A new tool to perform hot ion implantation for the creation of dense NV ensembles in diamond

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The Focused Ion Beam (FIB) has emerged over the past decade as an exceptionally powerful tool that has taken its place among other material science instruments. Whether configured as a single-beam or dual-beam microscope, this instrument can be used for a variety of purposes including ion microprobe, secondary ion mass spectroscopy, ion microscopy, lithography, microfabrication, ion beam etching, ion beam deposition, or ion implantation.
Combined with a Wien Filter capable of separating the different species of a Liquid Metal Alloy Ion Source (LMAIS) or plasma source, such a filtered FIB (ExB FIB) enables the use of a vast majority of ion species [1] and increases, even more, the potential applications.

ORSAY PHYSICS, in this presentation, introduces a new dedicated implantation tool, including an *in-situ* heating stage, and that can give access to a wide range of species for the implantation application.

More specifically, we will present an application where argon or nitrogen species have been used for the implantation and milling of diamond substrates. Indeed, the creation of dense and shallow nitrogen-vacancy (NVs) with good spin properties, is a prerequisite for the development of diamond-based quantum sensors with improved performance. Ion implantation is a key tool for precisely controlling the spatial localization and density of NV color centers in diamonds. However, the number of conversions from implanted ions to color centers suffers from a low creation yield while too high ion fluences lead to considerable damage to the crystal lattice. In this presentation, we will show that when ions are implanted *in-situ* at 800°C, NV photoluminescence emission is increased by more than a factor of 3. In addition, we observed that at this temperature, ion fluences above 2×10^{14} ions/cm² can be used without graphitization occurring, in contrast to room-temperature implantation.

[1] L. Bischoff, et al. (2016), Appl. Phys. Rev., 3 021101.
[2] Ngambou et.al (2023). https://doi.org/10.48550/arXiv.2311.05328

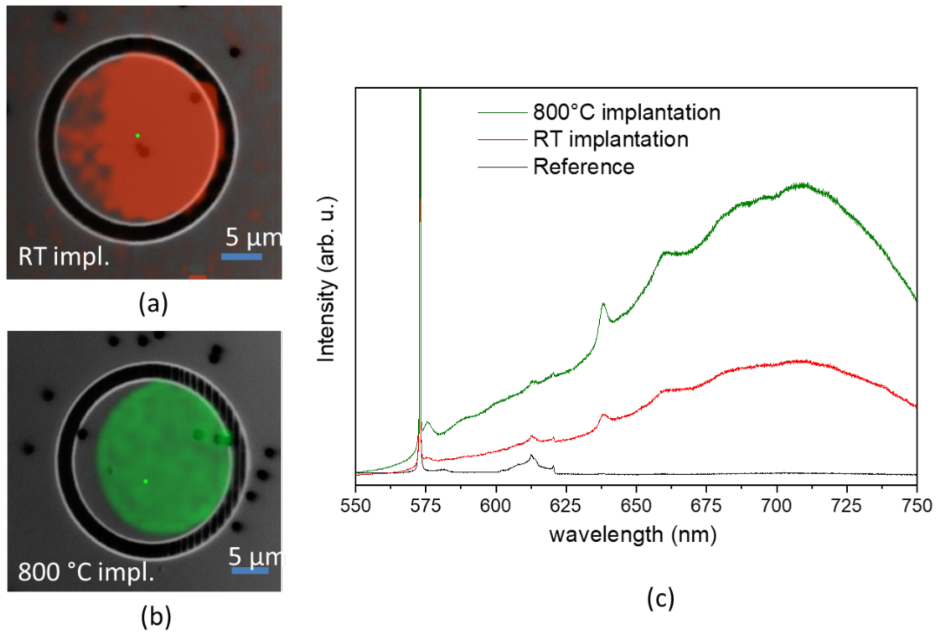

Figure 1: Photoluminescence maps acquired at a wavelength of 638 nm from two ellipses implanted at room temperature in red (a) or 800 °C in green (b) with the implantation tool. PL spectra in this spectral region are plotted in (c) to compare their intensity