

IVD Aluminum

B.T. Nevill, CAE Cleaning Technologies, Cincinnati, OH

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ABSTRACT

Ion Vapor Deposition (I.V.D) of Aluminum is a functional coating developed in the late 1960's by McDonnell Douglas as an environmentally safe alternative to electroplated Cadmium. It was initially developed by McDonnell Douglas for the Aerospace Industry as a functional coating on High Strength Steels, Aluminum Alloys and Titanium fasteners.

The first production facilities were installed in plating shops in the early 1970's. By the late 1980's there were over 70 installations worldwide. During this period, the I.V.D. process patent along with equipment manufacturing rights were sold to Abar Ipsen (now Ipsen International).

In the past, the majority, of technical papers focused on the substitution of I.V.D., aluminum for cadmium in aerospace and military applications. The paper will present a brief overview of existing successful installations as well as details of any recent commercial applications that have developed for this still emerging technology. It will communicate that I.V.D. continues to be a viable alternative to electroplating as well as other coating needs for the next millennium.

INTRODUCTION

The IVD process (Ivadizing) utilizes the Ion plating technique to apply a uniform, dense and highly adherent aluminum coating on a variety of metallic and non-metallic materials. In some applications where IVD Aluminum is applied after conventional plating the IVD process and equipment is easily integrated into an existing plating facility. In many cases the IVD process share similar preparation, processing and finishing operations with the conventional plating operation.

CLEANING: (PRE-TREATMENT)

The pre-treatment process is the single most important step to ensure consistent coating quality and performance. The effects of cleaning on coating performance are worthy of a more detailed description. However, the intention of this paper is to focus on the advantages of the IVD Aluminum coating and potential applications rather than the individual process steps.

The first step is to remove any surface contamination prior to a dry blasting operation. These contaminants include oils, dyes, greases, machine lubricants and fingerprints. Traditionally these contaminants were removed with chlorinated solvents in a vapor degreasing operation. However, increased legislation surrounding the Montreal protocol has resulted in the use of alternative solvent technology and aqueous cleaning systems with ultrasonics.

After cleaning the parts are dried and any areas not requiring IVD Aluminum Coating are masked using specialty tapes and metal foils. After masking the next step is a dry blasting operation with Aluminum oxide. The grade and purity of the oxide is chosen based on the substrate material and final application. The dry blasting operation can be carried out manually or automatically. Alternatively parts can be chemically etched prior to the vacuum deposition process. This process is limited by the substrate material and is less successful at providing good adhesion of the IVD Aluminum coating when compared to the dry blasting operation. The parts are loaded into the vacuum chamber within 4 hours to minimize potential oxidation or contamination of the substrate surface.

GAS CLEANING (IN-SITU CLEANING)

The next cleaning operation is carried out within the vacuum chamber (In-situ). The vacuum chamber is evacuated to 7×10^{-5} Torr to purge the system prior to backfilling with Argon at 2×10^{-5} Torr. A negative potential (1-2.kv-DC) is applied between the parts (Cathode) and the evaporation source (Anode). The ionization of the Argon Gas creates a glow discharge within the chamber. Positively charged ions are attracted to the substrate removing surface contamination (sputtering). This ion bombardment of the surface is the final cleaning operation and is largely responsible for the excellent adhesion between the aluminum coating and substrate interface. The gas cleaning cycle lasts between 10-20 minutes. (See Figure 1)

Coating

The evaporation source (Anode) consists of seven Intermetallic boron nitride or titanium diboride boats (crucibles). Each crucible has an independent wire feed unit providing a continuous supply of aluminum wire. (See Figure 2). The aluminum wire evaporates and passes through the glow discharge where the aluminum is ionized through collisions with high-

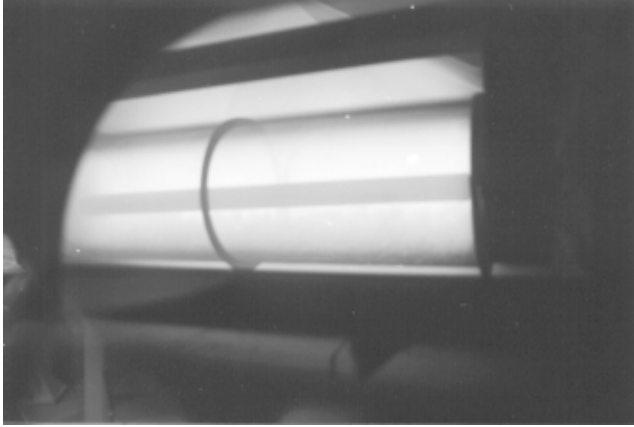


Figure 1. Gas cleaning process (barrel).

energy electrons or metastable gas atoms. These positively charged ions are then attracted to and deposited on the negatively charged substrate.

The evaporation source can be moved under the parts at any number of passes at varying speeds or the source remains fixed with the parts rotated on a rack or in a barrel. Coating thickness range from a few microns to 30 microns. Unlike PVD or CVD technologies, the IVD technology is not limited to a thin film deposition and can easily achieve 25-30 microns in a single layer or thicker coatings can be applied as a multi layer utilizing a multiple coating operation. The IVD coating is columnar in structure with grains extending outward from the substrate. The continual bombardment of the ionized gas during the coating cycle help to maintain coating uniformity and provide better bonding between columns to reduce coating porosity. Correct control of the substrate bias, gas pressure and surface roughness (during external cleaning) is necessary to produce a dense uniform coating with minimal porosity. However, in the “as coated” condition the IVD Aluminum is porous and requires a final finishing operation after vacuum deposition.

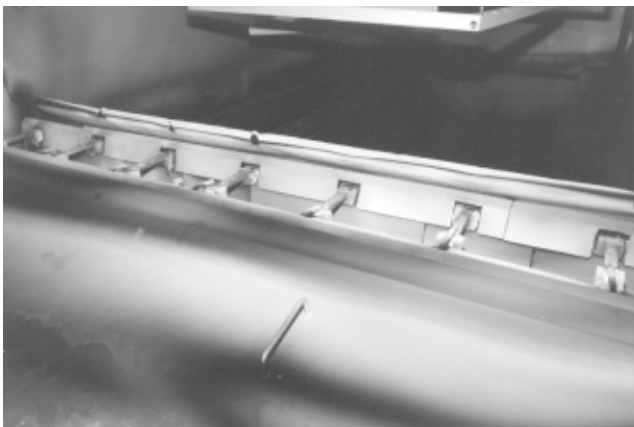


Figure 2. Evaporation source.

FINISHING (POST TREATMENT)

Porosity is further reduced by glass beading (burnishing) of the IVD Aluminum Coating at a pressure of 20-40 PSI. This essentially densifies the coating, improving the appearance and corrosion resistance performance. The glass beading operation also serves as a quality check for coating adhesion. The final post-treatment is a chromate conversion or sealing of the coating to provide improved corrosion resistance and better bonding for a paint finish or barrier coating. In some applications the coating is left in the “glass beaded” condition only.

Equipment

The IVD equipment consists of a steel vacuum chamber, a pumping system consisting of a three stage diffusion pump backed by a rotary vane and booster pump, cryogenic pumping system, a parts rack or barrel accessory, an evaporation source and high voltage power supply. Advances in technology have resulted in fully automated systems capable of monitoring system sequencing, process timing and data recording functions. Systems built prior to 1990 required a manual/semi automatic operation to allow for adjustments to process parameters during the gas cleaning and coating operation. During processing cleaning or coating parameters for each application are referenced by the operator in a logbook or procedure file. More recent IVD systems can be run through the entire process sequence from loading to unloading automatically.

Applications involving large complex parts or multiple parts are coated on a fixed rack assembly and turned through 180 degrees half way through the coating cycle. (See Figure 3). This step can be avoided by using a parts rack that rotates during the coating cycle. The volume of parts coated in a single cycle is limited by the part configuration or rack design.

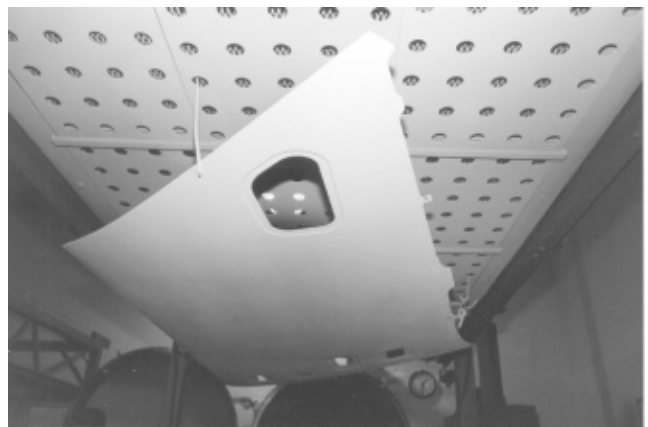


Figure 3. Fixed rack assembly (F-15 Wing Skin).

Barrel coating is carried out in a dedicated barrel coating chamber with one or two barrels. (See Figure 4). In applications involving small batches the barrel is located in the door for

manual loading and unloading. These smaller systems have the advantage of shorter process times, improved batch control, reduced coating thickness variation within the batch and improved coating uniformity. In applications involving large volume processing the chamber has two barrels and is equipped with a load/lock system for loading and unloading of the fasteners without breaking the vacuum. These systems can easily coat 100 pounds of fasteners in a single operation.

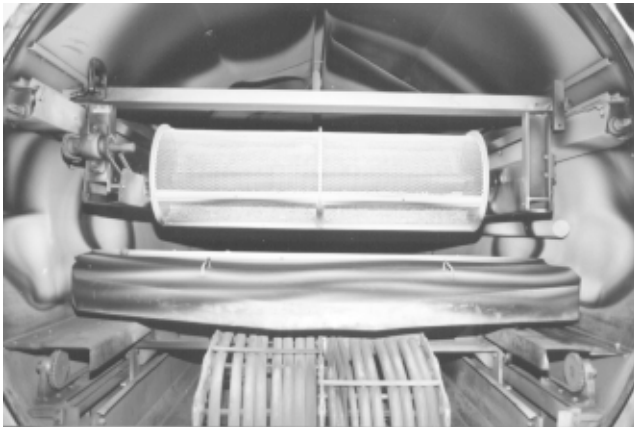


Figure 4. Barrel assembly.

Coating Uniformity & Thickness

The IVD process is not limited to ‘line of site’ coverage and provides excellent coverage and uniformity. The IVD coating does not build up or run off on sharp edges regardless of coating thickness. The uniformity of IVD aluminum on regular surfaces is approximately +/-10% of the medium thickness. Coating coverage can be achieved in recessed areas and bores. The thickness is difficult to control and in practice, the coating will coat a bore or recessed area one times the diameter of the opening. The thickness of the IVD Aluminum coating varies between applications and is based on three standards. These standards are shown below in Table 1. Typically fasteners close tolerance parts and magnets require a class 3 coating, internal structures a class 2 and outside structures or steels require a class 1. The IVD Aluminum coating has been applied less than 7 microns and greater than 25 microns. However, although it is possible to achieve over 50 microns, it is less practical or cost effective when you consider the increased processing time and final performance. Multiple layers of the IVD Aluminum can be applied without problems of adhesion at the interface between the individual coated layers to achieve a coating thickness greater than 50 microns.

Coating Characteristics

After the glass bead operation the IVD Aluminum coating as a surface roughness of approximately 50-70 micro inches. This may vary depending on the choice of media and process parameter used within the coating cycle. The IVD Aluminum

Table 1. Mil-C-83488.

Class	Thickness, microns	Salt Spray	
		Type 1	(hr) Type 2
1	25	504	672
2	12.5	336	504
3	7.5	168	336

Type 1: Without chromate conversion

Type 2: With chromate conversion

with Chromate conversion coating is electrically conductive and exhibits the same alloy composition as the basic 1100 series aluminum alloy evaporant. IVD Aluminum is a soft coating and is not suitable for erosion resistance when used alone. However, IVD Aluminum has proven to be equal or better than diffused nickel-cadmium coatings for erosion/corrosion applications. IVD Aluminum can be applied thicker than conventional coatings or can be coated with an abrasive resistant material to improve erosion resistance. Applications involving fasteners require cetyl alcohol or a dry film lubricant to prevent seizure during installation. The corrosion protection of IVD Aluminum has been compared to Cadmium on alloy steel substitutes using neutral salt fog, acidic salt fog or outdoor exposure. In all cases the conclusion was IVD Aluminum Coating provided the same or superior corrosion protection and was a suitable replacement to all Cadmium processes. IVD Aluminum can be used in applications at service temperatures up to 925°F.

APPLICATIONS

IVD has been used in a variety of aerospace applications for over 20 years. Applications have included landing gear, wing sections, missile casings and fasteners. Without exception all applications were on high strength steel, titanium and aluminum alloys. IVD Aluminum provided galvanic corrosion protection, EMI or RFI shielding, electrical bonding or improved adhesion for a final barrier coating. The ability to apply the IVD coating on difficult to coat substrates materials and the advantage of not requiring a “binding layer” provided additional cost savings over traditional plating technologies. In the early development stages of this technology the higher costs compared to electroplating were of less importance when applications involved high value components for the aerospace industry. Has the technology matured the costs of traditional electroplating have increased due to tighter legislation regarding waste disposal & control. IVD Aluminum costs have continued to go down with improvements to the equipment resulting in shorter cycle time and better process control. In September 1994 the Environmental Protection Agency (EPA) along with OSHA included the IVD technology in their publication “A Guide to Cleaner Technologies and Alternative

Metal Finishes” as a “available and well established technology” to replace Cadmium Electroplating.

A research project designed to investigate the replacement of Cadmium Electroplating at all five of Air Force Material Commands’ Air Logistics Centers began in Feb 1988 and ended in July 1992. This concluded that IVD Aluminum, if substituted for Cadmium Electroplating, would save \$1 million per year in treatment, disposal and labor costs.

When considering IVD Aluminum for commercial applications consider the main advantages of the process, coating performance and cost comparison with the current technology in use. In applications involving galvanic corrosion or marine environments the sacrificial nature of the IVD Aluminum makes it an excellent choice, particularly if the IVD Aluminum coating has a Chromate conversion or paint finish (barrier-top-coat). Where substrate materials are fatigue critical or sensitive to a traditional plating process (hydrogen embrittlement) the IVD process can provide a viable alternative with no risk of substrate damage. IVD Aluminum can be applied at low temperatures (100°F) making it possible to coat non-metallics. A successful application involving a substrate material sensitive to wet line-processing (plating) is the coating of neodymium iron boron rare earth magnets. This sintered material would disintegrate in the plating bath due to the hydrogen evolved at the surface or the plating would delaminate between layers. IVD Aluminum coating provided excellent coating uniformity, thickness control, corrosion resistance and surface bonding without any damage to the substrate during processing.

This application led to the development of a single barrel coater for batch processing small magnets. IVD Aluminum is ideal for applications involving Aluminum Alloy components. To meet adhesion requirements on aluminum alloys involving electroplating processes a multiple layer is required (strike or binding layer). Also the electroplating process can be detrimental to fatigue critical parts. IVD Aluminum can be applied directly to the substrate material without the risk of effecting fatigue strength with the advantage of superior sacrificial corrosion resistance. In some applications IVD Aluminum can be considered as an alternative to Anodizing on Aluminum Alloy materials. The throwing power and superior adhesion available with IVD Aluminum as proved successful on a number of applications involving the replacement of electroplating on large and small aluminum structures providing excellent compatibility, electrical bonding, corrosion resistance and adhesion for a paint finish.

The greatest advantage of the IVD Aluminum process is the ability to coat small parts in high volume with consistent thickness results in the range of 7 to 12 microns. This has proved to be the most successful application involving the coating of rivets for commercial aircraft. IVD Aluminum has a distinct

advantage over traditional barrel plating technologies. It provides uniform coating on the shank and head without build up in threaded areas. The coating cycle range from 20 – 80 minutes with cooling provided between coating cycles. Fasteners and rivets of different shank size and length can be coated in the same batch.

CONCLUSION

IVD Aluminum is a well-proven and mature technology in the aerospace industry. The majority of research & development surrounding this technology has focused on the applications involving Cadmium Electroplating. This technology is not limited to applications involving Cadmium replacement and can be easily applied to applications involving other electroplating processes. The main advantage of using this technology in place of electroplating is the ability to have a non-toxic and environmentally clean process.

It was the original purpose of this paper to present a number of commercial applications for this technology. Unfortunately the reality is that IVD Aluminum remains dominant in the aerospace industry and is emerging as a technology to be considered in commercial applications. Additional marketing and development work needs to be done to successfully establish this technology outside the current aerospace applications. Until then IVD Aluminum will remain the “best kept secret” within the aerospace sector.

REFERENCES

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