Fabrication of MIT layers in Diamond.

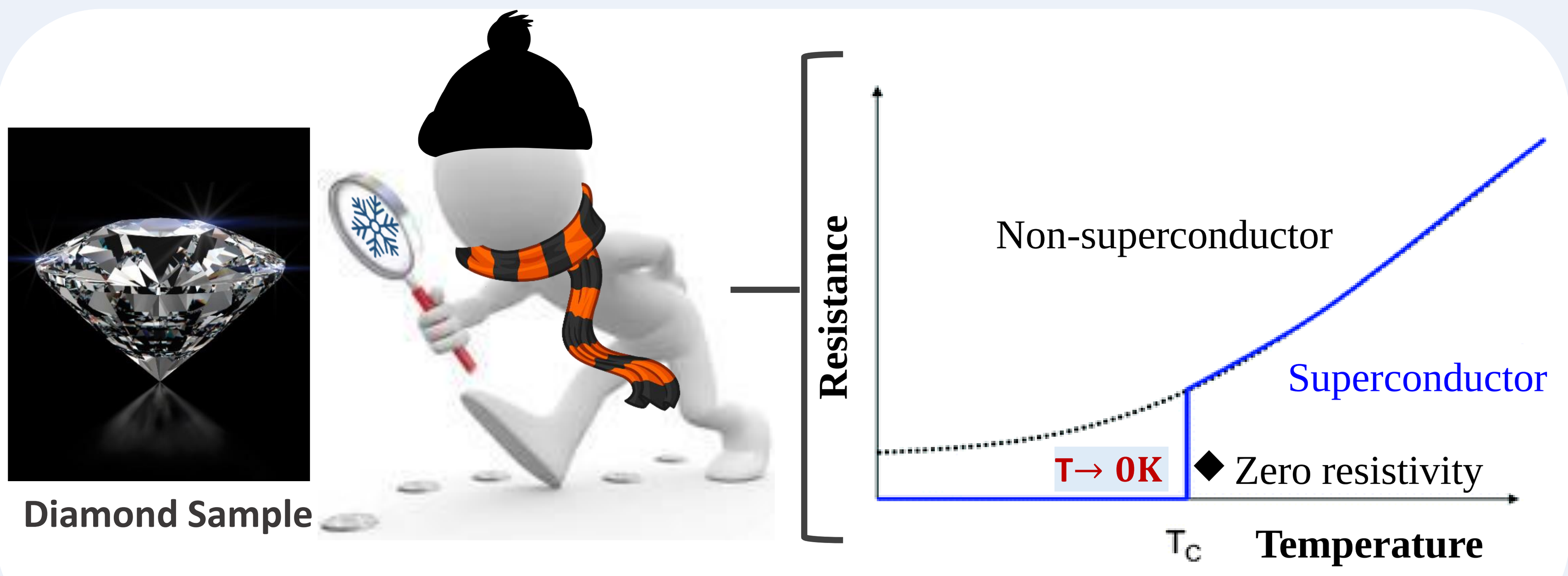
N. Mahonisi[1,2], **SR. Naidoo**[1,2]
[1]School of Physics, University of the Witwatersrand, Private Bag 3, Johannesburg 2050, South Africa
[2]DST-NRF Centre of Excellence in Strong Materials, Private Bag 3, Johannesburg 2050, South Africa
Email: nyiku.mahonisi1@students.wits.ac.za

ABSTRACT

The physio-chemical properties of semiconducting diamond materials under extremely low temperatures have fundamental implications in Condensed Matter Physics. Highly doped boron diamonds have been shown to reach a superconductive state at critical temperatures (T_c) ranging from $4-10\mathrm{K}$, albeit such properties are "at the moment" only attributed to heavily boron-doped synthesized samples via HPHT and CVD growth methods. Theoretical predictions have shown that by exceeding the current solubility limit of boron in diamond, an increase in T_c beyond the $4-10\mathrm{K}$ is possible, even close to room temperatures. However, in order to gain such a feat, an increase in active boron concentration beyond the metal-to-insulator transition (MIT) is an absolute necessity, and hence, non-equilibrium doping fabrication processes such as CVD growth and ion implantation are required. In this study, we explore carefully the properties of degenerate diamond layers with p-type impurity bands via low energy and low fluence ion implantation.

LOW TEMPERATURE PHYSICS IN DIAMOND

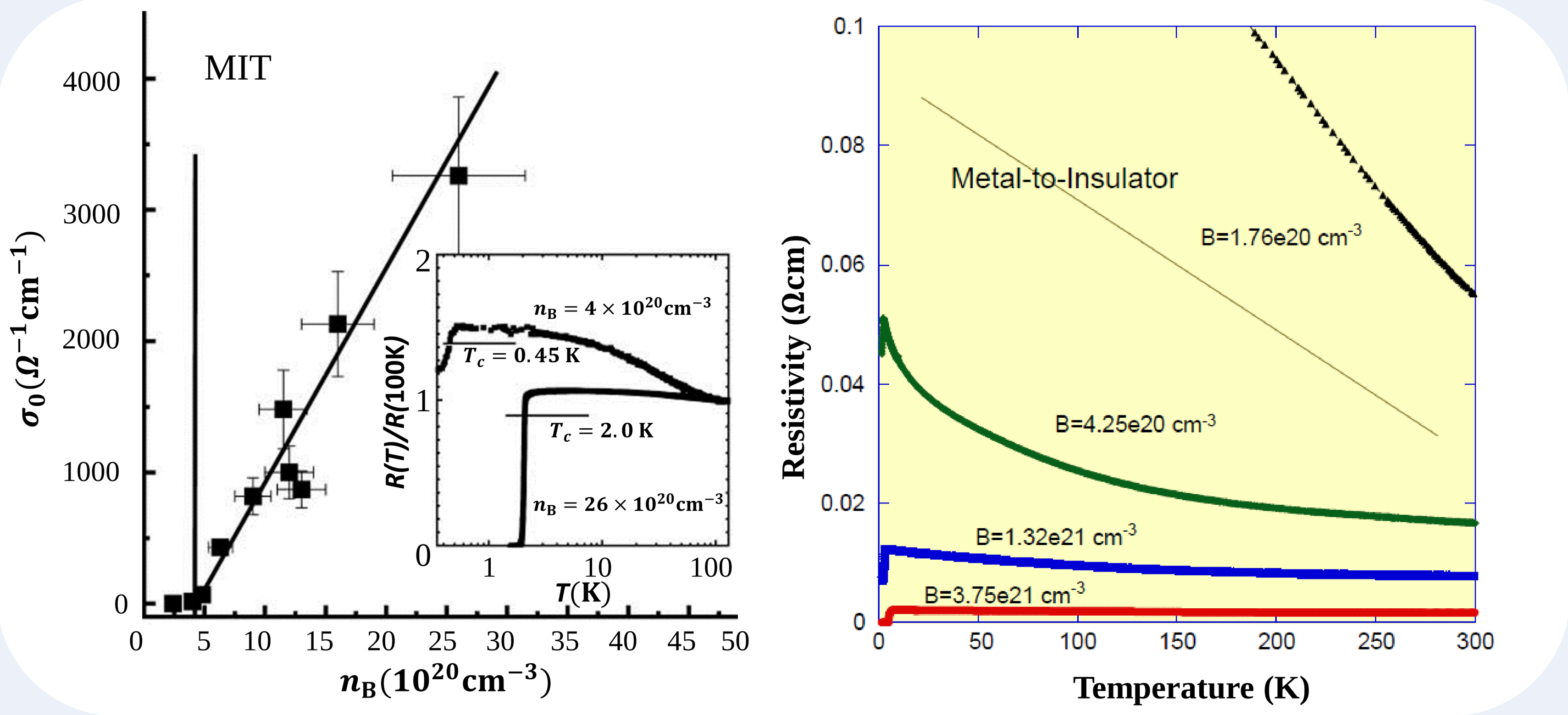
The characteristic of interest in low temperature Physics in diamond, among other things, is the abrupt disappearance of resistivity. The phenomena occurs below a critical temperature ($T_c \longrightarrow 0\mathrm{K}$), which varies for different materials.



The material undergoing such a sudden transition is said to have attained a highly conductive state known as superconductivity and showcases anomalous physical properties.

METAL-TO-INSULATOR TRANSITION (MIT) IN DIAMOND?

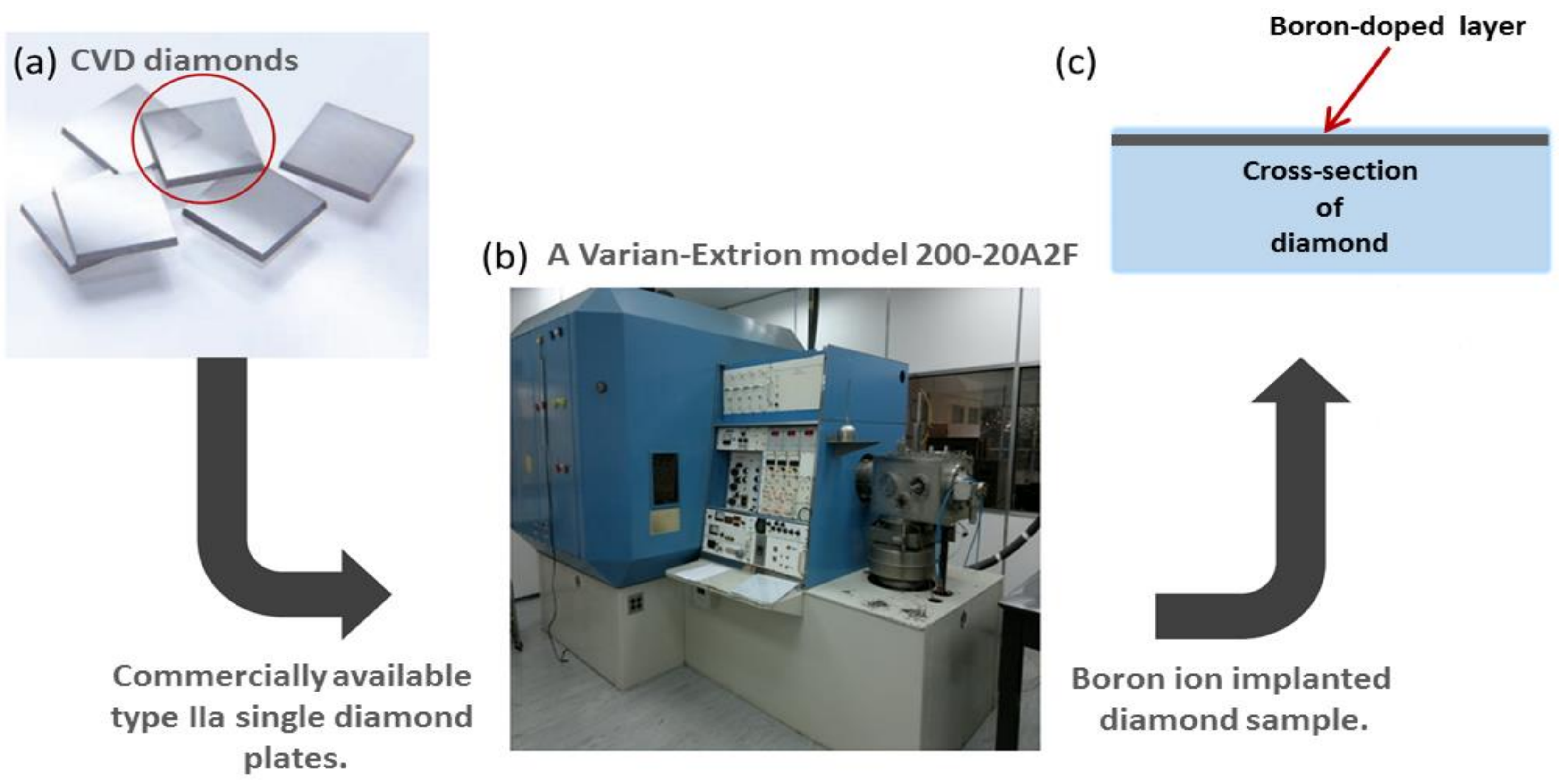
The superconductive state in a heavily boron-doped diamond arises close to the metal-to-insulator transition (MIT), related to the critical concentration of boron ranging from ~ $4 \times 10^{20} - 3 \times 10^{21}/\mathrm{cm}^3$.



Resistivity of current flow is prominent in diamond due to the wide energy transition for charge carriers. However, the carrier density can be substantially altered via p-type doping, thereby affecting the Fermi-energy (E_f) level of its electronic band structure.

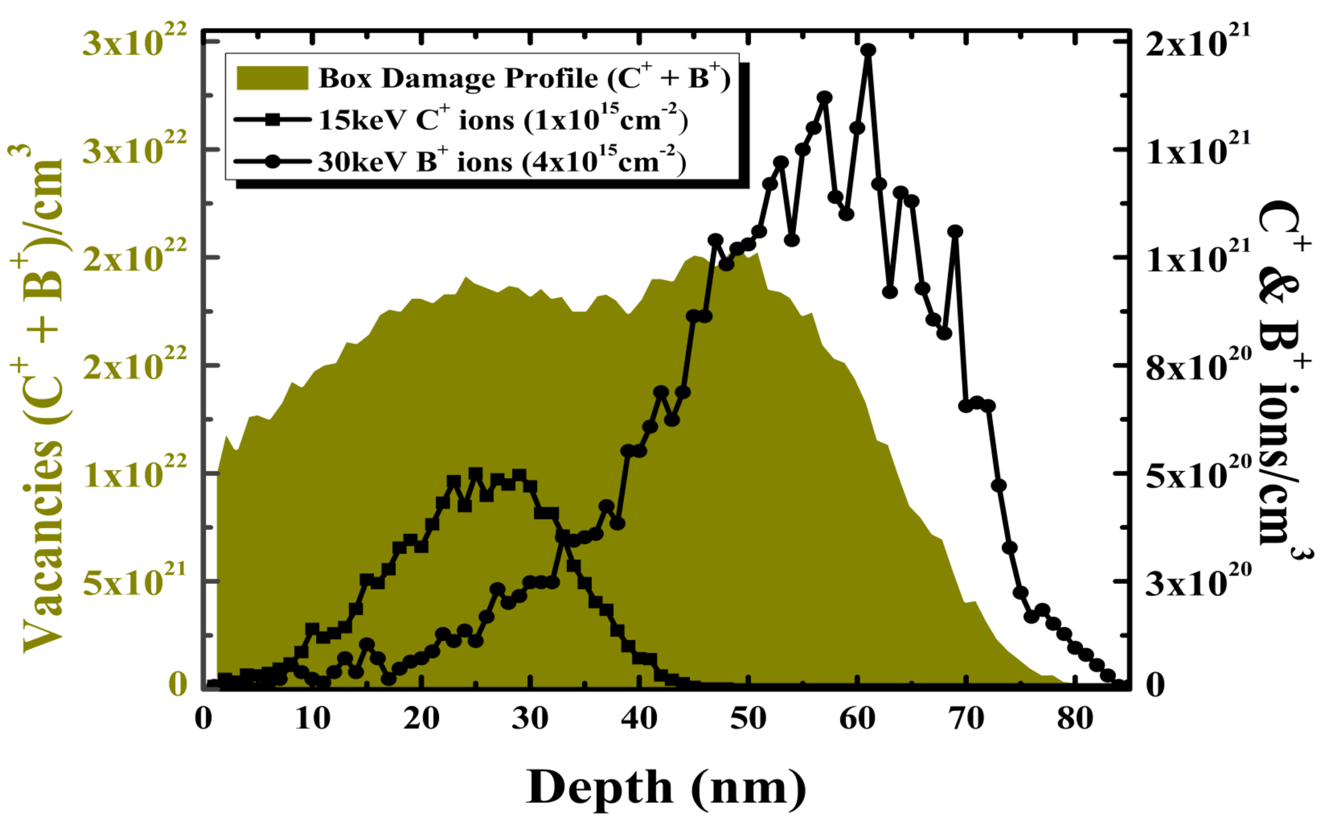
FABRICATION OF MIT LAYERS IN DIAMOND

We utilize the ion irradiation technique to heavily irradiate boron (B^+) ions within the diamond sample to establish a suitable amount of substitutional boron to create a MIT layer.



SRIM SIMULATION OF C & B IONS IN DIAMOND

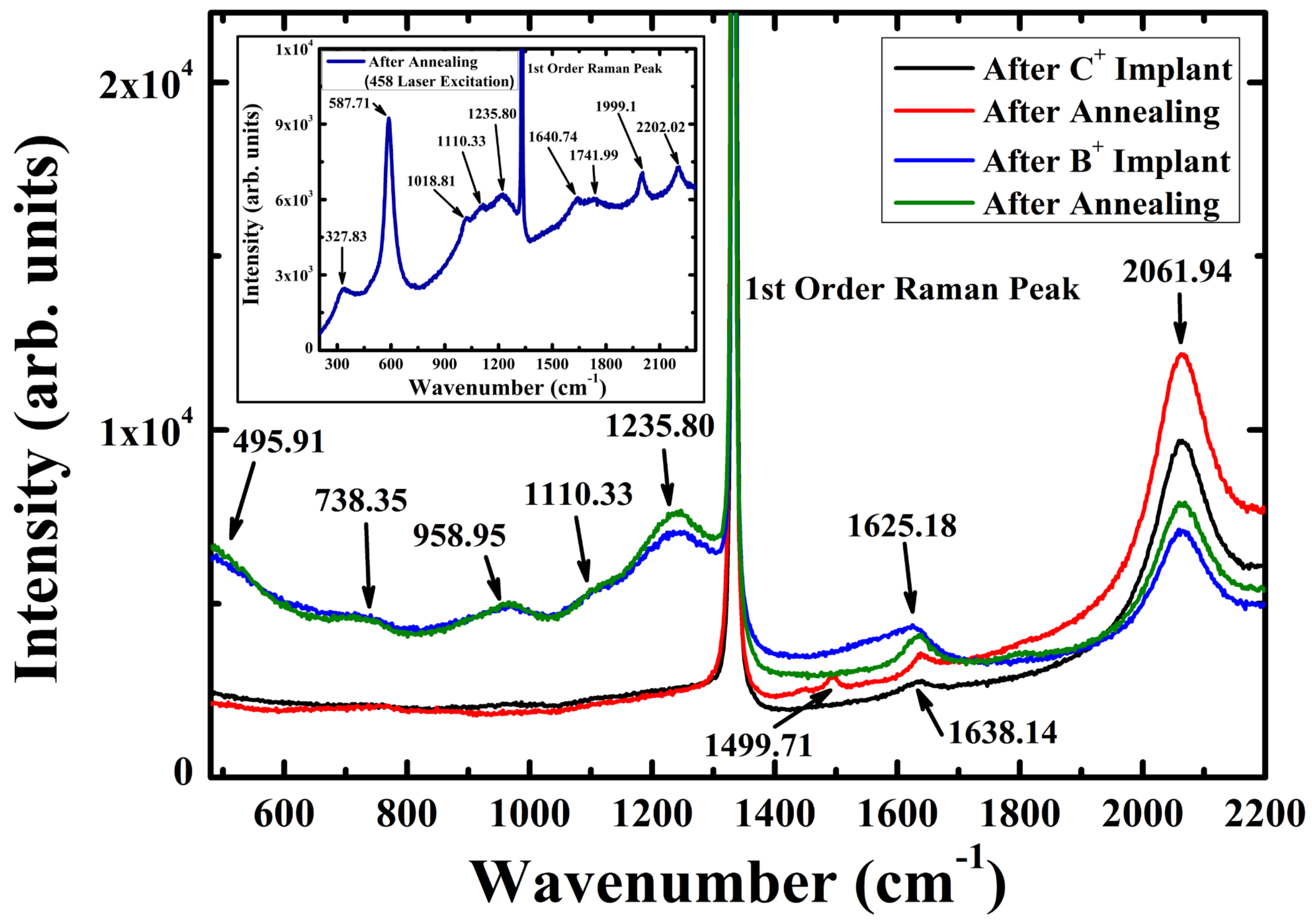
Stopping and Range of Ions in Matter (SRIM) simulation was conducted before the ion implantation process for 5000 C & B ions injected in a diamond material with 15keV & 30keV ion implant energy, respectively.



The penetration depth of the C^+ ions into the sample was estimated to be ~ 45nm from the sample surface with a depth peak of ~ 25nm, whilst for B^+ ions it was ~ 85nm and 62nm, respectively. Furthermore, the combined box damage profile was estimated to extend 80 nm into the sample from the surface.

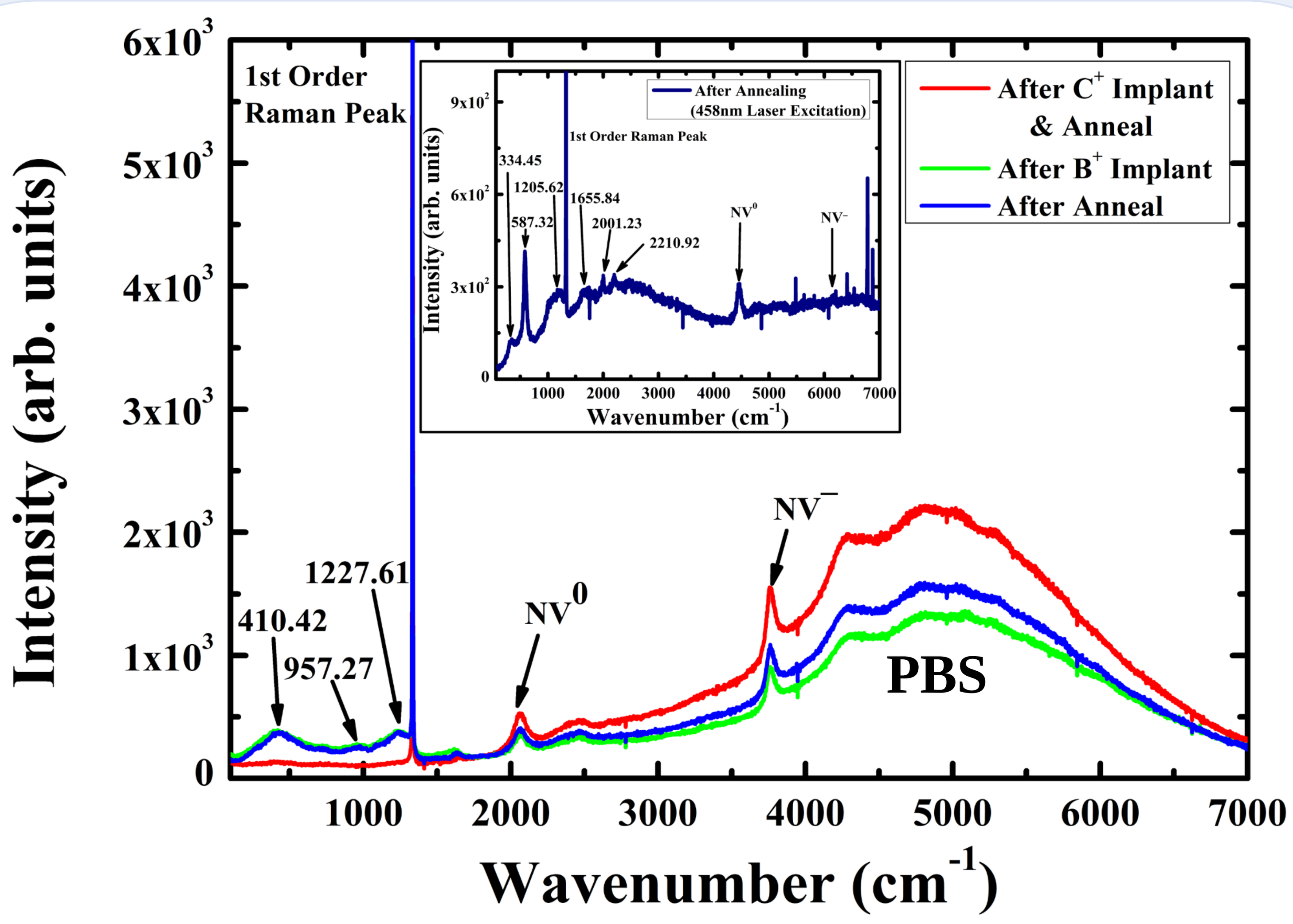
RAMAN SPECTRA OF C & B DOPED DIAMOND

The Raman spectra of the implanted samples with laser excitation length of 514 nm. The insert shows the Raman spectra of the same sample with a 458 nm laser excitation.



PL SPECTRA OF C & B DOPED DIAMOND

The PL spectra (converted to wavenumbers) ranging from 517 nm to 900 nm, covering a wider range, with a laser excitation wavelength of 514 nm. The insert shows similar PL conversion of the same sample with 458 nm laser excitation.



REFERENCES

[1] Sidorov, V. A., and E. A. Ekimov. "Superconductivity in diamond." *Diamond and related materials* 19.5-6 (2010): 351-357.
[2] Takano, Yoshihiko, et al. "Superconductivity in polycrystalline diamond thin films." Diamond and related materials 14.11-12 (2005): 1936-1938.
[3] Bustarret, Etienne, et al. "Metal-to-insulator transition and superconductivity in boron-doped diamond." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 366.1863 (2008): 267-279.