Manufacturing & Prototyping

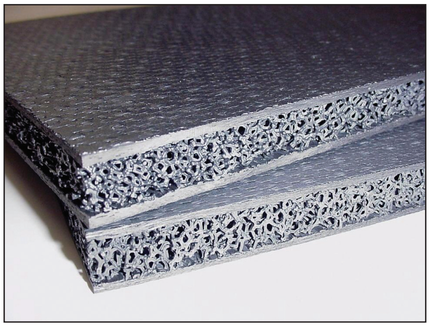
Improved Fabrication of Ceramic Matrix Composite/Foam Core Integrated Structures

CMC face sheets bonded to ceramic foam cores are delamination-resistant and reduce cost, weight, and maintenance.

John H. Glenn Research Center, Cleveland, Ohio

The use of hybridized carbon/silicon carbide (C/SiC) fabric to reinforce ceramic matrix composite face sheets and the integration of such face sheets with a foam core creates a sandwich structure capable of withstanding high-heat-flux environments (150 W/cm^2) in which the core provides a temperature drop of 1,000 °C between the surface and the back face without cracking or delamination of the structure. The composite face sheet exhibits a bilinear response, which results from the SiC matrix not being cracked on fabrication. In addition, the structure exhibits damage tolerance under impact with projectiles, showing no penetration to the back face sheet. These attributes make the composite ideal for leading-edge structures and control surfaces in aerospace vehicles, as well as for acreage thermal protection systems and in high-temperature, lightweight stiffened structures.

By tailoring the coefficient of thermal expansion (CTE) of a carbon fiber-containing ceramic matrix composite (CMC) face sheet to match that of a ceramic foam core, the face sheet and the core can be integrally fabricated without any delamination. Carbon and SiC are woven together in the reinforcing fabric. Integral densification of the CMC and the foam core is accomplished with chemical vapor deposition, eliminating the need for bond-line adhesive. This means there is no need to separately fabricate the core and the face sheet, or to bond the two elements together, risking edge delamination during use.


The **Foam Core Ceramic Matrix Composite** is a weave SiC and carbon fiber, which allows heat dissipation in-plane. Face sheet thickness is nominally 2.4 mm, and core thickness is 1.26 cm.

Fibers of two or more types are woven together on a loom. The carbon and ceramic fibers are pulled into the same "pick" location during the weaving process. Tow spacing may be varied to accommodate the increased volume of the combined fiber tows while maintaining a target fiber volume fraction in the composite. Foam pore size, strut thickness, and ratio of face sheet to core thickness can be used to tailor thermal and mechanical properties. The anticipated CTE for the hybridized composite is managed by the choice of constituents, varying fiber tow sizes and constituent part ratios.

This structural concept provides high strength and stiffness at low density — 1.06 g/cm^3 in panels tested. Varieties of face sheet constructions are possible, including variations in fiber type and weave geometry. The integrated structures possible with this composite could eliminate the need for non-load-bearing thermal protection systems on top of a structural component. The back sheet can readily be integrated to substructures through the incorporation of ribs. This would eliminate weight and cost for aerospace missions.

This work was done by Frances I. Hurwitz of Glenn Research 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 NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18126-1.

Inert Welding/Brazing Gas Filters and Dryers

This system can be used in any process requiring reduction of inert-gas moisture level.

John F. Kennedy Space Center, Florida

A system has been designed to reduce the hydrogen molecule content in inert gases that are used for shielding the welding arc and molten weld area during the manual fusion, automated welding, and induction brazing process. Two desiccant pipeline dryer cartridges are connected together using either aircraft or KC .250 fittings, and are installed in-line between the inert-gas facility source (argon and helium) and the welding machine. This process helps maintain alloy grain structure and integrity to engineering specifications during the welding and brazing processes. Also, this method enhances weldability when joining similar and dissimilar alloys. It is easy to restore the system to original drying capabilities by using a nitrogen purge or by oven drying. This design has low schedule impact or down time when being installed on machines or in systems. There is also a sight glass to indicate when servicing is needed.

Reducing the moisture level in ultra-high-purity gasses also lowers costs. The 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 °F (–72 °C). 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.

NASA's Jet Propulsion Laboratory, Pasadena, California

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.