Diamond quantum photonics platform enabled by femtosecond laser processing

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Diamond is a promising platform for sensing and quantum processing thanks to the remarkable properties of the nitrogen-vacancy (NV) impurity [1]. However, still lacking is an efficient photonic fabrication method for diamond akin to the photolithographic methods that have revolutionized silicon photonics. For the first time, we demonstrate waveguiding in diamond using femtosecond laser writing using a pulse width of 230 fs, 515 nm wavelength, focusing with a 1.25-NA lens and 50 µm below the surface of diamond (type II, optical grade, MB Optics). The inscribed Type II waveguide showed single mode behavior when scanning the input launch fiber transversely. To achieve single mode guiding, we wrote a second type II modification, consisting of two vertically offset lines (Fig. 1(b)). This supported a single mode at 635 nm with a similar transmission as the two-line modification. Fig2c is the PL spectra from the waveguide, both spectra show the first order Raman peak at 573 nm, the ZPL at 637 nm along with its broad phonon sideband from 600 to 800 nm. The spectrum in pristine diamond is the same as that in the waveguide.

Characterizing the waveguides using µRaman (Fig.2), it was found that within the laser modification written at 500-kHz rep. rate, a reduction of the characteristic diamond peak at 1332 cm⁻¹ is observed along with the appearance of the G-peak at 1575 cm⁻¹ and the D-peak at 1360 cm⁻¹, showing a transformation of the sp³ to sp² bonding. The width of D and G peaks (greater than 100 cm⁻¹) and the intensity ratio between them (I(D)/I(G) < 1) indicate that sp² clusters are mainly in amorphous carbon phase rather than graphite [2].

As repetition rate was reduced, we observed a sharper G-peak with a slight displacement to higher wavenumber, implying a greater concentration of nanocrystalline graphite [3]. We also found that the second order peaks appear for 5 and 25 kHz, but not for 500 kHz, evidencing increased graphitization at the lower repetition rates [4].