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ALUMINUM PLATING OF BERYLLIUM WIRE

Technological Spinoff Report

March 1973

Bendix Corporation
Kansas City, Missouri

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ALUMINUM PLATING OF BERYLLIUM WIRE

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Project Leader:
F. Clay
Department 814

Project Team:
J. C. Boley

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Technical Communications

**Kansas City
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ALUMINUM PLATING OF BERYLLIUM WIRE

Prepared by F. Clay

A fixture has been developed for the continuous plating of aluminum on 0.0005 inch diameter (120 μm) beryllium wire in a diethyl ether aluminum plating bath. Lengths of wire up to 20,000 feet (6.1 km) were plated. A total of 505,000 feet (154 km) were processed.

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SUMMARY

Static plating tests were made with short lengths of 0.005-inch (120- μ m) diameter beryllium wire to establish plating conditions. The results were used to design and build a fixture with a continuous plating capacity of about 1000 feet (300 m) of wire per week. Over 5,000 feet (1500 m) of wire were plated in this fixture. A second-generation, wire plater with a larger capacity was then designed and two were built.

The two second-generation platers were used over a seven-month period to plate 500,000 feet (150 km) of wire. Each plater has a capacity of about 15,000 feet (4.6 km) per week based on a 0.001-inch (25- μ m) thick aluminum coating. They were operated continuously and required attention for about two hours during the first shift of each day.

The experience gained with these fixtures confirms the design feasibility of a new plater with a capacity of 50,000 feet (15 km) per week.

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DISCUSSION

SCOPE AND PURPOSE

The objective of this project was to supply 500,000 feet (150 km) of aluminum-plated beryllium wire to the Sandia Laboratories Albuquerque for use in the development of metal-matrix composites. By winding the wire in a desired shape and compacting it under heat and pressure, a beryllium-reinforced aluminum structure can be produced that has a high strength-to-weight ratio. The plating was done at Bendix to take advantage of the aluminum plating process developed here under PDO 6984228.* Methods of activating beryllium for plating were studied; a prototype wire plater was designed, built, and proved out and a full-scale wire plater was designed. Two platers were built and proved out and the 500,000 feet (150 km) of wire were plated and shipped.

ACTIVITY

Study of Beryllium Activation

A naturally occurring oxide coating prevents beryllium from making direct contact with a plated metal. Direct contact is essential for a fully adherant coating. A metal coating applied over the oxide is primarily bonded to the substrate by mechanical interlocking and thus has a lower level of adhesion. Maximum adhesion was thought to be desirable, if not essential. Therefore, activation processes were studied to achieve metal-to-metal contact.

Several preplating processes were evaluated but only one gave a deposit that could not be peeled with a razor blade. The successful process involved a solvent clean followed by a reverse etch in the plating bath at 250 asf (2.7 ka/m^2) prior to plating. A fairly good bond was obtained using a 5 percent sulfuric acid etch pretreatment to roughen the surface. Chemical polish and electropolish treatments gave poor adhesion because the surface was too smooth. However, during this study, Sandia found that a mechanical bond was sufficient because it was converted to a strong, metallurgical bond during the heat and pressure cycle used to form the metal composite. The cleaning of the bare wire was therefore limited to a solvent wipe with isopropyl alcohol.

* F. A. Clay, W. B. Harding, and C. J. Stimetz, Plating, Volume 56, No. 9 (September, 1969), pp. 1027-1037.

Prototype Plater

The first Sandia order was for 5000 feet (1.5 km) of plated wire, in minimum lengths of 1000 feet, containing between 50 and 60 volume percent beryllium (0.3 km). An aluminum coating of 0.00075 to 0.001 inch (18 to 25 μm) thickness would meet the volume requirement.

A plating speed of 10 feet (3 m) per hour was selected for design purposes because it would allow a production rate of 1000 feet (300 m) each 5-day week. Since aluminum plates at about 0.001 inch (25 μm) per hour at the optimum current density of 20 asf (220 a/m^2) the plating zone had to be 10 feet (3 m) long to yield the desired production rate.

Using these operating conditions, a prototype plating fixture was designed and constructed. It was made from polypropylene, polymethyl methacrylate, and stainless steel--materials previously found to be compatible with the plating solution. In this plater the wire made four back-and-forth passes through the solution, each pass having a plating zone of 2.5 feet (0.75 m).

Each back-and-forth pass zone had its own cathode contact and anode and was powered by a separate rectifier, allowing individual current control. The cathode contact was a small stainless steel rod that rubbed lightly against the side of the wire. A variable speed motor located outside the glove box and connected through a flexible drive shaft to a take-up pulley in the glove box was used to pull the wire through the plating bath.

This fixture was built (Figure 1), placed in a dry nitrogen atmosphere glove box, and filled with plating solution. The plating bath was a diethyl ether solution* containing a 3.4-molar concentration of aluminum trichloride and 0.45-molar concentration of lithium aluminum hydride. Plating tests of one-half to two-hour durations were run to determine the maximum wire speed and current density that could be used. These indicated that the best plating current density was between 20 and 40 asf (220 and 440 a/m^2) and the maximum wire speed was 12 feet per hour (67 mm/s). During these tests periodic reverse current and superimposed ac on dc were evaluated in the first cell to determine if they improved the smoothness of the plate. Both techniques resulted in a slight, but not significant, improvement and were not used during subsequent runs.

* F. A. Clay, W. B. Harding, and C. J. Stimetz, Plating, Volume 56, No. 9 (September, 1969), pp. 1027-1037.

Experience with the fixture revealed several problems. The aluminum trichloride in the atmosphere of the glove box attacked the bare beryllium wire causing etching and breaking. This was overcome by enclosing both the plated and bare wire spools in polyethylene bags that were continuously purged with nitrogen. The original design of this fixture did not allow for rinsing the wire after plating, and the level-wind wire guide caused wire breakage as a result of excessive abrasion. These problems were solved by replacing the metal wire guide with a test tube clamp wrapped with a cloth. The plated wire was pulled through the clamp while the cloth was continually saturated with ether under controlled flow from a reservoir. The excess ether dripped into the plating solution. This technique both rinsed the wire after plating and helped make up ether evaporations from the plating solution.

After prove-in was completed, 5000 feet (1.5 km) of wire were run in five segments. The fixture was operated continuously but was attended during the first shift only.

Production Plater

After the above order was completed, a request was received for an additional 500,000 feet (150 km) plated with 0.0002 inch (5 μ m) of aluminum. Filling this order in a reasonable time required a larger capacity fixture. A figure of 25,000 feet (7.5 km) per week was selected as a reasonable production rate. A new fixture (Figures 2 and 3) was designed using these values. This fixture incorporated the modifications made to the original plater and several design changes to improve operation and increase capacity.

In the new design, the polyethylene bags covering the spools were replaced with polymethyl methacrylate boxes. Like the bags, they incorporated a nitrogen purge but the wire was more accessible. The bare-wire spool holder was changed so that it would accept the manufacturer's spool. Previously, the bare wire had to be transferred from the manufacturer's spool to a small plastic spool before it was loaded into the fixture. The changes eliminated one operation and increased the length of wire available to the fixture from 1000 feet (0.3 km) to 40,000 feet (12 km). The take-up spool was made larger so that it would hold up to 20,000 feet (6 km) of plated wire.

Also, the plating zone was lengthened to 5 feet (1.5 m) for each pass, and the reversing pulleys were located at different elevations to allow two passes of wire through a single zone. This increased the plating capacity of the fixture without changing its width. Width is important when working in a glove box since the ability to reach to thread the fixture is limited. Seven 5-foot (1.5 m) zones were obtained in a fixture having four sets of anodes and of the same width as the prototype.

In other changes the reversing pulleys were made from stainless steel having a carbon bushing and were used as the cathode contacts. This lessened the frictional drag on the wire and, since the pulleys were located further from the plating zone, reduced deposit build-up on the contact. The wire guide on the level wind system was changed from a cloth-wrapped test tube clamp to a carbide pin guide with attached felt pads. This allowed good ether rinsing of the wire after plating and reduced the frictional drag on the wire. Also, the felt pads could be changed more quickly than the cloth.

Finally, a tight-fitting, three-piece plating tank cover was added to reduce ether evaporation losses.

Large Order Production

A temporary facility using two glove boxes and two plating fixtures was set up so that the order could be filled in a minimum time. During the prove-in of these fixtures, it was found that a 0.0002-inch ($5\text{ }\mu\text{m}$) aluminum coating on the uncleaned wire was not continuous, so the Sandia order was changed to a thicker coating that was continuous [0.001-inch ($25\text{-}\mu\text{m}$)]. The best plating current density was still between 20 and 40 asf (200 and 400 c/m^2), but the wire speed was about four times greater because of the longer plating zone.

Two serious problems were encountered during the early production runs. One was improper design of the level winder; the other was excessive wire breakage.

The original level winder had a harmonic rather than a linear motion causing the plated wire to pile up at the edges of the take-up spool. Such tangling and snarling had not been encountered on the prototype unit because 1000 feet (300 m) of wire was not of sufficient bulk to cause trouble. The problem was corrected by replacing the designed system with an inexpensive fishing reel driven by rubber O-rings. The take-up spools were also changed at this time to match the winding width of the reels. Good level winding was obtained using this system.

The first shipment of bare wire from Sandia had brown Kraft paper between each layer of wire. Earlier material had not been interleaved, so no design allowances had been made for this condition. As the wire ran out on one layer, the paper had to be removed to expose the next layer of wire. Wire breakage frequently occurred when the paper was allowed to unreel unattended. Since bare wire will break under tension at about 2.5 pounds and will fail under shear at much lower values, it was common for the paper to hang up enough to break the wire. This problem was solved in the interim by manually aiding the removal of the paper, but the final solution was obtaining wire without interleaved paper.

After the aforementioned problems were solved, only an occasional fixture malfunction or a weak spot in the bare wire caused breakage. These problems were not serious and most of the plated lengths were 5000 feet (1.5 km) or more. These fixtures now appear capable of plating 15,000 feet (4.6 km) of wire per week while requiring only 10 to 15 man hours of attention. Larger capacity fixtures could be designed if desired.

ACCOMPLISHMENTS

A plating fixture was developed that allows continuous plating of 0.005-inch (120 μ m) diameter beryllium wire. A total of 505,000 feet (154 km) was plated.

Methods of activating beryllium for aluminum plating were investigated. Reverse etching in the plating bath produced the best plating bond. Plating adherence adequate for this application was obtained without pre-cleaning.

FUTURE WORK

Future work on this project depends on the successful application of beryllium-aluminum composites. If this system finds an application, scale up to a production operation will be possible.

Figure 1. Prototype Plater

Figure 2. Diagram of Production Plating Fixture

Figure 3. Production Plating Fixture