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Scope of Research

NV centers in diamond have been extensively interested because a single spin of the NV center can be manipulated and detected at room temperature. Furthermore, a spin-coherence time of the NV center is very long. The spin-coherence time is the time to retain coherence (superposition state) and directly relates to the sensitivity of sensors of magnetic field, electric field and temperature. Therefore, the unique and excellent properties of the NV center are expected to be applied for quantum computing, quantum communication, bio-imaging, and high-sensitive sensor with nano-scale resolution.

KEYWORDS

Diamond
Quantum Materials
NV Center
Quantum Sensing
Quantum Information Science

Recent Selected Publications

Nishikawa, T.; Morioka, N.; Abe, H.; Morishita, H.; Ohshima, T.; Mizuochi, N., Electrical Detection of Nuclear Spin via Silicon Vacancy in Silicon Carbide at Room Temperature, *Appl. Phys. Lett.*, **121,** 184005 (2022).

Kawase, R.; Kawashima, H.; Kato, H.; Tokuda, N.; Yamasaki, S.; Ogura, M.; Makino, T.; Mizuochi, N., *n*-Type Diamond Synthesized with *tert*-Butylphosphine for Long Spin Coherence Times of Perfectly Aligned NV Centers, *J. Appl. Phys.*, **132,** 174504 (2022).

Mizuochi, N., Magnetometry Goes Nuclear, *Nat. Phys.*, **18,** 1280 (2022).

Herbschleb, E. D.; Ohki, I.; Morita, K.; Yoshii, Y.; Kato, H.; Makino, T.; Yamasaki, S.; Mizuochi, N., Low-Frequency Quantum Sensing, *Phys. Rev. Appl.*, **18,** 034058 (2022).

Fujiwara, M.; Uchida, G.; Ohki, I.; Liu, M.; Tsurui, A.; Yoshikawa, T.; Nishikawa, M.; Mizuochi, N., All-Optical Nanoscale Thermometry Using Silicon-Vacancy Centers in Detonation Nanodiamonds, *Carbon*, **198,** 57-62 (2022).

Ultra-Long Coherence Times Amongst Room-Temperature Solid-State Spins

Solid-state single spins are promising resources for quantum sensing, quantum-information processing and quantum networks, because they are compatible with scalable quantum-device engineering. However, the extension of their coherence times proves challenging. Although enrichment of the spin-zero ^{12}C and ^{28}Si isotopes drastically reduces spin-bath decoherence in diamond and silicon, the solid-state environment provides deleterious interactions between the electron spin and the remaining spins of its surrounding. Here we demonstrate, contrary to widespread belief, that an impurity-doped (phosphorus) n-type single-crystal diamond realises remarkably long spin- coherence times. Single electron spins show the longest inhomogeneous spin-dephasing time ($T_2^* \approx 1.5$ ms) and Hahn-echo spin-coherence time ($T_2 \approx 2.4$ ms) ever observed in room-temperature solid-state systems, leading to the best sensitivities (amongst others such as temperature), which we confirmed for AC magnetic fields. From the analysis of the noise spectrum, the elongation of T_2 could be realised by optimising the phosphorus concentration and by continuing to decrease the paramagnetic impurities and defects.

The extension of coherence times in diamond semiconductor may allow for new applications in quantum technology.

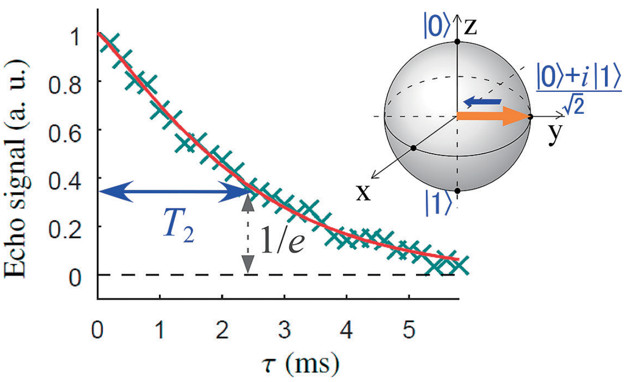

Figure 1. Echo signal of the single NV centre at room temperature. (Insert) Bloch sphere to show the coherence (superposition state).

Extension of the Coherence Time by Generating MW Dressed States in a Single NV Centre in Diamond

Nitrogen-vacancy (NV) centres in diamond hold promise in quantum sensing applications. A major interest in them is an enhancement of their sensitivity by the extension of the coherence time (T_2). In this report, we experimentally generated more than four dressed states in a single NV centre in diamond based on Autler-Townes splitting (ATS). We also observed the extension of the coherence time to $T_2 \sim 1.5$ ms which is more than two orders of magnitude longer than that of the undressed states. Numerical estimations show the sensitivity of the quantum sensing with the dressed states can be enhanced at least one-order of magnitude with experimentally observed $T_{2\rho}$ and T_2. Thus, we believe that the quantum sensing with the dressed states can be applicable for improving the sensitivity of a quantum sensing. As an example of a quantum application using these results we propose a protocol of quantum sensing, which shows more than an order of magnitude enhancement in the sensitivity.

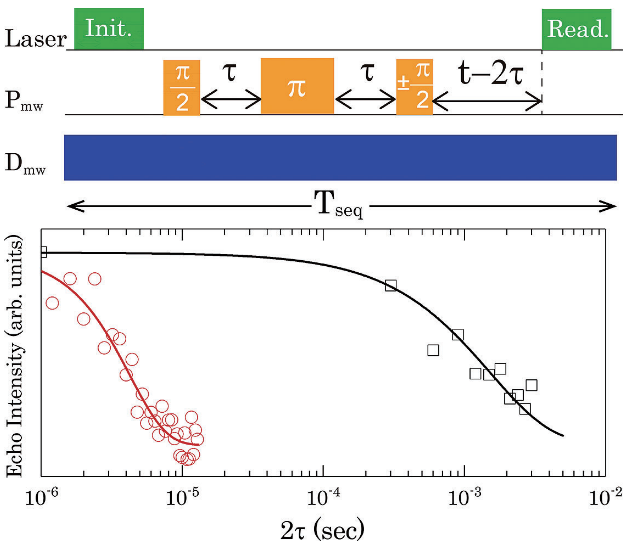

Figure 2. (Top) Pulse sequence to observe $T_{2\rho}$ and T_2 with applying a phase cycle to the final $\pi/2$ pulse. (Bottom) Black and red plots show the results of $T_{2\rho}$ and T_2 measurements, respectively. They are fitted by exponential decay curves described by black and red solid lines.