total cost of the system described here was less than $1,000 (at the time of this reporting). It has been in operation for 4.5 years with no maintenance or drying. The last test of the system indicated the gas moisture level was less than 2 ppm, with a dew point of less than –97 ºF (–72 ºC). Before the line dryers were installed, the inlet gases had a moisture rating of 15 ppm. With the installation of a one-canister system, the inert gas moisture level dropped to 3 ppm. When a two-canister system was installed, the inert gas moisture level dropped to 0.7 ppm.

These two pipeline dryers also act as a mixing chamber for both argon and helium gases, which is crucial for applications of certain critical welding processes. This innovation is applicable to any process or system that requires a reduction of any inert gas moisture level (in ppm). It may also be used in any process or system, such as avionics, that uses inert gases with a low moisture level requirement of 1 ppm or lower, depending on the cubic feet per minute (CFM) flow rate.

This work was done by Jerry Goudy of United Space Alliance for Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13189

Fabricating Copper Nanotubes by Electrodeposition

Relative to copper nanorods, copper nanotubes can be fabricated at lower cost.

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Copper tubes having diameters between about 100 and about 200 nm have been fabricated by electrodeposition of copper into the pores of alumina nanopore membranes. Copper nanotubes are under consideration as alternatives to copper nanorods and nanowires for applications involving thermal and/or electrical contacts, wherein the greater specific areas of nanotubes could afford lower effective thermal and/or electrical resistivities. Heretofore, copper nanorods and nanowires have been fabricated by a combination of electrodeposition and a conventional expensive lithographic process. The present electrodeposition-based process for fabricating copper nanotubes costs less and enables production of copper nanotubes at greater rate.

The demonstration of this process began with the selection of alumina membranes containing pores having diameters in the approximate range of 100 to 200 nm. The estimated porosity of these membranes was 43 percent. Each of these membranes was evaporation-coated on one side with a 100-nm-thick gold film to render that side electrically conductive. Each membrane was then mounted on a gold-coated silicon substrate by use of adhesive tape, and the substrate was carefully masked with tape to prevent electrodeposition on the substrate. Next, the membrane-and-substrate unit was immersed for about 10 minutes in a solution comprising 4 volume parts of water and 1 volume part of a potassium-based, buffered developer solution commonly used in lithography. The purpose and effect of this immersion was to render the surfaces of the pores electrically conductive.

Next, electrodeposition into the pores was performed at room temperature in a commercially available copper-plating solution, using platinum-coated titanium mesh counter electrodes and galvanostatic control set to a current density of, variously, 10 or 20 mA/cm^2. Copper nanotubes were thus formed in the pores at a deposition rate of 100 nm/min at the current density of 10 mA/cm^2 or 150 nm/min at the current density of 20 mA/cm^2.

This work was done by E. H. Yang, Christopher Ramsey, Youngsam Bae, and Daniel Choi of Caltech for NASA's Jet Propulsion Laboratory.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL. Refer to NPO-42261.