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Understanding Water Chemistry in a Submicron Scale Environment with Quantum Sensing

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Water is ubiquitous on Earth and plays innumerable roles in geochemical processes. The properties of water vary considerably due to confinement, surface adsorption and solute composition. These environmental influences can vary at the fine scale in soils, biofilms, porous rocks and other geosystems. Water properties can be investigated using numerous molecular spectroscopies, particularly by using the proton nuclear magnetic resonance (^{1}H-NMR) spectroscopy. However, a typical NMR spectroscopy requires large sample sizes and is unsuited to the study of heterogeneous natural systems. In order to elucidate the fine-scale properties of water, we have designed, constructed and are optimizing a quantum sensing microscope for submicron geochemistry.

We take advantage of the high sensitivity of negatively charged nitrogen vacancy (NV) centers in a single-crystal diamond which are controlled and interrogated by microwave pulses. This enables optically-detected NMR observations at a diffraction-limited spatial resolution of better than 200 nm. This quantum microscope is capable of measuring low-field ^{1}H-NMR, performing proton relaxometry and detecting paramagnetic ions in solution. We will show demonstrations performed in aqueous solutions with a less than picoliter volume with a negligible total power input. We will illustrate the application of optical NV-NMR for characterizing water chemistry in organic, mineral and confined environments, and give a perspective on geochemical research using quantum sensing.