Enhancing the fluorescence of single silicon carbide spin color centers

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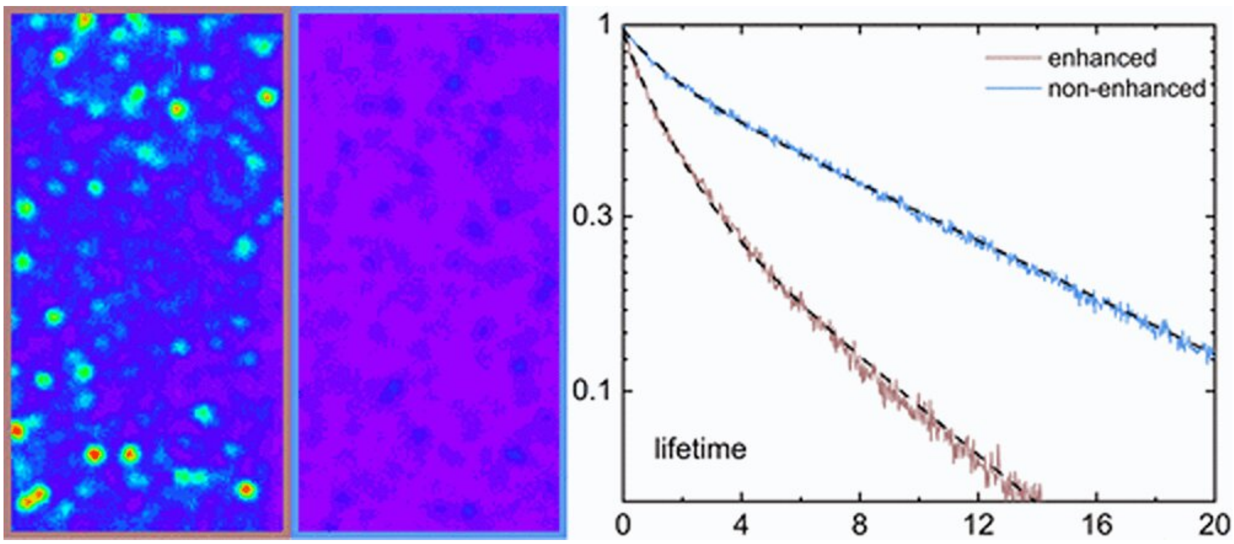

Credit: *Nano Letters* (2023). DOI: 10.1021/acs.nanolett.3c00568

In a study published online in *Nano Letters*, the team led by Prof. Li Chuanfeng and Dr. Xu Jinshi from the University of Science and Technology of China of the Chinese Academy of Sciences made progress in enhancing the fluorescence of single silicon carbide spin defects.

The researchers leveraged surface plasmons to markedly boost the fluorescence brightness of single silicon carbide double vacancy PL6 color centers, leading to an improvement in the efficiency of spin control using the properties of co-planar waveguides. This low-cost method neither calls for complex micro-nano processing technology nor compromises the coherence properties of the color centers.

Spin color centers in solid-state systems are crucial for quantum information processing, and the brightness of their fluorescence is a vital parameter for practical quantum applications.

Traditionally, enhancing the fluorescence of spin color centers involves coupling them with solid-state micro-nanostructures, a common method encompassing various schemes such as the fabrication of solid immersion lenses, nanopillars, bull's eye structures, photonic crystal microcavities, and fiber cavities. Nevertheless, challenges remain such as the susceptibility of color center spin properties to complex micro-nano fabrication processes, and the difficulty of aligning specific color centers with micro-nano structures.

Pioneering a new approach, the team used plasmons to enhance the fluorescence of spin centers in silicon carbide. The researchers prepared a silicon carbide thin film of about 10 micrometers in thickness via chemical and mechanical polishing. They used ion implantation technology to create near-surface divacancy color centers in the film.

The film was flipped and adhered to a silicon wafer coated with a coplanar gold waveguide, utilizing van der Waals forces. This positioning allowed the near-surface color centers to come under the influence of the surface plasmons of the gold waveguide, thereby enhancing the fluorescence of the color centers.

With an objective lens (with a numerical aperture of 0.85) and the enhancement effect of surface plasmons, the researchers achieved a seven-fold enhancement of the brightness of a single PL6 color center. With an oil lens with a numerical aperture of 1.3, the fluorescence of the color center exceeded one million counts per second.

Besides, the researchers managed to precisely manipulate the distance between the near-surface color center and the coplanar waveguide by adjusting the film thickness with a reactive ion etching process, which allowed them to study the optimal range of operation. Apart from generating surface plasmons, the coplanar gold waveguide can be used to efficiently radiate microwaves, significantly improving the efficiency of spin control.

The coplanar waveguide increased the Rabi frequency of a single PL6 color center by 14 times under the same microwave power compared with that in conventional microwave radiation methods.

Moreover, the researchers investigated the mechanism of fluorescence enhancement. By fitting the autocorrelation function using a three-level model and measuring the non-resonant excitation fluorescence lifetime, they confirmed that surface plasmons enhanced the fluorescence brightness by increasing the radiative transition rate of the color center energy level.

They also found that as the interaction distance decreased, the quenching effect of surface plasmons resulted in a decay in the fluorescence brightness of the color center.

This work marks the first implementation of plasmon-enhanced fluorescence from near-surface spin color centers in silicon carbide films. The preparation of the coplanar gold waveguide is straightforward without intricate enhancement structures or alignment processes. This method also enhances the fluorescence of other spin color centers in silicon carbide, representing a significant step forward in applying silicon carbide materials to the field of quantum science.

More information: Ji-Yang Zhou et al, Plasmonic-Enhanced Bright Single Spin Defects in Silicon Carbide Membranes, *Nano Letters* (2023). DOI: 10.1021/acs.nanolett.3c00568

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