Improving Diamond Color Center Yield via Ultraviolet Irradiation during High-Temperature Annealing

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Color centers in diamond show promise for a wide variety of applications, ranging from bioimaging, lattice strain measurement, electric and magnetic field sensing, to quantum information science. This utility arises from their ability to couple electronic spins with optical photons along with the capacity of scalable manufacturing. While nitrogen vacancies have been more commonly studied for these applications, silicon vacancies (SiVs) provide distinct advantages due to weaker electron-phonon coupling and stronger emission into zero-phonon lines. Focused ion beam (FIB) implantation of these defects allows for spatially precise implantation of SiVs, in principle making them an easily scalable quantum defect, ready for device integration. However, the conversion yield of implanted ions to optically active SiVs is low, such that the number of defect centers at a given location follows Poisson statistics. This leads to a non-negligible number of sites containing no SiV, or multiple adjacent SiVs, inhibiting the utility of devices which require individual, isolated defect centers. Therefore, implantation and post-processing methods that afford consistent and spatially precise production of single SiVs are highly sought-after. Recent density functional theory (DFT) calculations suggest that post-implantation annealing of SiV implanted diamond under ultraviolet (UV) irradiation can assist with the dissociation of divacancy sites, potentially increasing the activation yield of SiV. To test the theoretical results, we implant silicon ions in a lab manufactured high-purity (<1 ppb impurity concentration) diamond sample using FIB implantation at 70 keV, followed by annealing at 800C for different soak times where half of the sample is exposed to UV LED irradiation. The annealing setup is shown in Fig. 1. The presence of SiV is then measured using scanning photoluminescence (PL) spectroscopy, spatially resolved using a high-NA objective microscopy setup. Comparison between UV-irradiated and blanked regions of the sample shows increased PL brightness, suggesting that the UV annealing procedure increases the activation yield of SiV. While current results using an LED, pictured in Fig. 2, show only marginal increase in PL brightness by 18%, using a higher brightness UV laser or exposing the sample to UV light during a longer annealing step will likely improve upon this number. The presented technique therefore shows promise as a step in the deterministic manufacture of single SiV defect sites.

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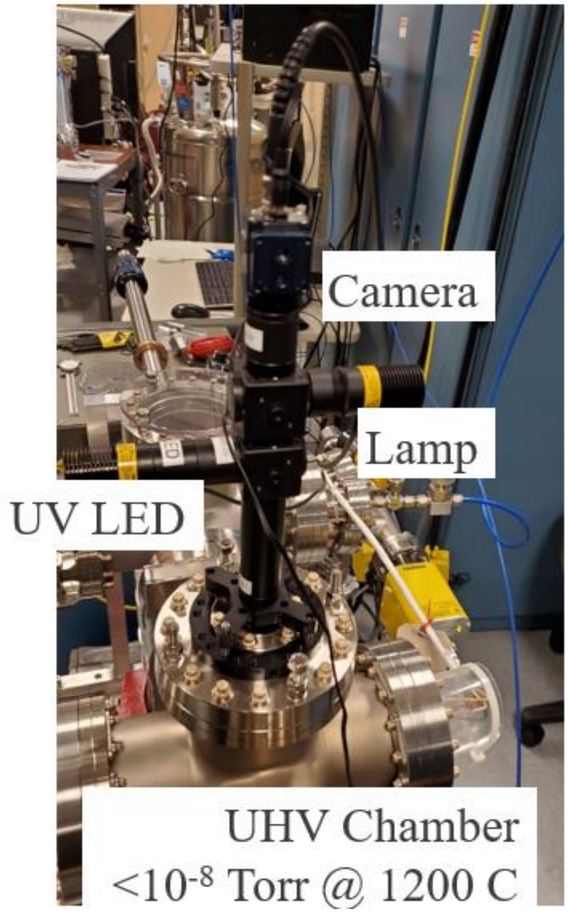

Figure 1: Sample is annealed in UHV chamber under UV irradiation.

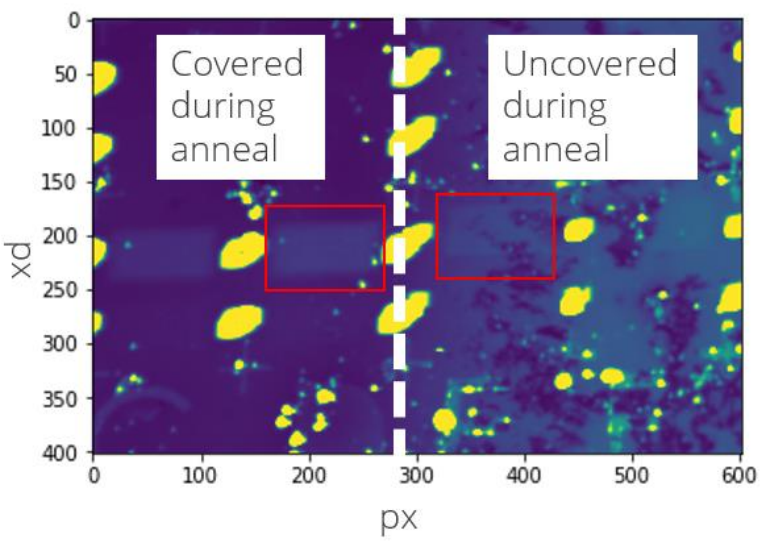

Figure 2: Preliminary PL measurements of the UV irradiated side of the sample show a modest increase in SiV- spectral line intensity compared to the blanked side of the sample.