

preferentially react with oxygen from the ruthenium oxide, and not oxygen from the environment.

Nanoparticulate iridium black and anhydrous ruthenium oxide are weighed out and mixed to 5–18 atomic percent. They are then heat treated at 300 °C under flowing argon (in order to create an inert environment) for a minimum of 14 hours. This temperature was chosen because it is approximately the creep temperature of ruthenium oxide, and is below the sintering temperature of both materials. In general, the temperature should always be below the sintering temperature of both materials. The iridium-doped ruthenium oxide catalyst is

then fabricated into a PEM-based membrane-electrode assembly (MEA), and then mounted into test cells.

The result is an electrolyzer system that can sustain electrolysis at twice the current density, and at the same efficiency as commercial catalysts in the range of 100–200 mA/cm². At 200 mA/cm², this new system operates at an efficiency of 85 percent, which is 2 percent greater than commercially available catalysts. Testing has shown that this material is as stable as commercially available oxygen evolution catalysts. This means that this new catalyst can be used to regenerate fuel cell systems in space, and as a hydrogen generator on Earth.

This work was done by Thomas I. Valdez, Sri R. Narayan, and Keith J. Billings of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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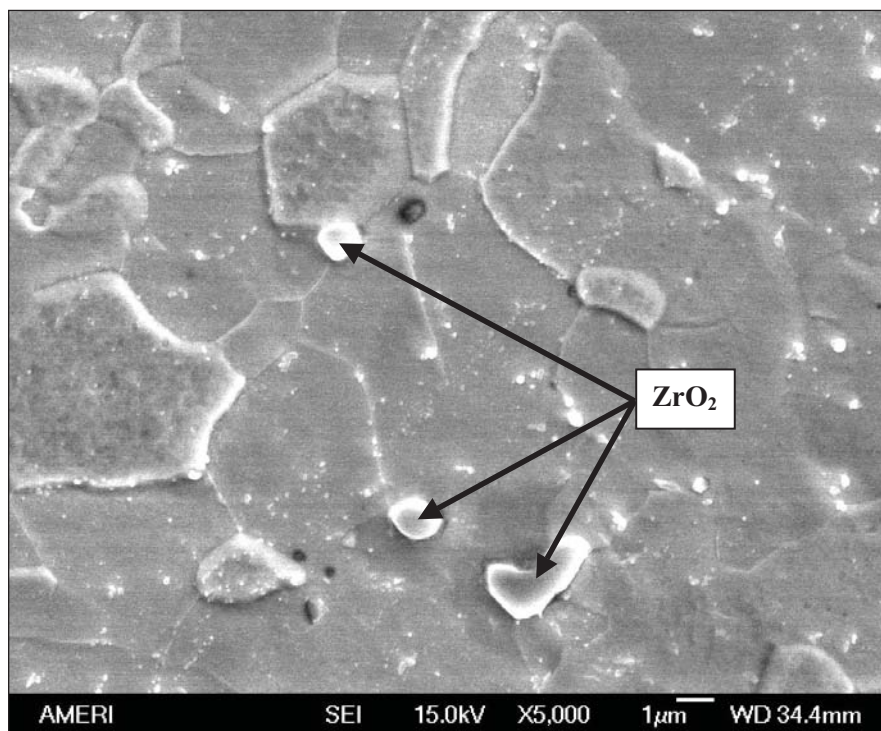
Improved Mo-Re VPS Alloys for High-Temperature Uses

Transition-metal ceramic dispersoids improve high-temperature properties.

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Dispersion-strengthened molybdenum-rhenium alloys for vacuum plasma spraying (VPS) fabrication of high-temperature-resistant components are undergoing development. In comparison with otherwise equivalent non-dispersion-strengthened Mo-Re alloys, these alloys have improved high-temperature properties. Examples of VPS-fabricated high-temperature-resistant components for which these alloys are expected to be suitable include parts of aircraft and spacecraft engines, furnaces, and nuclear power plants; wear coatings; sputtering targets; x-ray targets; heat pipes in which liquid metals are used as working fluids; and heat exchangers in general. These alloys could also be useful as coating materials in some biomedical applications.

The alloys consist of 60 weight percent Mo with 40 weight percent Re made from (1) blends of elemental Mo and Re powders or (2) Re-coated Mo particles that have been subjected to a proprietary powder-alloying-and-spheroidization process. For most of the dispersion-strengthening experiments performed thus far in this development effort, 0.4 volume percent of transition-metal ceramic dispersoids were mixed into the feedstock powders. For one experiment, the proportion of dispersoid was 1 volume percent. In each case, the dispersoid consisted of either ZrN particles having sizes <45 μm, ZrO₂ particles having sizes of about 1 μm, HfO₂ parti-



This Scanning Electron Micrograph of a dispersion-strengthened specimen shows ZrO₂ particles at grain boundaries of the Mo-Re alloy.

cles having sizes <45 μm, or HfN particles having sizes <1 μm. These materials were chosen for evaluation on the basis of previously published thermodynamic stability data. For comparison, Mo-Re feedstock powders without dispersoids were also prepared.

Tubular alloy specimens were fabricated by VPS onto rotating graphite

mandrels as follows: In each case, the VPS chamber was evacuated, then the rotating graphite mandrel was preheated by the plasma spray gun. Once the desired preheat temperature was reached, one of the powders prepared as described above was made to flow to the gun, causing the alloy to be deposited on the mandrel. [A nearly iden-

tical process for fabrication of tubes of non-dispersion-strengthened Mo-Re tubes was described in "High-Temperature Crystal-Growth Cartridge Tubes Made by VPS" (MFS-31540), *NASA Tech Briefs*, Vol. 32, No. 11 (November 2008, page 54).] Immediately after VPS and before removal from the VPS chamber, the deposit and mandrel were cooled under a partial pressure of argon. After removal from the chamber, the mandrel was mechanically removed, leaving the tubular specimen.

The specimens were subjected to aging/grain-growth tests and to both room-temperature and elevated-temperature tensile tests. The conclusions drawn from the test results include the following:

- It is possible, by use of VPS, to fabricate Mo-Re alloys of the type in question to

nearly net size and shape, having densities greater than 97 percent of the theoretical maximum.

- Microscopic examination of samples that had been aged at a temperature of 1,800 °C for 8 hours showed that average grain sizes in the samples containing dispersoids were significantly less than those of the samples that did not contain dispersoids. This result was interpreted as signifying that the dispersoids pinned Mo-Re grain boundaries (see figure) and thereby reduced grain growth.
- Room- and elevated-temperature tensile tests of two of the dispersion-strengthened alloys and of the corresponding nondispersion-strengthened alloys showed that dispersion strengthening afforded significant improvements in mechanical properties:
 - Dispersion strengthening did not

cause a decrease in room-temperature elongation.

- The elevated-temperature ultimate tensile strengths of the dispersion-strengthened alloys were between 16 and 18 percent greater than those of the non-dispersion-strengthened alloys.
- The room-temperature mechanical properties of the dispersion-strengthened alloys equaled or exceeded previously published values for alloys comprising 60 weight percent of Mo with 40 weight percent of Re.

This work was done by Robert Hickman and James Martin of Marshall Space Flight Center and Timothy McKechnie and John (Scott) O'Dell of Plasma Processes, Inc. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32581-1.