Modulation of Raman scattering of carbon nanotubes by micro-droplets of water

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Raman spectroscopy is a powerful tool for studying and characterizing single walled carbon nanotubes (SWNTs). Single-tube Raman analysis, however, is challenging when the excitation laser is off-resonance with the electronic transition of SWNTs. Surface-enhanced Raman spectroscopy (SERS), based on electro(less)-deposition of metal nanoparticles, has been one of promising approaches to enhance the Raman scattering of SWNTs. The strongly-bound metal deposits, however, require additional etching process for the removal, and thus limit further application of the approach. Here we report that lens-shaped micro-droplets of water modulate Raman scattering of nanotubes. When an electrical bias is applied across two droplets of salty water placed on both ends of SWNTs, salt crystals are formed along the nanotubes. These salt crystals absorb water in the atmosphere and become hemispherical lens-shaped micro-droplets of water that allow us to optically visualize individual nanotubes. In addition, the micro-lenses dramatically enhance or suppress Raman scattering. We investigated the mechanisms of our observation using finite-difference time-domain (FDTD) simulation. The droplets can be easily removed by a simple water rinse without degrading the properties of SWNTs. Therefore, our approach will serve as a useful tool for the non-invasive visualization and characterization of SWNTs.