Composites and Polyalloys:

The uniform dispersion of micron (<10 μm or <0.4 mil) or sub-micron particles in an electroless metal deposit will enhance the wear, abrasion resistance and/or lubricity over base substrates and conventional electroless deposits. Composites containing fluoropolymers (PTFE), natural and synthetic (polycrystalline) diamonds, ceramics, chromium carbide, silicon carbide and aluminum oxide have been co-deposited. Most commercial deposition occurs with an acid electroless nickel bath due to its unique physical characteristics available to the final co-deposit. The reducing agent used may be either a hypophosphite or boron complex.

The inclusion of these finely divided particles within an electroless matrix (25 to 30% by vol.) involves the need to maintain uniform dispersion of the foreign material during metal deposition. Specialized equipment is required and part size, configuration and deposit thickness are limited. Deposition rates will vary, depending upon the type of electroless bath utilized. The surface morphology of the inclusion (i.e., type, size, distribution in the matrix) will greatly influence the final co-deposit properties and composition. Wear resistance is related to particle size and concentration in the electroless bath.

Applications include molds for rubber and plastic components, fasteners, precision instrument parts, mating components, drills, gauge blocks, tape recording heads and guides for computers.

Due to the resultant matrix surface topography (when using diamonds or silicon carbide, for example), the final surface roughness must be considered. Special post-plate surface finish operations must be employed to regain the required RMS (micro-inch) finish. In severe abrasion applications involving high pressure foundry molding, it has been noted that the softer electroless nickel matrix wears first, exposing harder composite particles which create poor drawability of the resin/binder from the mold.

Polyalloys have been developed to produce deposits having three or four elements with specific coating properties. These include applications where unique chemical and high temperature resistance or electrical, magnetic or non-magnetic properties are requirements. The use of nickel-cobalt-iron-phosphorus polyalloys produce magnetic (for memory) properties. Other polyalloys include nickel-iron-phosphorus, nickel-cobalt-phosphorus, nickel-iron-boron, nickel-tungsten-phosphorus, nickel-molybdenum-boron, nickel-tungsten-tin-phosphorus, and nickel-copper-phosphorus. The final selection is dependent upon the final application and the economics of achieving the results required.

Electroless metal composites and polyalloys have made unique contributions to various engineering applications. Extensive field testing is ongoing to gain experience for proper applications, inclusions and sizes, plus proper electroless bath operating parameters for this new form of electroless plating.

IMMERSION PLATING

by Stanley Hirsch

Leeam Consultants Ltd., New Rochelle, NY

and

Charles Rosenstein

CP Chemicals, Inc., Sewaren, NJ

Immersion (displacement) plating is the deposition of a metallic coating on a base metal from a solution which contains the coating metal. One metal is displaced by a metal ion with a lower oxidation potential than the displaced metal ion. This differs from electroless plating because in immersion plating reducing agents are not required to reduce the metal ions to metal, as the base metal acts as a reducing agent. When a steel part is immersed in a copper sulfate solution, the following reaction occurs:

$$Fe + Cu^{+2} \rightarrow Cu + Fe^{+2}$$

The iron displaces the copper from its solution and the copper coats the steel part.

The thickness of deposits obtained by immersion plating is limited, because deposition stops when the entire surface of the base metal is coated. Higher temperatures increase reaction rates of immersion baths and stirring is sometimes beneficial. Parts must be properly cleaned prior to immersion.

Immersion baths are usually inexpensive and have excellent coverage. They permit plating on difficult surfaces, such as insides of tubing or in cases where there is difficulty in making electrical connections to isolated areas of the base metal. Immersion deposits are used for decorative purposes or as lubricants in drawing steel wire or shapes.

The accepted safety rules for handling acids, bases, cyanides and other solutions should be followed when operating an immersion bath. Fume hoods should be used when a process involves the liberation of hazardous or annoying fumes.

Table I gives the ingredients and operating temperatures for a variety of immersion deposits on different substrates.

Table I. Immersion Plating Formulations

Type of Deposit	*Base Metal*	*Ingredients*		*Temp, °F*	*Comments*
Brass	Aluminum	Zinc oxide Sodium hydroxide Copper cyanide Sodium cyanide Basic lead carbonate	112.5 g/L (15.0 oz/gal) 315.0 g/L (42.0 oz/gal) 13.1 g/L (1.75 oz/gal) 22.5 g/L (3.0 oz/gal) 0.14 g/L (0.018 oz/gal)	115	
Bronze	Steel	Stannous sulfate Copper sulfate Sulfuric acid	3.8 g/L (0.5 oz/gal) 1.5 g/L (0.2 oz/gal) 11.0 ml/L (1.4 fl oz/gal)	Room	Liquor finish on wire.
Cadmium	Aluminum	Cadmium sulfate Hydrofluoric acid, 70%	3.8 g/L (0.5 oz/gal) 70.0 ml/L (9.0 fl oz/gal)	Room	
	Copper alloys	Cadmium oxide Sodium cyanide	10.5 g/L (1.4 oz/gal) 90.0 g/L (12.0 oz/gal)	105-160	
	Copper alloys and steel	Cadmium oxide Sodium hydroxide	4.5 g/L (0.6 oz/gal) 540.0 g/L (72.0 oz/gal)	255	
Copper	Aluminum	Copper sulfate Ethylenediamine	99.8 g/L (13.3 oz/gal) 99.8 g/L (13.3 oz/gal)	Room	Alkaline solution. If difficulty arises in plating certain aluminum alloys, try acidic formulation below.
	Aluminum	Copper sulfate Hydrofluoric acid, 70%	202.5 g/L (27.0 oz/gal) 7.0 ml/L (0.9 fl oz/gal)	Room	
	Steel	Copper sulfate Sulfuric acid	15.0 g/L (2.0 oz/gal) 0.5 ml/L (0.06 fl oz/gal)	Room	

Table I. Immersion Plating Formulations (Continued)

Type of Deposit	*Base Metal*	*Ingredients*		*Temp, °F*	*Comments*
	Zinc	Copper sulfate Tartaric acid Ammonia	30.0 g/L (4.0 oz/gal) 52.5 g/L (7.0 oz/gal) 55.0 ml/L (7.0 fl oz/gal)	Room	
Gold	Copper alloys	Potassium gold cyanide Potassium cyanide	2.3 g/L (0.3 tr oz/gal) 12.0 g/L (1.6 oz/gal)	150-180	
	Copper alloys	Hydrogen tetra-chloroaurate Ethanol	1.0 g/L (0.1 tr oz/gal) 1000.0 ml/L (128.0 fl oz/gal)	Room	Ethanol rinse.
	Copper alloys and palladium	Potassium gold cyanide Ammonium citrate Urea	5.0 g/L (0.6 tr oz/gal) 20.0 g/L (2.7 oz/gal) 25.0 g/L (3.3 oz/gal)	150-180	Thiourea may be used in place of urea.
Lead	Copper alloys	Lead monoxide Sodium cyanide Sodium hydroxide	3.8 g/L (0.5 oz/gal) 26.3 g/L (3.5 oz/gal) 105.0 g/L (14.0 oz/gal)	180-200	
Nickel	Copper alloys	Nickel sulfate Ammonium nickel sulfate Sodium thiosulfate	60.0 g/L (8.0 oz/gal) 60.0 g/L (8.0 oz/gal) 120.0 g/L (16.0 oz/gal)	100-150	
	Steel	Nickel sulfate	15.0 g/L (2.0 oz/gal)	160	Adjust pH 3.0-4.0 with sulfuric acid.
	Zinc	Nickel sulfate Sodium chloride	60.0 g/L (8.0 oz/gal) 30.0 g/L (4.0 oz/gal)	150	Adjust pH to 5.0 with sodium carbonate or sulfuric acid.

Table I. Immersion Plating Formulations (Continued)

Type of Deposit	*Base Metal*	*Ingredients*		*Temp, °F*	*Comments*
Palladium	Copper alloys and nickel	Palladium (II) chloride Hydrochloric acid	8.2 g/L (1.0 tr oz/gal) 250.0 ml/L (32.0 fl oz/gal)	Room	Seal the porous deposit by immersion in 33% v ammonia solution.
Platinum	Copper alloys, nickel and gold	Chloroplatinic acid Hydrochloric acid	12.3 g/L (1.5 tr oz/gal) 250.0 ml/L (32.0 fl oz/gal)	150	
Rhodium	Copper alloys	Rhodium (III) sulfate Sulfuric acid	4.8 g/L (0.6 tr oz/gal) 25.0 ml/L (3.2 fl oz/gal)	Room	
Ruthenium	Copper alloys, gold and palladium	Ruthenium nitrosyl chloride Hydrochloric acid	11.5 g/L (0.6 tr oz/gal) 250.0 ml/L (32.0 fl oz/gal)	200	
Silver	Copper alloys	Silver cyanide Sodium cyanide	7.5 g/L (0.9 tr oz/gal) 15.0 g/L (2.0 oz/gal)	Room	
	Copper alloys	Silver nitrate Ammonia Sodium thiosulfate	7.5 g/L (0.9 tr oz/gal) 100.0 ml/L (12.8 fl oz/gal) 105.0 g/L (14.0 oz/gal)	Room	Caution: Avoid skin contact, as silver nitrate discolors skin.
	Zinc	Silver cyanide Potassium cyanide	6.0 g/L (0.7 oz/gal) 3.8 g/L (0.5 oz/gal)	Room	

Table I. Immersion Plating Formulations (Continued)

Type of Deposit	*Base Metal*	*Ingredients*		*Temp, °F*	*Comments*
Tin	Aluminum	Sodium stannate	45.0 g/L (6.0 oz/gal)	150-180	High sodium hydroxide causes blisters. Solution used for coating aluminum pistons.
	Copper alloys	Stannous chloride Sodium cyanide Sodium hydroxide	18.8 g/L (2.5 oz/gal) 187.5 g/L (25.0 oz/gal) 22.5 g/L (3.0 oz/gal)	Room	
	Copper alloys	Potassium stannate Potassium cyanide Potassium hydroxide	45.0 g/L (6.0 oz/gal) 105.0 g/L (14.0 oz/gal) 7.5 g/L (1.0 oz/gal)	100-150	
	Copper alloys	Stannous chloride Thiourea Sulfuric acid	3.8 g/L (0.5 oz/gal) 49.5 g/L (6.6 oz/gal) 12.0 ml/L (1.5 fl oz/gal)	80-120	
	Steel	Stannous sulfate Sulfuric acid	1.5 g/L (0.2 oz/gal) 7.0 ml/L (0.9 fl oz/gal)	180-Boiling	Produces white liquor finish on wire.
	Zinc	Stannous chloride	127.5 g/L (17.0 oz/gal)	Room	
Zinc	Aluminum	Zinc oxide Sodium hydroxide	90.0 g/L (12.0 oz/gal) 450.0 g/L (60.0 oz/gal)	Room	
	Steel	Zinc chloride Ammonium chloride	60.0 g/L (8.0 oz/gal) 30.0 g/L (4.0 oz/gal)	Room	Place parts in zinc baskets or mix parts with small zinc pieces.