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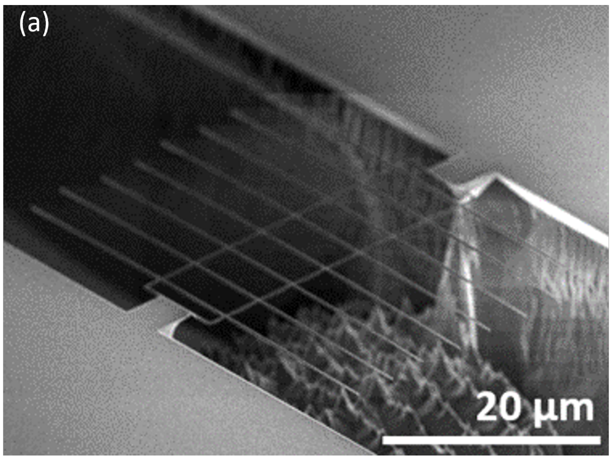
Abstract: We present our optimized diamond fabrication process based on quasi-isotropic crystal-plane-dependent reactive-ion-etching at low and high temperature plasma regime. We demonstrate successful integration of SnV centers in diamond waveguides showing quantum non-linear effects. We report on our latest results on all-diamond photonic crystal cavities.

1. Introduction

Future quantum networks, based on quantum processor nodes connected via optical channels, envision applications such as secure communication, distributed quantum computation and enhanced sensing. Optically active spin qubits in diamond represent an auspicious building block [1], with recent demonstration of a multinode quantum network of remote solid-state qubits [2] and qubit teleportation between non-neighbouring nodes [3]. Further scaling of such systems requires nodes that combine excellent spin qubit control and coherence with efficient spin-photon interfaces. Diamond Tin-Vacancy (SnV) centers have recently emerged as prime node candidates thanks to their long spin coherence times and strong optical coherence even when integrated in photonic nanostructures. This enables engineering of quantum light-matter interactions for efficient spin-photon interfaces. However, fabrication of free-standing nanostructures from bulk diamond substrates is challenging: we present our fabrication process flow and demonstrate that the designed structures can be undercut via quasi-isotropic crystal-plane-dependent reactive-ion-etching. On fabricated 1D photonic waveguides, we observe extinction of the transmitted signal due to efficient coupling of a single SnV to the waveguide mode. We verify the interaction at single-photon level by probing the effect on the photon statistics. We report on latest results on all-diamond photonic crystal cavities.



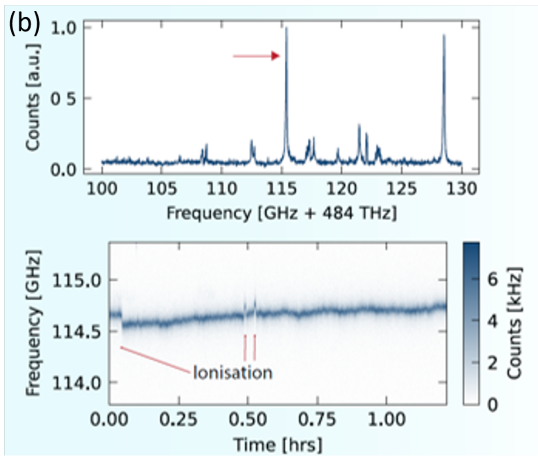


Fig. 1. Coupling SnV centers to a diamond waveguide. (a) SEM picture illustrating typical fabricated diamond chiplet with several nanowaveguides. (b) Top: photoluminescence excitation on a waveguide showing several SnVs. Bottom: consecutive PLE scans showing the stability of the integrated in waveguide SnV.

2. Results

The nanofabrication of the waveguides and photonic crystal cavities is based on the crystal-dependent quasi-isotropic-etch undercut method [4, 5]. We start by preparing a hard mask material for in-plane Si_3N_4 coverage, followed by the etching the structures into the diamond substrate. The vertical coverage of diamond structures sidewalls is realized by conformal Al_2O_3. For the waveguide structures, the crystal-dependent quasi-isotropic-etch undercut is demonstrated at a considerably lower temperature of the reactor wafer table of only 65 °C [6], a plasma regime different from earlier works [4, 7]. A typical diamond waveguide chiplet is illustrated in Fig. 1 (a), with photoluminescence excitation of a diamond integrated SnV illustrated in Fig. 1(b). For the photonic crystal cavities structures, the crystal-dependent quasi-isotropic-etch successfully undercuts the devices at a higher temperature of the reactor wafer table of 250 °C [4], with typical photonic crystal cavities diamond chiplets illustrated in Fig. 2(a). Simulated quality factors of the patterned cavities are Q $\sim 10^6$ with an optical mode volume V$\sim 0.46(\lambda/n)^3$ [5], while typical experimental measured values of Q are about 1.3×10^4.

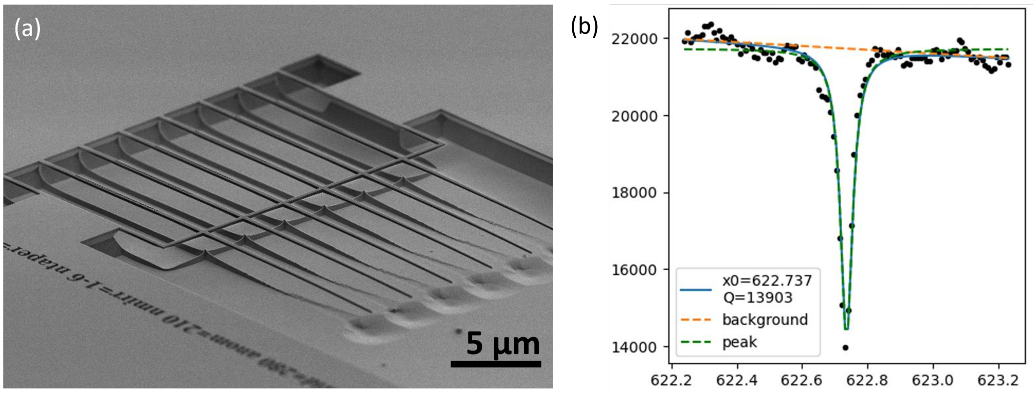


Fig. 2. Photonic crystal cavities in diamond. (a) SEM picture illustrating a typical fabricated diamond chiplet containing several one-sided photonic crystal cavities: on each chiplet, the number of mirror holes on the unbalanced side is varied in order to optimize the trade-off between quality factor Q and coupling to the cavity. (b) Typical measured resonance wavelength and quality factor Q of about 1.3×10^4.

3. Acknowledgment

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