Electroless Plating Process For High Density Ceramic Packages & MCM-C Substrates

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The electroless plating Ni-Au process for high-density ceramic packages , such as pin grid array (PGA), ball grid array (BGA) and ceramic based multichip modules (MCM-C) etc. is described in this paper. This process has advantages of good adhesion to electroless Ni-B, high rate of deposition, good selectivity and stability of the bath. The results of the practical applications show that it is suitable for surface finishing of high-density ceramic IC packages and ceramic MCMs in microelectronic packaging, and can meet the requirements of die attachment, wire bonding, lid sealing and soldering technologies etc..

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Introduction

At present, with the continuous increase of interconnect density, reduced line width and pitch in microelectronic packaging, requirements for advanced high density packages with high pins and fine pitches as well as high electrical and mechanical performances have been constantly increasing. Thus the plating technologies of these packages are challenged. For traditional plating process, the area which to be plated must be electrtrical connected for these packages, such as ceramic PGA (Fig.1). The bus-lines, which connect all of the interconnect conductors of the pins or the patterns to ensure the conductivity in electroplating, must be additionally designed on the quad sides of package. Generally, the bus-lines and interconnect conductors are made by W metallization paste printed on the green ceramic base by silk screen printing method, and then co-fired in H_2 atmosphere at high temperature. After the sintered PGA is electroplated with gold and nickel, the bus-lines are mechanically cut off. Obviously it is inconvenient for the fabrication of PGA. Using the bus-lines not only increases the process steps and costs of the packages, but also the routing among the layers of the packages needs more spaces and connections. With the bus-lines cut-off, the stubs which are the residual parts of these lines in the interior layers may have deteriors effects on the high frequency signal propagation of the packages.

It is similar to the PGA in the case of the BGA and MCM-C packages (Fig.2,3) which may have a greater number of the pads, conductors or patterns isolated each other. And for the plating of the large amounts of input/output (I/O) pins on these packages, it seems to be difficult to adopt the electroplating. For this reason, it is the best way to use the electroless Ni-Au plating instead of the electroplating, which can eliminate the bus-lines and electroless plate the areas that needs to be plated directly.

Pretreatment of plating

The alkaline cleaning and the ultrasonic cleaning are very important to obtain the good deposits and strong adhesion to the bases. It can not only eliminate the greasy dirt on the surface of the packages, but also the metallization particles or other impurities adhered on the ceramic surface, such as graphite which is produced by friction of the parts with graphite boat. If the impurities were not thoroughly removed, the "bridging" of the patterns may occur during the subsequent electroless plating process. The ultrasonic cleaning followed by the chemical etching of the metallization and package surface can ensure the packages with fresh surfaces to be plated.

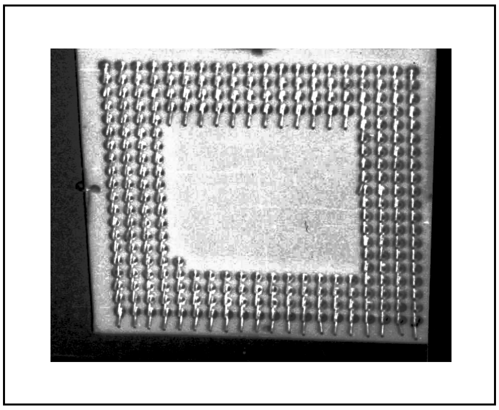
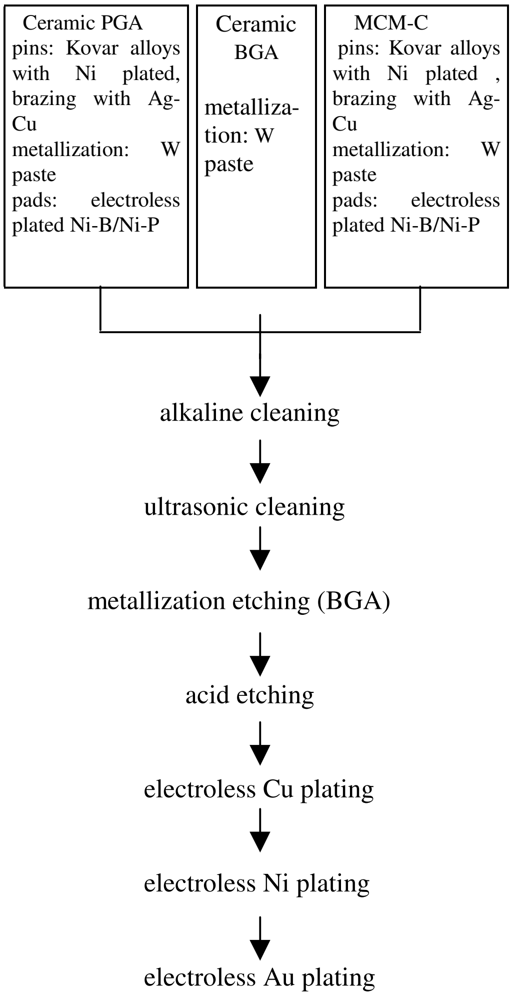


Fig1. 257 Pins Ceramic PGA(face-down)

Plating process



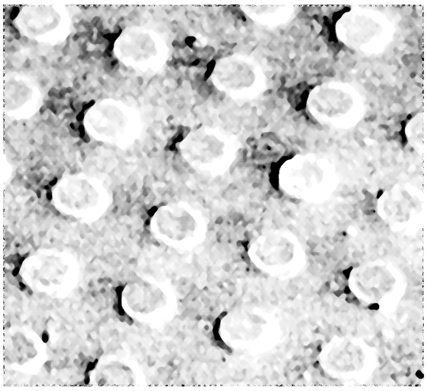


Fig.2 The pad array of BGA

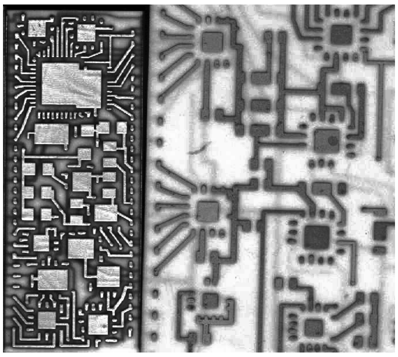


Fig.3 The circuit patterns of MCM-C substrates

Electroless Cu plating

There is a stability problem with the conventional electroless Cu plating bath using formaldehyde as the reducing agent, especially after the activation treatment, the copper can be very easy displaced on the ceramic base of the packages. Therefore, it is not adaptable for plating of the high-density packages. For this reason, we used hypophosphite as reducing agent to electroless plate copper. The composition of electroless Cu bath is as following[1]:

$CuSO_4 \cdot 5H_2O$	5g/L
Na_3Cit	15g/L
$NaH_2PO_2 \cdot H_2O$	30g/L
H_3BO_3	30g/L
$NiSO_4 \cdot 6H_2O$	a small amount
Additive	a small amount

T: 80~85•, pH=8.5~9.0 time:10~15min.

The bath is characteristic of direct plating on W metallization and strong adhesion to W film. Additionally, the copper can not be reduced and deposited on Al_2O_3 ceramic bases. And with the addition of a small amount of additives, the bath has some advantages of good stability, long service time, fine crystallization and up to 4•m/h deposition rate.

The main improvements for eletroless plated copper as the base layer of eletroless plated nickel are as follows: 1) intensified the adhesion of deposit to the basis; 2) omitted the initiation before the electroless plating. The conventional electroless plating needs to have the W metallization surface activated. And the usual method uses Pd salt, which requires to control the concentration, temperature and time of the activating solution. Improper operation may lead to failed initiation of plating which may results in non-deposition , bad adhesion or "bridging" of large area of the deposit etc.. Furthermore, the accumulation of the Pd^{2+} ions introduced may cause the bath to be unstable and then decompose; 3) Since the activation step is omitted, the eletroless plating can not be initiated by the adsorption of the Pd^{2+} ions on the surface of the ceramic basis, which may cause "sticking" or "bridging" of undesired areas for plating, thus provides a much higher yielding.

Eletroless nickel plating

Nickel plating after the eletroless copper plating adopts the eletroless Ni-B alloys. Such choice is due to: 1) direct eletroless Ni-B plating on the eletroless plated copper surface without any initiation; 2) It is much easier to plate Au on the eletroless Ni-B alloy than on the eletroless Ni-P alloy. And good adhesion can be provided.

The basic composition of the bath for eletroless Ni-B alloy plating is:

$NiCl_2$	30g/L
NaOH	40g/L
Ethylene diamine	50ml/L
KBH_4	1.5g/L
Stabilizer	a small amount

temperature: 80•85•, pH>12, time: 30•40 min. Its deposition rate can be up to 8~10•m/h. The B contents of the deposit are about 3~8% (Fig.4). The surface morphology of the deposit is as Fig.5.

In order to obtain the good Ni-B deposit, it is essential to critically control the process and the

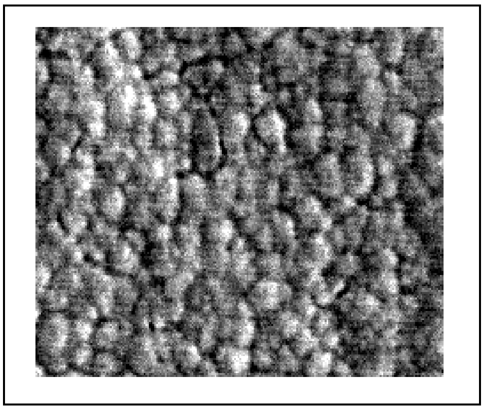


Fig.4 The surface morphology of electroless Ni-B.×1500

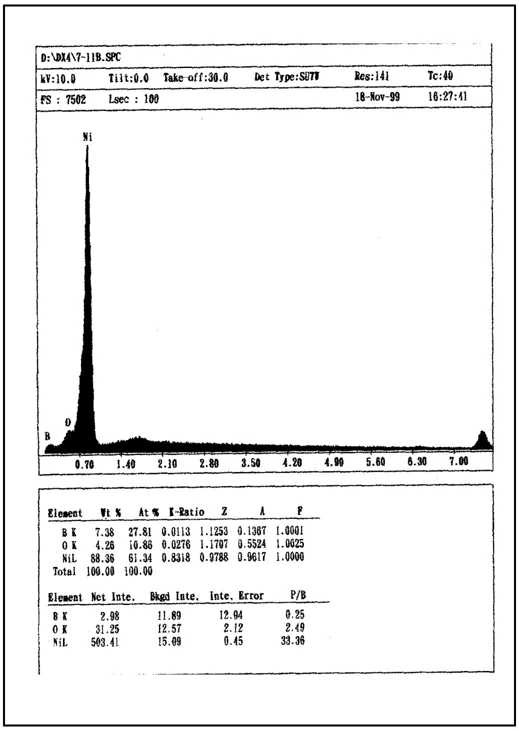


Fig.5 The result of AES analysis of electroless Ni-B

composition of the bath. Similar to other process control of electroless plating, the temperature of the bath affects greatly the deposition rate. The higher the temperature is, the faster the deposition rate can be obtained, but which may cause the bath to decompose. When the temperature is below 65•, the reaction rate is very slow relevantly, even with no deposits appeared. The deposition rate of the electroless Ni-B alloy increases with the increase of the Ni^{2+}, NaOH and KBH_4 concentration, while decreases with the increase of the concentration of ethylene diamine. Too high concentration of the reducing agent may give rise to rapid decomposition of the bath. Therefore, a small amount of stabilizer should be added to ensure the stability of the bath.

Eletroless Au plating

The basic composition of the bath for eletroless Au plating[2] is :

Au^{3+}	2g/L
Au^{+}	2g/L
KOH	40g/L
Complex	20g/L
F^-	5g/L
Reducing agent	30g/L
Stabilizer	a small amount

temperature: 90~95•, pH > 12, time: 30•45 min.

The main features of the above bath are: it uses aqueous mixer of aurocyanide complex and auric compound .The added auric compound can be replenished in form of $KAuO_2$ or $Au(OH)_3$ to avoid the accumulation of the CN^-ions in the bath, which may improve the stability of the bath and increase the deposition rate. The deposition rate can be maintained at 3~5•m/h. However, with the prolonged operation time and the accumulation of the impurities in the bath, the deposition rate may be lowered[3].

To avoid the pollution of metal ions in the bath, the cleaning before the Au plating after the eletroless Ni plated is very important. Ultrasonic cleaning is preferable. The way of a plated thin layer of Au over the Ni-B film by immersion Au plating and then another electroless Au plated is recommended so as to eliminate or reduce the pollution of the metallic ions and the impurities.

Process control

To obtain the plated Au film of good quality, process control in practice is of paramount importance.

1) The ratio of Au^{3+} concentration to Au^{+} is 1:1•3:1. The higher the Au^{3+} concentration, the faster the deposition rate is. But much higher Au^{3+} concentration has no prominent effects on the deposition rate. With the increase of the OH^- concentration, the deposition rate increases also and the bath is rather stable. Instead, too much higher concentration of the base can reduce the deposition rate.

2) The function of F^- has not been

thoroughly studied yet. It is supposed to be a kind of stabilizer and used to improve the adhesion of the deposit and the ceramic metallization. But with the $F^{\bullet}$ concentration raised, the deposition rate may decrease and the ceramic bases may be eroded.

3) The addition of complex can improve the stability, pollution resistance of the bath and the appearance of the deposit.

4) With the increase of the concentration of reducing agent , the deposition rate increases. But too much higher concentration and temperature of the reductive can make the bath to decompose. Therefore, a small amount of stabilizer can be added and meanwhile control the temperature of the bath at 90~95• to keep the bath in normal operational state.

Performance and application

1) Under the appropriate operation conditions, the appearance of the eletroless Au deposit is lemon yellow, with fine crystallization (Fig. 6). It is close to purity gold by AES analysis. The microhardness of the deposit is 540 N/mm^2, and the resistivity is 2.6×10^{-6}• ·cm.

2) With 4•m of eletroless Ni-B alloy plated over the W metallization surface on the 96% Al_2O_3 ceramic and then 1.5•m of electroless Au plated , the color of the surface can keep unchanged for 3 min. at 400• in the air.

3) With 4•m of eletroless Ni-B alloy plated over the Kovar alloy and then electroless Au plated of 1.5•m, the zero-crossing time is less than 0.3 seconds using Sn-Pb(60~40) solder to test the solderability. After the lid sealing with Au-Sn solder, hermetic testing can meet the requirements of the device specifications

4) When the die attachment is made in the PGA, BGA and MCMs etc., the good wetting of the Au-Si eutectic mixture and strong adhesion of the die to the package can be obtained. The results of using gold wire bonding are shown table 1:

Conclusion

The above results demonstrate that the electroless Au plating has quite good capabilities of die attaching and wire bonding, which can meet the needs of the VLSI manufacturing. For the plating of complicate packages such as PGA, BGA and MCMs etc. , the electroless Au plating can instead of the Au electroplating, which can simplify the package design, shorten fabrication period, lower the cost as well as improve the performance of the packages and the cost/performance ratio.

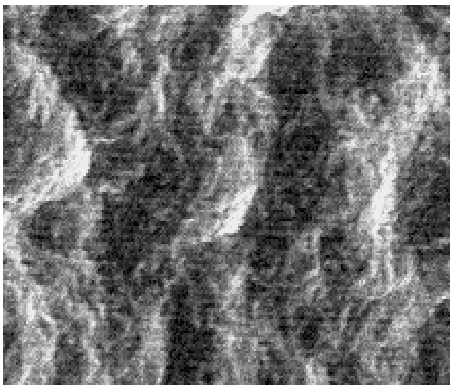


Fig.6 The surface morphology of electroless Au. ×2000

Table 1. The results of electroless gold with gold wire bonding

	Pull off strength (mN)	
No.	As-plated	After aging at 150•for 24hr
	gold wire(d = 30 •m)	
017	135	120
016	105	110
015	140	110
014	120	110
013	100	100
012	120	105
011	120	105

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3. Y. Okinaka, R. Sard, C. Wolowodiuk et al., *J. Electrochem. Soc.* 1974, 121(1):56