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Article

Photoactivation of Color Centers Induced by CW Laser Irradiation in Ion-Implanted Diamond

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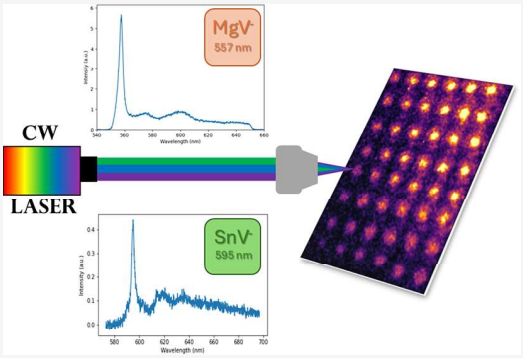
ABSTRACT: Split-vacancy color centers in diamonds are promising solid-state platforms for the implementation of photonic quantum technologies. These luminescent defects are commonly fabricated upon low-energy ion implantation and subsequent thermal annealing. Their technological uptake will require the availability of reliable methods for the controlled, large-scale production of localized individual photon emitters. This task is partially achieved by controlled ion implantation to introduce selected impurities in the host material and requires the development of challenging beam focusing or collimation procedures coupled with single-ion detection techniques. We report on the protocol for the direct optical activation of split-vacancy color centers in diamond via localized processing with a continuous-wave laser at mW optical powers. We demonstrate the activation of photoluminescent Mg- and Sn-related centers at both the ensemble and single-photon emitter levels in ion-implanted, high-purity diamond crystals without further thermal processing. The proposed lithographic method enables the activation of individual color centers at specific positions of a large-area sample by means of a relatively inexpensive equipment offering real-time, in situ monitoring of the process.



KEYWORDS: *color centers, split-vacancy, single-photon, diamond, ion implantation, laser activation*

INTRODUCTION

Color centers in diamond represent promising platforms for the implementation of quantum technologies.[1−3] Their capability to generate single photons on demand represents a viable tool for realizing high-density photonic platforms operating at room temperature.[4,5] Among the known single-photon emitters (SPEs) in diamond, the negatively charged nitrogen-vacancy (NV^-) center,[6−8] offers enticing applications in the field of quantum sensing and metrology in virtue of its outstanding optically addressable spin properties at room temperature[9,10] and its sensitivity to external electromagnetic fields.[11,12] The latter feature, combined with a low Debye−Waller factor and a long radiative lifetime, could nevertheless represent a significant drawback for other specific applications in the framework of quantum technologies, in which the generation of indistinguishable photons at a high rate is required.[1,13] Various alternative color centers have therefore drawn increasing attention in the past few years, including the group-IV related defects (also known as G4 V color centers)[14−18] and the magnesium-vacancy emitter.[19] These systems, all of which are based on the split-vacancy structural configuration, display substantially better properties in terms of zero-phonon line (ZPL) emission line width, Debye−Waller factor, and emission rate, and they offer lower environmental sensitivity in addition to energy level configurations that allow the implementation of coherent control schemes.[4,20]

In particular, this work focuses on the formation of two of the aforementioned luminescent defects in diamond, namely, the negative charge state of the tin-vacancy (SnV)[21,22] and magnesium-vacancy (MgV) defect complexes.[19] The SnV^- center has emerged as an important quantum platform in the field of quantum communication due to its long coherence time, even at relatively high temperatures.[15,23] On the other hand, the MgV^- center is a newly discovered emitter that holds substantial potential for implementation in quantum sensing and photonics.[19,24] Understanding the dynamics related to the formation and activation of these defects is therefore of crucial importance for fully exploiting their quantum-optophysical properties in quantum technologies.

To date, the most widely employed method for creating defects in diamond is based on ion implantation followed by a high-temperature annealing to promote the formation of stable

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