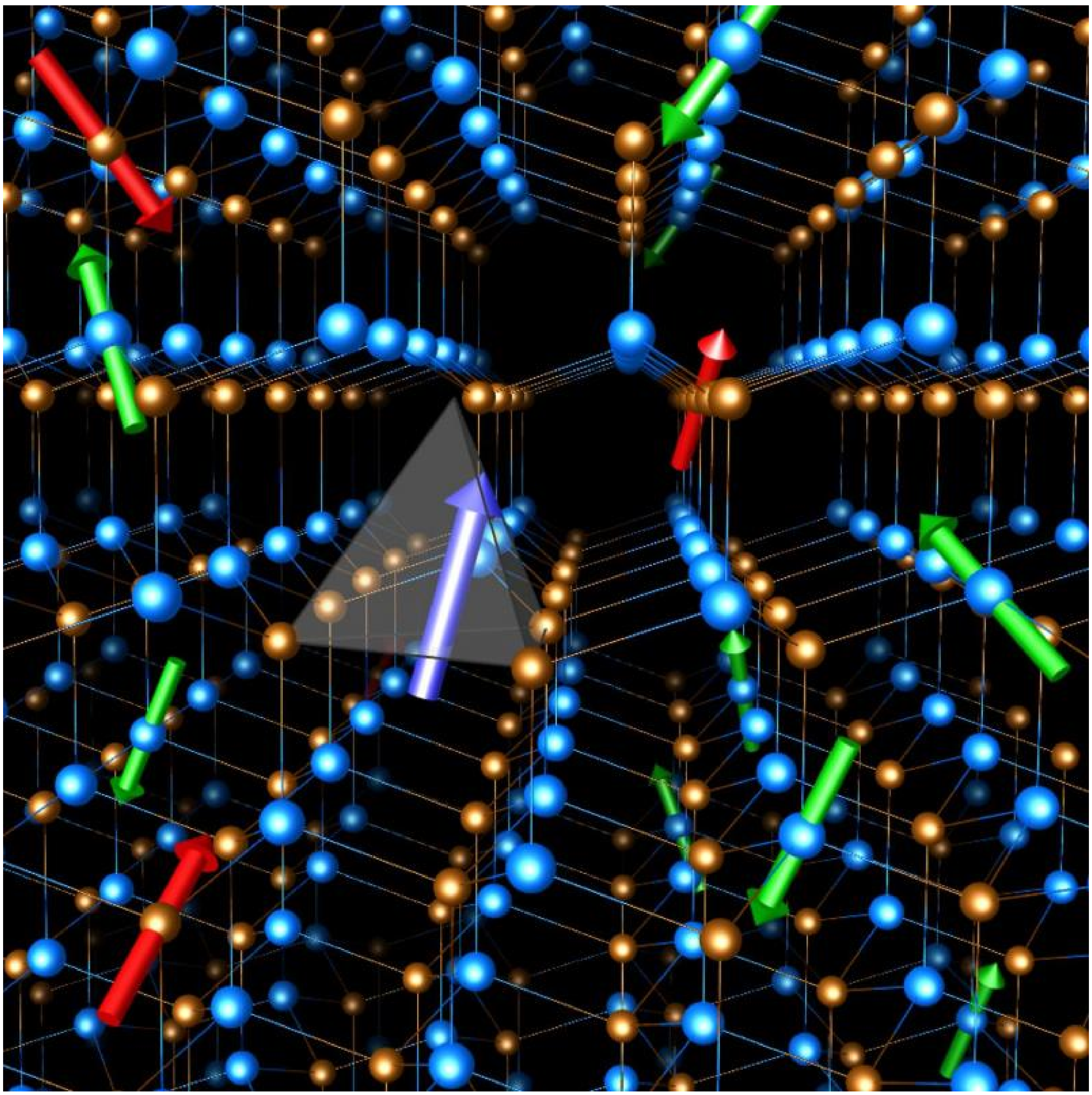
PHYS.ORG

Exceptionally robust quantum states found in industrially important semiconductor

October 14 2016



This image shows an electron quantum bit (purple arrow near center) in a silicon carbide crystal interacting with nuclear spins that are derived from naturally occurring 29Si (green arrows) and 13C (red arrows) isotopes. A grey pyramid indicates the local crystal symmetry environment of the qubit. The qubit would eventually lose its quantum properties in the presence of the magnetic noise produced by the random nuclear spin fluctuations in these materials, the process known as quantum decoherence.

Harnessing solid-state quantum bits, or qubits, is a key step toward the mass production of electronic devices based on quantum information science and technology. However, realizing a robust qubit with a long lifetime is challenging, particularly in semiconductors comprising multiple types of atoms.

The close collaboration between experiments in Prof. David Awschalom's group and theory and simulations in Prof. Giulia Galli's group, both in the Institute for Molecular Engineering, has enabled a crucial step toward solid-state qubits in industrially important semiconductors. In a paper, published Sept. 29 in *Nature Communications*, the two groups showed that electron qubits bound to atom-like defects in a commercial silicon carbide wafer can exhibit the longest electronic coherence times ever measured in a natural crystal.

"Quantum coherence underlies all quantum information technologies, such as quantum communication and quantum sensing. However, the coherence time in materials is eventually limited by the magnetic noise produced by the fluctuating nuclear spins in a crystal," said Hosung Seo, an IME postdoctoral researcher and the paper's lead author.

Defects in silicon carbide have recently attracted attention as potential candidates for solid-state qubits. Due to its extensive use in the optoelectronics and power electronics industries, silicon carbide also has a strong potential for mass production.

However, spin qubits in silicon carbide have been expected to have inherently short coherence times because of the high concentration of magnetic nuclei in the crystals. Counterintuitively, the electron coherence time in silicon carbide reaches 1.3 milliseconds—the longest time measured in a naturally isotopic crystal.

Based on the tight integration of theory and experiment, the two IME groups identified the key mechanisms behind the remarkably robust spin coherence in silicon carbide. They found that the binary nature of its crystal plays a central role in suppressing the magnetic noise produced by the nuclear spin fluctuation.

"Our work has important implications beyond silicon carbide. The essential physics and the dynamics responsible for the coherence found in silicon carbide, a binary crystal, may allow qubits in ternary and quaternary crystals to have even longer spin coherence times," said Abram Falk, now a researcher at IBM's T.J. Watson Research Center and the paper's primary experimental author.

Seo and Falk also emphasized that interesting host crystals with useful functionalities are normally found in binary or ternary crystals such as carbides, nitrides and oxides. The results suggest that developing defect spin qubits in complex polyatomic crystals would be a promising route to realize novel, multifunctional, quantum systems.

More information: Hosung Seo et al. Quantum decoherence dynamics of divacancy spins in silicon carbide, *Nature Communications* (2016). DOI: 10.1038/ncomms12935

Provided by University of Chicago