Engineering crystal defect position in diamond for atomic-scale sensing applications

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A certain crystal defect in diamond, nitrogen-vacancy (NV) center is now known to show excellent single electron spin properties at room temperature. Single spins associated with NV centers can be manipulated and read out by pulsed microwave and lasers with a technique similar to electron spin resonance (ESR). Researchers investigate spins in NV centers as a test block for quantum communication and processing schemes, as well as for atomic-scale magnetic sensor applications for chemical structure analysis or living cell diagnostics. For these magnetometry applications, it is a crucial engineering requirement to control position, particularly depth, of these NV centers close to the surface since magnetic interaction decreases rapidly when NV centers are deep in the crystal. I developed a crystal growth technique to precisely control depth of NV centers at nanometer scale,[1] Nitrogen source gas is briefly introduced at specific timing during synthetic growth of diamond to achieve such nm-scale depth precision. Moreover, this technique preserves resulting NV center spin properties even they are located less than 10 nm from the surface. These engineered NV centers are harnessed to demonstrate shrinking down nuclear magnetic resonance (NMR) technique to nanometer scale,[2] a first important step towards single molecule structure analysis which is extremely difficult to achieve with current induction-based NMR techniques.