Carbon-Fiber Brush Heat Exchangers

High thermal conductance between uneven surfaces could be achieved with low clamping force.

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Velvetlike and brushlike pads of carbon fibers have been proposed for use as mechanically compliant, highly thermally conductive interfaces for transferring heat. A pad of this type would be formed by attaching short carbon fibers to either or both of two objects that one desires to place in thermal contact with each other.

The purpose of using a thermal-contact pad of this or any other type is to reduce the thermal resistance of an interface between a heat source (e.g., a module that contains electronic circuitry) and a heat sink (e.g., a common finned heat sink). Conventionally, to obtain high thermal conductance, a thermal interface is assembled by use of high contact pressure between faying surfaces that match each other precisely (e.g., both are precisely flat). Unfortunately, high contact pressure necessitates rigid components and strong fasteners and does not allow relative motion between the clamped parts. Compliant rubber pads or thermally conductive greases or adhesives are often used alternatively or in addition to precisely matching surfaces and high contact pressure.

The proposed carbon-fiber brush heat exchangers would offer high thermal conductance with mechanical compliance and low contact pressure, even in the case of surfaces that are uneven, do not match each other precisely, are separated by relatively wide gaps, and/or move relative to each other. In a given interface, the effective surface area of the carbon fibers could be orders of magnitude larger than the nominal footprint area of an interface.

A given thermal interface could be either single-sided (consisting of a brush on either the heat source or the heat sink) or double-sided (consisting of brushes on both the source and the sink). If the carbon fibers had high thermal conductivity and were well connected to a substrate, they would tend to isothermalize with the substrate and become thermally efficient fins. High-thermal-conductivity fibers would be well suited for brush heat exchangers because they are straight, are available in small diameters, and are compatible with many materials, even at high temperatures.

Double-sided carbon-fiber brush heat exchangers would be related to interleaving metal-fin heat exchangers, but for a given footprint area, the carbon-fiber brush heat exchangers would have larger radiating surface areas and would weigh less. The high thermal conductances occasioned by the use of carbon-fiber brush heat exchangers could be utilized to decrease the sizes and weights of heat sinks (including radiators) for a given heat-dissipation rate, increase heat-dissipation rates for heat sinks of a given size and weight, and/or enable heat-generating equipment to operate at lower temperatures. The elimination of the need for structures to resist large thermal-interface clamping forces would enable further weight reductions.

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