Cadmium Plating

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Applications

Cadmium is used for providing sacrificial (cathodic) protection to steel, ranking next to zinc for this purpose. In marine environments, cadmium is better than an equal thickness of zinc, but in industrial environments, zinc is superior.

Cadmium's lubricity and capability to prevent galling between sliding surfaces is a key property responsible for many of its applications. It is also readily solderable with non-acid fluxes, has good electrical conductivity and, when corroded, forms thinner and less harmful corrosion products than zinc does.

For installing fasteners, a predictable high tension is obtained at low torque with cadmium. This feature, combined with its compatibility with aluminum, has made cadmium a popular finish for aircraft fasteners and other components for that industry. Cadmium is also used by the automotive industry for disc brakes, radiator hose fittings, door latches and tension-bar bolts. Its solderability, low contact resistance, and corrosion resistance have been pursued for connectors, relays and chassis by the electronics industry.

Processes

Cadmium coatings are applied by vacuum deposition, mechanical plating and electroplating. Some manufacturers use all three methods for different types of parts. However, electroplating in cyanide solutions is the only method used by many shops because fine-grained deposits with relatively good thickness uniformity are obtained. Typical solutions contain 20-25 g/L of cadmium oxide (CdO) dissolved in 75-100 g/L of sodium cyanide and 10-12 g/L of sodium hydroxide. The hydroxide contributed by CdO brings the total sodium hydroxide concentration up to about 18-25 g/L. During operation, 30-60 g/L of sodium carbonate is formed as a result of cyanide decomposition.

Sodium cyanide not only supplies conductivity but is important for ensuring good anode dissolution. For control purposes, the ratio of sodium cyanide to cadmium metal is monitored—about 4:1 being typical. Sodium hydroxide also provides conductivity and should be maintained to ensure good cathode efficiency, which ordinarily is in the range of 80-85 percent when the bath temperature is 72-75 °F and the current density between 5 and 20 A/ft^2. A higher current density (30 to 40 A/ft^2) can be used with good efficiency if the cadmium metal concentration is raised to 40 g/L. Proprietary additives that include combinations of organics such as gelatin, dextrin, aldehydes and organic sulfur compounds refine grain size and brighten the deposits. However, additives should be adopted with caution because they may tend to aggravate hydrogen embrittlement problems, even when plated steel parts are heat-treated to drive out hydrogen. For this reason, some titanium salt specifications prohibit bright cadmium plating, especially for high-strength steel.

Because hydrogen embrittlement is restrained when a titanium salt and hydrogen peroxide are added to a cyanide bath, this approach has been used for aircraft parts. Fluoborate solutions containing about 100 g/L cadmium, 60 g/L ammonium fluoborate, and 25 g/L boric acid have a cathode efficiency near 100 percent, so these baths are sometimes used to avoid or minimize hydrogen embrittlement. However, they also have poor throwing power; hence, deposit thickness is non-uniform. Proprietary non-cyanide alkaline and acid sulfate baths have been introduced recently. However, reliable information on their capabilities and drawbacks is limited.

Post-plating

A dip for 5 to 20 sec in a 0.25 to 0.5 percent by vol nitric acid solution can be used to remove dark surface films and brighten matte deposits. Supplemental chromate conversion coatings inhibit cadmium corrosion and prolong the life of the plated product. Thus, many specifications call for either clear or yellow chromate films after cadmium plating. The yellow coating is more protective than a clear film. Adherent yellow films are obtained in acid sodium or potassium dichromate solutions. A chromic/sulfuric acid bath produces clear films. If baking is required to provide hydrogen relief, the chromate treatment must be applied after baking because heat destroys the film.

The fatigue strength of steel is reduced by any hydrogen embrittlement introduced by cadmium plating. Steel with a hardness above Rockwell C35 is susceptible. Cathodic alkaline cleaning and acid pickling before plating aggravate embrittlement. Baking at 350 to 400 °F for 3 to 24 hr soon after plating is frequently specified for hydrogen relief. Porous deposits that tend to be promoted by high-current density plating facilitate the removal of hydrogen during heating.

Health Impact

Cadmium is an extremely toxic metal and its use is prohibited for food-handling applications. Mixing cadmium oxide with sodium cyanide to prepare a plating solution generates heat and dust, requiring ventilation, goggles, rubber apron, boots and respirator. Toxic fumes develop when cadmium-plated parts are welded or otherwise heated. The threshold limit value (TLV) for cadmium in the workplace is 0.1 mg/m^3 for fumes and 0.2 mg/m^3 for dust.

Environmental Status

Wastewater limits under EPA's Metal Finishing Regulations are 0.69 mg/L for any single day and 0.26 mg/L as a monthly average. However, new sources must comply with 0.11 and 0.07 mg/L, respectively, limits considered difficult to meet today. With increasing trends toward more complex, surfacemount boards, the demand for circuit uniformity and higher aspect ratio holes has sparked considerable attention to additive control and research. The industry has recently observed the introduction of several full-build electroless copper solutions with superior physical properties. Although the electroless solutions are still considerably more expensive than their electrolytic counterparts, there are designs in existence that cannot be manufactured with today's electrolytic technology. Since this trend is likely to continue, suppliers are seeking new additives and control methods to improve deposit uniformity and throwing power.

Editor's note: This section on cadmium was written by William Safranek, CEF, former technical editor of *Plating and Surface Finishing*. Before his death, Mr. Safranek made many contributions to the surface finishing industry.

His book, *The Properties of Electrodeposited Metals and Alloys*, now available in a second edition, is considered a "must" for any finisher's library (550 pages/l986/hardcover; order number 20-10; AESF members $72; non-members $82; shipping and handling additional). This book and others are available from AESF. All are contained in a catalog that is available on request.

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