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Evaluation of ENEPIG Surface Treatment for High-reliability PCB in Mobile Module

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Abstract

We evaluated characteristics of ENEPIG (Electroless Nickel Electroless Palladium Immersion Gold) surface treatment for mobile equipment that requires high reliability, in addition to investigating surface treatment processes for semiconductor boards that require high reliability such as regular PCB-package systems, board-on-chip, chip-scaled package (CSP), etc and application for semiconductor package board of SIP, BOC. As a result, it appeared that ENEPIG has superior properties compared to ENIG surface treatment in corrosion resistance, solder junction, wetting, etc. We anticipate that these results will be able to lend credibility to ENEPIG as a low-cost alternative for producing mobile devices such as the cell phones, especially when applied to mass production.

Keywords: ENIG(electroless Nickel Immersion Gold), ENEPIG(Electroless Nickel Electroless Palladium Immersion Gold), Solder, PCB, MTO

1. Introduction

PCB (Printed Circuit Board) is the most important component of electronic devices, and the final process in the production of PCB is surface treatment to prevent oxidation of copper surfaces contained in circuits, in which processes such as HASL (Hot Air Solder Leveling), OSP (Organic Solderability Preservative), Immersion Tin, Immersion Silver, ENIG (Electroless Nickel Immersion Gold) are routinely selected depending on conditions. However, the problem with Black Pad that occurs from parts that are treated with ENIG is yet to be resolved and is a serious liability in expanding treatment and gaining reliability. Therefore as a new and improved treatment for overcoming the limitations of ENIG, ENEPIG (Electroless Nickel Electroless Palladium Immersion Gold) is becoming a subject of interest. ENEPIG is an electroless 3-layer plating of electroless Ni/electroless Pd/substitution Au in which the Palladium layer prevents the formation of a layer of oxidized Nickel that is problematic in ENIG treatment and stops the formation of Black Pad in its roots. In production of PCB used for mobile devices, this technique has the advantage of lowering the cost of masking and removal treatment from multiple plating, thereby lowering production costs.

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2. Experimental Techniques

2.1 Plating Process for Sample Production

Typically, the process for the production of standard specimen samples of ENEPIG plating consists of washing, pickling, soft etching, activation, Electroless Nickel, Electroless Palladium, Electroless Gold Plating. For ENIG the double Electroless palladium process was omitted.

2.2 Evaluation of Corrosion Resistance

Evaluation of corrosion resistance for test specimen was done using a Salt Spray Test. Corrosion resistance specimens were prepared each with standard thickness using BGA substrates - ENIG Process (Goal thick electroless Ni: 5.0~7.0 um, substituted Au: 0.05~0.10 um), ENEPIG Process (Goal thick electroless Ni: 5.0~7.0 um, electroless Pd: (0.05~0.15 um), electroless Au: (0.05~0.10 um)).

Conditions of salt spray test were established according to JEDEC test regulation JESD22-A107 at NaCl 5.0%, salt pH 6.0~7.5, Chamber Temperature 35°C, and salt spray tester set 30 g/m^2/24Hr and after continuous spraying for 48Hr the sample was observed with an optical microscope (×40) and abnormalities were observed by SEM to be determined.

2.3 Solder Joint Reliability

There are many different types of Solder Joint Reliability Tests, but the most widely used CBP (Cold Ball Pull) Test was administered. Test specimen were produced in lab for the CBP test as shown in Fig. 1 and ENEPIG/ENIG plating was carried out. Diameter 0.760 mm, Pb Free SAC-305 Solder Ball was used on plated specimen to produce specimens joined to Solder at 260°C Peak Temperature.

In order to evaluate the reliability of the connection joints of Solder balls, an evaluation of mechanical characterization of the connection joint, as well as the temperature, moisture, vibration, and voltage stress on joints under various short and long term reliability testing environment is required. To ensure this reliability, a Pull Test - a kind of CBP (Cold Ball Pull) test - was conducted to measure the natural bonding strength of the interfacial bonding between the solder and substrate land. For test specimen, as shown in Table 1, a substrate was used that was produced in lab according to reliability standards

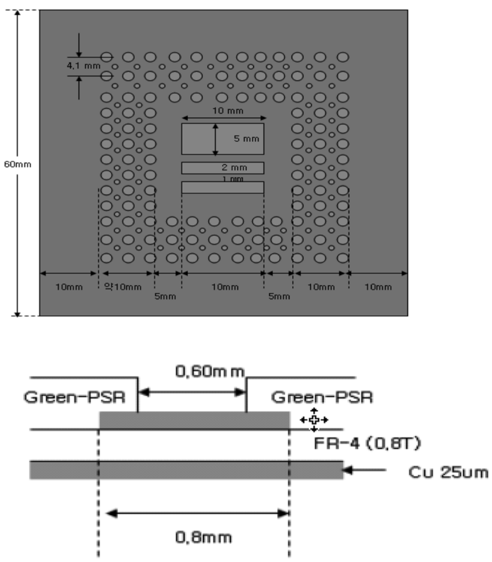


Fig. 1. PCB(printed circuit board) of test CBP.

Table 1. Standard of testing board on solder junction

Division		Contents
Test board	Material	PCB(Print Circuit Board) FR-4
	Thickness	0.8 mm
	Minimum Size	20×20 mm
Pad	Surface Treatment	Electroless Ni/Au Plating
	Thickness	Ni : 2.54~7.00 um Au : 0.7 um or lower
	Size	80~85% of Solder Ball diameter
Flux	Form	RMA(Rosin Mildly Activated)

Table 2. Condition of ball pull test and specimen processing

Division	Contents	
Ball Pull Test conditions	Pull Speed	150 um/sec
Test Specimen processing	Specimen A	Plating(ENIG & ENEPIG) → Solder Ball splicing → 1Hr rest at room temperature → Pull Test
	Specimen B	Plating(ENIG & ENEPIG) → Solder Ball splicing → Reflow ×3 → 1Hr rest at room temperature → Pull Test

established in early 2003 by Korea's reliability standards for lead-free solder balls (RSD0015). Also, pull-test method was not prescribed, but the pull speed was set to 100~200 um/sec and the usual specification was recorded in Table 2 and followed.

2.4 Impact Test

Impact resistance test was run in stages, first

Table 3. Conditions of an impact test and specimen processing

Division		Contents
Test conditions	Temperature	15~35°C
	Relative humidity	25~85%RH
	Atmospheric pressure	86~106 kPa (0.85~1.05 atm)
Impact conditions	Impact size	1,500 G
	Impact direction	Vertical
	Impact number	30 Cycle
Test Specimen processing	Solder Ball	SAC-305, Φ0.76 mm
	Specimen A	Plating(ENIG & ENEPIG) → Solder Ball splicing (Φ760 um) → Impact test
	Specimen B	Plating(ENIG & ENEPIG) → Solder Ball splicing (Φ760 um) → MRT (Level 2) → Impact test

Table 4. Conditions of ball shear test and specimen processing

Ball Shear Test conditions	Equipment	BT 4000 (DAGE)
	Shear Speed	200 um/sec
	Shear Height	150 um
Test Specimen processing	Condition A	Plating(ENIG & ENEPIG) → Solder Ball splicing → Shear Test
	Condition B	Plating(ENIG & ENEPIG) → Solder Ball Splicing → Impact test(1500G, 30Cycle) → Shear Test
	Condition C	Plating(ENIG & ENEPIG) → Solder Ball splicing → MRT Level 2 (85°C-60%RH, 168Hr) → Impact test(1500G, 30Cycle) → Shear Test

separate impact test PCB were created and two kinds of specimens for each surface treatment (ENEPIG and ENIG process) were prepared. Then impact tests after joining to SAC-305 Solder Ball and after environmental testing (MRT, Level 2) were conducted and results were assessed. Under atmospheric conditions, 30 cycles at impact size 1500G, vertical direction were conducted.

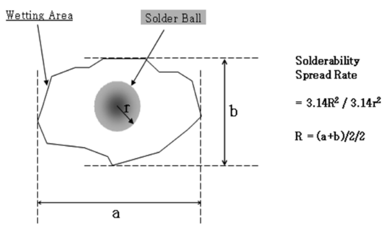
Ball shear test is a way to measure the bonding strength using a constant velocity shear tip to push the solder ball. Shear test conditions after impact test were as shown in Table 4.

2.5 Comparison of Solder Spread Rate

Solder spreading characteristic of electroless Ni coatings is typically known as Ni-B > Ni-P (low) > Ni-P (high)[1]. Factors known to affect Spread rate are the surface treated substrate, Flux, Solder type, heating conditions, etc and this experiment is designed to determine the degree to which the surface treated substrate affects Spread rate while holding all other conditions equal. So a Spread test method was used in which a certain amount of Solder was melted on top of the substrate and the area which the Solder spread was measured.

Specimen were fabricated according to each of previous ENIG process, ENEPIG process on PCB board with standard thickness. In order to confirm the difference in Solder Spread rate specimen that underwent thermal shock were made and evaluated for Spread rate according to Table 5.

Table 5. Conditions of spreading test and formula

Division		Contents
Test Specimen processing	ENIG	Plating → Thermal shock (175°C-16Hr) → Solder Reflow
	ENEPIG	
Spread rate Formula		

3. Results and Observations

3.1 Plating Section Observations

After performing surface treatment using ENEPIG, FIB was used to observe a section of the treated surface. Only if the Palladium layer provides a uniform barrier layer for Ni in the ENEPIG process is it expected that the thermal shock and environmental acceleration tests will have no effect. As shown in Fig. 2, it was confirmed that the Palladium layer was formed uniformly above the Nickel layer.

3.2 Evaluation of Corrosion Resistance

Typically, corrosion characteristics of PCB surface treated substrates is determined by the distribution of porosity, and the shape and distribution of porosity are affected by various factors such as surface roughness, surface morphology, processing, plating thickness, adhesion, coating thickness, stirring, filtration

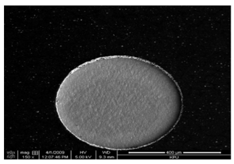
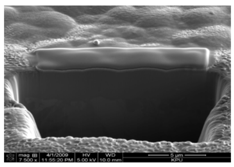
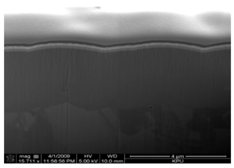
Division	FIB image
Board surface after ENEPIG process	
	×150
Section image of ENEPIG process	
	×7,500
	
	×15,000

Fig. 2. One side image of ENEPIG Process (FIB).

of impurities, etc. In order to evaluate corrosion resistance of the ENEPIG process, a comparison study against ENIG and electrolytic Ni/AU (Soft Gold) was initiated. As shown in Fig. 3, BGA board was produced in lab and a salt spray test was conducted.

As a result of observing a specimen that was treated continuously with salt spray for 48Hr, a few stains and a black morphology was observed from an optical microscope starting from the corner of the ENIG processed substrate. As shown in Fig. 4, corrosion only occurred in the ENIG process. In order to exclude the effects of the highly corrosion-resistant Gold layer, the Au plating was produced with similar thickness in specimens for both ENIG process and ENEPIG process, but corrosion was completely absent in ENEPIG process. This is thought to result from the uniformly formed Pd layer alleviating the galvanic corruption caused by a difference in electric potential in the salt spray.

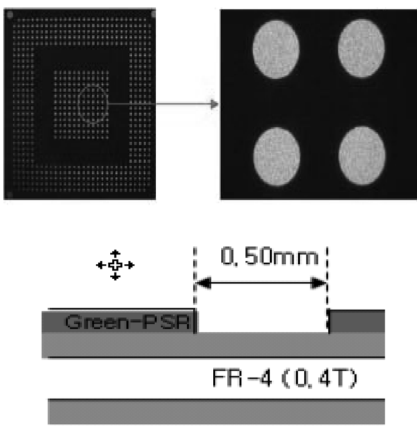


Fig. 3. Structure of BGA board used by anti-corrosion evaluation.

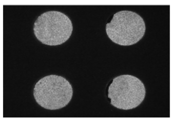
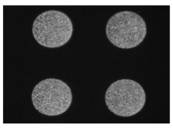
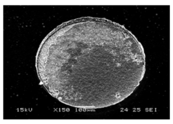
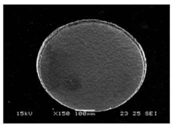
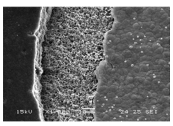
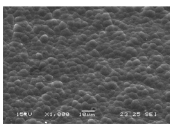
Division	ENIG Au-0.091 um Ni-6.500 um	ENEPIG Au-0.108 um Pd-0.097 um Ni-6.722 um
Optical microscope (×40)		
Electron microscope (×150)		
Electron microscope (×1,000)		
Results after 48Hr spray	NG	OK

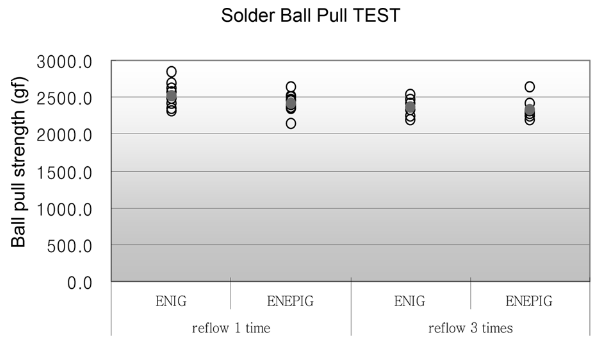
Fig. 4. Specimen images & results after salt spray testing.

3.3 Evaluation of Solder Joint Reliability

As a result of Solder Joint Reliability test, both ENIG process and ENEPIG process showed a pull value of over 2,000 gf and were good in Failure mode.

3.4 Evaluation of Impact Test

In order to increase intensity of the Solder Ball joint strength test, an Impact test was administered on the joined Solder Ball. Results of the test were confirmed with 3 different methods, first, visual observation of whether the Solder Ball dropped, second, the presence of a Crack after polishing up the cross section of the tested specimen, third, Ball



ENIG : Ni-5.08um, Au-0.089um
ENEPIG : Ni-5.37um, Pd-0.117um, Au-0.093um

Fig. 5. The result of ball pull test.

Table 6. The result of an impact test

Division		Specimen A	Specimen B	Results
Process name	Plating thickness			
ENIG	Au 0.057 um Ni 6.350 um	0/25 (0.00%)	0/25 (0.00%)	Solder Ball No drop
	Au : 0.100 um Ni : 5.656 um	0/25 (0.00%)	0/25 (0.00%)	Solder Ball No drop
ENEPIG	Au : 0.046 um Pd : 0.103 um Ni : 5.498 um	0/25 (0.00%)	0/25 (0.00%)	Solder Ball No drop
	Au : 0.099 um Pd : 0.112 um Ni : 5.559 um	0/25 (0.00%)	0/25 (0.00%)	Solder Ball No drop

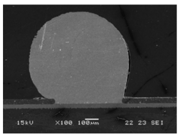
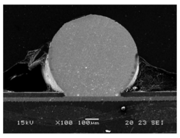
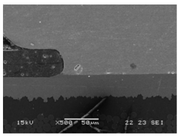
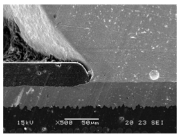
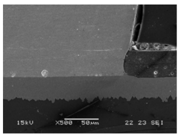
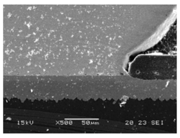
Division	Impact condition A	Impact condition B
Cross-section of tested Ball after Impact test	 ×100	 ×100
	 ×500	 ×500
	 ×500	 ×500
Results	No Crack on joint surface	No Crack on joint surface

Fig. 6. One side result of test sample after an impact test in ENIG process.

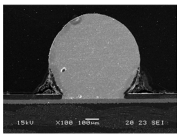
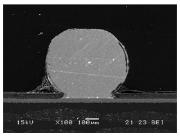
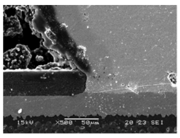
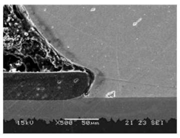
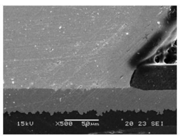
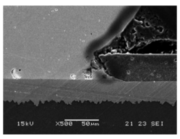
Division	Impact condition A	Impact condition B
Cross-section of tested Ball after Impact	 ×100	 ×100
	 ×500	 ×500
	 ×500	 ×500
Results	No Crack on joint surface	No Crack on joint surface

Fig. 7. One side result of test sample after an impact test in ENEPIG process.

Shear Test of the tested specimen. In Table 6, all specimens showed good results with lack of dropping. Both ENIG process and ENEPIG process

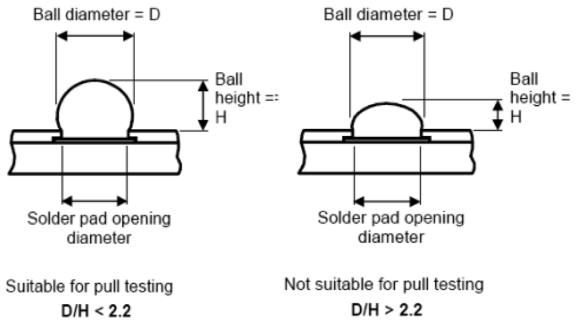


Fig. 8. Sizes between proper ball and pad when solder ball shear testing.

showed lack of a Crack upon examination of the cross section. Fig. 6 and Fig. 7 represent results for ENIG process and ENEPIG process respectively.

The Ball Shear Test is a method of measuring joint strength by using a shear tip to push the Solder Ball at a constant velocity. This method can be confirmed using JEDEC standards, and it is important to make sure the crucial shear tip's height is not lower than 1/4 the ball's height. In addition, the value changes according to shear velocity experimental conditions (shear strength increases with higher velocity), so the shear velocity must be clearly stated. General provisions 200~300 μm/sec were ordained in 2004.[3)]

There are no provisions for Shear strength, but as in Fig. 8 the relationship D/H between ball height (H) and solder pad (D) must be less than 2.2. At normal conditions (ball size in diameter 0.76 mm, diameter of bearing pad 0.60 mm) a value of approximately 900~1,000 gf is known to be obtained[4)].

The results of the Ball Shear Test showed that substrates that did not undergo impact test after plating with ENIG process or ENEPIG process showed the best values, and the substrate that underwent environmental acceleration test (MRT Level 2, 85°C, 60%RH (relative humidity), 168Hr), which was expected to have the worst conditions, showed the lowest Shear Strength, and in the case of ENIG process, a lower value than the general standard value of 1,000 gf was obtained as illustrated in Fig. 9. Lower than standard values may possibly result because the pad size is small, but as confirmed by comparing the result values, ENEPIG process is expected to be a more environmentally stable surface treatment process than ENIG process. After measuring the joint resistance of existing ENIG process and ENEPIG process, the results show almost no difference between ENIG process and ENEPIG process. The resulting values are indicated in Table 7.

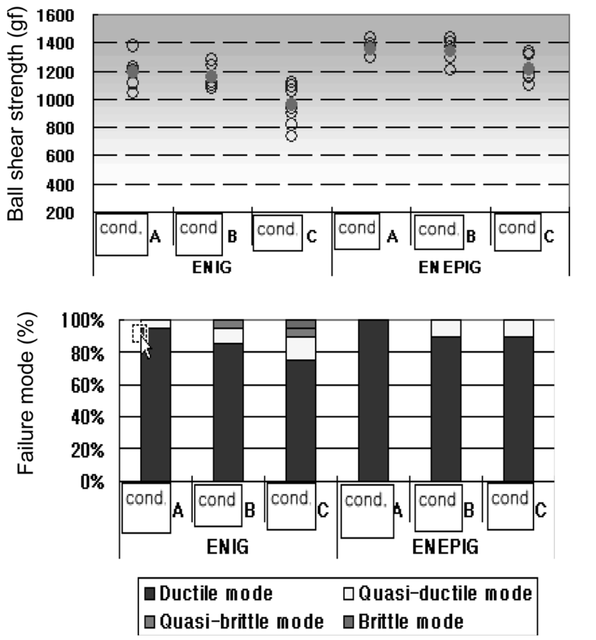


Fig. 9. Broken mode and results of ball shear test before/after impact test.

Table 7. Contact resistance measurement results

Division	Electrical Resistance (mΩ)	
Plating	ENIG	ENEPIG
Thickness	Au-0.103 um Ni-5.932 um	Au-0.103 um Pd-0.112 um Ni-5.293 um
Average	8.076	7.911

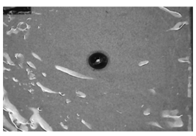
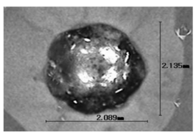
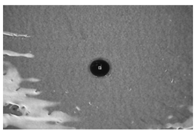
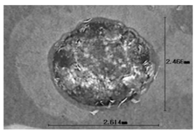
Division	Before Reflow	After Reflow	Spread rate results
ENIG			Spread rate = 7.723
ENEPIG			Spread rate = 11.170

Fig. 10. Results of spreading appraisal of solder.

3.5 Evaluation of Solder Spread Rate

As shown in Fig. 10, test results indicate that solder spread rate for ENIG process shows about 7.723, while for ENEPIG the spread rate was 11.170, confirming that Solder Spread rate is considerably superior than the ENIG process.

4. Conclusion

The properties of ENEPIG surface treatment products were superior to previous ENIG treated products. In other words, in corrosion resistance, it showed excellent properties in the Salt Spray Test compared to ENIG. In particular, specimen corruption due to Au substitution plating was nearly non-existent compared to ENIG, so it was considered to be able to solve the problem with black pad that is the greatest weakness of ENIG. In the case of ENEPIG process products, the results of the ball pull test after thermal shock indicated superior qualities compared with ENIG products. Even after MRT level 2 test, ENEPIG process products showed stable properties and as a result of Solder wettability test, showed significantly greater wettability than ENIG. Solder Joint flaws were assessed to be reducible during the process of mass-production.

Acknowledgements

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