

Palladium-Nickel as a Gold Substitute

AN EVALUATION FOR ELECTRONIC CONNECTORS

Probably the first use of palladium plating as a substitute for gold dates back to the 1960s, when it was successfully adopted for the plating of printed circuit connectors and allied contacts by the Automatic Telephone & Electric Company of Liverpool. Although, even with a gold price then of \$35 per ounce, palladium still showed a substantial advantage in terms of metal cost, the reasons for its use in this case were technical in that it was used to eliminate cold welding problems occurring in the mating of connectors plated with a conventional cyanide gold deposit. At this time a further problem with cyanide gold plating was associated with attack by the plating solution on the adhesive system used in bonding copper foil to the supporting laminate, which led to weakening of the bond and often to exfoliation of the foil. Here again, palladium offered a solution since the ammoniacal electrolytes then mainly available were only mildly aggressive. For these reasons palladium found significant, if not extensive, use during this period by a number of major companies, with satisfactory performance reported in respect of protective value, contact resistance and wear properties. Further development at this time was effectively halted with the development of the acid gold systems, which largely eliminated the problems of cyanide baths and offered a new spectrum of applicational properties combined with the cachet of high reliability conventionally associated with this noble metal. It is only with the escalation in the gold price of recent years, leading to a very active search for economic alternatives, that palladium plating has re-emerged as a leading challenger, as evidenced by the increasing number of literature references relating to process development, and deposit properties and performance.

The level of activity in this context at the present time is well illustrated by a recent paper from the Berg Electronics Division of Du Pont,

reporting an extensive evaluation of coatings from eight proprietary electrolytes, five for pure palladium and three for palladium-nickel alloy plating, as possible substitutes for cobalt-hardened gold deposits on pin and female electronic connectors (A. H. Graham, M. J. Pike-Bieganski and S. W. Updegraff, *Plating Surf. Finish.*, 1983, 70, (11), 52-57).

Comparative assessment against the reference hard gold deposit was based on solution stability and on the properties of coatings produced under simulated high-speed conditions (rotating disc), in terms of contact resistance; electrographic porosity; solderability by dip test (Military Standard 202) with prior steam exposure to simulate long-term storage; ductility, by a bend test; and internal stress, by distortion of plated discs.

All coatings studied showed satisfactory contact resistance and solderability, with the exception, in the latter case, of one pure palladium deposit which required a mildly activated flux to achieve the requisite 95 per cent coverage. The others gave satisfactory performance either with a non-activated or a mildly activated flux. Outstanding solderability is reported for the palladium-nickel coatings with a top coat of 0.125 μm of soft gold, giving 100 per cent coverage. Palladium-nickel also scored strongly in porosity tests, on nickel. While coatings from some of the more recently developed pure palladium electrolytes showed lower porosity levels than hard gold at all thicknesses investigated, there was a high standard deviation in lengthy laboratory runs, indicating sensitivity of the deposits to normal process variations. Palladium-nickel coatings showed a porosity level more than an order of magnitude below that for hard gold, and in addition the standard deviation of results for palladium-nickel was much less than for pure palladium. In ductility tests based on scanning electron microscope observation of surface

cracking produced by a 180° bend of coatings on 0.64 mm square wires around pins of varying radius, palladium-nickel also outperformed all others, initial cracking occurring at a bend radius of less than 1.27 mm, compared with 6.4 mm for hard gold. In internal stress observations on thick deposits on disc specimens, discs carrying palladium-nickel coatings were flat as plated and remained so after prolonged storage, while similar samples plated with the "best" pure palladium coating, although flat as plated, with little porosity and good ductility, curled into a U-shaped bend after only one day, with severe microcracking at the bend, caused by out-gassing of hydrogen.

Product Evaluation

On the basis of the above results, three systems were selected for product evaluation on fabricated connectors, namely: [i] 0.75 μm palladium-nickel, [ii] 0.75 μm palladium-nickel + 0.125 μm soft sold and [iii] 0.75 μm hard gold.

Tests included on-going exposure in a variety of industrial atmospheres; accelerated laboratory environmental tests in mixed water vapour, chlorine, hydrogen sulphide and nitrogen dioxide atmospheres; and exposure to high hydrogen sulphide environments in a study of creep corrosion, that is the creep of corrosion products from exposed substrate across the plated surface. Cyclic wear tests were also carried out in which plated pins were mated with hard gold plated female connectors.

In atmospheres with high chlorine content contact resistance of hard gold was unchanged during a test period simulating ten years' exposure, while bare palladium-nickel showed a small increase of about 1 mohm, well within the acceptable specified maximum. Palladium-nickel with a soft gold top coat performed as well as hard gold. In a high hydrogen sulphide environment all coatings showed constant contact resistance after a similar exposure period. In galvanic compatibility tests, performance of a palladium-nickel hard gold couple was reported as excellent, with no change in contact resistance during a simulated ten year period, and a low standard deviation (only

0.3 mohm) of data points. Similar tests on tin-lead/palladium-nickel and tin-lead/hard gold couples gave erratic results with high deviation, indicating the inadvisability of these combinations in practice. In creep corrosion studies sulphide creep across hard gold was 5 mm in a five year simulation, compared with only 0.90 mm for palladium-nickel. Interestingly, similar good results were reported with a soft gold top coat, which is apparently without effect on the creep resistance of the underlying alloy coating.

No difference was found between palladium-nickel and hard gold coatings in the first 100 to 200 wear test cycles, a typical purchaser requirement. After 500 cycles the contact resistance of bare palladium-nickel increased by 1 mohm, which is still below the maximum specified in Military Standards. However, for critical applications the authors suggest the use of palladium-nickel with the soft gold top coat, which shows equivalent performance to that of hard gold. In the light of the results reported, the conclusion that the preferred palladium-nickel alloy is a viable alternative to gold on electronic connectors is not surprising.

Conclusion

While this paper represents a valuable contribution to the literature on palladium plating, particularly in furnishing much-needed quantitative information on service performance of deposits, it might have been of considerably more general interest had the authors specified, if only by general type, the palladium plating baths investigated. For example, in the case of pure palladium solutions, reference to solutions developed prior to and since 1980 is not too informative, particularly in view of the level of activity in process development of recent years. Naturally enough, emphasis is to be expected on successes rather than failures in an evaluation of this kind, aimed at a specific application, but some comparative results on the pure palladium baths could have been of possible interest to workers pursuing this line, notwithstanding that palladium-nickel alloy appears to come out as the clear leader at the present time.

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