BOEING
ENVIRONMENTAL TECHNOTES

May 2003 Volume 8, Number 2

# Sputter Aluminum Coating Project at OO-ALC (Hill AFB)

Aircraft landing gears made from steel have various surface treatments and coatings applied to make the steel more corrosion resistant and to improve the overall life of the part. For corrosion resistance, steel landing gears typically are cadmium plated. Cadmium is classified as a hazardous material, and its usage needs to be eliminated at the Air Force Air Logistics Centers (ALCs). One technology that the Air Force has been using since the 1980's to replace cadmium has been with the application of an aluminum coating using IVD (Ion Vapor Deposition) equipment developed by McDonnell Douglas (now Boeing). Aluminum is an excellent choice because it is an environment friendly replacement for cadmium on landing gear parts and the IVD aluminum process does not cause hydrogen embrittlement of high-strength steel landing-gear parts during the IVD coating process. The Air Force currently has IVD aluminum coating equipment installed at all of their ALCs. Unfortunately, the IVD aluminum process cannot be used to coat the internal surfaces of parts when the length of the internal surface exceeds the internal diameter of the part. This article will briefly describe a project that targeted cadmium replacement on internal surfaces of landing-gear parts by installing a sputter aluminum coating system in an IVD coater located at Hill AFB (Figure 1).

Use of sputter aluminum to replace cadmium plating on internal surfaces has been evaluated and tested by Boeing (St. Louis, MO) and Marshall Laboratories (Boulder, CO) since 1996. The sputtering deposition process is performed in a vacuum chamber (similar to IVD) where argon atoms are ionized and accelerated to strike an aluminum "target" material. Coating material enters the vapor phase through a physical process (momentum exchange) rather than by a chemical or thermal process. The argon atom dislodges aluminum atoms when it strikes the target, then these ejected aluminum atoms strike the steel part to be coated, and this continuous process eventually applies a dense aluminum coating to the steel part. Figure 2 diagrams the basic sputter technology.

**Figure 1. Hill AFB – Ogden Air Logistics Center (OO-ALC) situated near the Wasatch Mountains by Ogden, Utah.**

By simply adding a magnetic field to the target material, the sputter rate can be greatly increased.



NEW NOTICE:: Tech Notes is intended for Boeing customers, sucontractors and suppliers. To be added to Tech Notes electronic distribution, please submit your e-mail address, as well as your company name, SBMS# (subcontractors/suppliers), and company mailing address, to: mailto:paul.e.rempes@boeing.com

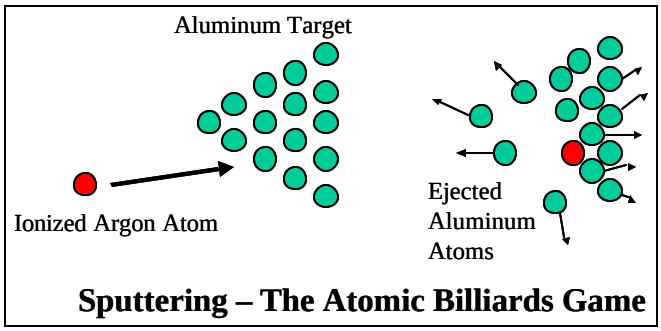


**Figure 2. Basics of Sputter Technology.**

The magnetic field causes more of the ionized argon atoms to strike the target and this increases the amount of aluminum atoms being ejected (see Figure 3). This process is called magnetron sputtering. The magnetron sputter process can apply a 0.5 mil thick aluminum coating in approximately 30 minutes. The sputter system built for Hill AFB was a "Plug & Coat" magnetron sputtering process. By definition, the aluminum sputter probe is "plugged" into the part's cavity and the inside surface is "coated" with aluminum vapor. A typical "Plug & Coat" sputter probe is shown in Figure 4.

The "Plug & Coat" sputter probe was specifically designed to work with an IVD aluminum coater chamber in order to keep installation costs low. Boeing had the first "Plug & Coat" sputter probe system installed in one of the IVD coaters at St. Louis, and demonstrated this technology for the first time to the Air Force in October 2000. A large KC-135 main landing gear part was sputter aluminum coated on the inside, and IVD aluminum coated on the outside during this demonstration. Upon successful completion of the demonstration, the

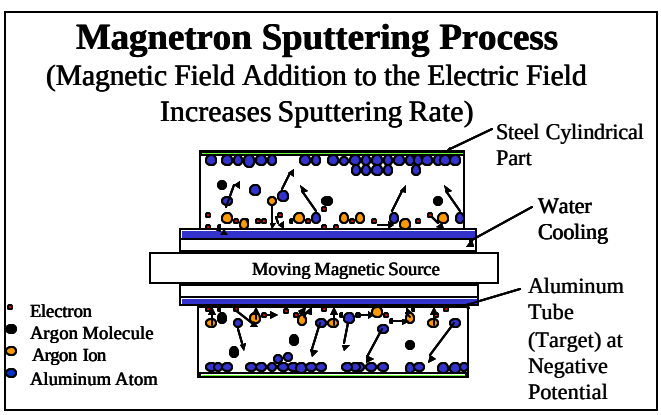


**Figure 3. Basics of Magnetron Sputtering**

decision was made by the Air Force to have this "Plug & Coat" sputter system installed in an IVD coater at Hill AFB.

After the sputter aluminum equipment was updated with lessons learned from the Boeing - St. Louis demo, the sputter aluminum equipment was installed into an existing IVD aluminum coater chamber that is located at Hill AFB, Utah (see Figure 5). The ultimate goal of this project was to have a combined sputter/IVD system apply pure aluminum coatings (per MIL-DTL-83488 – Detail Specification for High Purity Aluminum Coating) on the internal surfaces of parts with the sputter equipment and on the external surfaces of parts with the IVD aluminum equipment.

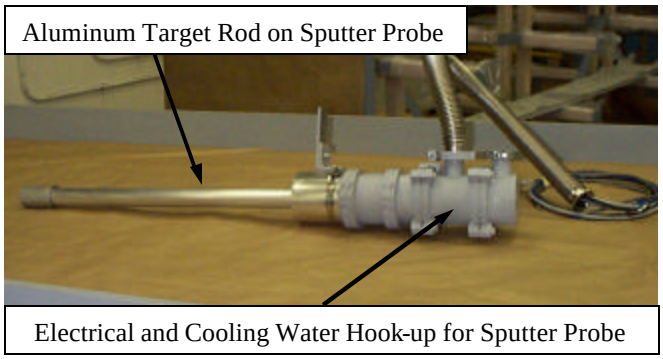


**Figure 4. Plug & Coat Sputter Probe.**

Boeing (St. Louis, MO) and Marshall Laboratories (Boulder, CO) installed the sputter aluminum equipment at Hill AFB. Boeing's extensive experience with IVD aluminum coating systems and Marshall Laboratories' extensive experience with magnetron sputter coating technology formed a team that was very capable of accomplishing this project on time and under budget. After installation, the sputter equipment was thoroughly checked out and certified to meet the requirements in MIL-DTL-83488, Class 2, Type II for applying high-purity aluminum coatings onto steel parts. The basic mil spec requirements include: minimum coating thickness of 0.5 mils, bend-to-break adhesion testing, salt spray corrosion resistance of 504 hours minimum, and no detrimental effects to the high strength steel (300M alloy). The aluminum sputter coating applied with the "Plug & Coat" system had no problem meeting these requirements.


Figure 5. IVD Coater #1 at Hill AFB.

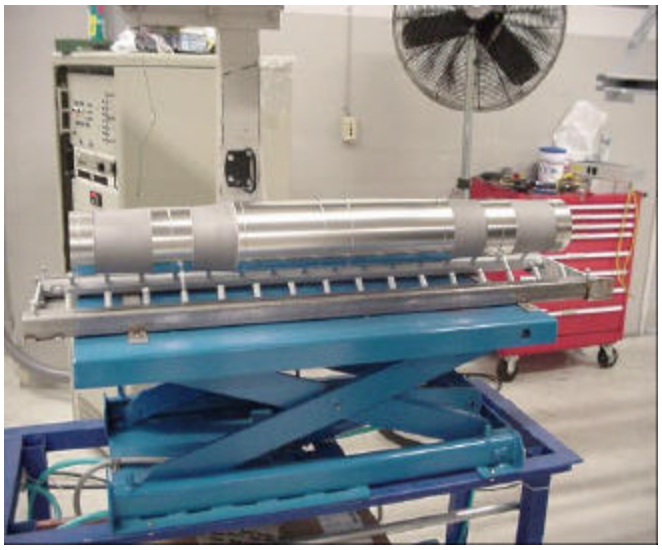

Figure 6. Chrome Plated Areas of C-17 Axle are Masked and Axle is Positioned on "Skate Board" Loading Rack.

After the equipment was certified, shop workers at Hill AFB were trained on how to operate and conduct preventive maintenance on the new sputter/ IVD coating system. The shop workers then used the sputter/IVD process to successfully coat both the internal and external surfaces of KC-135, C-17 and B-2 landing-gear axles.

To process, the "Plug & Coat" sputtering probe and part are installed in the IVD aluminum coater, the vacuum coater is evacuated to the mid $10^{-5}$ Torr range and backfilled with argon gas to a specified pressure. The part's internal surface undergoes a final reverse cleaning before it is sputter aluminum coated. Also the part's external surface is glow discharge cleaned before it is IVD aluminum coated. During cleaning the part has a negative potential applied to it. It becomes the cathode and surfaces are sputter cleaned by bombardment with argon ions removing surface gases and a minute amount of oxides.

Figures 6 through 12 show the "Plug & Coat" sputter probe in operation with an IVD coater to apply aluminum coatings to internal and external surfaces of a C-17 main landing gear axle. The axle is 46.25" long with a nominal 4" ID.

Hill AFB now has the capability to apply an environment friendly aluminum coating that meets MIL-DTL-83488 requirements to landing-gear parts

Figure 7. "Skate Board" Loading Rack with C-17 Axle is shown being slid onto IVD Rack with Sputter Probe being inserted into ID of Axle.

Figure 8. IVD Rack with C-17 Axle being loaded in IVD Coating Chamber.

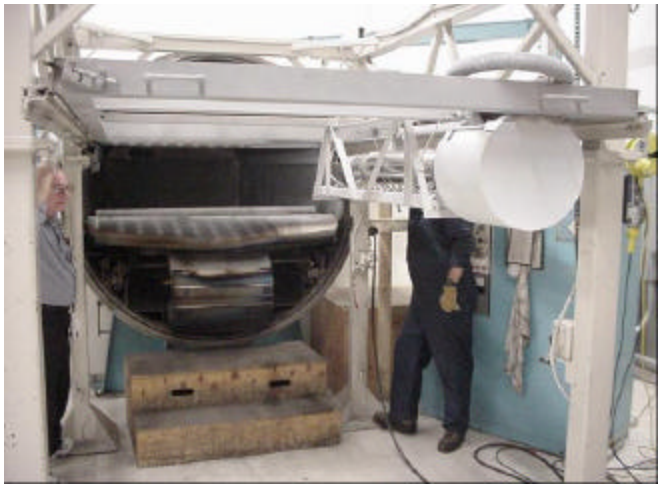

**Figure 9. Sputter Probe Utilities hooked up to Pass Through on IVD Coater. Coating Chamber Door may now be closed and coating operations can begin.**

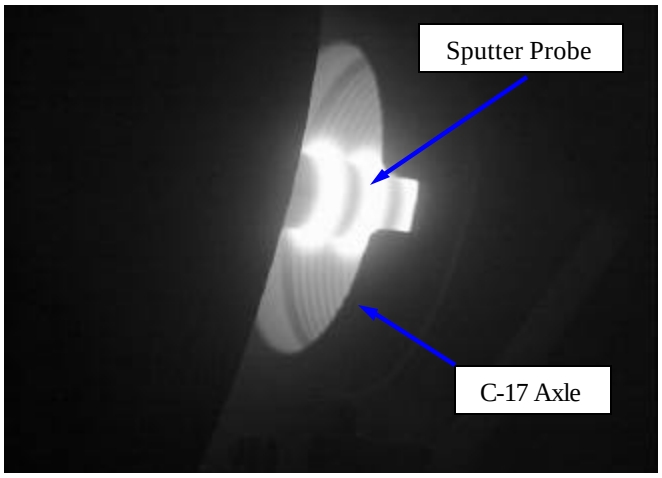


**Figure 10. C-17 Axle being sputter aluminum coated on ID surface. Rings on Sputter Probe Indicate Zones of High Magnetic Field and High Sputtering Rates.**

on both internal and external surfaces. This will allow Hill AFB to replace cadmium on parts that they could not consider in the past (such as parts with cadmium on internal surfaces).

The future for magnetron sputter coatings and "Plug & Coat" sputter probes looks promising. Plans are being developed to build a magnetron sputter chamber that applies sputter coatings to external and internal surfaces with aluminum and other metal alloys.

The possibilities are limitless with this environment friendly technology that does not pollute air or water and is safe for the shop workers that are applying these types of sputter coatings. Magnetron sputter coatings could very well be the preferred aerospace coating process of the 21st century, and has the potential of replacing the hazardous aqueous electroplating processes that have been used during the past 100 years.

***For more information contact:***
***Steve Gaydos at 314-233-3451***
***(mailto:stephen.p.gaydos@boeing.com)***
***Vernon Holmes at 314-233-8665***
***(mailto:vernon.l.holmes@boeing.com).***

**Figure 11. IVD Coating Operation underway. IVD Aluminum Evaporation Boats being passed under the C-17 Axle to apply aluminum coating to the external surfaces.**

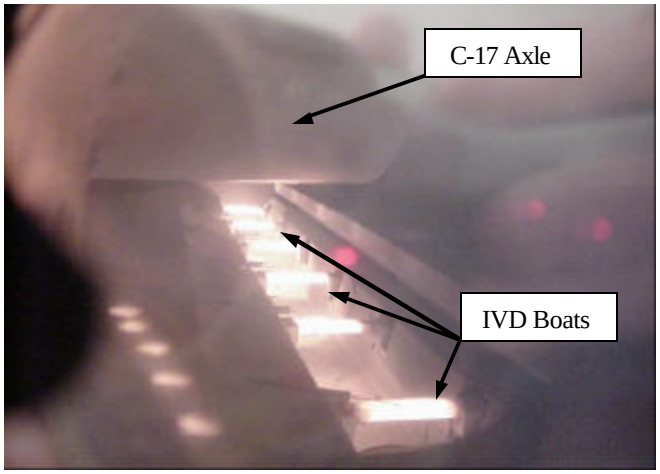


**Figure 12. C-17 Axle after sputter and IVD aluminum coatings applied being pulled from the sputter probe and off of the IVD rack.**