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Magnesium-Vacancy Optical Centers in Diamond

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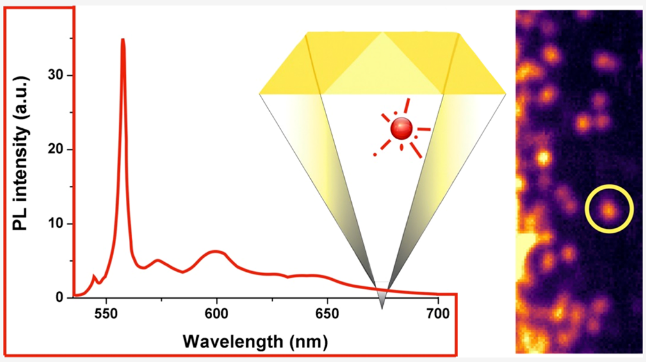

ABSTRACT: We provide the first systematic characterization of the structural and photoluminescence properties of optically active centers fabricated upon implantation of 30−100 keV Mg^+ ions in synthetic diamond. The structural configurations of Mg-related defects were studied by the electron emission channeling technique for short-lived, radioactive ^{27}Mg implantations at the CERN-ISOLDE facility, performed both at room temperature and 800 °C, which allowed the identification of a major fraction of Mg atoms (∼30 to 42%) in sites which are compatible with the split-vacancy structure of the MgV complex. A smaller fraction of Mg atoms (∼13 to 17%) was found on substitutional sites. The photoluminescence emission was investigated both at the ensemble and individual defect level in the 5−300 K temperature range, offering a detailed picture of the MgV-related emission properties and revealing the occurrence of previously unreported spectral features. The optical excitability of the MgV center was also studied as a function of the optical excitation wavelength to identify the optimal conditions for photostable and intense emission. The results are discussed in the context of the preliminary experimental data and the theoretical models available in the literature, with appealing perspectives for the utilization of the tunable properties of the MgV center for quantum information processing applications.

KEYWORDS: *diamond, ion implantation, magnesium, color centers, emission channeling, lattice location*

1. INTRODUCTION

Diamond is a promising material platform for photonic quantum technologies, which offers single-photon sources for quantum information processing and sensing schemes based on the optical activity of lattice defects. These systems, commonly known as "color centers", can be engineered upon the controlled introduction of impurities in the diamond crystal structure by ion implantation.[1−3] Besides the well-known and widely investigated negatively charged nitrogen-vacancy center (NV^-), offering unique photophysical properties (photo-stability at room temperature, high quantum efficiency, and optically addressable spin properties) for quantum sensing and computing applications,[4−9] additional single-photon-emitting color centers with appealing features have emerged in the last decade, including group-IV impurities,[10−18] noble gases,[19−21] and other impurity-related defects.[22−24]

Particularly, recent work has shown a preliminary demonstration of the optical activity of Mg-related color centers in diamond. The available experimental data suggested the formation of an optically active defect (magnesium-vacancy center, MgV in the following) upon Mg ion implantation and annealing, denoted by a sharp emission line at 557.4 nm, low phonon coupling denoted by a high Debye−Waller factor, high (>0.5 Mcps) emission intensity, and 2−3 ns radiative lifetime.[25] Furthermore, these results fed the deployment of a detailed numerical ab initio study of the color center's structure,[26] offering an intriguing insight in its opto-physical properties, including the prediction of a large and tunable and spin-dependent ground-state splitting, thus offering an appealing tool for quantum information processing purposes.

In this work, we report on a systematic investigation of the MgV color center in diamond. The analysis covers both its structural properties and efficiency of structural formation, as evidenced from the determination of the lattice sites of implanted Mg by the emission channeling technique, and the optical emission properties, studied in the photoluminescence

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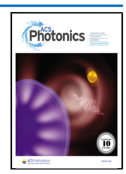

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