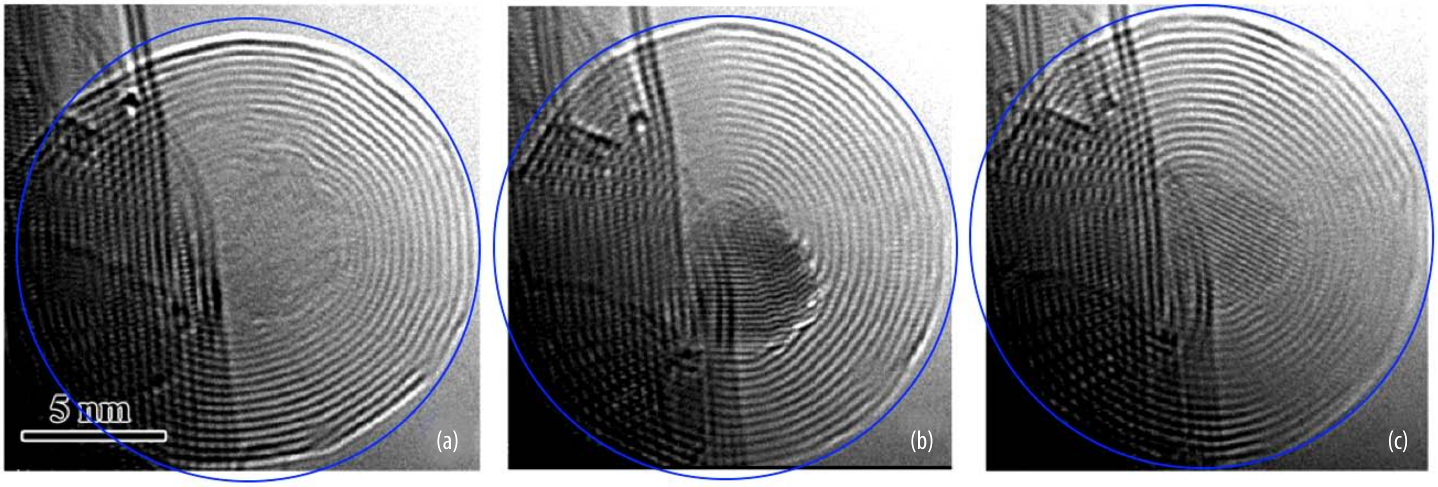
Materials Science and Technology
Nanoscience



In-situ Observation of "Molten" Diamond

Nanoscale carbon structures allow researchers to simultaneously achieve the extremely high pressures and temperatures needed to melt diamond.

The behavior of materials under extreme conditions of high pressure and temperature has long been of interest to researchers in physics, astronomy, and geology. Since diamond possesses the highest hardness, thermal conductivity, and melting temperature of all materials, it has been the focus of numerous studies at extreme conditions. Under normal atmospheric pressure and very high temperatures, diamond does not melt but instead turns into graphite. It is believed that melting will occur only at both extremely high pressures and temperatures. Until now, no one had been able to simultaneously achieve these conditions *in-situ* for melting diamond.

Sandia researchers created these extreme conditions for melting at the nanoscale. They used carbon nanotubes as high-temperature heaters and spherical "carbon onions" as high pressure cells (Fig. 1). The onions are roughly spherical nanoscale concentric shells of graphite-like carbon that are bound to the nanotubes. By heating the onions via the nanotubes, and then applying electron beam irradiation, the temperatures inside the onions can be raised to higher than 2000ºC. Furthermore, because the outer onion layers act essentially as a containment cell, pressures of up to 400,000 atmospheres are obtained in the center. Observations through a transmission electron microscope (TEM) showed that under these conditions, the diamond was formed and underwent a kind of "quasi-melting," in which the diamond fluctuates between crystal forms by continually melting and refreezing in a different configuration (size, shape, internal structure, and crystal orientation, Fig. 1).

This is the closest anyone has ever come to directly melting diamond. No one really knows what molten carbon looks like. The graphite form seems to break down into liquid-like blobs when heated to high temperatures, although they have not been examined while still molten. Our discovery offers unprecedented opportunities to studying the structures of carbon at extreme conditions *in-situ* and at an atomic-scale. On the geologic scale, these studies may increase our understanding of the extreme conditions in the earth's mantle.

Figure 1: (Above) Sequential transmission electron microscopy (TEM) images showing quasi-melting of diamond crystals at the center of a "carbon onion." The diamond crystal structure at the center fluctuates from a polycrystal (a) to a multiple twinned crystal (b), to a single crystal (c) in a matter of seconds.

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PUBLICATIONS

The results were published this summer in Nano letters [1], and a news article about the results appeared in the July 26, 2007, issue of *Nature* [2].

References

1. J.Y. Huang, *Nano letters 7*, 2335 (2007).
2. P. Ball, *Nature* 448, 396 (2007).

Sandia National Laboratories

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