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Generation of luminescent defects in hBN by various irradiation methods

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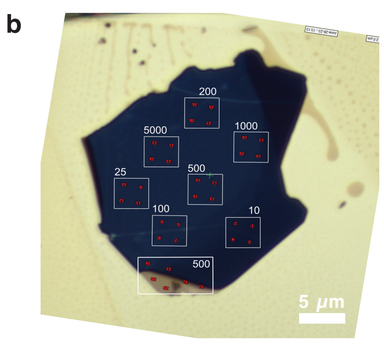
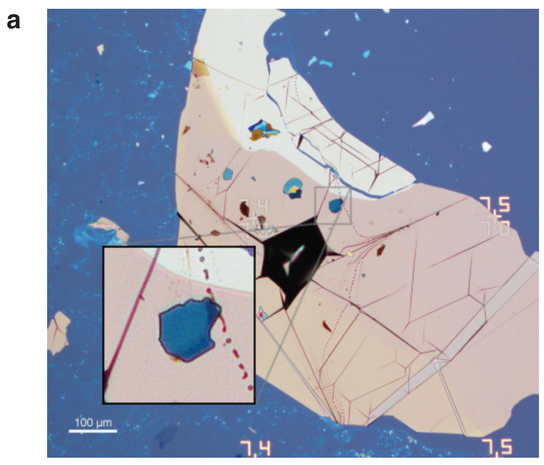
Abstract

• Luminescent centres in hBN show good brightness and excellent quantum properties at room temperature, making them potential competitors with state-of-the-art quantum emitters **[1]**.
• The charged Boron vacancy (V_B^-) is a luminescent centre featuring broad photoluminescence (PL) spectrum centered around 850 nm, along with magnetic properties with important applications in quantum sensing schemes **[2]**.
• In the present work, we use a Helium Ion Microscope (HIM) for irradiating hBN flakes to generate luminescent centres. We perform thorough PL characterization of these centres, showing that this technique can systematically produce high-quality luminescent emitters in hBN.

Samples production: Stacking

• We exfoliate high quality hBN flakes on Si/SiO_2 substrates, and we stack them on thick Graphite flakes.
• For stacking we use the PC/PDMS technique **[3]**, with PDMS droplets and cleaning PC leftovers in chloroform.
• After pre-PL characterization of the flakes, we irradiate them with He-ions.





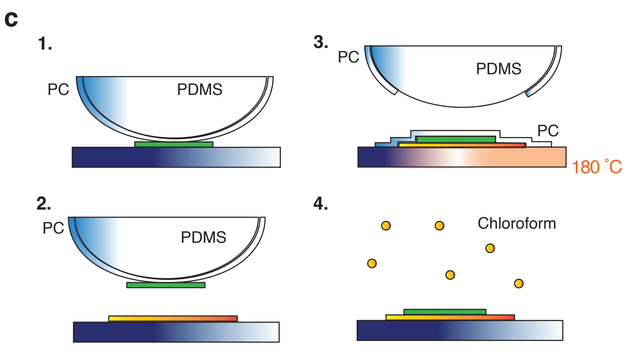


Figure 1: Illustration of the fabrication process: **(a)** optical image of stacked hBN on Graphite after cleaning in Chloroform; **(b)** HIM irradiation pattern on hBN flake on graphite. Doses are in $\mu C/cm^2$. **(c)** Schematic illustration of the PC/PDMS technique, adapted from **[3]**.

Ion Irradiation for Defects Generation

• It's possible to create charged boron vacancies (V_b^-) defects in hBN by shooting a focused Helium ions beam on thick hBN flakes.
• By stacking hBN on graphite, we try to create carbon-based defects in hBN by pure momentum transfer from He-ions to carbon atoms, as they try in **[4]**.
• To get insights of the behaviour of the ion beam in the material stack, we use the SRIM Monte Carlo simulation software.

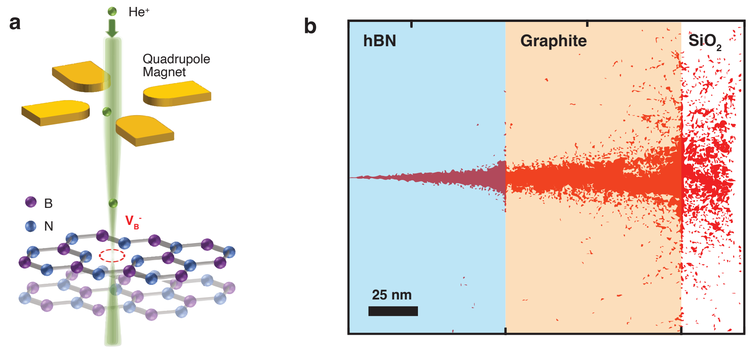


Figure 2: Illustration of the fabrication process from **[5]** for the generation of V_b^- defects: **(a)** Helium (He) ions are accelerated and focused on the hBN flake and create a charged vacancy in the lattice; **(b)** He-ions trajectories extracted from a SRIM simulation for hBN (80 nm) on top of graphite (90 nm) deposited on a SiO_2/Si stack (1000/5000 nm).

Characterization of Generated Defects

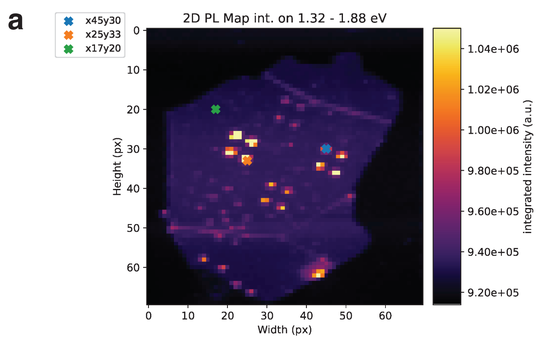
• After irradiation, we do PL characterization of the hBN flakes in a home-built photoluminescence (PL) setup, at different excitation energy and temperatures.

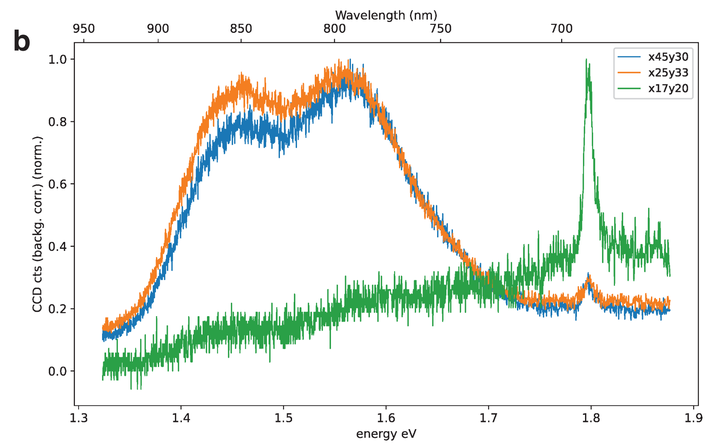
• The generated emitters have a PL spectrum with a characteristic strong, double-featured emission line centered around 825 nm (1.5 eV).

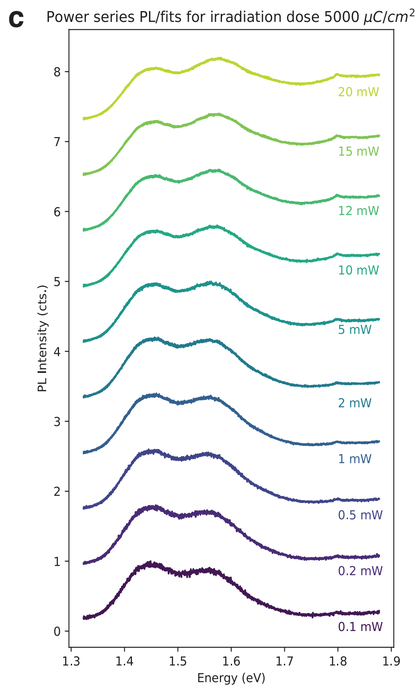
• Additionally, we performed laser power, time, polarization, temperature series measurements.

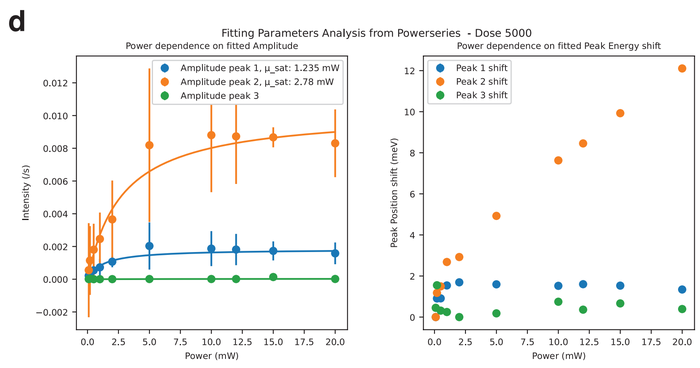
• A big challenge has been to reproduce the double feature, trying different laser excitation wavelengths, but so far it has been unsuccessful.

• Differential reflectance measurements have been also performed to rule out possible cavity effects.









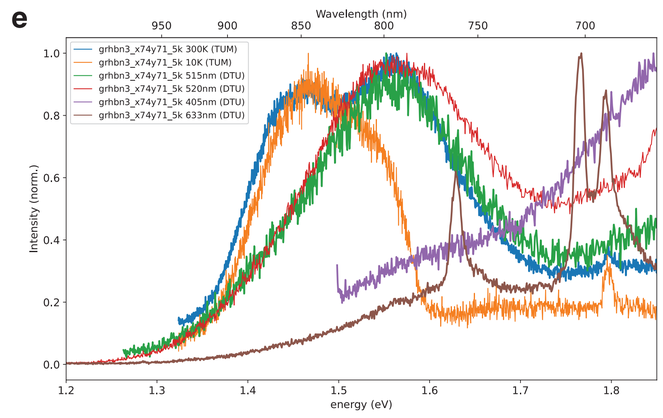


Figure 3: PL post-characterization results for 5k dose: **(a)** PL Map with irradiation spots well resolved; **(b)** PL spectra of example positions; **(c)** PL Power Series Measurements with fits for each spectrum; **(d)** Plot of the extracted Voigt peaks amplitude and center energy, as a function of excitation power, with corresponding error bars from the fit; **(e)** Spectral comparison between different measurements in TUM and DTU labs on 5k irradiation spot, for different excitation wavelengths and temperatures.

Acknowledgements & Outlook

Samples production and part of PL characterization has been performed in DTU. HIM-irradiation, PL characterization and low-T measurements have been performed in TUM.

Possible next steps are:
• perform ODMR (Optically Detected Magnetic Resonance) contrast, crucial for claiming that we are really dealing with V_b^- defects;
• use a supercontinuum laser, coupled with a spectral filter to conduct photo-luminescence excitation (PLE) measurements, in which PL spectra are taken at different excitation energies.

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