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Single-Photon Emitters in Lead-Implanted Single-Crystal Diamond

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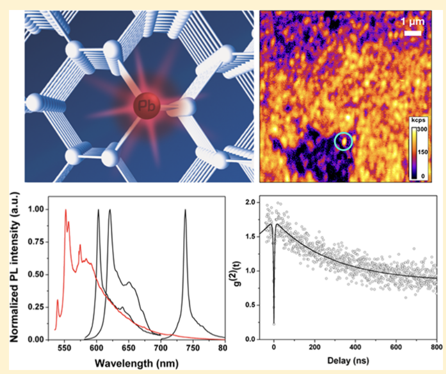
ABSTRACT: We report on the creation and characterization of Pb-related color centers in diamond upon ion implantation and subsequent thermal annealing. Their optical emission in the photoluminescence (PL) regime consists of an articulated spectrum with intense emission peaks at 552.1 and 556.8 nm, accompanied by a set of additional lines in the 535−700 nm range. The attribution of the PL emission to stable Pb-based defects is corroborated by the correlation of its intensity with the implantation fluence of Pb ions. PL measurements performed as a function of sample temperature (in the 143−300 K range) and under different excitation wavelengths (i.e., 532, 514, 405 nm) suggest that the complex spectral features observed in Pb-implanted diamond might be related to a variety of different defects and/or charge states. The emission of the 552.1 and 556.8 nm lines is reported at the single-photon emitter level, demonstrating that they originate from the same individual defect. This work follows from previous reports on optically active centers in diamond based on group-IV impurities, such as Si, Ge, and Sn. In perspective, a comprehensive study of this set of defect complexes could bring significant insight on the common features involved in their formation and opto-physical properties, thus offering a basis for the development of a new generation of quantum-optical devices.



KEYWORDS: *diamond, lead, color centers, single-photon source, ion implantation, photoluminescence*

Diamond is a promising platform for the development of solid-state quantum devices with applications in quantum information processing and sensing.[1−5] In recent years, the search for optically active defects with appealing properties has led to the discovery of several classes of color centers[6−11] alternative to the widely investigated negatively charged nitrogen-vacancy complex (NV^- center).[12] This is motivated by the fact that the NV^- defect, although extremely promising for its peculiar spin features,[13] is limited in several applications by suboptimal opto-physical properties, such as a spectrally broad emission with intense phonon sidebands, the presence of charge state blinking, and a relatively low emission rate.[14−16] In particular, the silicon-vacancy center (SiV)[17] has attracted significant attention due to a near transform-limited emission,[18,19] good photon indistinguishability,[19,20] the capability of coherently controlling its spin properties,[21−24] and the emergence of reliable techniques for its deterministic fabrication.[25−28]

The recently explored emitters related to group-IV impurities, such as the germanium-related (GeV)[29−31] and tin-related (SnV)[32−34] color centers, are characterized by similar defect structure and opto-physical properties to those of the SiV center, such as photostability, narrow zero-phonon line (ZPL), relatively small phonon coupling, and high emission rate. This brings further interest in this class of optically active defects. In particular, these recent discoveries open the question of whether the whole set of group-IV-based complexes (SiV, GeV, SnV, and now PbV) result in stable optically active emitters, and second whether the properties of these color centers exhibit any common features.

In this work, we present evidence of photoluminescence (PL) emission from color centers created upon the implantation of Pb ions in diamond followed by thermal annealing. To the best of the authors' knowledge, in a recent work[35] promisingly similar results were obtained from low-fluence Pb implantations in diamond, although with several differences, which could be ascribed to different experimental conditions (excitation wavelengths, spectral filtering, measurement temperature).

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