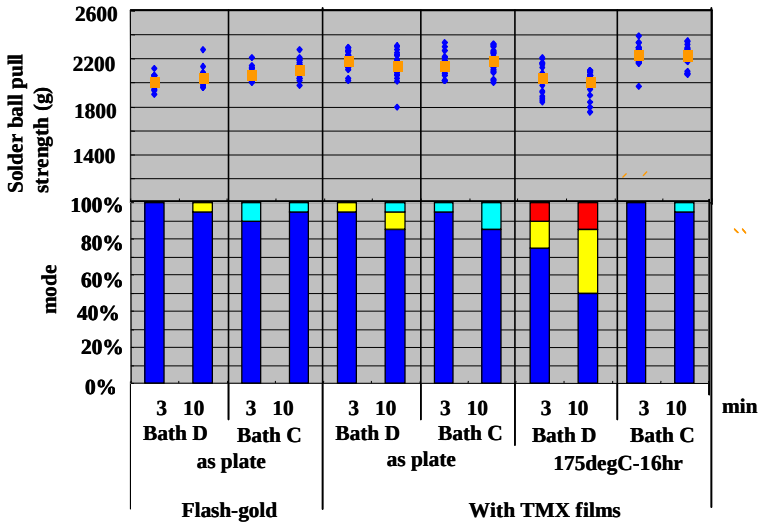


Fig.7 Influence of flash gold plating conditions on solder pull test results of TMX films.

Table 2. Wire bonding conditions

Wire bonding Test conditions
Equipment : KS4524A
Wire: 1.0mils gold
Temp.: 180℃
Step: 0.812mm
1st bond: Power=130 m W,
Time=10 m sec., Force=30 g
2nd bond: Power=190 m W,
Time=15 m sec., Force=90 g

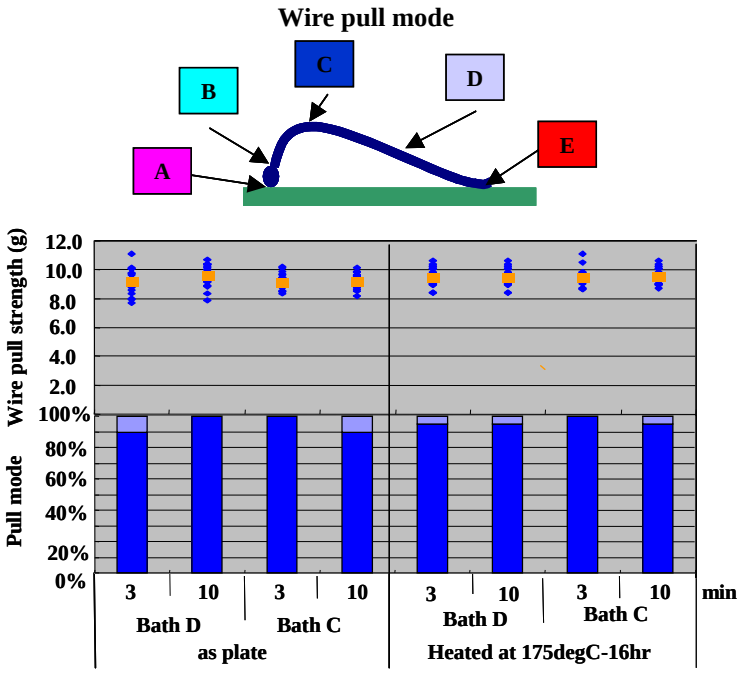


Fig.8 Influence of immersion gold plating conditions on wire bonding test results of Bath A deposits.

3. Conclusion

In this study, we measured the rest potentials of gold deposition and EN film dissolution regarding an alkaline-cyanide electroless gold bath and a neutral pH non-cyanide electroless gold bath. The results indicate as follows.

1) A non-cyanide neutral pH gold (Bath A) bath has the possibility of dissolving the electroless nickel deposit during plating. However, an alkaline-cyanide type (Bath B) bath does not possess this characteristic.
2) The ability to dissolve the electroless nickel deposit depends on the reducing agent type. Also, the reducing agent of Bath A is mildest in this character.

Furthermore, we investigated the influence of immersion gold bath conditions, which is considered to influence the initial reaction of a neutral pH non-cyanide autocatalytic gold plating bath. As a result, it was confirmed that although immersion gold bath conditions have minimum influence on wire bonding, it has a more significant influence on solder joint connections. The solder joint reliability of thick gold deposits (Bath A) with the immersion gold (Bath D) deposit depends on the dwell time in the immersion gold solution. That is, a thick gold deposit (Bath A) with a 10 min. plating time in immersion gold (Bath D) had average solder joint strength. On the other hand, solder joint reliability of a thick gold (Bath A) film with a semi-auto catalytic immersion gold (Bath C) film is not influenced by immersion gold plating time. Therefore, we confirmed that the solder joint reliability of the thick gold (Bath A) deposit does not depend on the coverage characteristic of immersion gold plating, but on the surface condition of the electroless nickel layer after immersion gold plating. Moreover, as the solder ball pull strength of the displacement flash gold (Bath D) + heavy gold (Bath A) film is lower than the displacement flash gold (Bath D) plating deposit, the EN deposit may have been corroded during heavy gold (Bath A) plating, depending on the immersion gold conditions.

Therefore, in order to achieve improved wire bonding and solder joint reliability by utilizing a neutral non-cyanide auto-catalytic heavy gold electroless plating bath, it is important to chose an optimum immersion gold bath that has minimum influence on the electroless nickel deposit. Furthermore, it was confirmed in this study that a semi-auto catalytic type flash gold plating (Bath C) + non-cyanide autocatalytic type electroless gold plating (Bath A) process can possess excellent wire bondability and solder joint reliability characteristics.

References:

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