OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY
FACT SHEET

Signature and Heat Management

Highly Conductive Graphite Foam

Military Issues and Technology Impact

The military must contend with and manage heat in radiators for tactical and fighting vehicles and control temperatures for electronics and personnel. A highly advanced thermal-transport material has the potential to radically improve heat transfer while it reduces the size and weight of affected equipment. The use of graphite foam products can simultaneously increase efficiency and capabilities.

Graphite foam is extremely lightweight with very high thermal conductivity. Invented only four years ago, it has already demonstrated the ability to improve the transfer of unwanted heat—by factors of more than 100 in some applications. This graphite foam has the potential to improve many systems, including

- electronics and electronic systems cooling;
- radiators and brakes for vehicles;
- signature management of heat, sound, and electromagnetic pulses;
- cooling systems;
- personal microclimate systems for warfighters;
- weapons systems (barrels, recoil mechanisms, etc.) cooling;
- fuel and process gases combustion;
- missile and engine components cooling;
- personal heating and cooling for improved trauma care; and
- phased-array radar.

Technical Concept

ORNL has developed a relatively simple technique to produce a graphitic foam with thermal conductivity equivalent to aluminum alloys at one-fifth their weight. This foam has an open porous structure with a surface area more than 100 times greater than that of typical heat exchangers (>4m^2/g). The cell walls are made of highly oriented graphite planes, which have been estimated to exhibit a thermal conductivity of over four times greater than that of copper. Advantages of using highly conductive graphite foam include

- reducing the size and weight of heat sinks and heat exchangers,
- improving heat transfer efficiencies, and
- absorbing acoustic and electromagnetic signatures.

Development Approach

Three areas of development would focus on priority applications for deploying this advanced technology to meet immediate needs.

1. Computer Chip Cooling. Current computer chip design is not suited for significant heat dissipation. In a new "flip-chip" design, the silicon chip is inverted, with the smooth back of the printed chip oriented towards the top of the package. Using this design and graphite foam to replace the material currently used to dissipate heat with evaporative cooling, a power density of 100 W/cm^2 was attained—more than 350% greater that previously attainable. ORNL researchers expect that when they optimize the foam's properties, significantly higher power densities will be attained.

Benefits of graphite foam for computer chip cooling are

- passive system,
- power densities more than 350% of current designs, and
- potential for faster processing speeds with much higher power densities.

2. Radiators. In heavy vehicles, the weight of the radiator creates significant drag, accounting for up to 12% of the fuel use at highway speeds in heavy trucks. ORNL research has shown that the use of graphite foam in radiator fins can produce extremely efficient and lightweight heat exchangers. A smaller radiator will allow the redesign of the front cab and dramatically improve efficiency.

Benefits of graphite foam for radiators are

- reduce weight and size of radiators;
- dissipate more heat; and
- improve aerodynamics, fuel efficiency, and load-carrying capacity of heavy vehicles.

3. Signature Management. Graphite foam provides a triple opportunity to manage thermal conductivity as well as acoustic and electromagnetic signatures using a single material. The unique features of the graphite foam result in a material that is both an excellent thermal conductor and an excellent acoustic absorber. Furthermore, the high electrical conductivity of the graphite foam makes it an effective electromagnetic shield, a critical property for protecting important electronics.

Benefits of graphite foam for signature management are

- excellent lightweight thermal management,
- excellent acoustic absorber, and
- excellent electromagnetic shield.

ORNL Facilities

As a multidisciplinary research laboratory, ORNL is using its unique position as the inventor of high-thermal-conductivity graphite foam to investigate multiple applications for this product. Currently, more than $2.3M of research is being conducted in more than 11 programs at ORNL. These programs range from basic science investigations to power electronics cooling and fuel cell interconnects, evaporative cooling for electronics and aircraft leading edges, radiators for vehicles, nuclear reactor cores with no moving parts, brake and clutch cooling, microclimate cooling for personnel, and hydrogen storage substrates.

ORNL worked in cooperation with the National Security Agency (NSA) to develop the unique evaporative cooling application for electronics. The technology for the manufacture of the foams has been licensed to Poco Graphite, Inc., of Decatur, Texas, and Poco is interested in partnering in the development of both military and commercial applications.

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