Selection & Application of Inorganic Finishes: Metal Deposits for Specialized Characteristics—Part I

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

"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[6] to prevent substrate corrosion.

Decorative Deposits

"Deposits of zinc (with clear-bright or dyed chromate), bright tin or bright nickel have important decorative applications for indoor or mild environments, but suffer degradation of appearance during severe outdoor exposure.

"Nickel deposits sufficiently thick to protect a corrodible substrate, simply require a very thin (0.3 to 0.8 µm; 0.01 to 0.03 mil) chromium deposit to enable retention of a bright, reflective tarnish-free surface under a variety of exposure conditions. Decorative chromium deposits are often described [under the subject heading "double-layer nickel"] because of the common use of the nickel-plus-chromium combination. This deposit system is extensively used for auto trim and bumpers, household appliances, plum-bing fixtures, tubular furniture, spotlights/flashlights, hardware items, etc.

"A ternary alloy (tin-cobalt-zinc) deposit has been suggested[1] as an alternative to decorative chromium for mild exposures, with the advantages of superior throwing power and deposition at lower cathode current density.

Silver

"Silver deposits have been used for many decades for ornamental purposes because of the pleasing white color of the polished metal on flatware, holloware, jewelry and art objects. A disadvantage to the use of silver is the rapid tarnishing of the surface when exposed to household environments, and, in recent years, electropolished stainless steel flatware has made significant inroads in what had been almost exclusively an application of electrodeposited silver.

"However, silver is still widely used and clear organic coatings are applied to purely decorative objects to effectively prevent tarnishing with little loss of visual appeal. Chemical and electrochemical treatments are also available to apply a tarnish-retarding invisible film.[2] A very thin rhodium deposit on silver effectively suppresses tarnishing. Rhodium is itself an attractive, non-tarnishing, wear-resisting (though very expensive) metal that is used on jewelry, usually on sterling silver or bright nickel-plated surfaces.

Gold

"Gold, in spite of its current high cost, finds numerous decorative applications, particularly for jewelry, because of its beautiful distinctive color. Bright gold is often applied upon a bright nickel deposit; 0.18 µm (0.007 mil) gold, the legal minimum for 'gold plate,' is often used for decorative applications though considerably thinner deposits are also employed. Heavier deposits are required for such applications as watch cases, bracelets, pens and rings, for which abrasive wear is expected and use of hard, wear-resistant, gold-alloy deposit is advisable. In addition to the characteristic yellow color of pure gold, a variety of attractive color modifications (*e.g.*, green, pink, rose, red, antique) can be obtained by codeposition of other metals with gold.

Brass

"Yellow brass is commonly plated from cyanide-based baths for its attractive color and to simulate solid brass objects. Many ornamental objects such as handles, knobs and lamp parts are brass plated over bright nickel and may be antiqued (darkened at recesses) for decorative effects. Bright brass deposits are used on such items as furniture components and handbag trim and then clear lacquered (sometimes with incorporated inhibitors) to prevent tarnishing.

"A unique characteristic of yellow brass is its ability to bond adherently to vulcanized rubber; brass deposits on steel have been used for this purpose by the auto tire industry. Copper and 'bronze' deposits (copper/12 percent tin or copper/8 percent zinc) also find decorative applications by virtue of their color and are normally lacquered, after desired decorative effects have been produced, to preserve the finish.

Tin-Nickel

"The intermetallic compound SnNi can be plated to produce a bright, highly attractive deposit with a slight pink cast. It is inherently tarnish resistant and thus need not be chromium plated for decorative applications. The deposit is also wear-resistant and easily solderable.

Hard Deposits

"High deposit hardness is often indicative of a high degree of wear resistance, though the interaction of such properties as ductility, adhesion and coefficient of friction can also contribute to performance or lack thereof.

Chromium

"Chromium is the hardest of the commonly electrodeposited metals and is widely used on steel where wear/abrasion resistance is required under demanding service conditions. Conventional sulfate-catalyzed baths (250 g/L CrO_3) are usually used at 54°C (130°F) and at 32 A/dm^2 (300 A/ft^2) for this purpose. Mixed-catalyst (sulfate plus fluosilicate) baths tend to produce somewhat harder and more wear-resistant deposits. For applications requiring wear resistance, chromium deposits of 25 µm (1 mil) or more are normally applied; Federal Specification Q-C-320B calls for a minimum of 51-µm thickness unless otherwise specified.

"Some of the almost endless applications include chromium plating of drawing dies, molds for plastics, mixing equipment, gun-barrel interiors, thread guides, hydraulic shafts, piston rings, gears, rolls of various types, punch and die sets, gages and diesel-engine cylinder liners.[3] Such chromium deposits are referred to as 'hard,' 'engineering' or 'industrial' chromium, and usually have a hardness in excess of 850 kg/mm^2 (Vickers). Chromium also has a high melting point (about 1900°C; 3450°F) and deposits may be useful where exposure to high temperature is involved. Chromium deposits can reduce fatigue life of high-strength steels; thus shot peening of steels, Rockwell C40 or harder, is advisable before plating to prevent reduced fatigue life.

"The low coefficient of friction of chromium with other metals is a contributing factor in its effective use on reciprocating surfaces. Thin (1.2 to 2.5 µm; 0.05 to 0.1 mil) chromium deposits on cutting tools increase tool life and cutting effectiveness; one gram of chromium coated 100,000 razor blades.[4] Chromium deposits may be made 'porous' (MIL-C-20218) with suitable etchants to provide lubricant-retaining properties for parts such as piston rings and cylinder bores (liners) of internal combustion engines.

Electroless Deposits

"Nickel deposits produced by the electroless (autocatalytic chemical reduction) process are characterized by high hardness and have found significant commercial applications for providing resistance to wear and abrasion. Deposits are most commonly applied from hypophosphite-based baths at pH 4 to 5.5 and contain about 7 to 11 percent phosphorus. These deposits, as plated, have a hardness of about 550 kg/mm^2 (Vickers) and can be brought to optimum hardness (~1000 kg/mm^2, Vickers) by heating plated parts for 1 hr at 400°C (750°F). At optimum hardness, the deposits approach or may even exceed the hardness of 'hard' chromium and excellent wear resistance is obtained. Heat treatment also tends to improve deposit adhesion. It is sometimes more convenient to heat-treat at a lower temperature, *e.g.*, 16 hr at 280°C (535°F) with a minor sacrifice in hardness.

"Electroless nickel deposits have been applied to air compressors, pumps, missile fuel-injection plates, and dies for molding or extruding plastics for wear resistance. It can be anticipated that heat-treated electroless nickel deposits will find increased application as a substitute for 'hard' chromium, particularly when the excellent uniformity of electroless deposit thickness is advantageous.

"Electroless nickel-boron deposits (from amine borane- or borohydride-based baths) are often even harder, both as-plated and heat-treated, than the nickel-phosphorus deposits and have found some application to knife blades, end mills and drills and are being considered for use on thread guides, glass molds and polymer embossing tools. Electroless-plated ternary alloys,[5] (*e.g.*, nickel-tungsten-phosphorus), may be particularly useful when elevated temperatures are encountered.

"Aluminum, usually zincated, is readily electroless nickel-plated to combine the light weight with a hard, wear-resistant surface. The plated aluminum should be heated 1 hr at 190°C (375°F) to obtain optimum deposit adhesion.

Refractory Coatings

"Tungsten is a high-melting-point, wear-resistant metal that can be deposited from a fused-salt bath, by thermal decomposition of vapors, plasma spraying or sputtering. Tungsten alloys can be electrodeposited from aqueous solution and some of these (*e.g.*, cobalt-tungsten, nickel-tungsten) have found wear-resistance applications. A number of refractory metals and compounds (*e.g.*, aluminum oxide, silicon nitride, tungsten carbide, tantalum) can be deposited as a wear-resistant finish by the processes of sputtering, ion vapor deposition[6] or plasma spraying.[7] Boriding of steel (formation of an iron-boride diffusion layer) provides a hard, abrasion-resistant surface at up to 850°C (1560°F). Boriding can be accomplished by metalliding[8] (cathodic treatment in a fused salt bath) or by other means of high-temperature diffusion of boron into a substrate. Some commercial applications of proprietary boride coating are aircraft fuel-pump components, dies for powder-metallurgy fabrication, extrusion dies and loom carrier needles.

Metals with Dispersed Particles

"A variety of finely divided insoluble particles may be suspended in a plating bath such that the particles are codeposited with the metal. Nickel is the most commonly used deposit as a matrix for dispersed particles. A metal, in which finely divided, nonmetallic particles are incorporated, is 'dispersion strengthened,' *i.e.*, increased in high temperature strength.[9] When the dispersed particles are of extremely hard materials, a high degree of wear resistance may be obtained from the composite coating. Particles of aluminum oxide, titanium oxide, silicon carbide, boron carbide or tungsten carbide considerably improve the wear resistance of electrolytic or electroless nickel deposit matrix.[10,11] Nickel deposits in which diamond particles are incorporated are used commercially for preparing dental drills or other abrasive instruments. A cobalt-chromium carbide composite deposit has found important applications in aircraft equipment, diesel-engine piston rings and helicopter motor shafts.[12,13] *P&SF*

Acknowledgment

"The author wishes to thank Leon W. Bell, Head of Preservation and Packaging Branch, ASO, for his cooperation in this effort and for providing secretarial assistance in preparation of this paper."

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Editor's Note: 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 that 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.

This first half of the article dealt with the specialized deposit characteristics for decorative properties and hardness. The remainder of the article will continue next month, with deposit characteristics for electroforming, salvage, lubricity, electronics, solderability, and plating on non-conductors.