Sealing Materials for Use in Vacuum at High Temperatures

These materials retain favorable handling properties in vacuum for usefully long times.

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Sealing materials that can be applied and left in place in vacuum over a wide range of temperatures (especially temperatures of a few thousand degrees Celsius) have been conceived and investigated for potential utility in repairing thermal-protection tiles on the space shuttles in orbit before returning to Earth. These materials are also adaptable to numerous terrestrial applications that involve vacuum processing and/or repair of structures that must withstand high temperatures. These materials can be formulated to have mechanical handling characteristics ranging from almost freely flowing liquid-like consistency through paste-like consistency to stiff puttylike consistency, and to retain these characteristics in vacuum until heated to high curing temperatures.

A sealing material of this type can be formulated to be used in any of several different ways — for example, to be impregnated into a high-temperature-fabric patch, impregnated into a high-temperature-fabric gasket for sealing a patch, applied under a patch, or applied alone in the manner of putty or wallboard compound. The sealing material must be formulated to be compatible with, and adhere to, the structural material(s) to be repaired. In general, the material consists of a vacuum-compatible liquid containing one or more dissolved compound(s) and/or mixed with suspended solid particles.

Depending on the intended application, the liquid can be chosen to be of a compound that can remain in place in vacuum for a time long enough to be useful, and/or to evaporate or decompose in a controlled way to leave a useful solid residue behind. The evaporation rate is determined by proper choice of vapor pressure, application of heat, and/or application of ultraviolet light or other optical radiation. The liquid chosen for the original space shuttle application is a commercial silicone vacuum-pump oil.

The solids are chosen to contribute desired properties to the residue. The solids can be obtained in the form of fine powders prior to suspension and/or dissolution in the liquid; alternatively or in addition, solid particles can be generated from chemical reactions as the liquid evaporates and/or decomposes. The relative amounts of solid and liquid are chosen to obtain the desired consistency. The liquid and solids are mixed thoroughly in air at room temperature. To prevent bubbling, foaming, and swelling during application in vacuum, the mixture must be degassed by heating in a vacuum oven at a temperature of 90 °C for at least 4 hours, then stored, until use, in a water- and gas-impermeable container.

In a typical case, the solids can include (1) the ingredients of a frit or bonding phase (e.g., a low-melting-temperature glass) that melts at a temperature expected to be encountered in use, and (2) a refractory compound (e.g., SiC fibers mixed with irregularly shaped SiC particles) that does not melt at the expected maximum temperature. Upon heating after application, the liquid evaporates or decomposes and the solids form a refractory residue held together by the surface tension of the glass phase while at and above the glass-formation temperature. After cooling to lower temperature, the residue remains bonded together by the solid glass.

This work was done by Donald R. Pettit and Charles J. Camarda of Johnson Space Center, and Wallace Lee Vaughn of Langley Research Center. For further information, contact the Johnson Commercial Technology Office at (281) 483-3809. MSC-23959-1

Radiation Shielding System Using a Composite of Carbon Nanotubes Loaded With Electropolymers

A lightweight and replenishable system is effective against all types of radiation particles.

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Single-wall carbon nanotubes (SWCNTs) coated with a hydrogen-rich, electrically conducting polymer such as polyethylene, receive and dissipate a portion of incoming radiation pulse energy to electrical signals that are transmitted along the CNT axes, and are received at energy-dissipating terminals.

In this innovation, an array of highly aligned nanowires is grown using a strong electric field or another suitable orientation procedure. Polyethylene (PE), polymethymlethacrylate (PMMA), or other electrically conducting polymer is spin-coated onto the SWCNTs with an average thickness of a few hundred nanometers to a few tenths of micrometers to form a PE/SWCNT composite. Alternatively, the polymer is spin-coated onto the nanowire array or an anodized alumina membrane (AAM) to form a PE/metal core shell structure, or PE can be electropolymerized using the SWCNTs or the metal nanowires as an electrode to form a PE/SWCNT core shell structure.

The core shell structures can be extruded as anisotropic fibers. A monomer can be polymerized in the presence of SWCNTs to form highly cross-linked PE/SWCNT films. Alternatively, Pb colloid solution can be impregnated into a three-dimensional PE/SWCNT nanostructure to form a PW/SWCNT/Pb composite structure. A face-centered cubic

(FCC) arrangement provides up to 12 interconnection channels connected to each core, with transverse channel dimensions up to 20 nm, with adequate mechanical compressive strength, and with an associated electrical conductivity of around 3 Seimens/cm for currents ranging from 0.01 to 10 mA. This three-dimensional nanostructure is used as a host material to house appropriate radiation shielding material such as hydrogen-rich polymer/CNT structures, metal nanoparticles, and nanowires.

Thicknesses of this material required to attenuate 10 percent, 50 percent, and 90 percent of an incident beam (gamma, X-ray, ultraviolet, neutron, proton, and electron) at energies in the range of 0–440 MeV are being determined, for example, by measuring fluence rate reduction.

For example, a radiation field arrives first at an exposed surface of the innovation and produces an associated first electric field within the metal-like fingers of the three-dimensional nanostructure. This field is intensified near the exposed tips of the fingers, and this intensified field generates an intensified second electric field near the adjacent exposed tips of the coated CNSs. This generates an associated electrical current in the CNSs, and the associated electropolymer coating. The current is received by the second substrate transport component and is transported to the dissipation mechanism located contiguously to the second substrate.

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