Minnesota Finisher Offers High-Purity Aluminum As an Environmentally Friendly Coating

In an industry in search of alternatives for environmentally toxic processes, plating with aluminum is seldom mentioned. The worldwide holder of one aluminum plating process, however, says aluminum plating has unique properties that enable it to provide superior corrosion resistance without harming the environment. It combines the surface properties of a high-purity aluminum layer with the bulk properties of just about any substrate—including steel, copper and aluminum alloys.

AlumiPlate, Inc., Minneapolis, MN, is a service jobshop, providing electroplating with high-purity aluminum in applications where resistance to corrosion is required, or where other properties of aluminum are desired over other metals.

According to Hal Galvin, Chief Executive Officer of AlumiPlate, aluminum has not been widely used as a plating alternative, because it can be electrodeposited only from a water-free electrolyte—a process previously unexplored in the plating industry. A non-aqueous process for electrodepositing aluminum, however, was developed by Siemens AG over the course of 30 years. AlumiPlate purchased the technology in 1995. "We are the only electroplater in the U.S. that is offering this service, and we are the patent holder worldwide for this technology," Galvin said.

Water-free Electroplating

Water is used in most electroplating processes. It is not feasible, however, when depositing aluminum, because water is electrolyzed, generating hydrogen and oxygen. A water-free solution has been developed to solve this problem. According to Galvin, this patented organic solvent-based process greatly reduces exposure to free hydrogen, both in amount and duration, especially when compared with cadmium or zinc plating.

Galvin says high-purity aluminum anodes slowly dissolve in the electrolyte when the anode is polarized. The electrolyte bath provides for the transport of dissolved aluminum onto the parts, which are polarized as cathodes. Electrodeposited aluminum, he says, is of a higher purity (99.9+%) than the aluminum in the anode, because impurities and alloying elements in the anode are insoluble in the electrolyte. Impurities are continuously eliminated by filtering the electrolyte bath, so that a refined layer of aluminum actually is deposited on parts.

Aluminum plating requires a fully enclosed cell to prevent harmful reaction of the electrolyte bath with oxygen.

The aluminum is deposited in an enclosed plating cell to prevent harmful reaction of the electrolyte bath with oxygen, which would degrade the electrolyte and shorten its useful life. In addition, the special process control and plating equipment increase the life of the electrolyte bath. The plating process is nearly 100 percent efficient when properly operated and controlled. Life of the solution can exceed one year. According to Galvin the deposition rate is about 12µm (0.005 in.) per hour, and the throwing power of the electrolyte is comparable to that of electrolytic cadmium.

Coating Properties

The pure aluminum layer is pore-free, has a randomly oriented crystalline structure, and provides excellent corrosiion protection with just an 8µm (0.003 in.) thickness. The non-degenerating oxide surface acts as a barrier layer, and the high-purity aluminum serves as a sacrificial anode to nearly any base metal substrate, even when the aluminum surface is scratched. A chromated aluminum layer typically provides more than 2,000 hours of protection, with no red rust. (See Table 1 for results of ASTM B117 tests on fasteners for a manufacturer of heavy equipment.)

Environmentally Friendly

In addition to providing corrosion protection, aluminum plating is less hazardous to the environment than cadmium or chromium, Galvin said. The aluminum is plated in a completely closed-loop system, which keeps chemical consumption low. Disposal of depleted chemicals, however, is safe and efficient.

Fewer HE Problems

Hydrogen embrittlement (HE) is less of a problem for parts plated with aluminum, Galvin said. Because parts are plated in a proton-free, non-aqueous electrolyte, they are not exposed to free hydrogen. Aluminum plating also has reduced susceptibility to environmentally assisted crack-

Table 1—Salt Spray Test

Coating	Time, hr/result
Phosphate & oil	24/red rust
Zinc/dichromate	24/white rust
Metal-containing organics	187/red rust
Proprietary aluminum*	2500/no corrosion

ing. The aluminum surface is anodic to the metal substrate. When the coating surface is broken and the substrate is exposed, the oxide layer forms immediately. This "heals" the surrounding aluminum and prevents further oxidation corrosion of the base metal.

Applications for Use

According to Galvin, electroplated aluminum can provide high value in applications with a wide range of requirements, including corrosion resistance, temperature, galvanic or chemical compatibility, machinability, hardness, lubricity and cost. Some applications are:

Heavy Equipment

Pure aluminum can be applied in a very thin layer, and has the ability to better resist corrosion, perform at high temperatures, and protect aluminum alloy components from galvanic corrosion caused by steel fasteners. Galvin said the pure aluminum layer reduces exposure to environmentally generated hydrogen more effectively than cadmium or zinc plating. Because of this, parts are much less susceptible to environmentally assisted cracking. (See Table 2 for comparisons.)

Marine Components

An option for replacing cadmium for corrosion resistance on steel parts is to plate them with a thin, dense aluminum layer that is ductile and will withstand high temperatures. Electroplated aluminum has performed well in chloride and sulfur dioxide-rich atmospheres. In one modified cyclic salt spray test, aluminum plating survived more than 7200 hr.

Proprietary aluminum plating is a rack process that is most suitable for larger parts. High strength steel bolts are a good candidate, because of the diminished likelihood of hydrogen embrittlement.

Optical Mirrors

Plating high-purity aluminum onto metal mirrors, and then diamond-turning that aluminum, provides a highly reflective surface with less scatter for infrared and visible spectrum applications. The process can be applied to the high-end optical mirrors in commercial, astronomical and military applications. The National Optical Astronomy Observatories plated a series of mirrors for the Gemini Telescope's infrared spectrograph. The mirrors tested well during temperature cycling from -208° to 27°C (-340° to 80°F).

Aerospace

Aluminum plating is a viable alternative to cadmium plating for aerospace applications. The process is less toxic and less harmful to the environment, while reducing the risk of galvanic corrosion. Plus, critical high-strength components can benefit from aluminum's reduced risk of hydrogen embrittlement.

Automotive

One application for the automotive industry is to use aluminum plated parts in proximity with the engine or the exhaust system, because it can withstand temperatures exceeding 430°C (800°F). Aluminum plating's high ductility also enables its use on springs or other parts that must flex. Plus, galvano aluminum-plated parts can be bent or drawn, after plating, without creating cracks. Aluminum-plated steel fasteners can also prevent contact corrosion in applications where the chassis is made of aluminum alloy. Applications using high-strength steels are also excellent candidates for aluminum plating (*e.g.* brake bolts), where hydrogen embrittlement must be avoided.

Galvin said AlumiPlate has been investing in technology and market development for more than six years, and has developed an impressive list of users. The company is planning a second plating shop to open in early 2003. It also is making the technology available under license to other electroplaters. ***P&SF***

Table 2—A Comparison of Various Industrial Corrosion Coatings with Aluminum Plating

	Aluminum Plating*	Cadmium	Organic Coatings	Zn Alloy Coatings	IVD Al
Nominal recommended thickness	0.3 mil	0.3 mil	1-2 mil	0.3 mil	0.3 mil
Salt spray (B-117) performance	1,000+ hr	1000 hr	500 hr	400-1000 hr	500 hr
Non-embrittling	Yes	No	Yes	No	Yes
Fully dense and pore-free	Yes	Yes	Yes	Yes	No
Sacrificial protection	Yes	Yes	Partial	Yes	Yes
No galvanic reaction with Al parts	Yes	Yes	Partial	No	Yes
Complex geometries and IDs	Yes	yes	No	Yes	No
Tightly adhering	Yes	Yes	No	Yes	No
Environmentally friendly	Yes	No	Yes	No	Yes
High temp. applicability	Up to 1000°F	Up to 500°F	Up to 500°F	Up to 500°F	Up to 1000°F
Drop-in cad replacement	Yes	--	No	No	No
No peening required	Yes	Yes	Yes	Yes	No
Ductile, formable and stampable	Yes	Partial	No	No	No
Low process temperature	Yes	Yes	Yes	Yes	No
Anodizeable	Yes	No	No	No	No

*AlumiPlate® aluminum plating is the tradmark process of AlumiPlate, Inc., Minneapolis, MN.