A Strongly Interacting, Two-Dimensional, Dipolar Spin Ensemble in 111-Oriented Diamond for Quantum Sensing and Simulation

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BACKGROUND

Diamond is at the forefront of solid-state quantum technologies due to unique defects known as Nitrogen-Vacancy (NV) centers. Ensembles of NVs have become an important platform for quantum sensing and simulation. These systems show great potential for both entanglement-enhanced metrology, leading to sensitivities beyond the standard quantum limit. To date, the majority of experiments with NV ensembles have studied three-dimensional spin systems. However, the exploration of two-dimensional systems yields several advantages. There has been a tremendous amount of interest and progress in generating 2D spin systems in diamond via delta-doping during plasma-enhanced chemical vapor deposition (PECVD) growth on the (001) crystallographic plane. These techniques have already facilitated the exploration of the decoherence dynamics of two-dimensional NV spin ensembles. Despite this advancement, limitations related to (001) NV systems leave room for further improvement, foremost, dipolar interactions exactly average to zero leading to a broad obstruction for exploring dipolar-driven, many-body physics.

DESCRIPTION

Researchers at the University of California, Santa Barbara have overcome the challenges associated with spin ensembles in (001) 2D spin systems by demonstrating the synthesis and characterization of NV center ensembles in (111)-oriented diamond, which provides unique advantages for quantum technologies that cannot be achieved with three-dimensional ensembles or (001)-oriented diamond. Among the advantages of spin ensembles in (111)-oriented diamond is their reproducibly high magnetic field sensitivity. Without applying advanced measurement procedures, the samples can be used in simple DC or AC magnetic field sensing. Additionally, there is demonstrated utility in entanglement-enhanced sensing (such as spin squeezing), which opens the door to a new regime of sensing beyond the standard quantum limit. This method represents foundational developments in diamond materials synthesis that will yield new advances in quantum sensing and simulation.

ADVANTAGES

- ~60x greater nitrogen incorporation compared to (001)-oriented diamond
- 2D NV densities (up to 5.5 ppm*nm)
- High magnetic field sensitivity
- Can be used in DC or AC magnetic field sensing
- Demonstrates utility in entanglement-enhanced sensing

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OTHER INFORMATION

KEYWORDS

quantum, solid-state quantum, diamond, quantum sensing, quantum simulation

CATEGORIZED AS

- **Semiconductors**
  - Other

RELATED CASES

2025-368-0

APPLICATIONS

- Quantum sensing and simulation

PATENT STATUS

Patent Pending

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