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COPPER PLATING THE GROUND TEST ACCELERATOR RFQ

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Abstract

The copper-plating process for the Ground Test Accelerator (GTA) radio frequency quadrupole (RFQ) vanes required a full development program and tight quality control procedures. The copper plating development program utilized full-size RFQ major and minor vane mockups to develop plating fixturing and to establish the plating parameters necessary to meet the GTA RFQ plating specifications. After several modifications to the fixturing and plating processes, the mockup vanes were copper plated to GTA specifications and the actual GTA RFQ could then be copper plated. This development technique, using full-size mockups for establishing reliable and accurate plating fixtures and proven plating processes, is the key to success for copper-plating any special piece of technical and expensive hardware. This paper discusses the GTA RFQ copper-plating critical issues; the plating-fixture development; the copper-plating processes; RFQ plating specifications as they apply to thickness, uniformity, and adhesion; and the quality assurance procedures.

I. INTRODUCTION

The Ground Test Accelerator (GTA) Radio Frequency Quadrupole (RFQ) was successfully copper plated through a joint effort of the Los Alamos National Laboratory (hereafter refered to as the University of California) and the Industrial Plating Company, Seattle, Washington.

The GTA RFQ is a 50-mA cryogenically cooled rf accelerator with an exit-beam energy of 2.5 MeV. The aluminum core tank design, of eight major vane / minor vane segments, allows for simplified assembly. The core tank is 2.794 m in length. There are two longitudinal sections of approximately 1.397m each and four transverse sections (see Fig. 1). The RFQ vanes were machined by the Mechanical and Electronics Support Division (MEC), at the University of California from thick 2219 T851 aluminum plate. This material was chosen for its high strength, stability during machining, and its excellent weldability [1]. The vane segments are bolted together transversely, with dowel pins between the major and minor vanes to ensure precision section-to-section alignment.

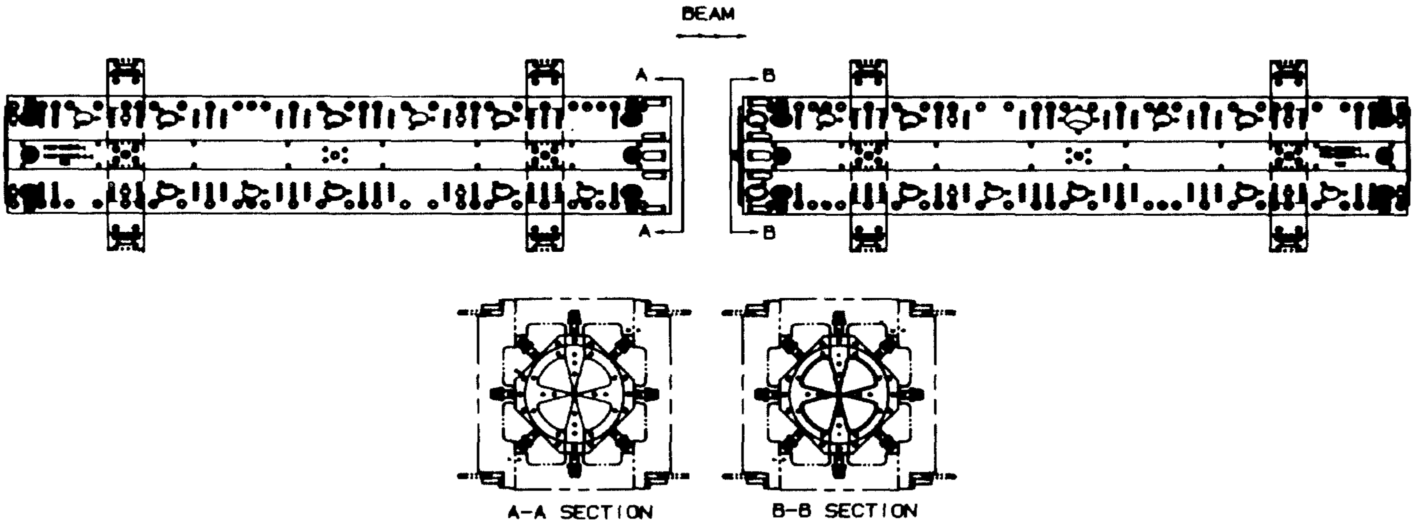
The GTA RFQ was copper plated using the UDYLITE Bright Acid Copper High Speed (UBAC-HS) Bath Process. This paper will focus on the GTA RFQ copper-plating requirements, the plating development program, the final plating results, and quality assurance.

II. GTA RFQ PLATING CRITICAL ISSUES

A critical issue that required special consideration was the handling of the RFQ vanes, because of their delicacy and extreme complexity. Specific handling and shipping instructions had to be devised to ensure that the vanes would not be damaged in any way. For a representation of the RFQ core tank assembly before plating (see Fig. 2).

Other critical issues included determining the technical plating specifications and the finished product plating requirements; and establishing quality assurance procedures to meet final inspection requirements.

The technical plating specifications pertain to the thickness and uniformity of the plating, and were defined on two levels: those for critical and those for noncritical surfaces. The thickness and uniformity specification for the critical



A-A SECTION

B-B SECTION

Figure 1. GTA RFQ core tank.

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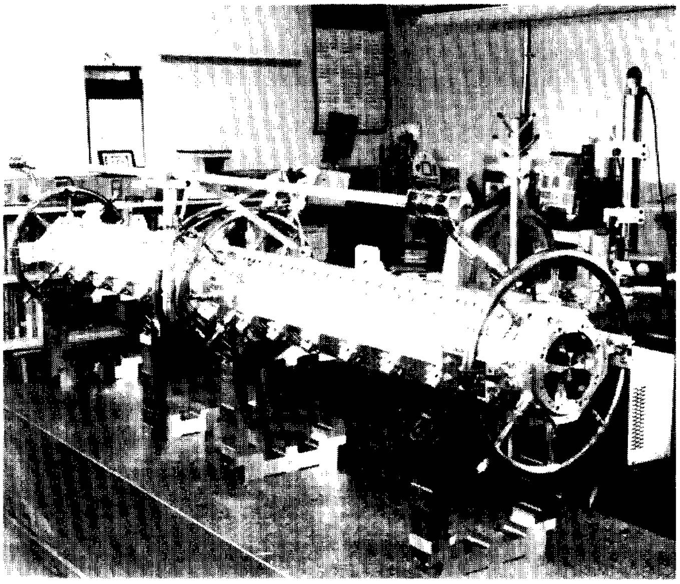

Figure 2. RFQ core tank assembly before plating.

surfaces was 0.001 in. ±0.0003 in., and that for noncritical surfaces was 0.001 in ±0.0005 in. Those surfaces not requiring plating were masked.

The finished product plating requirements were stringent on surface finish thickness and uniformity. The surface finish of the copper plating was specified to be no worse than the substrate finish before plating, which was approximately a 50 μ in. finish. Small nodules, fines, steps, roughness, or other defects on critical vane surfaces potentially arising from the plating processes were specified unacceptable.

Quality Assurance (QA) procedures were established and implemented to assure compliance with the specifications and requirements during copper electroplating and delivery of the components. A major goal of this QA program was to generate and maintain a permanent record of compliance.

III. GTA RFQ PLATING DEVELOPMENT PROGRAM

To ensure that the RFQ copper plating specifications and requirements could be met, we set up a plating development program to qualify a fixture and a process for copper plating the RFQ vanes. Full-size mockups of both the major and minor vanes were copper plated and used to verify compliance with all plating specifications. These mockup vanes were also used as development models to verify correct anode and cathode configurations and placements with respect to the specific vane contours and porthole locations required for plating (see Fig. 3). Next, a plating fixture was developed that combined correct placement of both anode and cathode arrangements, and served as a handling fixture to for transfering the vanes from one bath to another.

Finally, we developed the precise bath parameters and characteristics: plating solution mixtures, bath temperatures, electroplating power settings, and time in baths.

The UDYLITE UBAC 2X Acid Copper Plating Process is a bright acid copper bath for the deposition of a brilliant, ductile copper plate. The outstanding advantages of the deposit are its high brightness, excellent leveling, and exceptional ductility. This deposit has practically the same ductility as a deposit from a pure acid copper solution free from addition agents. More important, the UBAC 2X Acid Copper Process has the ability to produce this finely leveled and ductile plate continuously in heavy production, because no harmful breakdown products are formed during electrolysis. The excellent leveling is very important, because the specific radio frequency (rf) requirements do not allow polishing and/or buffing of the surface.

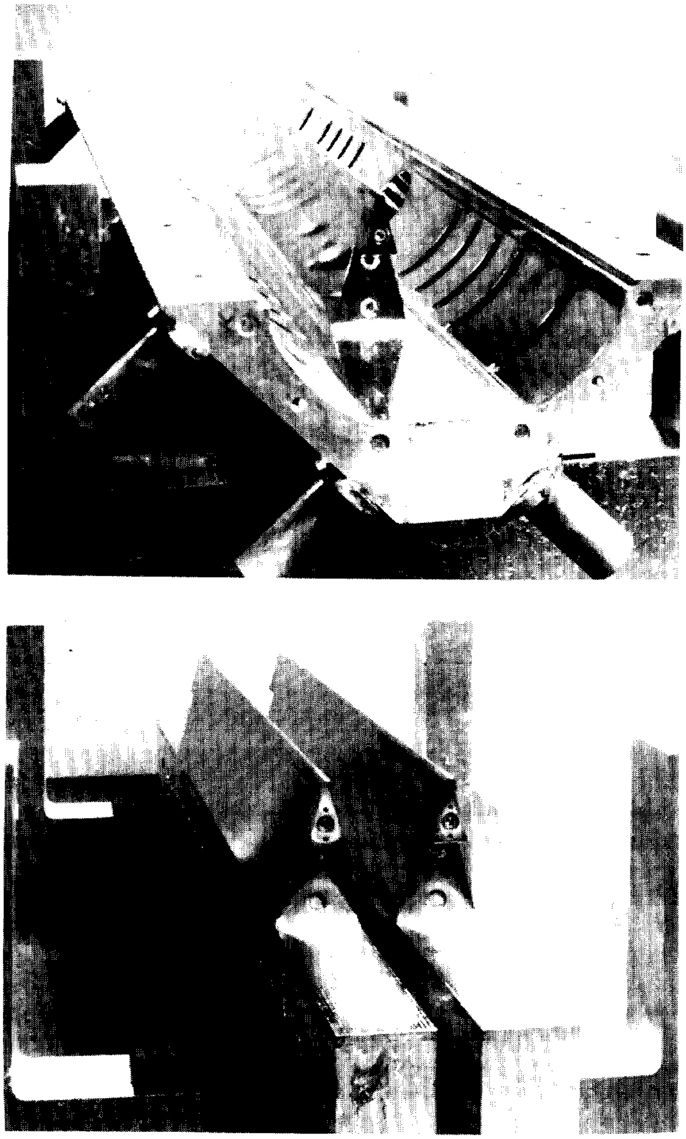

Figure 3. RFQ major and minor vane mockups.

Before plating, an anode was placed in the slug tuner port of the major vanes to ensure that the port hole would be uniformly copper plated. The current density settings required to plate the minor vanes were approximately 22 Amp/in. at 0.001 in./hr., and for the major vanes, approximately 44 Amp/in. at 0.001 in./hr.

The main steps in the copper plating sequence of the vanes were as follows excluding details such as cleaning, rinsing, and plating preparation:

1. The vanes were cleaned with soap and mild cleanser to get rid of water brake on the surface.
2. The vanes were dipped in an actane solution for preparation and activation of aluminum pores.

3. The vanes were dipped in 50% nitric acid to eliminate foreign contaminants on the aluminum surface.
4. The vanes were given a 10-second zincate dip to increase surface adhesion properties.
5. The vanes were dipped in 50% nitric acid for removal of excess zincate.
6. Again, the vanes were dipped in zincate for approximately 40 seconds.
7. The vanes were dipped into an electrolysis nickel bath until a thickness of approximately 0.0002 in had been deposited.
8. The vanes were put through a copper strike process, again for a thickness of approximately 0.0002 in.
9. The vanes were rinsed with pumice to remove excess copper strike.
10. Next, the vanes were dipped in 10% sulfuric acid to reactivate the copper.
11. Finally, the vanes were put into a bright acid copper dip of approximately 20 minutes for minor vanes, and approximately 40 minutes for the major vanes.

Only after acceptance of the mockup plating to the specified requirements were the actual RFQ vanes copper plated. The actual plating took place immediately after mockup plating acceptance, to ensure correct plating bath parameters and characteristics.

IV. QUALITY ASSURANCE PROCEDURES

The thickness and uniformity of the copper plating on the vanes was measured using two different techniques. Our first measuring technique was the standard one for coating thickness, which uses the BETA backscatter principle. This technique can be used to measure the thickness of any coating having an atomic number sufficiently different from that of the substrate material. The maximum measurable thickness for a given coating is that thickness beyond which the intensity of the backscattered radiation is no longer sensitive to small changes in thickness. This technique can also be used to determine the mass of a coating per unit of area. When calibrated under specified operating conditions, the instrument measures the coating thickness to within an accuracy of 10 percent of its true thickness.

The other measuring technique uses the DEA coordinate measuring machine (CMM) and a master set of dowel pins located in the back of each vane. CMM data from initial, pre-plating inspection of the vanes was stored and later compared with data for the plated vanes. The difference between the two gives an accurate representation of the plating thickness.

The surface finish was inspected using a portable surface profilometer. The surface finish of the plated vanes was specified to be no worse than the substrate finish before plating.

Adhesion of the copper plate to the vane surface was specified as a metallurgical bond with the substrate material. Tests were conducted to verify compliance with this specification using the mockups and component adhesion test coupons. An "X" 1 in. high was scribed on the copper plating on the upper half of each coupon, penetrating the plating to verify that the substrate material was clearly visible. At the points formed by the intersecting lines of the "X", several attempts were made to separate the copper plating from the substrate material by prying and gouging with a sharp pointed instrument. In addition, adhesion was checked by bend tests. Any separation of the copper plating from the substrate material during either type of test would have been cause for rejection of the plated mockups.

V. CONCLUSIONS

The copper plating process described in this paper was shown to be workable and to produce accurate results (see Fig. 4).

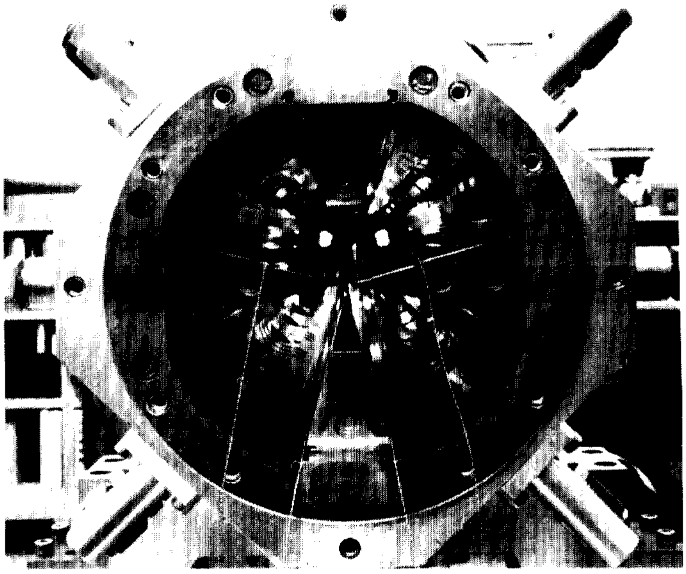

Figure 4. RFQ copper plated.

The plating was well within the tolerance of 0.001 ± 0.0003 in. on the vane tips, and 0.001 ± 0.0005 in. on noncritical surfaces. The uniformity and thickness results are tabulated in Fig. 5.

Minor Vanes:

$\overline{x}$(VD1) = 0.0009 in. s(VD1) = 0.0003 in.
$\overline{x}$(VU1) = 0.0010 in. s(VU1) = 0.0002 in.
$\overline{x}$(VU3) = 0.0011 in. s(VU3) = 0.0001 in.
$\overline{x}$(VD3) = 0.0010 in. s(VD3) = 0.0002 in.

Major Vanes:

$\overline{x}$(VD4) = 0.0010 in. s(VD4) = 0.0002 in.
$\overline{x}$(VU4) = 0.0010 in. s(VU4) = 0.0001 in.
$\overline{x}$(VU2) = 0.0013 in. s(VU3) = 0.0002 in.
$\overline{x}$(VD2) = 0.0012 in. s(VD2) = 0.0003 in.

Figure 5. RFQ Plating Results

VI. REFERENCES

[1] Nathan K. Bultman, "Mechanical Fabrication Aspects of the GTA RFQ", *1990 Neutral Particle Beam Technical Symposium*, San Diego, CA (May, 1990).