Ultra-thin PdCo/Au Surface Finishes For Electronic Packaging

by C. Fan,* C. Xu, E.J. Kudrak & J.A. Abys

Table 1
Specific Density of Palladium & its Alloy Electrodeposits

Deposit	Specific Density, g/cm^3 (lb/in^3)
Pd	11.7 (0.423)
PdNi (80/20 wt%)	10.7 (0.387)
PdCo (80/20 wt%)	10.8 (0.390)

Table 2
Thickness of Different Deposits

Deposit	Thickness
Nickel	0.5 – 1.0 μm (20 – 40 μ-in)
PdCo (80/20 wt%)	250 – 375 Å (1.0 – 1.5 μ-in)
Gold flash	15 – 50 Å (0.06 – 0.20 μ-in)

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

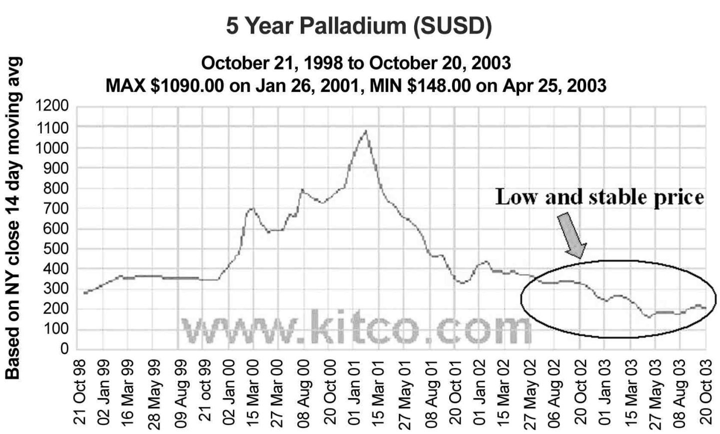

Fig. 1—Price of palladium (data from Kitco).

Nuts & Bolts: What This Paper Means to You

Because of the pressure to use lead-free materials, as well as cost considerations, there is renewed interest in nickel/palladium pre-plated frame (PPF) technology in the electronics industry. Further, thickness can be reduced without sacrificing performance. In this study, the wirebonding and solderability properties of these ultra-thin surface finishes (palladium-cobalt (80/20 wt%) alloy with a gold flash) on a nickel underlayer over leadframes are presented. The finishes meet requirements for packaging applications.

The electronics industry has recently renewed interest in nickel/palladium pre-plated frame (PPF) technology because of the tremendous pressure to use lead-free materials coupled with the lowered and relatively stable price of palladium metal over more than one year (Fig. 1). In addition, the improvement of the technology and the modification of the specifications allow industry to dramatically reduce the thickness of the precious metal deposits without sacrificing performance. Considerable cost saving can be achieved. In semiconductor leadframe packaging, the tin-lead post plating will soon be replaced by environment-friendly finishing processes. Pure tin and some lead-free tin alloy finishes could be substitutes for tin-lead. However, tin whisker growth and some compatibility issues remain concerns with using these finishes. Meanwhile, nickel/palladium PPF has been a well-established technology[1-3] and there is considerable cost reduction potential 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 savings can be further achieved by plating palladium alloys to replace pure palladium in the finishes.

Using a palladium alloy deposit can achieve cost savings not only from its composition but also because of its lower specific density compared with pure palladium (Table 1).

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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. From a previous study[4] comparing the material and functional properties of different precious metal finishes, palladium-cobalt showed significantly lower porosity, lower contact resistance and better wear behavior than did palladium-nickel. Low porosity is beneficial for increasing corrosion resistance, particularly for thin finishes. With plating palladium-cobalt, the quality control issue of measuring the composition and thickness of palladium-nickel over nickel by x-ray fluorescence (XRF) can be also resolved. Therefore, ultra-thin palladium-cobalt (80/20 wt%) alloy finishes were chosen in this study. They were plated on a conformable nickel underlayer over leadframes and studied for their gold wire bonding and solderability performance under as-plated condition or after different pre-treatments.

Table 3
Sample Treatment Before Wirebonding & Solderability Test

Pre-treatment	Test
As-plated	For wirebonding and solderability test
2 hr, 175°C (347°F) bake	For wirebonding
8 hr, 85°C (185°F)/ 85%RH steam aging (SA)	For solderability test
2 hr, 175°C (347°F) bake + 90° bend, R=250 μm (10 mils) + 8 hr, 85°C (185°F) / 85%RH SA	For solderability test

Table 4
Pull Force (in grams) on the Ni/PdCo/Au PlatedLeadframes,
Bonding Temperature: 180°C (356°F)
Finish: 295 Å (1.18 μ-in) PdCo / 17.5 Å (0.07 μ-in) Au

Test	Mean	Std Dev	Min	Max	Pass
As-plated					
15	7.93	0.88	5.97	9.51	100%
After 2 hr, 175°C (347°F) bake					
15	8.30	0.75	6.47	9.07	100%

Table 5
Pull Force (in grams) on the Leadframes with or without Gold Flash;
Bonding Temperature: 180°C (356°F)
As-plated

Test	Mean	Std Dev	Min	Max	Pass
Finish: 325 Å (1.3 μ-in) PdCo / 25 Å (0.1 μ-in) Au					
15	7.59	0.91	6.51	9.55	100%
Finish: 325 Å (1.3 μ-in) PdCo					
9	4.11	1.45	2.18	6.34	33%

Table 6
Pull Force (in grams) on the Ni/PdCo/Au Plated Leadframes
With Different Bonding Temperatures
Finish: 375 Å (1.5 μ-in) PdCo / 37.5 Å (0.15 μ-in) Au
After 2 hr, 175°C (347°F) bake

Test	Mean	Std Dev	Min	Max	Pass
Bonding temp.: 180°C (356°F)					
15	8.73	1.19	6.71	10.79	100%
Bonding temp.: 150°C (302°F)					
15	7.31	1.78	3.54	9.66	87%

Experimental

Surface Finish

Proprietary nickel, palladium-cobalt and gold plating chemistries were used for deposition of the surface finishes on 250 μm (10 mil) thick copper alloy leadframes. The thickness of the different deposits is shown in Table 2. The precious metal deposits were much thinner than conventional ones, *i.e.*, more than 750 Å (3 μ-in) palladium with a 250 to 500 Å (1 to 2 μ-in) gold flash. The patented nickel underlayer was specifically designed for leadframe packaging applications. It is highly ductile and conformable with the deformation of the substrate surface to minimize cracking during forming operations.[2,5]

In this study, the composition of the palladium-cobalt deposits was determined by atomic absorption (AA). The deposit thickness was measured by Rutherford backscattering spectrometry (RBS) and confirmed by Auger electron spectrometry (AES). A typical AES spectrum is shown in Fig. 2. In this finish, the gold layer was plated to around 20 Å (0.08 μ-in). Although AA and RBS were used in this study, a calibrated x-ray fluorescence (XRF) machine with a vacuum facility is believed to be capable of measuring the thickness and composition for these ultra-thin alloy finishes.

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).

Wire Bonding

Gold wire bonding and destructive pull tests were conducted on the Ni/PdCo/Au plated leadframes to determine bondability and strength of the bonds. The wirebonds, including first ball bonds and then wedge bonds, were made by using a manually controlled thermosonic bonder**. An alumina capillary*** was set up on the bonder. The gold wire had a diameter of 25 μm (1.0 mil), an elongation of 3 to 6% and a breaking load of 8 to 10 g. The bonding temperature set for the working stage was chosen as either 150 or 180°C (302 or 356°F). 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**** 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 the leadframe surface. The force needed to break the bonding was defined as the pull force. A pull force of ≥5 g was required as the criterion for the test.

** *Model 4124, Thermosonic Bonder, K& S, Willow Grove, PA.*
*** *Micro-Swiss, P/N 40472-0010-320, K&S Micro-Swiss, Willow Grove, PA.*
**** *Model BT22PC, Dage Precision Industries, Inc., Fremont, CA.*

Table 7
Solderability Test Results

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

**2 hr, 175°C (347°F) bake + 90° bend + 8 hr, 85°C (185°F) / 85% RH steam aging*

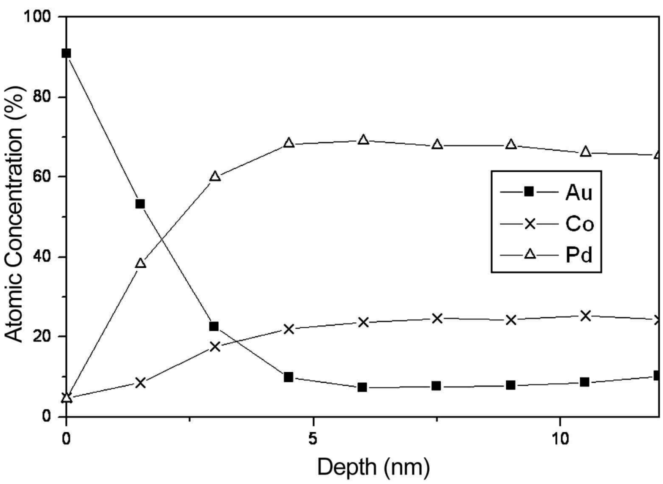

Fig. 2—AES depth profile on a surface of PdCo/Au finish plated on leadframe.

Solderability Test

The solderability dip-and-look test was carried out on the leadframes using Sn60/Pb40 solder at 245°C (473°F) and two fluxes: R-type non-activated (NA) and no-clean mildly activated (MA). The sample dipping time in the molten solder was 5 sec. The solder coverage on the tested samples was checked using a microscope at 10X magnification. To pass the test, a smooth solder coverage of ≥95% was required.

Results & Discussion

Wire Bonding

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 attempted bondings were made (100% bondability was achieved.). On either the as-plated or the thermally treated leadframes, the ultra-thin surface finish provided the required wirebonding performance. The results are considered as comparable between the as-plated and thermally treated leadframes.

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 so thin that it could barely be visually observed on the leadframe surfaces. However, it dramatically improved the wirebonding performance.

The effect of wirebonding temperature was also examined in this work at 150 and 180°C (302 and 356°F). In both cases, 100% wirebondability was obtained. However, some low pull force readings were obtained when the setting temperature was lowered to 150°C (302°F) (Table 6). As reported in the literature, an insufficient bonding temperature can reduce the bond strength between a gold wire and a surface due to insufficient effective bonding area between the wire and the surface.[3]

Solderability

The dip-and-look test results of the leadframes using different thermal 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 after undergoing a thermal treatment. Using the non-activated flux, however, failure occurred on most of the thermally 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.

Nickel/palladium plated leadframes can provide required solderability with both eutectic tin-lead (Sn63/Pb37 or Sn60/Pb40) and lead-free solders (such as Sn/Cu0.7 or Sn/Ag3.8/Cu0.7 alloys).[6] The solderability of the ultra-thin palladium-cobalt/gold finishes will be checked with lead-free solders in the future work.

Summary

- The ultra-thin PdCo/Au finish can provide leadframes with the required wirebonding performance and solderability with a mildly activated flux.
- A significant cost saving can be achieved using an ultra-thin palladium alloy surface finish compared with 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.[7]

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About the Authors

Chonglun Fan is a senior scientist with Enthone, Inc. of Cookson Electronics, Jersey City, NJ. His primary responsibilities are to characterize the material properties and functionality of different surface finishes and to develop new surface finishes. Before joined Enthone, he worked with Electroplating Chemical & Services at Lucent Technologies/ Bell Labs as a Member of Technical Stuff. He holds a B. Eng. from Beijing University of Science and Technology (China) and a PhD in Electrochemical Engineering from Katholieke Universiteit Leuven (Belgium). He worked on electrocatalysis and electroplating as a post-doctoral fellow at Ecole Polytechnique de Montréal (Canada). He has over 50 scientific and technical publications and holds 9 US patents.

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