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Diamond-based quantum technology for properties characterization of nanoscale materials

Jiangfeng Du

School of Physical Sciences, University of Science and Technology of China, Hefei, 230026, China

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Magnetic field is a controlled fashion for smart materials. Magnetic resonance (MR) is one of the most important techniques for characterizing compositions, structure and dynamics of these kinds of materials. However, current methods need billions of uniform units on centimeter-scale to accumulate large enough signal-to-noise ratio. High sensitivity MR techniques are urgently needed for new applications on nanoscale. A sensor to accomplish nanoscale targets detection is the recently developed atomic sized magnetic field sensor based on the nitrogen-vacancy (NV) defect center in diamond. By combining the quantum controls and long coherence time of NV, we have experimentally realized nanoscale nuclear MR and electron spin resonance. In detail, we firstly realized detection of $(5nm)^3$ hydrogen nuclear spin sample including a few thousand atomic nuclei under ambient conditions, which is “a first step toward imaging complex molecular structures directly”. Then we chose a nuclei dimer 13C-13C as a target and realized atomic-scale structure analysis of the dimer by measuring its coupling vector. Further, nuclear magnetic resonance spectroscopy with single spin sensitivity was accomplished. Recently, we have realized nanoscale microwave field imaging and even detection of single protein electron spin resonance spectroscopy. We not only recorded the single-protein magnetic resonance spectroscopy, but also inferred the motions of the protein by analysis the shape of spectra. This work is “an important milestone toward the goal to image individual proteins in living cells in real time as they go about their business of sustaining life”. These results, together with the relation works in the field, open a door to nanoscale MR and will be potentially used as a new tool on smart materials.

Keywords: nanoscale magnetic resonance. Single molecule . Nitrogen vacancy. Quantum control. Magnetic resonance imaging