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Semiconductor Isotope Engineering of Silicon and Diamond for Quantum Computation and Sensing

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Abstract

Advancements in isotope engineering of semiconductors for quantum computation and sensing purposes are reviewed.

Since our proposal of using isotopes in semiconductor silicon as qubits [1], our effort has been focused on a wide variety of proof-of-the-concept experiments to demonstrate the feasibility. The present talk introduces three successful examples of spin manipulation enabled by isotope engineering; 1) formation and detection of entanglement between phosphorus electron spins and ^{31}P nuclear spins in isotopically enriched ^{28}Si [2], 2) coherent transfer of quantum information between electron spin states and the nearest neighbor ^{29}Si nuclear spins in silicon [3], and formation of negatively charged NV centers in a 5nm thick, isotopically enriched ^{12}C diamond layer for quantum metrology applications [4].

In the diamond work, NV$^-$ centers were formed in isotopically enriched diamond ([^{12}C]=99.99%) based on the method described in Ref. 4. The resulting NV$^-$ placed within 5 nm from the surface demonstrates T_2~45 μs, T_2^*~800 ns, and T_1~3.2 ms at room temperature. It will be shown that these properties are sufficient for detection of single proton nuclear spins placed on the surface. Experimental detection of a small number of nuclear spins using single NV will be presented at the conference.

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References

[1] T. D. Ladd, J. R. Goldman, F. Yamaguchi, Y. Yamamoto, E. Abe, and K. M. Itoh, Phys. Rev. Lett. **89** (2002) 017901.
[2] S. Simmons, R. M. Brown, H. Riemann, N. V. Abrosimov, P. Becker, H.-J. Pohl, M. L. W. Thewalt, K. M. Itoh, and J. J. L. Morton, Nature **470** (2011) 69.
[3] W. Akhtar, V. Filidau, T. Sekiguchi, E. Kawakami, T. Itahashi, L. Vlasenko, J. J. L. Morton, and K. M. Itoh, Phys. Rev. Lett. **108** (2012) 097601.
[4] T. Ishikawa, K.-M. C. Fu, C. Santori, V. M. Acosta, R. G. Beausoleil, H. Watanabe, S. Shikata, and K. M. Itoh, Nano Lett. **12** (2012) 2083.