Ultra-thin PdCo/Au Surface Finishes for Electronic Packaging

Chonglun Fan, Chen Xu and Joseph A. Abys

Enthone Inc. / Cookson Electronics

Jersey City, NJ and Orange, CT, USA

The electronics industry has recently renewed the interests in the nickel/palladium pre-plated frame (PPF) technology because of the pressure of using lead-free materials and the lowered and stable price of palladium metal over more than one year. In addition, the improvement of the technology and the modification of the specification allow the dramatic reduction of the thickness of the precious metal deposits without sacrifice of performance, while achieving considerable cost saving. Additional cost saving can be even achieved by plating palladium alloys to replace palladium. In this study, ultra-thin surface finishes of a palladium-cobalt (80/20wt%) alloy with a gold flash were plated on a conformable nickel underlayer over leadframes and investigated for wirebonding and solderability. The finishes can meet the requirements for the packaging applications.

For more information, please contact

Chonglun Fan
Enthone Inc. / Cookson Electronics
600 Route 440
Jersey City, NJ 07304

Tel: 201-434-6778 x2032
Fax: 201-434-2529
e-mail: clfan@cooksonelectronics.com

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Introduction

The electronics industry has recently renewed the interests in the nickel/palladium pre-plated frame (PPF) technology because of the tremendous pressure of using lead-free materials and the lowered and relatively stable price of palladium metal over more than one year (Figure 1). In addition, the improvement of the technology and the modification of the specification allow the industry to dramatically reduce the thickness of the precious metal deposits without sacrifice of performance and to achieve considerable cost saving. In semiconductor leadframe packaging, the tin-lead post plating will be soon replaced by environment-friendly finishing processes. Pure tin and some lead-free tin alloy finishes would be substitutes for tin-lead. However, tin whisker growth and some compatibility issues are concerns of using these finishes. Meanwhile, nickel/palladium PPF has been a well-established technology[1-5] and there are considerable cost reductions when assessing the overall operation of integrated circuit (IC) packaging using nickel/palladium. Higher production speed and yields, less waste and lower disposal all contribute to reducing the total cost of converting to this finish. Additional cost saving can be even achieved by plating palladium alloys to replace pure palladium in the finishes.

In this study, ultra-thin surface finishes of a palladium-cobalt (80/20wt%) alloy with a gold flash were plated on a conformable nickel underlayer over leadframes and investigated for gold wire bonding and solderability performance under as-plated condition or after different pre-treatments.

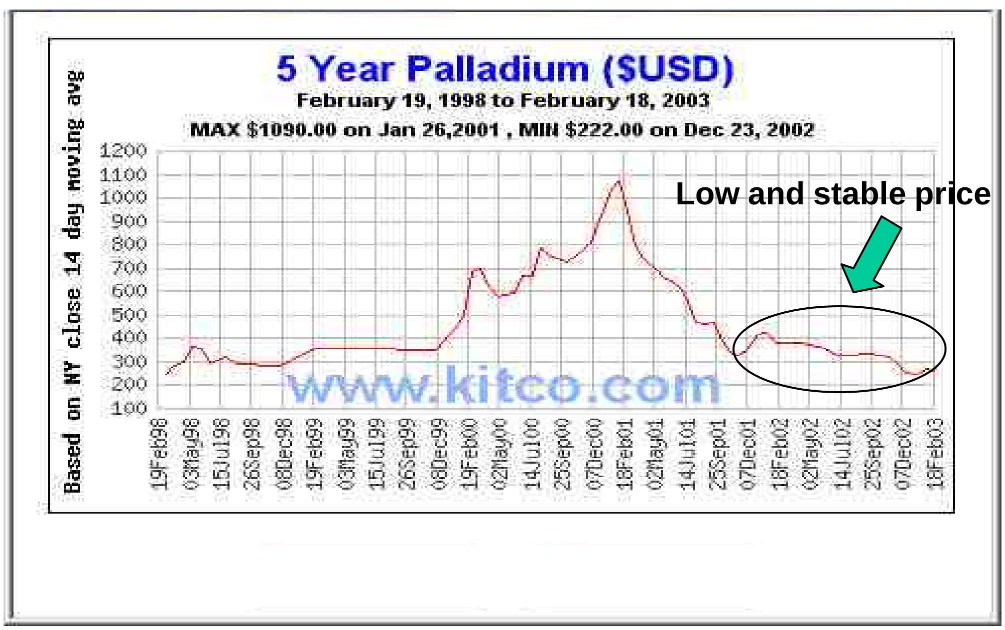

Figure 1. Price of palladium (data from Kitco).

Experimental

Surface Finish

Proprietary nickel, palladium-cobalt and gold plating chemistries were used for deposition of the surface finishes on copper alloy leadframes (250µm/10mil thick). The thickness of the different deposits is shown in Table 1. The precious metal deposits are much thinner than the conventional ones, *i.e.* more than 750Å (3µin) palladium with 250 – 500Å (1 – 2µin) gold flash. The nickel underlayer was designed for leadframe packaging applications; it is highly ductile to minimize cracking during forming operation.[4]

Table 1. Thickness of different deposits.

Deposit	Thickness
Nickel	0.5 – 1.0 µm (20 – 40 µin)
PdCo (80/20 wt%)	250 – 375 Å (1.0 – 1.5 µin)
Gold flash	15 – 50 Å (0.06 – 0.2 µin)

Using a palladium alloy deposit can achieve cost saving not only from its composition but also because of its lower specific density compared with pure palladium (Table 2). With an identical thickness covering an identical surface area, the reduction of palladium usage in the 80/20 alloy deposits is 26-27% compared with plating a pure palladium finish. In this study, the composition of the palladium-cobalt deposits was determined by atomic absorption (AA) and the deposit thickness was measured by Rutherford Backscattering Spectrometry (RBS) and confirmed by Auger Electron Spectrometry (AES, Figure 1).

Table 2. Specific density of palladium and its alloy electrodeposits.

Deposit	Specific Density ($g.cm^{-3}$)
Pd	11.7
PdNi(80/20 wt%)	10.7
PdCo(80/20wt%)	10.8

The plated leadframes were tested for wirebonding and solderability under as-plated conditions or after undergoing a thermal treatment to simulate production processes (Table 3).

Table 3. Sample treatment before wirebonding and solderability test.

Pre-treatment	Test
As-plated	For wirebonding and solderability test
2hrs, 175°C bake	For wirebonding
8hrs, 85°C/85%RH steam aging (SA)	For solderability test
2hrs 175°C bake + 90° bend (R=250µm) + 8hrs 85°C/85%RH SA	For solderability test

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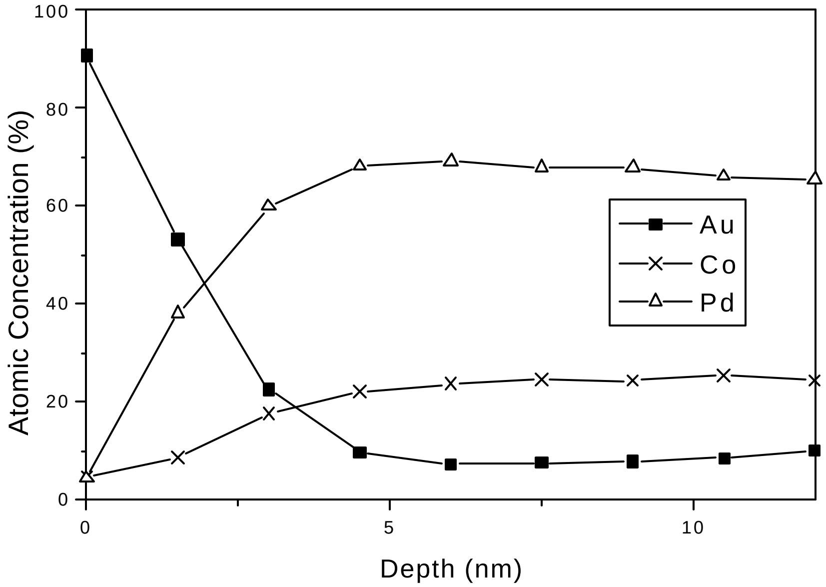

Figure 1. AES depth profile on a surface of PdCo/Au finish plated on leadframe.

Wirebonding

Gold wire bonding and destructive pull test were conducted on the Ni/PdCo/Au plated leadframes to determine the bondability and the strength of the bonds. The wirebonds including first ball bonds and then wedge bonds were made by using a manually controlled thermosonic bonder (Kulicke and Soffa, model 4124). An alumina capillary (Micro-Swiss, P/N 40472-0010-320) was set up on the bonder and the gold wire had a diameter of 25 µm (1.0 mil), an elongation of 3-6% and a breaking load of 8 - 10 grams. The bonding temperature set for the working stage was chosen as 150 or 180°C. Wirebondability was assessed based on the number of bonding failures resulting from non-adhesion of the wire on the leadframe surface. A computer-controlled pull tester (Dage, model BT22PC) was used for the pull test to evaluate the strength of the bonds. During the test, a force was applied to the wire by pulling it with a metallic hook in the center of the bonding loop. The force was increased until the wire broke or a bond lifted off from the leadframe surface. The force needed to break the bonding is defined as pull force. The pull force of ≥ 5 grams was required as the criterion for the test.

Solderability Test

The solderability dip-and-look test was carried out on the leadframes using Sn60Pb40 solder at 245°C and two fluxes: R-type non-activated (NA) and no-clean mildly activated (MA). The sample dipping time in the molten solder was 5 seconds. The solder coverage on the tested samples was checked using a microscope under 10X magnification. To pass the test, a smooth solder coverage of ≥ 95% was required.

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Results and Discussion

Wirebonding

Table 4 shows the wirebonding and pull test results on the Ni/PdCo/Au plated leadframes either as-plated or after the thermal aging. On these samples, all the attempted bondings were made (100% bondability was achieved.). On either the as-plated or the thermally treated leadframes, the ultra-thin surface finish provides required wirebonding performance.

Table 4. Pull force (gram) on the Ni/PdCo/Au plated leadframes, bonding temperature: 180°C.

Finish: 295Å (1.18µin) PdCo / 17.5Å (0.07µin) Au					
Test	**Mean**	**StdDev**	**Min**	**Max**	**Pass**
As-plated					
15	7.93	0.88	5.97	9.51	100%
After 2hrs, 175°C bake					
15	8.30	0.75	6.47	9.07	100%

The effect of the gold flash on the wirebonding performance was checked in this work. With the gold flash, the wirebondability was 100% and the required pull force was achieved. Without the gold flash, however, bonding failure appeared at the attempted wedge bonds and only one third of the pull force readings met the requirement (Table 5). The gold flash was such thin that it could hardly be visually observed on the leadframe surfaces. However, it dramatically improved the wirebonding performance.

Table 5. Pull force (gram) on the leadframes with or without gold flash bonding temperature: 180°C.

As-plated					
Test	Mean	StdDev	Min	Max	Pass
Finish: 325Å (1.3µin) PdCo / 25Å (0.1µin) Au					
15	7.59	0.91	6.51	9.55	100%
Finish: 325Å (1.3µin) PdCo					
9	4.11	1.45	2.18	6.34	*33%*

The effect of wirebonding temperature was also examined in this work using 150 and 180°C. In both cases, 100% wirebondability was obtained. However, some low readings in the pull force occurred when the setting temperature was lowered down to 150°C (Table 6). As reported in a previous literature,[5] an insufficient bonding temperature can reduce the bond strength between a gold wire and a surface due to an insufficient real sticking area between the wire and the surface.[5]

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Table 6. Pull force (gram) on the Ni/PdCo/Au plated leadframes with different bonding temperatures.

Finish: 375Å (1.5µin) PdCo / 37.5Å (0.15µin) Au after 2hrs, 175°C bake					
Test	Mean	StdDev	Min	Max	Pass
Bonding temp.: 180°C					
15	8.73	1.19	6.71	10.79	100%
Bonding temp.: 150°C					
15	7.31	1.78	3.54	9.66	*87%*

Solderability

The dip-and-look test results of the leadframes using different pre-treatments and different fluxes are provided in Table 7. As can be seen from the results, all the tests with the mildly activated flux showed good solderability under the test conditions either as-plated or undergoing a pre-treatment. Using the non-activated flux, however, failure occurred on most of the pre-treated leadframes and even on one of the as-plated leadframes. Therefore, it is necessary to use a mildly activated flux to ensure the required solderability on the leadframes plated with the ultra-thin palladium-cobalt deposit even with a gold flash on the top surface.

Table 7. Solderability test results.

Sample	**Pre-treat**	**Flux**	**Result**
250Å (1µin) PdCo	As-plated	NA	*Fail*
		MA	Pass
	8hrs SA	NA	*Fail*
		MA	Pass
250Å (1µin) PdCo / 25Å (0.1µin) Au	As-plated	NA	Pass
		MA	Pass
	8hrs SA	NA	*Fail*
		MA	Pass
325Å (1.3µin) PdCo	As-plated	NA	Pass
		MA	Pass
	8hrs SA	NA	*Fail*
		MA	Pass
325Å (1.3µin) PdCo / 25Å (0.1µin) Au	As-plated	NA	Pass
		MA	Pass
	8hrs SA	NA	Pass
		MA	Pass
295Å (1.18µin) PdCo / 17.5Å (0.07µin) Au	3 steps*	NA	*Fail*
		MA	Pass

*: 2hrs, 175°C bake + 90° bend + 8hrs 85°C/85% RH steam aging

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Summary

--- The ultra-thin PdCo/Au finish can provide leadframes the required wirebonding performance and solderability with a mildly activated flux.

--- A significant cost saving can be achieved using the ultra-thin palladium alloy surface finish compared with using pure palladium.

--- A United State patent has been granted covering the ultra-thin composite surface finish: a layer of palladium alloy and a layer of wirebondable and solderable material on top.[6]

Acknowledgement

The authors would like to thank Mr. Jimmy Kwok of Rambo Chemicals, Hong Kong, for providing the plated leadframes.

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