

Silicon carbide turns quantum

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Color centers—atomic-scale defects in crystalline materials—are remarkably versatile quantum systems. They have already had a major impact on quantum sensing and are promising building blocks for quantum communication and quantum networks. Yet, despite being solid-state systems, they have so far benefited only to a limited extent from the great strengths of modern semiconductor technology: wafer-scale production, mature nanofabrication, and straightforward integration into electronic and photonic devices. One reason is that the most established color-center platforms rely on comparatively unusual materials such as diamond. The work of Chen and colleagues has the potential to change this situation by establishing a particularly promising class of color centers in silicon carbide.¹

The authors resolve the long-standing question of the microscopic origin of the PL5 and PL6 centers in 4H-SiC. These defects are especially attractive because they retain favorable optical and spin properties at distances of only a few nanometers from the surface. Although PL5 and PL6 were already known, their precise atomic structures remained uncertain, and no efficient method existed for producing them. By addressing both challenges, this work opens the way towards controlled fabrication and practical technological applications.

A major strength of the study is its powerful combination of complemen-

tary experimental and theoretical approaches. Correlative imaging demonstrates that PL5 and PL6 form independently of macroscopic stacking faults, challenging their previous classification. Implanting oxygen into SiC then increases their formation yields by more than an order of magnitude. Most compellingly, implantation with the spin-carrying isotope ¹⁷O produces a characteristic sixfold splitting in the optically detected magnetic resonance spectra. This provides direct spectroscopic evidence that oxygen forms part of the defect itself.

Angular-resolved measurements, detailed spectroscopy of individual defects, and first-principles calculations allow the authors to assign PL5 and PL6 to two distinct atomic configurations of an oxygen–silicon–vacancy complex (Figure 1). The assignment of PL5 is particularly convincing because it is supported by several independent observations, including the defect's spatial orientations, symmetry, and interactions with nearby ¹³C and ²⁹Si nuclear spins. The convergence of these different measurements provides a strong foundation for the proposed atomic models.

The implications for quantum sensing are substantial. The sensitivity and spatial resolution of a nanoscale sensor improve dramatically as the quantum system approaches the object being measured. PL5 and PL6 remain optically bright, coherent, and electrically stable at depths of approximately 2

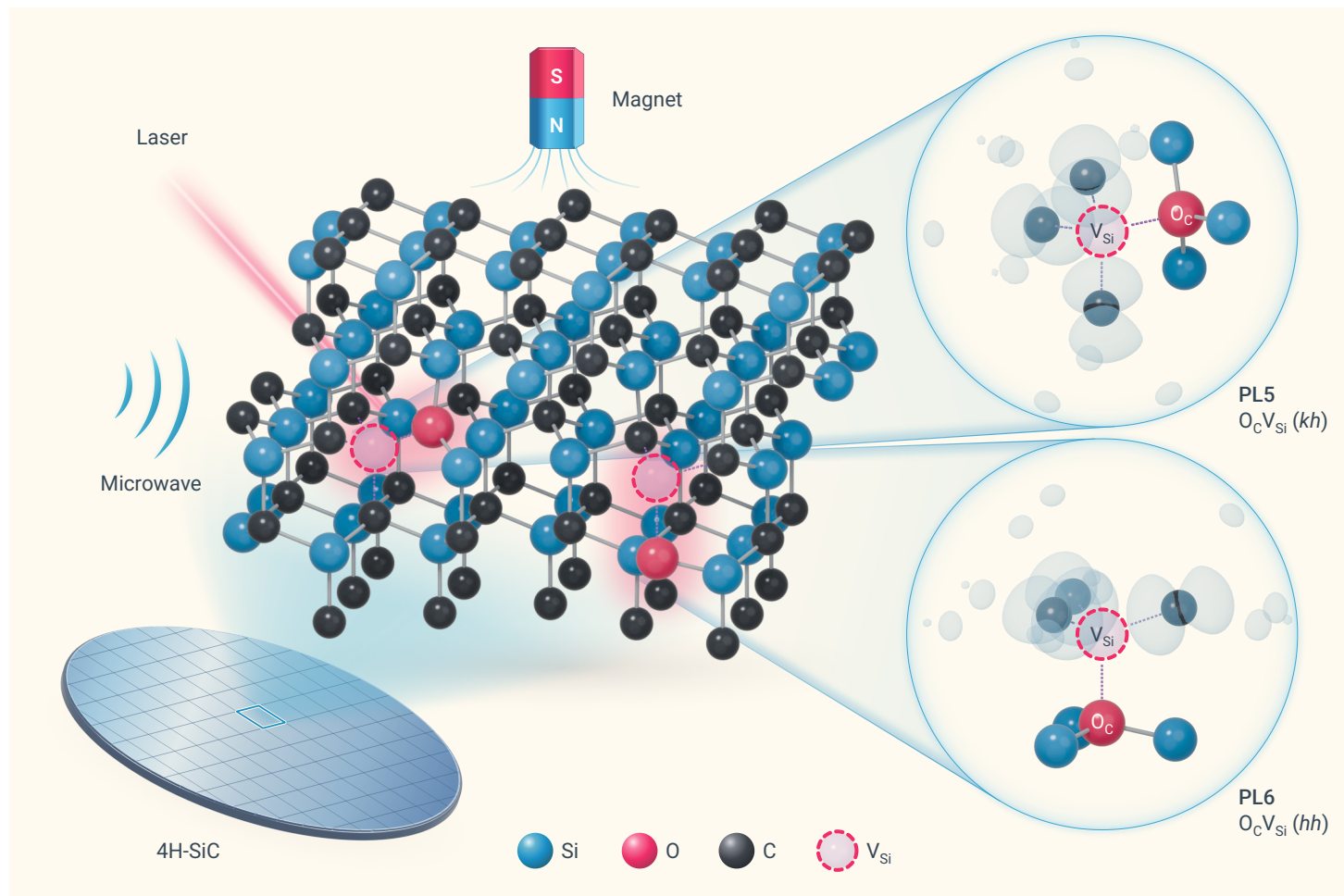


Figure 1. Revealing the microscopic origin of PL5 and PL6 centers in 4H-SiC.

nm, where many other solid-state spin defects lose performance.² Combined with their strong room-temperature readout signal and near-infrared emission, these properties make them outstanding candidates for nanoscale magnetic resonance, investigations of two-dimensional materials, and sensing in biological environments.

More broadly, the work transforms PL5 and PL6 from useful but structurally uncertain defects into quantum systems that can be engineered rationally. The identification of oxygen as an essential component provides a clear route for optimizing implantation, thermal processing, doping, and charge-state control. The increase in formation yield demonstrated here is already impressive. Further optimization could enable both the reproducible placement of individual quantum defects and the creation of dense ensembles with greatly enhanced sensing performance.

These prospects are particularly exciting because silicon carbide is already available as a high-quality, wafer-scale semiconductor and is compatible with established device-processing methods. Controlled generation of PL5 and PL6 centers could therefore facilitate their integration into scanning probes, membranes, microfluidic sensors, optical cavities, and photonic circuits. Beyond sensing, such integration may also support efficient connections between stationary spin qubits and photons—a key requirement for

quantum communication and distributed quantum technologies.

Overall, the work by Chen et al. is a highly significant achievement. It resolves a central question in silicon-carbide defect physics while translating microscopic understanding directly into a practical strategy for improved quantum-device fabrication. The study is likely to stimulate considerable activity and further establish silicon carbide as a leading platform for scalable quantum sensing, integrated quantum photonics, and future quantum networks.

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AUTHOR CONTRIBUTIONS

J.W. wrote the manuscript.

DECLARATION OF INTERESTS

The author declares no competing interests.