# Selection & Application of Inorganic Finishes: Metal Deposits for Specialized Characteristics—Part II*

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## Electroforming

"The formation of articles by electrodeposition is called electroforming. Nickel and copper are most often used for this purpose and are usually deposited from acid baths to provide low-stress deposits. Some exceedingly intricately shaped items have been readily formed by electrodeposition and extremely fine detail has been reproduced. Typical applications are phonograph-record stampers [and the compact disc equivalent], pens, parabolic reflectors, radar wave guides, objects of art, whisker guides for electric razors, precision screens and filters, miniature bellows, electrotype printing plates and hypodermic needles.

*"The metal deposits discussed previously in this series are applied primarily for protection of a corrodible substrate, though they may provide other useful properties, some of which have already been alluded to. Many metal deposits are applied by the plating industry primarily for specialized characteristics other than, or in addition to, their ability to prevent substrate corrosion.*

*Based on an original article from the "AES Update" series [*Plating*, **66**, 42 (June 1979)]

"Deposits may be applied to reusable, permanent mandrels or to mandrels that are dissolved or melted out after the electroform has been completed. Electroforms can be made from any electrodeposited metal that can be produced smoothly or densely at the desired thickness that is sufficiently free of internal stress to resist deformation or cracking when separated from the mandrel. Successful electroforms have been produced from gold, cobalt-tungsten and aluminum [from non-aqueous solution].

## Salvage of Worn Parts

"Worn, corroded or overmachined parts are often salvaged by metal deposition. Electrodeposits of nickel, chromium or iron are most commonly used for this purpose. Hard deposits of iron[1] are applied primarily because of the low cost of the metal. Diesel crankshafts[2] and engine cylinders are examples of items salvaged in this way. Selective (brush) plating has been advantageously used for rapid buildup of localized areas of a large shaft, for example, without necessitating involved masking and complete submersion. Flame/plasma-sprayed metal coatings have also been applied for buildup of undersized parts.

## Lubricity/Bearings

"Metal deposits are applied to provide a soft bearing surface during motion of a mating surface. The soft metal provides lubricity without galling or seizing, may allow embedding of abrasive particles and permits sufficient deformation to correct minor defects of the bearing surfaces. Silver is effectively used for low-load sleeve bearings. For high-load, high-speed bearings such as for aircraft applications, an overcoating of lead-tin or lead-indium should be applied. A lead/7 percent tin (MIL-L-46064) electrodeposited alloy has found widespread use for bearing surfaces. The retainers of some ball and roller bearings used on naval aircraft are silver plated to reduce friction of the rolling element.

"It has been found that hard metal deposits such as chromium or electroless nickel are greatly improved in high-pressure wear resistance by application of a very thin silver deposit;3 the silver apparently ensures breaking-in of the sliding surfaces without scoring or galling. Incorporation of soft particles such as graphite, molybdenum sulfide or polytetrafluoroethylene in electrolytic/electroless nickel deposits provides in-depth solid-film lubrication.

"Thin metal deposits have been used as a lubricant for such operations as cold drawing, stamping, bending and wire reduction. Tin, tin-copper or copper, applied by immersion (displacement) or by electrodeposition has been very useful in this regard and also serves as a low-cost decorative finish.

## Electronics

"[*The reader should be mindful of the time that the material in this particular section was written: 1979, before the significant emergence of personal computers. Much has changed ... and much has not.—Ed.*] Reliable electrical contacts are usually obtained by use of noble/precious metals because of their resistance to surface oxidation that could otherwise produce voltage (IR) drops, localized heating and ultimate failure of the device. Gold electrodeposits have low contact resistance and are widely used for low-voltage contacts and a variety of connectors. It is desirable to harden the gold deposit for this application by alloying with as little as 0.1 percent cobalt or nickel for improved wear resistance and reduced galling tendency, but at the expense of somewhat increased contact resistance.

"The high cost of gold has promoted development of selective-coating techniques to limit deposition to the desired sites.[4,5] Palladium is also a metal of reasonably low contact resistance and deposits have been used as a lower-cost alternative for gold; palladium is particularly useful for "noise-free" contacts used in the communications industry. Rhodium is quite hard as plated, has a high melting point and low contact resistance that makes it ideal where a high degree of wear resistance is needed and where arcing can occur from make-and-break contacts.

"Nickel deposits are widely used as an underplate for the precious metals and act as a barrier to diffusion between copper and gold. Tin-nickel underplates are said to permit thinner gold deposits than normal for application to contacts where aggressive environments are involved.[6] Silver is the most highly conductive metal and deposits are used for electrical contacts on household appliances, for example, but heavy tarnish can seriously increase contact resistance. Silver deposits are not used on printed circuit boards because the phenomenon of "silver ion migration" in the board can lead to current leakage paths.

"Very pure, soft gold deposits are required for applications involving bonding of such devices as diodes and transistors to lead frames and beam leads for both hybrid and integrated circuits. Pure gold is necessary to achieve a suitable eutectic with the silicon semiconductor for effective ultrasonic, die or thermal compression bonding to be obtained. An alternative to the use of gold for this application is vacuum-evaporated aluminum on the silicon wafer and attachment of fine aluminum lead wires.

## Solderability

"Tin-lead (solder) electrodeposits are used on printed circuit boards to delineate the circuit and act as a resist while stripping away surrounding, unwanted copper. The tin-lead deposit provides solderability (even after long storage periods) when the various components are attached to form the finished board. A high-throwing-power bath is used to ensure adequate deposition in the holes of the board. Tin-lead has largely replaced gold deposits, which previously had been widely used for these same purposes. Tin deposits are useful for imparting solderability to electronic components, terminals and wires, though the possibility of spontaneous growth of tin whiskers must be considered. Cadmium [at the time of this writing] is also a readily solderable metal and has been applied to electronic chassis for this property as well as for the protection it provides against substrate corrosion. Thin electroless nickel deposits have been applied to aluminum to facilitate soldering. A ternary alloy, copper-tin-zinc, may be used to provide corrosion resistance and solderability to complex-shaped parts (MIL-P-47141).

## Plating on Nonconductors

"Modern production plating of plastics to provide an attractive and durable finish was made possible by the following developments: (1) effective etching of plastics; (2) room-temperature electroless plating baths; and (3) bright, leveling electrodeposits.

"A grade of acrylonitrile-butadiene-styrene (ABS) was first used commercially because it could be chemically-etched in a chromic-sulfuric acid solution to enable mechanical bonding of an electroless nickel or copper deposit after suitable catalytic activation of the surface. The thin electroless deposit supplies the conductivity necessary for conventional electrodeposition that follows. Polypropylene and polysulfone plastic has also found use as a base for plating and, recently, a conductive polypropylene material has been developed for direct electrodeposition.[7]

"A bright acid-sulfate copper deposit of about 13 µm (0.5 mil) is applied for its leveling and brightening effect and resistance to loss of adhesion during changes in temperature to which the plated part may be subjected. A 7 to 15 µm (0.3 to 0.6 mil) bright nickel deposit usually follows to develop additional luster and serve as a suitable base for the final decorative deposit which is normally, though not always, chromium. If severe service conditions are expected (such as exposure to corrosive environments and physical impact), a double-layer nickel deposit and microdiscontinuous chromium is recommended atop the initial copper deposit.

"A large number of products have been produced from plated plastic which, except for the weight, is indistinguishable from nickel and chromium-plated metal. A variety of knobs, handles, auto grilles and headlamp bezels, interior automotive parts, plumbing fixtures, cosmetics containers, jewelry, camera equipment, marine hardware, household appliance components and office furniture represent some of the major applications of plated plastics.[8]

"The preparation of printed circuit boards required that the drilled holes between the circuits on the top and bottom layers (including intermediate layers of multilayer boards) be plated to provide electrical connection. This is accomplished by catalytic activation of the nonconductive board, application of a conductive electroless copper film and buildup with copper from a pyrophosphate or high-throw acid copper bath.

"Conductive layers on non-conductors can be applied by a variety of conductive inks available commercially and used for specialized purposes. The silvering process (simultaneous spray of silver solution and reducing agent), long used for mirror-making, is used to some extent for imparting conductivity. For example, a thin silver film is applied to the original sound recording on a plastic disc upon which nickel is plated to produce a faithful reproduction of the grooves. [Of course, drastic improvements in technology in the intervening decades have brought analogous processes for CD and DVD discs.]

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## References

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The preceding article is based on the original piece written by Fred Pearlstein for the AES Update series that ran in this journal in the late 1970s and early 1980s. The series, begun and coordinated by the late Dr. Donald Swalheim, and carried on by many others brought practical information to the metal finisher. Much of the material remains relevant today and is presented here in the hope that those in today's industry might learn from past pioneers and practitioners. In some cases, words were altered [in brackets] for context. Certain sections were omitted which dealt with processes, such as cadmium and lead, which, for environmental and workplace safety reasons, are less prevalent today. Still, some material is left in for historical perspective.

Last month, the first half of this article dealt with the specialized deposit characteristics for decorative properties and hardness. This month, the remainder of the article discussed other specialized deposit characteristics, including those for electroforming, salvage, lubricity, electronics, solderability and plating on non-conductors.

The valuable articles contributed by Mr. Pearlstein actually consisted of a seven-part series on the selection of inorganic coatings/finishes, and only a portion of them have been presented here. At the end of his last article in the series, he summarized, by listing several important factors that should be considered in selecting inorganic coatings/finishes. The last, concerning energy, was written during another era of energy tumult. It is very worthwhile to add them to this particular article:

1. "The intended purpose of the finish is of paramount importance in the selection of a finishing system with due regard to corrosion prevention of substrate and durability of finish under the expected service conditions and environmental exposures. Past experience is of invaluable aid when it is available.
2. "Cost of application will usually be a determining factor in finish selection and may be dependent upon the available facilities. Increasing the deposit thickness usually adds little to costs when considerable hand labor is involved in the finishing operations.
3. "The size, shape and surface condition of the item may be a major factor in selection of a finish. A plating process may be selected on the basis of its ability to adequately cover a complex-shaped part without need of auxiliary anodes or to level and brighten without mechanical polishing.
4. "Any adverse effects the deposit may have on the substrate or product should be considered: (a) hydrogen embrittlement of high-strength steels, (b) reduced fatigue life of structural metals, (c) intergranular embrittlement (primarily zinc, cadmium, tin or lead deposits on steel at elevated temperatures; cadmium or silver on titanium), (d) diffusion of substrate and coating to form brittle intermetallic coating interface, or (e) filamentary "whisker" formation (primarily with tin, cadmium or zinc deposits).
5. "In-house capabilities may favor selection of one finishing process over another that would otherwise be preferable.
6. "Waste-treatment facilities, requirements and local effluent regulations may be a deciding factor in selection of one of several candidates.
7. "In these days of energy expense and shortages, energy considerations may well be a factor in the selection of a finishing process."

## Specifications

Specifications for coating processes discussed in this article include:

- Decorative nickel and chromium deposits: ASTM B-456, "Electrodeposited Coatings on Nickel plus Chromium."
- Silver deposition for decorative and functional applications: QQ-S-365 B, "Silver Plating, Electrodeposited; General Requirements for."
- Rhodium deposition for decorative finish or sliding electrical contacts: MIL-R-46085A, "Rhodium Plating, Electrodeposited."
- Gold plating for decorative or electronic applications: MIL-G-45204B, "Gold Plating, Electrodeposited," ASTM B-488, Electrodeposited Coatings of Gold for Engineering Uses."
- Decorative and engineering chromium deposits: QQ-C-320 B, "Chromium Plating (Electrodeposited);" ASTM B-177, "Chromium Plating on Steel for Engineering Use."
- Porous chromium deposits: MIL-C-20218E, "Chromium Plating, Electrodeposited, Porous."
- Shot peening to increase fatigue life: MIL-S-13165B, "Shot Peening of Metal Parts."
- Electroless nickel deposits: MIL-C-26074B, "Coatings, Electroless Nickel, Requirements for."
- Carbon particles dispersed in nickel matrix: MIL-N-55392 (EL), Nickel-Carbon, Porous, Electrodeposited, for Camouflage."
- Nickel-tungsten alloy deposit for wear resistance: MIL-P-47184 (MI), "Plating, Nickel-Tungsten, Electrodeposit on Aluminum Alloys, By Selective (Brush) Method."
- Solutions suitable for electroforming: ASTM B-503, "Use of Copper and Nickel Electroplating Solutions for Electroforming."
- Preparation of metal and non-conducting mandrels for electroforming: ASTM B-431, "Processing of Mandrels for Electroforming."
- Tin deposits for solderability, anti-galling, nitriding stop-off: ASTM B-545, "Electrodeposited Coatings of Tin."
- Tin-lead deposits for solderability and printed circuit board applications: ASTM B-579, "Electrodeposited Coatings of Tin-Lead Alloy (Solder Plate);" MIL-P-81728A, "Plating, Tin-Lead (Electrodeposited)."
- Displacement tin deposits on copper for solderability: MIL-T-81955, "Tin Plating: Immersion for Copper and Copper Alloys."
- Copper-tin-zinc alloy for solderability: MIL-P-47141 (MI), "Plating, Ternary Alloy (Electrodeposited)."
- Tin-nickel deposits for decorative or protective properties: ASTM B-605, "Electrodeposited Coatings of Tin-Nickel Alloy."
- Bath composition and operating conditions to deposit lead/7 per cent tin bearing alloy: MIL-L-46064 (MR), "Lead-Tin Alloy Coating (Electrodeposited)."
- Plating on plastics: ASTM B-604, "Decorative Electroplated Coatings of Copper/Nickel/Chromium on Plastic."
- Solar absorbing coating: MIL-C-14538B (MR), "Chromium Plating, Black (Electrodeposited);" MIL-P-18317, "Plating, Black Nickel (Electrodeposited) on Brass, Bronze or Steel." *P&SF*

## Correction

The "Shop Talk" series that appeared in the May issue of *P&SF* (p. 8) contained some errors. The most serious was the presentation of thickness data throughout the feature in "mm." The data should have been presented in "mils."

Also, in the third paragraph of the article, a comma was inadvertently inserted between "contrast" and "with," drastically changing the meaning of the sentence on sacrificially protective coating. Our apologies for the errors.—Editor