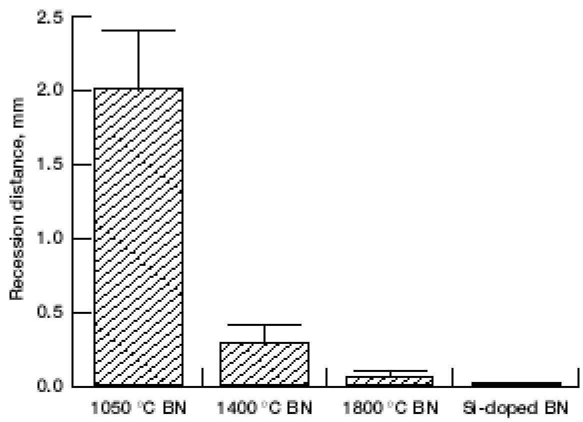
Stable Boron Nitride Interphases for Ceramic Matrix Composites

Ceramic matrix composites (CMC's) require strong fibers for good toughness and weak interphases so that cracks which are formed in the matrix debond and deflect around the fibers. If the fibers are strongly bonded to the matrix, CMC's behave like monolithic ceramics (e.g., a ceramic coffee cup), and when subjected to mechanical loads that induce cracking, such CMC's fail catastrophically. Since CMC's are being developed for high-temperature corrosive environments such as the combustor liner for advanced High Speed Civil Transport aircraft, the interphases need to be able to withstand the environment when the matrix cracks.

The state-of-the-art interphase for silicon carbide (SiC) fiber-reinforced SiC matrix composites is boron nitride (BN). Unfortunately, in the presence of oxygen and water vapor at temperatures ranging from 600 to 1000 °C, composites made with these interphases have severe embrittlement problems because of environmental attack of the interphase. A liquid or solid reaction product is formed that attacks the fibers and/or strongly bonds the fibers to the matrix. The stability of the BN interphases in water-containing environments can be improved by processing the interphases at higher temperatures or by doping the BN with silicon (ref. 1). However, it is a costly process to develop interphase coatings and incorporate them into large composite pieces suitable for testing.

The basic environmental degradation processes are known: the oxidation of BN and volatilization of the liquid oxidation product due to its reaction with water vapor. A simple test was developed at the NASA Lewis Research Center to compare the durability of different BN interphases subjected to severe environments. The different interphases were made on a small scale and composited as single-tow minicomposites. These minicomposites were then cut to lengths of about 2 cm and subjected to temperatures of 700 or 800 °C and different environmental conditions ranging from 0.2 to 90 percent H_2O (the balance being O_2). The minicomposites were then polished along their lengths, and the distance that the BN interphase receded from the exposed end was measured for a number of different fiber/matrix interphases.



Recession distance of different BN interphases in single-tow SiC/SiC minicomposites. The BN interphases were either processed at different temperatures or doped with Si (~20 wt %).

The figure shows the results for a test performed at 800 °C for 88 hr with an environment of 10 percent O_2 and 90 percent H_2O (a total pressure of 1 atm). The BN interphases usually used in CMC's are the low-temperature variety. Environmental durability is improved dramatically by increasing the processing temperature of BN deposition and/or by doping the BN with Si. Unfortunately, in order to get very durable BN interphases by processing at higher temperatures, the BN has to be processed at temperatures greater than 1800 °C. This is impractical because BN deposition at these temperatures is nonuniform, resulting in poor composite mechanical properties.

The most promising interphase was the Si-doped BN interphase. This interphase had three orders of magnitude improvement over the low-temperature BN. The Si-doped BN interphases in this study were processed at 1400 °C, yet they even outperformed the undoped BN interphases processed at 1800 °C. Work is continuing to assess the mechanical behavior of composites with Si-doped interphases as well as to determine the optimum Si content for mechanical properties and environmental durability.

Reference

1. Moore, A.W., et al.: Improved Interface Coatings for SiC Fibers in Ceramic Composites. Ceram. Eng. Sci. Proc., vol. 6, no. 4, 1995, pp. 409-416.

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