New Journal of Physics
The open access journal at the forefront of physics

Deutsche Physikalische Gesellschaft DPG
IOP Institute of Physics

Published in partnership with: Deutsche Physikalische Gesellschaft and the Institute of Physics

CrossMark

OPEN ACCESS

RECEIVED
2 February 2021

REVISED
15 May 2021

ACCEPTED FOR PUBLICATION
20 May 2021

PUBLISHED
14 June 2021

PAPER

Spectral features of Pb-related color centers in diamond – a systematic photoluminescence characterization

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Keywords: diamond, ion implantation, single photon emitters, luminescent centers, Pb-related color center

Abstract

We report on the systematic characterization of the optical properties of diamond color centers based on Pb impurities. An ensemble photoluminescence analysis of their spectral emission was performed at different excitation wavelengths in the 405–520 nm range and at different temperatures in the 4–300 K range. The series of observed spectral features consist of different emission lines associated with Pb-related defects. Finally, a room-temperature investigation of single-photon emitters under 490.5 nm laser excitation is reported, revealing different spectral signatures with respect to those already reported under 514 nm excitation. This work represents a substantial progress with respect to previous studies on Pb-related color centers, both in the attribution of an articulated series of spectral features and in the understanding of the formation process of this type of defect, thus clarifying the potential of this system for high-impact applications in quantum technologies.

1. Introduction

Diamond color centers have been extensively studied in the last decades as appealing systems for applications in quantum optics and quantum information processing, ranging from the use as single photon emitters to quantum sensing of magnetic and electric fields and of temperature, pressure and strain [1–7]. Despite the increasing interest of these systems among the scientific community, only a fairly limited number of emitters related to impurities incorporated in the diamond lattice has been demonstrated so far [6, 8, 9], and most of the preliminary practical demonstrations of diamond-based quantum technologies rely on the peculiar spin properties of the negatively-charged nitrogen-vacancy color center (NV) [10–15].

Indeed, even if NV centers present several interesting properties, they are also subject to significant drawbacks, such as broad spectral emission, charge state blinking, relatively low emission rate [16, 17], thus prompting for the search of alternative new centers overcoming this limits and/or presenting complementary properties.

Besides the already consolidated color centers related to group-IV impurities such as SiV, GeV, and SnV complexes [6, 18–27], two independent works have recently demonstrated the creation of optically-active defects in diamond upon Pb ion implantation and subsequent annealing, and have reported their characterization at the single-photon emitter level [28, 29].

The Pb-related defects exhibited appealing emission properties for quantum information processing applications, with room temperature photoluminescence (PL) emission rates exceeding 10^6 photons s^{-1} [28], an emission mainly concentrated in the zero phonon line (ZPL) due to the low phonon coupling and a