Development of High Thermal Conductivity, Low Density Graphite Foam

OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

OFFICE OF TRANSPORTATION TECHNOLOGIES

FOR THE 21ST CENTURY

Background

In recent years, the number of applications requiring more efficient and lightweight thermal management, such as high-density electronics, hybrid diesel-electric vehicles, communication satellites, and advanced aircraft has increased. The primary concerns in these thermal management applications are high thermal conductivity, low weight, and high specific strength. Many materials have been examined for these qualities, including metallic and pitch-derived carbon foams. However, these materials generally exhibited high specific strengths but low thermal conductivities. Researchers at Oak Ridge National Laboratory (ORNL) were the first to identify the potential of carbon foams for enhancing heat transfer. Their research has resulted in a new, faster process for fabricating pitch-based graphitic foams. The new foam has a thermal conductivity equivalent to aluminum but at one-fifth its weight, which makes ORNL graphite foam an attractive thermal management material in weight sensitive applications, such as aerospace equipment. It could also be used in heat sinks for electronic equipment, greatly increasing the reliability of the next generation of computer microprocessors. In June 1999, Poco Graphite, Inc. of Decatur, Texas, acquired the exclusive license to manufacture ORNL graphite foam. ORNL and Poco Graphite were both awarded the prestigious R&D 100 Award by *R&D Magazine* for their work on developing this unique material.

The Technology

Materials such as diamond and graphite are good thermal conductors because their crystal structures are nearly perfect with very few crystallographic defects. The ORNL graphite foam is derived from a mesophase pitch precursor in which, during the foam's manufacture, mesophase crystals align themselves along the foam's cell walls. When the foam is subsequently graphitized at temperatures exceeding 2800°C, a highly aligned, defect-free graphitic structure better than that found in carbon fiber is obtained. The thermal conductivity of the well-aligned foam ligaments is estimated to be comparable to diamond films (> 1700 W/m·K). The bulk thermal conductivity of the foam is somewhat less due to the thermal resistance added by more disordered textures observed at the cell wall junctions. Current manufacturing methods typically produce material in the 100 to 150 W/m K range, with bulk thermal conductivities of 187 W/m K achievable under laboratory conditions.

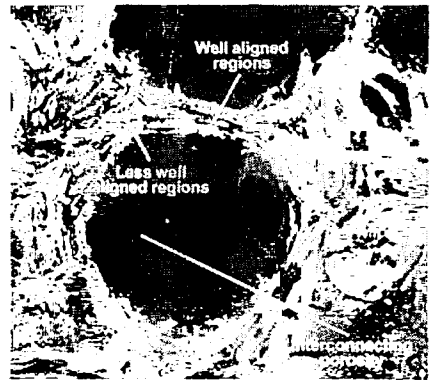
The ORNL graphite foam has an open and permeable structure which yields a relatively large surface area, improving heat transfer to a working fluid. This could lead to novel solutions for thermal management problems ranging from radiators and satellite panels to aircraft heat exchangers. Heat exchangers incorporating the ORNL graphite foam have been produced that exhibit heat transfer coefficients more than two orders of magnitude greater than for existing equipment. This offers new design possibilities for the future of automobile engine cooling systems. For example, prototype radiators have been designed and built that provide 20% to 30% greater heat transfer capabilities over aluminum cores of similar design. Also, a radiator for an 800-horsepower racing engine has been fabricated at roughly one-fifth the size of current designs used in the Winston Cup racing circuit. The weight reduction achieved by using a graphite foam heat exchanger in the radiator of light-duty vehicles could eventually lead to significant fuel savings.

Commercialization

Under the trade name PocoFoam,™ Poco Graphite is manufacturing graphite foam for heat transfer products for a wide range of applications. The company's agreement with ORNL includes field-of-use licenses for finished products including heat exchangers, as well as cooling systems or heat sinks for the aerospace, chemical process, glass, ceramic, and medical industries. Prototype PocoFoam™ radiators, designed and built by Performance Research in Denver, North Carolina, were displayed at the Motorsports Engineering Conference and Exhibition in November 2000. As a leading manufacturer of premium, specialty graphites and silicon carbides with over 35 years of experience in major markets, Poco's products have been used in space systems starting with the Voyager I mission and continuing to the Mars Microprobe Deep Space 2 mission.

Benefits

- Thermal conductivity equivalent to aluminum achievable at one-fifth the weight
- Low bulk density suitable for weight-sensitive applications
- Open structure ideal for core of heat transfer devices
- Easier to fabricate than traditional graphite foams



The microstructure of ORNL Graphite Foam showing the open structure, the structurally well-aligned ligament regions, and the less well-aligned cell wall junctions.

For more information on how DOE is helping America remain competitive in the 21st century, please contact:

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