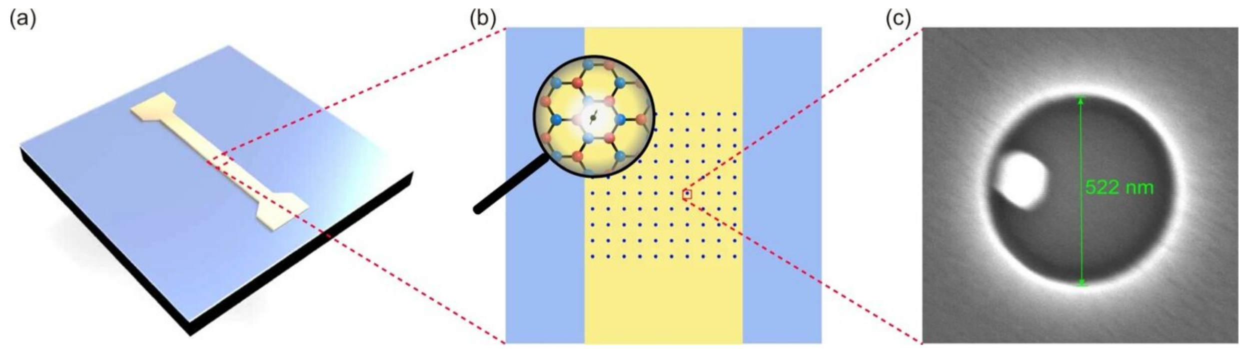
Researchers achieve coherent control of two-dimensional material solid-state spin defects

June 14 2023



Schematic of hBN arrays on the gold film MW waveguide. **a** A schematic of a gold film MW waveguide on silicon wafer generating a uniform and stable local MW field. **b** A schematic of hBN arrays by dispersing the hBN suspension into the holes formed by electron beam lithography. Inset: Schematic of the atomic structure of hBN. **c** Scanning electron microscope image of an isolated hBN flake in one hole of the array before the PMMA resist was dissolved. Credit: *Nature Communications* (2023). DOI: 10.1038/s41467-023-38672-6

A team led by Prof. Guo Guangcan, with the collaborative efforts from Wigner Research Centre for Physics, revealed a new approach to discovering a new spin defect with an excellent probability of 85% and achieved coherent control of an ultrabright single spin in hexagonal boron nitride (hBN) at room temperature. The study was published in *Nature Communications*.

Solid-state spin defects are of great importance in quantum information, such as the nitrogen-vacancy (NV) center in diamonds, which has been widely applied in quantum computing and quantum networks. The two-dimensional material hBN is considered a remarkable host for color-center spin defects. The spin defects in hBN have attracted great attention with their advantages in two-dimensional quantum devices and integrated quantum nanodevices.

Among the discovered spin defects in hBN, the negatively charged boron vacancy (V_B^-) defect is the most prevailing one. Researchers from Prof. Guo's team in their previous research conducted the measurement of temperature dependence based on the V_B^- defect and demonstrated the coherent dynamics of the multi-spin V_B^- center.

They found it hard to detect a single V_B^- defect for its low-quantum efficiency for the optical transition. Despite several reports of enhanced photoluminescence of the V_B^- defect, observing the coherent control of a single spin is still a challenge.

In this study, the researchers managed to isolate individual color centers in hBN powder samples with the help of capillary force. They discovered a class of ultrabright single-spin color centers with an excellent probability of 85%, which is enhanced by 21-fold compared with previous methods.

The researchers then measured its optical properties with significant antibunching characteristics and photon emissivity up to 25 MHz, which is the highest fluorescence count of single spin color centers found in hBN so far. They further captured its Rabi oscillation signal and conducted Hahn echo experiments. It was the first time that a single-spin color center in hBN was manipulated at room temperature, representing a new stage in the application of quantum information.

Moreover, the researchers realized the first principles calculations to clarify the structure of this color-center defect. It was found that the complex of carbon-oxygen dopants may be the source of this type of single-spin color-center defects, and the simulated optically detected magnetic resonance (ODMR) spectra of the C_NC_{B3} model are consistent with the experimental results.

The coherent control of an ultrabright single spin in hBN at room temperature takes a leap in quantum areas, which provides a possibility for addressing spins that can be optically controlled.

More information: Nai-Jie Guo et al, Coherent control of an ultrabright single spin in hexagonal boron nitride at room temperature, *Nature Communications* (2023). DOI: 10.1038/s41467-023-38672-6

Provided by University of Science and Technology of China