Diamond Window Pressure and Temperature Sensors

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The push towards electrification of mobile systems from cell phones to airplanes has forced high power electronics into smaller and smaller packages to meet modern mobility and power needs. The consequence of having powerful electronics in smaller packages is large power density and reduced surface area. This in-turn makes cooling these emerging devices difficult, and motivates the need for cooling approaches that address limited surface area. In addition to addressing a smaller surface area, these electronic systems require thermal management schemes be responsive to quick electronic switching, and heat energy distributed throughout the electronic system. Thermal management therefore needs to smartly respond to the dynamic and dispersed cooling needs of the electronic system. Thermal circuits, analogous to the electronic circuits they serve, may be the solution to managing the device's operating temperature. A key research question is: can we design thermal circuit components, such as a thermal on-off switch, that responds passively to temperature changes (25 – 35ºC) small enough to fit in microscale electronics (1 – 10 μm), and is rated to switch between large thermal fluxes, by varying the thermal conductivity by several orders of magnitude (0.10 – 1000 W/m-K)?

Diamond films may be part of an approach to make a thermal switches for three reasons. First, since displacements in diamond films can be caused by changes in temperature or pressure suggests their use as passively responsive structures. Second, diamond films can be synthesized to nanoscale thicknesses show that submicron scale devices can be developed. Finally, the upper limit on thermal conductivity has been measured as high as 1500 W/m-K suggesting that diamond films could be used to supply the necessary thermal conductivity. However, to design an actual thermal switch, we need to answer a basic research question: what are the values of mechanical displacement of diamond films in response to temperature and pressure changes? Also, what is the relationship between thermal conductivity and the mechanical properties of the diamond film?

To answer the above research question we propose to build diamond film temperature and pressure sensors. measure young's modulus and the thermal conductivity of diamond films supported by silicon and amorphous silica substrates. Suspended flexible diamond films supported by silicon and silica will be made using modern micro-fabrication techniques. Optical fibers, a light source, and detector will be integrated within the diamond film structure. The structure will be immersed in a variable pressure field (constant temperature), and the Young's modulus will be extracted by measuring the displacement of the diamond film using the optical system. The temperature of the structure will also be changed, and film displacement relative to temperature changes (constant pressure) will be measured. Finally, in-plane and cross-plane thermal conductivity of the suspended diamond films will also be measured. The results of this work will not only lead to the development of thermal circuit components, but also to nanoscale infrared sensors for biomedical applications.