

Temperature Dependence of Photoluminescence from Heavy Group-IV Color Centers in Diamond

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Color centers in diamond are a promising candidate for quantum network applications, requiring excellent optical and spin properties. Although a nitrogen-vacancy (NV) center has been most intensively studied, it suffers from a low fraction of the zero phonon line (ZPL) in its total fluorescence, only ~4%. In contrast, color centers based on group-IV elements show sharp ZPLs with suppressed phonon side bands. Among them, a tin-vacancy (SnV) center shows a high fluorescence intensity and is expected to possess a long spin coherence time in the Kelvin range [1], compared with milli-Kelvin for a silicon-vacancy (SiV) center [2], due to the large energy-level splitting induced by spin-orbit interaction in the ground state. Temperature dependence of the fluorescence is an important characteristic to understand the optical properties of color centers. In this study, we report the detailed temperature behavior of the fluorescence from the SnV in diamond, and also from a heavier element center, called lead-vacancy (PbV) centers [3,4].

The ensemble SnV and PbV centers were formed by ion implantation and HPHT anneal [1] in a single crystal diamond. The PL measurements were performed using a cryostat confocal fluorescence microscope system with an excitation laser of 515 nm. For the SnV center, at cryogenic temperatures, the split ground and excited states give rise to four optical transition paths, labelled from A to D, as shown in Fig. 1. With increasing temperature, the four obvious peaks merge into two, then into a single broaden peak. A weak phonon side band at ~1.97 eV is also observed. Then, we plotted the variation trends of the B, C, and D peaks as shown in Fig. 2 (A-transition is too weak to provide reliable data). Their shifts take on the same tendency: relatively flat at low temperatures and decreasing rapidly after a threshold temperature, in agreement with ref. [5]. We found that the difference in the peak shift values among the transitions resulted in temperature-dependent splittings in the ground and excited states of the SnV centers in diamond. We also observed the red shifts of the two peaks (C, D) in the PbV centers as increasing the temperature, but other two peaks (A, B) did not appear. This is probably due to the large excited state splitting of the PbV centers.

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[1] T. Iwasaki et al., Phys. Rev. Lett. 119, 253601, 2017. [2] D. D. Sukachev et al., Phys. Rev. Lett. 119, 223602, 2017. [3] S. D. Tchernij, et al., ACS Photon. 5, 4864, 2018. [4] M. E. Trusheim et al., Phys. Rev. B 99, 075430, 2019. [5] J. Görlitz, et al., New J. Phys. <https://doi.org/10.1088/1367-2630/ab6631>.

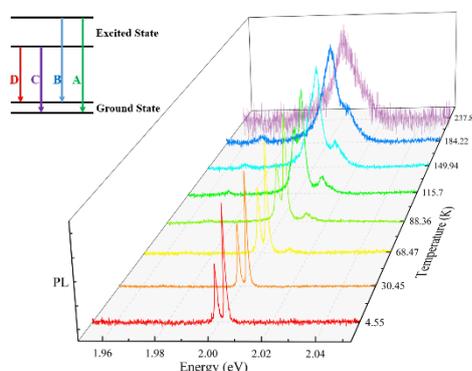


Figure 1. Temperature dependence of PL spectrum of SnV centers. Inset: energy level with four transitions.

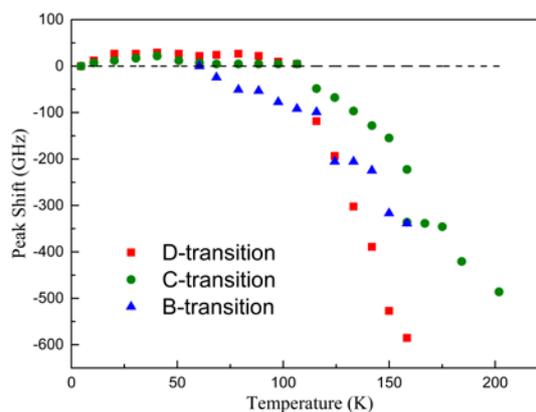


Figure 2. Peak shift of B, C, and D transitions.