Manufacturing

Treatments To Produce Stabilized Aluminum Mirrors for Cryogenic Uses

Selected heat treatments are performed between and after fabrication steps.

Goddard Space Flight Center, Greenbelt, Maryland

Five metallurgical treatments have been tested as means of stabilizing mirrors that are made of aluminum alloy 6061 and are intended for use in cryogenic applications. Aluminum alloy 6061 is favored as a mirror material by many scientists and engineers. Like other alloys, it shrinks upon cool-down from room temperature to cryogenic temperature. This shrinkage degrades the optical quality of the mirror surfaces. Hence, the metallurgical treatments were tested to determine which one could be most effective in minimizing the adverse optical effects of cool-down to cryogenic temperatures. Each of the five metallurgical treatments comprises a multistep process, the steps of which are interspersed with the steps of the mirror-fabrication process. The five metallurgical-treatment/fabrication— process combinations were compared with each other and with a benchmark fabrication process, in which a mirror is made from an alloy blank by (1) symmetrical rough machining, (2) finish machining to within 0.006 in. (≈ 0.15 mm) of final dimensions, and finally (3) diamond turning to a mirror finish. Two specimens — a flat mirror and a spherical mirror — were fabricated in each case. The blanks for all the specimens were cut from the same plate of aluminum alloy 6061-T651. (The suffix "T651" denotes a stress-relieving treatment that involves reducing residual stresses by mechanical stretching of the previously untreated alloy.) Of the five metallurgical-treatment/fabrication-process combinations tested, the one found to exert the greatest stabilizing effect comprises the following ten steps:

1. Rough machining.
2. Solution heat treatment at a temperature of 985 °F (≈ 529 °C).
3. Quench within 15 s in a solution of 28 percent UCON Quenchant A (or an equivalent aqueous quenching liquid) at a temperature of 90 °F (≈ 32 °C).
4. Uphill quench: Allow to reach room temperature, slowly dip into a tank of liquid nitrogen followed by rapid immersion in a tank of boiling water.
5. Age at 350 °F (≈ 177 °C).
6. Finish machine leaving about 0.006 in. (0.15 mm) for polishing.
7. Age again as in step 5.
8. Three thermal cycles with heating and cooling rates not to exceed 3 °F/min (1.7 °C/min) as follows: Cool to -310 °F (-190 °C), hold for 30 min, heat to room temperature, hold for 15 min, heat to 300 °F (150 °C), hold for 15 minutes, and cool to room temperature.
9. Diamond turning/polishing.
10. Three thermal cycles as in step 7.

Separate tests showed that forged AL6061 with the same processing method would yield slightly better mirrors than those made from AL6061-T651 plates.

This work was done by Wahid Zewari, Michael Barthelmy, and Raymond Ohl of **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Goddard Space Flight Center, (301) 286-7351. Refer to GSC-14736-1.

Making AlN_x Tunnel Barriers Using a Low-Energy Nitrogen-Ion Beam

Ion-beam parameters can be controlled to optimize properties of AlN_x layers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A technique based on accelerating positive nitrogen ions onto an aluminum layer has been demonstrated to be effective in forming thin (<2 nm thick) layers of aluminum nitride (AlN_x) for use as tunnel barriers in Nb/Al-AlN_x/Nb superconductor/insulator/superconductor (SIS) Josephson junctions. AlN_x is the present material of choice for tunnel barriers because, to a degree greater than that of any other suitable material, it offers the required combination of low leakage current at high current density and greater thermal stability.

While ultra-thin AlN films with good thickness and stoichiometry control are easily formed using techniques such as reactive molecular beam epitaxy and chemical vapor deposition, growth temperatures of 900 ºC are necessary for the dissociative adsorption of nitrogen from either nitrogen (N_2) or ammonia (NH_3). These growth temperatures are prohibitively high for the formation of tunnel barriers on Nb films because interfacial reactions at temperatures as low as 200 to 300 ºC degrade device properties. Heretofore, deposition by reactive sputtering and nitridation of thin Al layers with DC and RF nitrogen plasmas have been successfully used to form AlN barriers in SIS junctions. However, precise control over critical current density J_c has proven to be a challenge, as is attaining adequate process reproducibility from system to system.

The present ion-beam technique is an alternative to the plasma or reactive sputtering techniques as it provides a highly controlled arrival of reactive species, independent of the electrical conditions of the substrate or vacuum chamber. Independent and accurate control of parameters such as ion en-