Engineering Germanium-Vacancy Center Arrays in Diamond Nanopillars for Quantum Applications

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Abstract: Germanium-vacancy centers were fabricated in electronic-grade diamond using FIB implantation. Subsequent nanopillar fabrication enhanced photon collection eightfold. Photoluminescence and antibunching measurements revealed single emitters in up to 33% of nanopillars, demonstrating precise positioning and promising quantum photonics applications.

Among the color centers in diamond, germanium-vacancy (GeV) centers, are gaining attention for their potential in quantum technologies. These defects exhibit strong zero-phonon line (ZPL) emissions at 603 nm, even at room temperature, short excited-state lifetimes, and high optical coherence due to their inversion-symmetric (D3d) structure [1].

In this study, we fabricated GeV centers in electronic-grade diamond using a Focused Ion Beam (FIB) with a liquid metal alloy ion source. FIB implantation offers precise, mask-free fabrication of GeV centers, ensuring accurate spatial positioning with minimal ion straggling [2].

Implantation was performed at 35 keV and 70 keV with Ge ion doses from 10 to 1000 ions per beam spot. Post-implantation, the samples underwent thermal annealing in ultra-high vacuum at 1000°C for two hours.

To enhance emission efficiency, nanopillar structures (20 nm in diameter) were precisely fabricated at the sites of the single-photon emitter arrays using electron-beam lithography and plasma etching. This process led to a significant improvement of a factor 8 in photon collection, emphasizing the effectiveness of this nanoscale engineering approach for quantum photonics applications.

Photoluminescence (PL) measurements together with antibunching measurements, revealed that up to 33% of the fabricated nanopillars contained single emitters, with the exact percentage depending on ion implantation parameters.

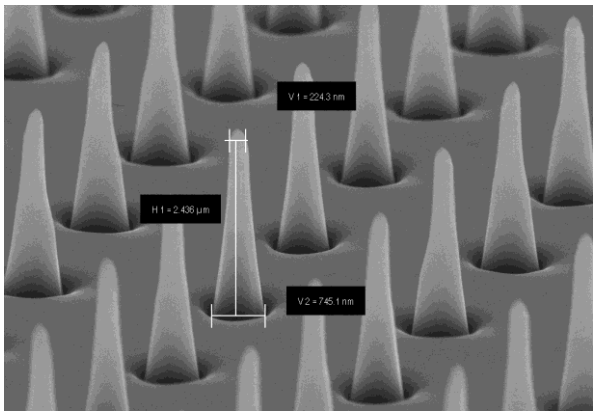

Fig. 1 SEM image of the array of diamond nanopillars

References

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[2] Y. Zhou, et al. New J. Phys. 20 (2018), 125004