

Looking at light to explore superconductivity in boron-diamond films

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More than a decade ago, researchers discovered that when they added boron to the carbon structure of diamond, the combination was superconductive. Since then, growing interest has been generated in understanding these superconducting properties.

With this interest, a research group in India focused on a Fano resonance in a heavily [boron](#)-doped diamond (BDD) that involves the vibrational mode of diamond. The researchers, from the Indian Institute of Technology Madras, report their findings this week in *Applied Physics Letters*.

In probing the vibrational properties of BDD films, the researchers used Raman scattering and presented a comprehensive analysis of the Fano effect as a function of boron concentration and the excitation frequency used in the Raman measurement.

Fano Effect

The Fano resonance in a diamond can be seen in Raman scattering, which is a resonant scattering of light that involves an incident photon interacting with a vibrational mode of the diamond and in the process shifting the photon energy, and therefore its frequency, up or down by the energy of the vibrational mode. Interference between scattering from a discrete transition like the zone center vibrational mode in diamond, and that from a continuum background resulting from the boron-induced

impurity band, produces an asymmetric-shaped signal known as a Fano resonance.

"Fano parameterization is a well-thought-out experiment by us to understand the nature of impurity band evolution with boron doping that leads to superconductivity in diamond," said Ramachandra Rao, a co-author of the paper. "Our objective was to gain a deeper understanding of the interaction of light with the impurity band by varying the boron concentrations in diamond films and also by using various laser excitations."

"An increase in boron concentrations increases the impurity bandwidth," said Dinesh Kumar, the paper's first author. "The Fano resonance is sensitive to modification in the impurity bandwidth brought about by the increased boron concentration in BDD."

The group looked closely at the interaction, systematically studying heavily doped samples in the semiconducting and superconducting regimes using ultraviolet and visible wavelengths of the laser excitation sources for the Raman measurement.

The asymmetric Fano line shape revealed that the phase shift in diamond undergoes a remarkable change that can be tuned either by the impurity bandwidth or by the scattering frequency.

Reaching a Higher Temperature

The researchers also wanted to gain better understanding of the relationship between the doping and superconductivity to learn how the superconducting transition [temperature](#) in BDD can be increased.

Superconductors offer no electrical resistance to the flow of current. To reach this state, however, the materials must typically be in extremely

cold temperatures, close to absolute zero. Over the last 10 years the superconducting transition temperature in diamond has increased and is now near 10 kelvins (or about -263 degrees Celsius). This is much less than the theoretically predicted value of 55 K.

While 55 K is still too low for practical applications, understanding why BDD's [transition temperature](#) is so far below the theoretical limit may provide insights into how to improve the transition temperatures of other superconductors. Increasing the temperature in BDD remains a problem in the doping process, during which researchers inadvertently damage the structure of the diamond lattice.

"Due to heavy boron doping, the diamond lattice undergoes a complex transformation resulting in an increase in the disorder of the system, which is detrimental to the superconducting properties. We have explored this problem at length by tuning the boron concentration in the present study," Rao said.

More information: "Effect of boron-doping on first-order Raman scattering in superconducting boron-doped diamond films," *Applied Physics Letters* May, 9, 2017. [DOI: 10.1063/1.4982591](https://doi.org/10.1063/1.4982591)

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