

actor, the aerosol was generated by use of an ultrasonic plate nebulizer excited at a frequency of 2.5 MHz; for the vertical-cold-wall reactor, a syringe pump delivered the solution at a rate of 1.5 mL/min to the nebulizer, wherein the aerosol was generated by use of an atomizing ultrasonic nozzle excited at a frequency of 120 kHz. In the horizontal hot-wall reactor, the portion of the wall in the evaporation zone was heated to a temperature of 130 °C, while the portion of the wall in the deposition zone was

heated to about 400 °C. In the vertical cold-wall reactor, as its name suggests, the wall was not heated; instead, the substrate was heated to 400 °C.

The CuInS<sub>2</sub> films produced in the experiments have been characterized by x-ray diffraction, scanning electron microscopy, energy-dispersive spectroscopy, and four-point-probe electrical tests. The results of these tests have provided some guidance for refinement of the spray CVD processes and for annealing and possibly other post-process steps to im-

prove the quality of the deposited CuInS<sub>2</sub> films.

*This work was done by Kulbinder K. Banger, Jerry Harris, Michael H. Jin, and Aloysius Hepp 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-17447-1.*

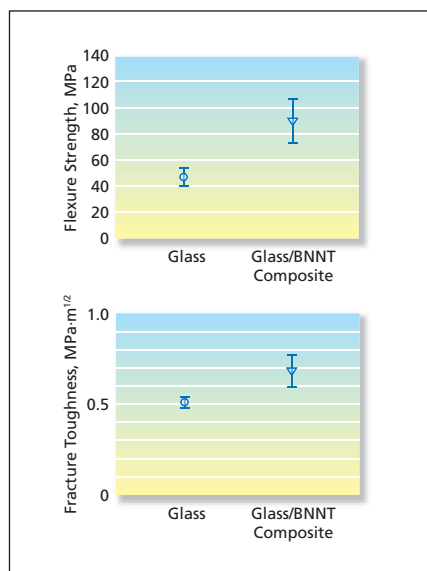
## Glass/BNNT Composite for Sealing Solid Oxide Fuel Cells

**Boron nitride nanotubes contribute to strength and fracture toughness.**

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A material consisting of a barium calcium aluminosilicate glass reinforced with 4 weight percent of boron nitride nanotubes (BNNTs) has shown promise for use as a sealant in planar solid oxide fuel cells (SOFCs). The composition of the glass in question in mole percentages is 35BaO + 15CaO + 5Al<sub>2</sub>O<sub>3</sub> + 10B<sub>2</sub>O<sub>3</sub> + 35SiO<sub>2</sub>. The glass was formulated to have physical and chemical properties suitable for use as a planar-SOFC sealant, but has been found to be deficient in one aspect: it is susceptible to cracking during thermal cycling of the fuel cells. The goal in formulating the glass/BNNT composite material was to (1) retain the physical and chemical advantages that led to the prior selection of the barium calcium aluminosilicate glass as the sealant while (2) increasing strength and fracture toughness so as to reduce the tendency toward cracking.

In preparation for tests, panels of the glass/BNNT composite were hot pressed and machined into test bars. Properties of the test bars, including four-point flexure strength, modulus of elasticity, mi-



**Flexure Strength and Fracture Toughness** of the glass and the glass/BNNT composite are compared here, with error bars signifying one standard deviation.

crohardness, and density were determined. In addition, fracture toughness was measured by the single-edge V-notch-beam method. Among the conclu-

sions drawn from the results of the tests were that the flexure strength and fracture toughness of the glass/BNNT composite specimens were greater than those of neat glass specimens by amounts of about 90 percent and about 35 percent, respectively (see figure). It was further concluded that these increases would greatly prolong the lifetimes of SOFC seals, yet there would be little adverse effect on sealing behavior of the glass because the relatively small concentration of BNNTs needed to obtain these increases would not cause much change in the viscosity of the composite sealant material.

*This work was done by Narottam P. Bansal and Janet B. Hurst of Glenn Research Center and Sung R. Choi of the University of Toledo. 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-18094-1*