Thermal Conductivity of Natural Type IIa Diamond

The conductivity of a specimen was measured at 500 to 1,250 K.

A report describes the application of the flash diffusivity method to measure the thermal conductivity of an 8.04 x 8.84 x 2.35-mm specimen of natural, white, type-IIa diamond at temperatures between 500 and 1,250 K. This is the first time that the thermal conductivity of diamond has been measured at temperatures greater than 450 K. The results, presented graphically, provide a baseline for comparison to recently obtained results on isotopically pure (^{12}C) diamond, which has a measured thermal conductivity at room temperature about 50 percent greater than that of single-crystal type IIa diamonds (the best-heat-conducting type of natural diamond). The results can also be used as a reference against which diamond films produced by chemical-vapor deposition at low pressures can be compared. The high thermal conductivity of diamond can be exploited for a wide variety of applications, and the present results could be used to estimate the heat-conduction performances of diamond films in high-temperature applications.

In the particular implementation of the flash diffusivity method, a xenon flashlamp applied a pulse of heating radiation to one face of the specimen via a sapphire light pipe, while an InSb infrared detector measured the resulting temperature rise of the opposite face of the specimen. The output of the detector was fed through a differential amplifier into a digital storage oscilloscope, which displayed temperature rise versus time.

The sample specimen was coated (sputtered) all over with a layer of tantalum a few micrometers thick, on top of which was sputtered a layer of graphite a few micrometers thick. This combination coating was necessary to obtain adequate absorption of radiation at the surface while preventing the radiation from passing directly through the specimen. The diffusivity was measured both through the specimen along the short dimension (2.35 mm) and through the specimen along the long dimension (8.04 cm). The thermal conductivity was calculated from the diffusivity computed from the measurements, the measured density (3.5 g/cm^3), and the published specific heat.

The resulting data from high temperatures were found to be a reasonable extension of previously published data that were obtained at low temperatures. Although the data from the long-direction and short-direction measurements agreed well between 700 and 1,000 K, the slopes of the logarithm (thermal conductivity)-vs.-logarithm (absolute temperature) curves through the two sets of data points were different: the slope based on the long-direction measurements was 1.13, while that based on the short-direction measurements was 1.54. An extrapolation of the data via the long-direction slope down to 300 K agreed with previously reported data on three type-IIa diamonds, whereas an extrapolation via the short-direction slope agreed well with data on isotopically pure diamond. At the time of the report, the authors were awaiting results of additional measurements at Cornell University to decide whether the "long" or the "short" data are the most accurate.

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