Fabrication and Tuning of Photonic Crystal Cavities in Hexagonal Boron Nitride by Electron Beam Induced Etching

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Exceptional efforts have been undertaken in recent years to identify suitable platforms for solid state quantum photonic technologies[1] and to develop new fabrication schemes to exploit the full potential of these materials. Ideally, such a material hosts on-demand single photon emitters and can be easily processed in a robust and reliable manner to yield functional nanostructures on a large scale. While the first criterion is fulfilled for hexagonal Boron Nitride (hBN) due to the discovery of room-temperature, stable, ultra-bright quantum emitters[2], the second remains a challenge as, until recently, fabrication of complex hBN geometries was not viable. As hBN is a layered van der Waals crystal, several established processing steps, such as vapor release techniques, or angled bulk etching neither tackle the weaknesses nor exploit the advantages of this material. Yet, the intriguing characteristics of this materials necessitate a robust fabrication scheme to exploit it in qunatum photonic devices that have applications in quantum information processing. Here, we demonstrate a new processing approach for the fabrication of complex photonic nanostructrues in suspended hBN[3]. Using the technique of Electron Beam Induced Etching (EBIE)[4] we demonstrate photonic crystal cavities with quality factors of close to 2000 (Fig. 1). The EBIE technique employs an electron beam and a precursor gas - in this case H_2O vapour - to induce dry etching through chemical reactions that volatilize hBN. It is minimally invasive, as evidenced by no changes in Raman spectra obtained before and after processing. A further highlight of our study is the demonstration of cavity tuning using mask-free, direct-write focused electron beam induced etching (Fig. 2). This approach is appealing as it allows iterative, selective tuning of individual devices on a chip. Even more intriguingly, we discovered that electron beam processing of hBN can give rise to the creation (or activation) of single photon emitters. This compelling effect suggests that electron beam processing may provide a pathway for deterministic fabrication of single photon emitters with high spatial resolution. Overall, our methodology and results set the foundation for cavity quantum electrodynamics experiments to be performed using hBN and other material platforms.

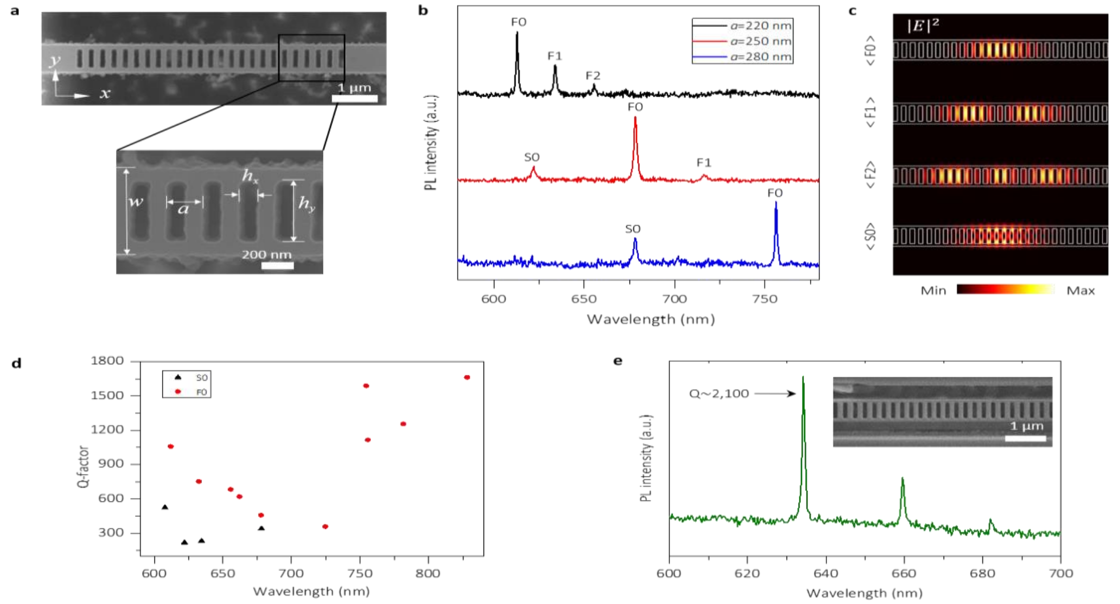

Figure 1 Photonic Crystal cavity fabricated in hBN a, SEM image of a 1D ladder cavity, showing the geometrical parameters; width (*w*), lattice constant (*a*), air hole width (h_x), and air hole height (h_y), whose dimensions determine the resonant wavelength of the cavities. **b,** by using different geometries, various resonances in the cavities were realised.

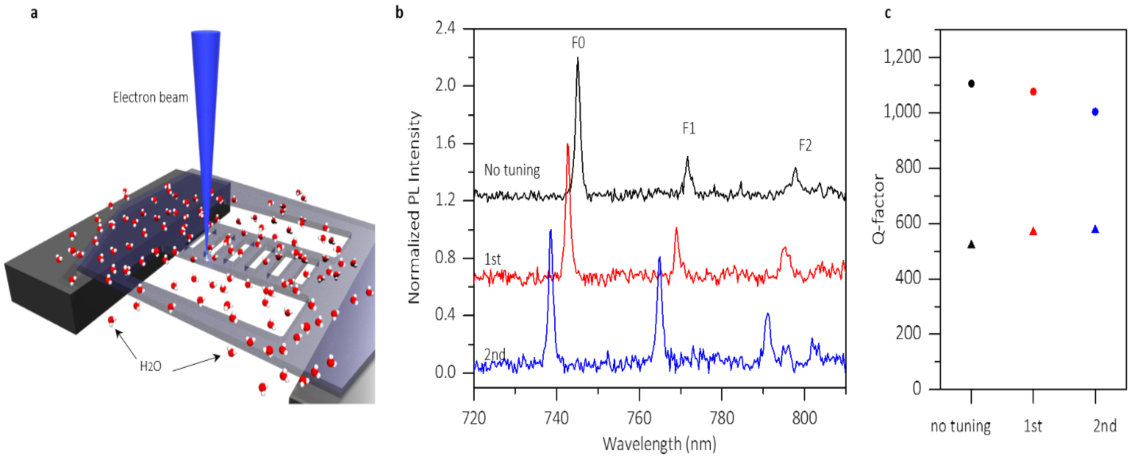

Figure 2 Direct-write iterative editing of a single cavity using FEBIE a, Schematic depiction of the editing process in which a focused electron beam (blue) etches selected areas of the cavity, resulting in an effective dimension change of the cavity. **b,** the resonant modes of the cavity can be shifted deterministically using this technique.

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