Quenching Spin Decoherence in Diamond through Spin Bath Polarization

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Introduction

Overcoming spin decoherence is critical to spintronics and spin-based quantum information processing devices. For spins in the solid state, a coupling to a fluctuating spin bath is a major source of the decoherence. One approach is to bring the spin bath into a well-known quantum state that exhibits little or no fluctuations. A prime example is the case of a fully polarized spin bath. The spin bath fluctuations are fully eliminated when all spins are in the ground state. Here we investigate the relationship between the spin coherence of nitrogen-vacancy (N-V) centers in diamond and the polarization of the surrounding spin bath consisting of nitrogen (N) electron spins. The N-V center in diamond is the most promising solid-state spin system for room temperature quantum information processing devices.

Experimental

We employed 240 GHz continuous wave (cw) and pulsed EPR spectrometers in the EMR program at the NHMFL.

Results and Discussion

The temperature dependence of spin decoherence time ($T_2$) for the N-V center is shown in Fig.1. Between room temperature and 20 K, we observed almost no temperature dependence with $T_2$. Below the Zeeman energy (11.5 K), $T_2$ increases drastically. By lowering the temperature further, $T_2$ increases up to 250 $\mu$s at 1.7 K and does not show noticeable increase below 1.7 K. At high magnetic field, the fluctuations in the bath are mainly caused by energy-conserving flip-flop processes of the N spins. The spin flip-flop rate in the bath is proportional to the number of pairs with opposite spin and thus it strongly depends on the spin bath polarization. At 240 GHz and 2 K, the N spin bath polarization is 99.4% which almost eliminates the spin flip-flop process. This experiment therefore verifies that the dominant decoherence mechanism of the N-V center in diamond is the spin-flop process of the N spin bath.

As shown in Fig. 1, agreement between the model and the $T_2$ data is excellent. Thus the result confirms the decoherence mechanism of the N spin bath fluctuation. Saturation of $T_2$ below 1.7 K proves that spin decoherence due to the N spin bath is quenched by complete polarization of the N spin bath. In addition, this saturation indicates that there exists a temperature-independent spin decoherence source.

Conclusions

We have demonstrated that we can strongly polarize the N spin bath and quench spin decoherence. See Ref. [1] for details.

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References