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Creation and characterization of He-related color centers in diamond

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ABSTRACT

Diamond is a promising material for the development of emerging applications in quantum optics, quantum information and quantum sensing. The fabrication and characterization of novel luminescent defects with suitable opto-physical properties is therefore of primary importance for further advances in these research fields.

In this work we report on the investigation in the formation of photoluminescent (PL) defects upon MeV He implantation in diamond. Such color centers, previously reported only in electroluminescence and cathodoluminescence regime, exhibited two sharp emission lines at 536.5 nm and 560.5 nm, without significant phonon sidebands.

A strong correlation between the PL intensities of the above-mentioned emission lines and the He implantation fluence was found in the 10^{15}–10^{17} cm^{-2} fluence range. The PL emission features were not detected in control samples, i.e. samples that were either unirradiated or irradiated with different ion species (H, C). Therefore, the PL features are attributed to optically active defects in the diamond matrix associated with He impurities. The intensity of the 536.5 nm and 560.5 nm emission lines was investigated as a function of the annealing temperature of the diamond substrate. The emission was observed upon annealing at temperatures higher than 500 °C, at the expenses of the concurrently decreasing neutral-vacancy-related GR1 emission intensity. Therefore, our findings indicate that the luminescence originates from the formation of a stable lattice defect. Finally, photoluminescence from He-related defects was observed under different laser excitations wavelengths (i.e. 532 nm and 405 nm), thus providing promising evidence of a broad spectral range for optical stimulation.

1. Introduction

In the last decade diamond has been thoroughly investigated as a promising material for applications in the field of quantum optics, due to the discovery and the characterization of several luminescent point defects with appealing light emission and spin properties [1–3].

Up to date, the most prominent system in this field is the negatively-charged nitrogen-vacancy center (NV^-), whose well established high quantum efficiency, stability at room temperature and appealing spin properties structure represent an intriguing potential for applications in quantum photonics, cryptography, sensing and computing [4–9]. On the other hand, some of its limitations (relatively long radiative lifetime, charge state blinking and broad spectral emission [10]) led to the exploration of alternative luminescent centers for single-photon source applications, such as the Si-V center [11,12], Ni- [13–15], Eu- [16] and Ge-related [17,18] impurities, as well as radiation-damage related defects [19] and other bright NIR emitters [20,21], which demonstrated up to tenfold higher emission rates, as well as a strongly polarized and spectrally narrower emission. Thus, the fabrication of novel luminescent defects with desirable properties upon the implantation of selected ion species still represents a crucial strategy to achieve further advances in the aforementioned research fields.

In this work, we report on the investigation of the photoluminescence (PL) properties of optically active defects in diamond obtained upon the implantation of MeV He^+ ions and subsequent thermal annealing at temperatures >500 °C. The measured PL

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