Functionally Graded Nanophase Beryllium/Carbon Composites

The main advantage, relative to Co/WC/diamond composites, is less weight.

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Beryllium, beryllium alloys, beryllium carbide, and carbon are the ingredients of a class of nanophase $Be/Be_2C/C$ composite materials that can be formulated and functionally graded to suit a variety of applications. In a typical case, such a composite consists of a first layer of either pure beryllium or a beryllium alloy, a second layer of B_2C, and a third layer of nanophase sintered carbon derived from fullerenes and nanotubes. The three layers are interconnected through interpenetrating spongelike structures.

These $Be/Be_2C/C$ composite materials are similar to Co/WC/diamond functionally graded composite materials, except that (1) W and Co are replaced by Be and alloys thereof and (2) diamond is replaced by sintered carbon derived from fullerenes and nanotubes. (Option-

ally, one could form a $Be/Be_2C/$diamond composite.) Because Be is lighter than W and Co, the present $Be/Be_2C/C$ composites weigh less than do the corresponding Co/WC/diamond composites. The nanophase carbon is almost as hard as diamond.

WC/Co is the toughest material. It is widely used for drilling, digging, and machining. However, the fact that W is a heavy element (that is, has high atomic mass and mass density) makes W unattractive for applications in which weight is a severe disadvantage. Be is the lightest tough element, but its toughness is less than that of WC/Co alloy. Be strengthened by nanophase carbon is much tougher than pure or alloy Be. The nanophase carbon has an unsurpassed strength-to-weight ratio.

The $Be/Be_2C/C$ composite materials are especially attractive for terrestrial and aerospace applications in which there are requirements for light weight along with the high strength and toughness of the denser Co/WC/diamond materials. These materials could be incorporated into diverse components, including cutting tools, bearings, rocket nozzles, and shields. Moreover, because Be and C are effective as neutron moderators, $Be/Be_2C/C$ composites could be attractive for some nuclear applications.

*This work was done by Oleg A. Voronov and Gary S. Tompa of Diamond Materials Inc. for **Johnson Space Center**. Further information is contained in a TSP (see page 1)..*
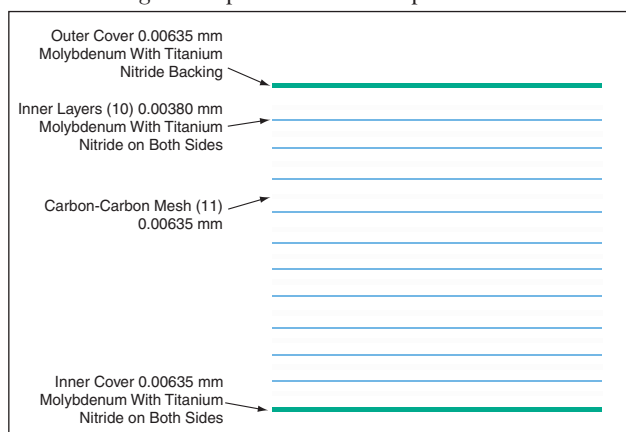*MSC-23274*

Thin Thermal-Insulation Blankets for Very High Temperatures

One blanket would have about the thickness of several sheets of paper.

Goddard Space Flight Center, Greenbelt, Maryland

Thermal-insulation blankets of a proposed type would be exceptionally thin and would endure temperatures up to 2,100 °C. These blankets were originally intended to protect components of the NASA Solar Probe spacecraft against radiant heating at its planned closest approach to the Sun (a distance of 4 solar radii). These blankets could also be used on Earth to provide thermal protection in special applications (especially in vacuum chambers) for which conventional thermal-insulation blankets would be too thick or would not perform adequately.

A blanket according to the proposal (see figure) would be made of molybdenum, titanium nitride, and carbon-carbon composite mesh, which melt at temperatures of 2,610, 2,930, and 2,130 °C, respectively. The emittance of molybdenum is 0.24, while that of titanium nitride is 0.03. Carbon-carbon composite mesh is a thermal insulator.

Typically, the blanket would include

0.25-mil ($\approx$0.00635-mm)-thick hot-side and cold-side cover layers of molybdenum. Titanium nitride would be vapor-deposited on both surfaces of each cover layer. Between the cover layers there would be 10 inner layers of 0.15-mil ($\approx$0.0038-mm)-thick molybdenum with vapor-deposited titanium nitride on both sides of each layer. The thickness of each titanium nitride coat would be about 1,000 Å. The cover and inner layers would be interspersed with 0.25-mil (0.00635-mm)-thick layers of carbon-carbon composite mesh. The blanket would have total thickness of 4.75 mils ($\approx$0.121 mm) and an areal mass density of 0.7 kg/m^2. One could, of course, increase the thermal-insulation capability of the blanket by increasing number of inner layers (thereby unavoidably increasing the total thickness and mass density).

*This work was done by Michael K. Choi of **Goddard Space Flight Center**. Further information is contained in a TSP (see page 1). GSC-14386*

Outer Cover 0.00635 mm
Molybdenum With Titanium
Nitride Backing

Inner Layers (10) 0.00380 mm
Molybdenum With Titanium
Nitride on Both Sides

Carbon-Carbon Mesh (11)
0.00635 mm

Inner Cover 0.00635 mm
Molybdenum With Titanium
Nitride on Both Sides

This **Thermal-Insulation Blanket** would be very thin and lightweight. The blanket would be made of materials that melt at temperatures greater than 2,100 °C.