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Atomic Manipulation of hBN with Transmission Electron Microscopy for Quantum Optics Applications

Defects in hexagonal Boron Nitride (hBN) have recently been of great interest in the area of quantum optics, as they have shown to be promising platforms for single photon emission even at room temperature [1]. However, at the moment, the atomic composition of such defects is not well understood. Transmission electron microscopy (TEM) is an ideal tool for studying defects in two dimensional materials, as the sub-Angstrom resolution allows imaging a sample's lattice directly while simultaneously inducing the types of defects we would like to study. Furthermore, promising studies on graphene have shown manipulation of single Silicon atoms within a lattice [2][3], so we hope to expand this atomic-scale control to single photon emitters in hBN.

Using intensity contrast, we can resolve separate atomic species in our lattice, including Boron and Nitrogen, and identify what type of defect is created. By optimizing microscope parameters such as beam energy, dosage, exposure time, and dwell time, we can control the damage produced in the imaging area by the electron beam. Figure 1 shows the TEM image of the atomic structure of ~10nm-thick hBN. Three regions of interest are highlighted in the dashed boxes, showing pristine area (A), boron vacancy (B), and nitrogen vacancy (C).

Furthermore, by using a feedback loop of fabrication, imaging, spectroscopy, and density functional theory (DFT) simulations, we can link the atomic composition of such point defects and vacancies to photophysical properties and single-photon emission [4]. By optimizing STEM operation, we hope to deterministically and selectively remove atomic species in a pattern and develop large-scale single-photon emitter arrays.

References

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Figures

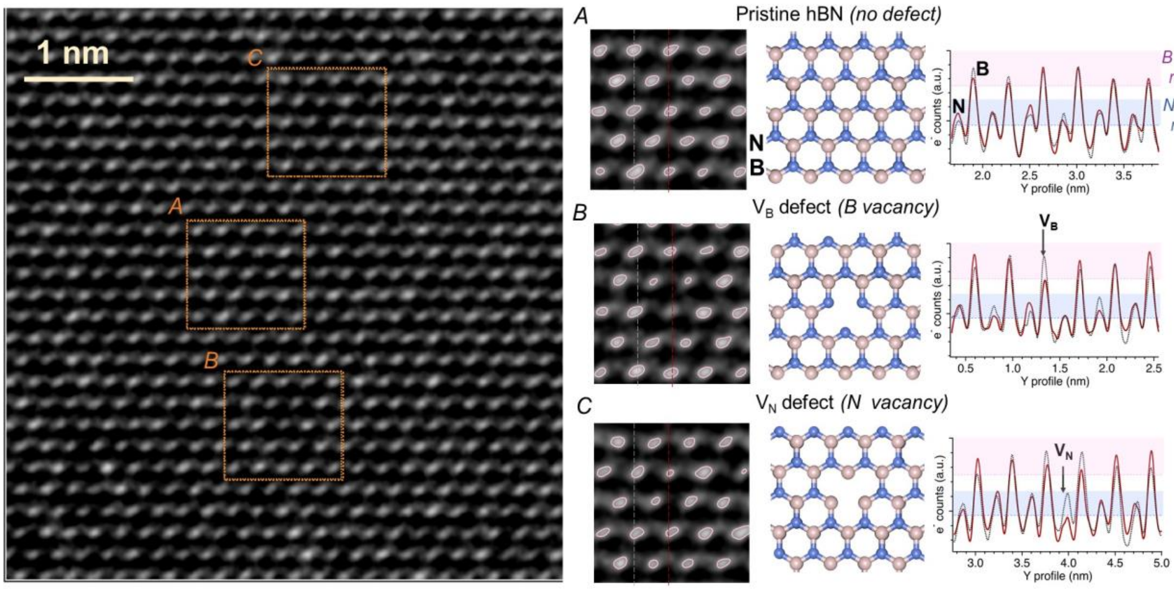

Figure 1: TEM Images showing single boron and single nitrogen vacancies in multilayer hBN. Atomic species are identified using intensity contrast, where, on average, boron atoms are 30 percent brighter than nitrogen.