Electroplated aluminum: the effective, money-saving alternative to Ion Vapor Deposition (IVD).

Surface finishing and materials professionals have long understood the many advantages and desirable physical properties of high-purity aluminum. But performance limitations and high costs have prevented the wide use of aluminum as a general-purpose anti-corrosion coating. Now, however, electroplating of high-purity aluminum is a well-established, commercially available substitute for IVD aluminum, offering performance and cost advantages for a wide variety of industries and applications.

- ***Corrosion resistance.*** High-purity aluminum is highly corrosion-resistant. As a coating in specialized and corrosive environments, it will outlast most industrial metal coatings.
- ***Useful in high-temperature applications.*** With a functional temperature range of up to 1000° F, aluminum can be used in many high-temperature applications.
- ***Environmentally superior.*** Aluminum is non-toxic and poses little threat to the environment. Neither handling nor disposal are problematic.
- ***Low risk of hydrogen embrittlement.*** The patented aluminum plating process is non-aqueous and instead uses an aprotic (proton-free) electrolyte. This leads to a very low potential for hydrogen embrittlement, and the process has been certified non-embrittling based on tensile, fatigue, and field-customer test data. Coated high-strength components do not require a post-plating heat treatment for hydrogen relief, and the coating minimizes environmentally assisted cracking (EAC) of installed parts.
- ***Electrical applications.*** Because aluminum is electrically conductive, it is ideal for electrical applications across many industries.
- ***Ductility.*** Electroplated aluminum is highly ductile, allowing for post plating forming or crimping operations on the plated part.
- ***Aluminum can be anodized.*** Anodization offers enhanced corrosion resistance and surface durability, as well as various cosmetic options.

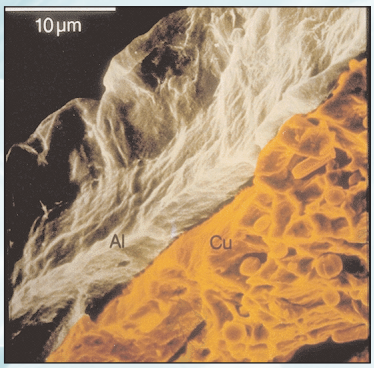

fig. 1
This photomicrograph illustrates electroplated aluminum's density and demonstrates the integrity of the coating/substrate interface. Note the lack of voids and pores in the coating.

Why an IVD Al alternative?

Despite its many advantages, high-purity aluminum has only been used in limited industrial, commercial, and defense-related applications to date. This limited use is due primarily to the complex and expensive Ion Vapor Deposition (IVD) process and the sub-par physical properties of the coating this process produces. The disadvantages of IVD include:

- ***Porosity diminishes corrosion resistance.*** IVD produces a porous coating, and this can lead to attack on the substrate material by harsh or corrosive environments. IVD suppliers commonly try to overcome this limitation by "peening," or smoothing over, the aluminum surface to close the pores and approximate a denser coating. While peening can extend the life and anti-corrosive properties of the coating, the result ultimately falls far short of the protection a fully dense coating provides.
- ***IVD is applicable to only a small subset of complex geometries.*** Because IVD is a line of sight process, it can severely limit the range of geometries that can be coated successfully. IVD service providers try to overcome this limitation by repositioning the objects being plated a number of times during the course of the plating process, adding significant handwork costs.
- ***IVD depositions are not ductile.*** Unpeened IVD Al has a porus, columnar structure that lack inherint ductility. The densification of IVD Al results in a highly stressed, brittle coating that can crack or spall during loading.
- ***IVD aluminum cannot be anodized.*** This is due to the porosity of the coating and the propensity of the anodizing chemicals to penetrate and attack the substrate.

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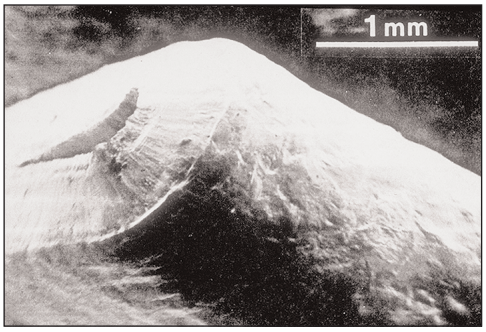

fig. 2

This photograph illustrates the formability and ductility of electroplated alumiunum. Note the absence of cracks at the tightest bend radius. (bend test performed per ASTM B-489).

How electroplated aluminum can counteract problems associated with IVD.

Electroplated aluminum is fully dense and pore free. Electroplated aluminum is fully dense, with no voids and no post-densification procedures needed. The coating presents an impermeable barrier to corrosive chemicals and environments (See *fig. 1*).

No post-plating densification (peening) necessary. Because it is fully dense, electroplated aluminum alleviates the need for mechanical densification to bring the coating up to a minimum corrosion resistance standard. By switching to electroplated aluminum, the user eliminates the risk of densification processing that is performed either inadequately or not at all — which can render the coating ineffective in its end-use environment, or can warp thin parts.

Electroplated aluminum can be anodized. Electroplated aluminum can be anodized and offers superior results over anodized aluminum alloys. Due to its high purity, the anodized layer is smooth and pit free, accepts color very well over any substrate and can be bright-dipped prior to anodization. Anodized high-purity aluminum renders a high-potential insulating layer and has dielectric properties ideal for many applications. In addition, testing based on B-117 shows that high-purity aluminum's corrosion resistance can be as high as 3,600 hours in salt fog.

Electroplated aluminum offers enhanced formability. Products coated with electroplated aluminum can be formed or stamped without corrosion protection failure. IVD aluminum, on the other hand, is not particularly ductile as deposited, and densification makes the deposit even more brittle. (See *fig. 2*)

Immediate opportunities for IVD users. Aluminum is the U.S. Government's choice as a cadmium replacement for all branches of the military. In fact, MIL-HDBK-1568 identifies IVD and electroplated aluminum as alternative to cadmium, citing its corrosion protection and non-toxic properties. Because electroplated aluminum is a drop-in replacement for IVD aluminum coating, users of IVD have an immediate opportunity for increased corrosion resistance across a broader range of components and offers significant cost savings.

Electroplated aluminum is available, effective, and economical.

The technology for electroplating aluminum is well established and commercially available in both the U.S. and Europe, and availability is expanding rapidly as plating costs continue to drop and capacity continues to expand. Electroplated high-purity aluminum offers an immediate drop-in replacement for IVD coatings, since electroplating is now included in most industry and defense specifications calling for aluminum coatings.

Superior performance, significant cost savings, and applicability across a wider than ever range of products and components make electroplated high-purity aluminum today's best coating alternative.

MIL-DTL-83488D Rev D Table 1 Salt Spray Test Expectations for Aluminum Coatings				Test Results for Electroplated Aluminum	
	Minimum Coating Thickness	***Type I Hours***	***Type II Hours***	***As plated Hours***	***With Conversion Coat Hours***
Class 1	.001"	504	672	4000+	4500+
Class 2	.0005"	336	504	2000+	2500+
Class 3	.0003"	168	336	1000+	1500+

The current military specification for this is Mil-DTL-83488, Revision D. In this specification, there are three classes and two types.
The coating thickness is controlled by the class call out.
Class 1 is used for the best corrosion resistance. Class 2 is used where dimensional tolerances do not allow use of Class 1. Class 3 is for use with close tolerance applications, like finely threaded parts.
The Type I call out is for "as coated". The Type II call out is for a chromate conversion coat.
Plus sign for Electroplated Aluminum hours indicates that many users have experienced test results exceeding the stated hours of protection.

	Electroplated Aluminum	***IVD Al***
Pricing	Less expensive	More expensive
Salt Spray (B-117)	1000 hrs	672 hrs
Exceeds MIL-DTL-83488D corrosion resistance requirements	Yes	No
Fully Dense after coating application	Yes	No
No peening required for best corrosion resistance	Yes	No
Sacrificial protection	Yes	Yes
Eliminates contact corrosion with Al assemblies	Yes	Yes
Limits hydrogen embrittlement	Yes	Yes
Limits susceptibility to EAC	Yes	Yes
Environmentally friendly	Yes	Yes
High temp. applicability	Up to 1000° F	Up to 1000° F
Drop-In cadmium replacement	Yes	No
Can throw into holes and around parts (not line-of-sight limited)	Yes	No
Able to plate inside of tubes and ID's	Yes	No
Anodizeable	Yes	No
Ductile coating formable or stampable after coating	Yes	No
Bright metallic finish (as opposed to dull or matte finish)	Yes	No
Brazeable	Yes	No