# Optical and spin properties of color centers in diamond needles

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Diamonds, the hardest natural material, have unique properties that are essential for industrial and scientific applications. Made of carbon atoms arranged in a crystalline structure, diamonds also exhibit remarkable optical clarity and high thermal conductivity. Beyond their use in jewelry, diamonds are crucial for cutting, grinding, and drilling tools. Additionally, fluorescent point defects, known as color centers, have been actively researched in recent decades, enhancing diamond's value for advanced technological applications. These color centers exhibit bright, stable fluorescence even at room temperature, making them ideal for imaging and optical sensing. High-precision optical registration of pH [1] and temperature [2] using color centers has been demonstrated. Combined with diamond's biocompatibility, the unique optical properties of color centers hold promise for bioimaging and medical diagnostics at the cellular level. Moreover, color centers often function as single molecules with quantum features, making diamond a promising solid-state platform for quantum applications. Leveraging these properties, diamonds have shown potential in various quantum fields. In quantum sensing, diamonds serve as nano-thermometers [3] and sensors for magnetic and electric fields [4,5] and mechanical stress [6]. In quantum computing, diamonds have enabled the creation of quantum processors with 27 nuclear-spin qubits [7]. In quantum communication, diamond color centers have introduced single-photon emitters [8] and multi-qubit quantum network nodes [9]. In quantum imaging, nitrogen-vacancy (NV) centers in diamonds have allowed the imaging of current flow in graphene [10].

This work focuses on single crystal diamond needles (SCDNs) as a promising material to enhance the technological implementation of diamond color centers. SCDNs, with a pyramidal shape and square base, are produced using a combination of chemical vapor deposition (CVD) and selective oxidation from methane and hydrogen gases [11]. Optimization of experimental procedures and post-processing techniques allows for the production of SCDNs with tip sizes down to a few nanometers, length control from hundreds of nanometers to hundreds of micrometers, and color centers distributed with sub-micrometer precision along the SCDN [12].

We present the results of our recent research on the optical and spin properties of color centers typically forming in SCDNs during synthesis. We discuss fluorescence lifetimes, photoluminescence excitation (PLE), and spin properties, highlighting the potential of fluorescent diamond needles in quantum sensing, computing, and other applications.

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