Investigation of Ni clusters inside single-walled carbon nanotubes on the sub-wavelength scale

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We used scattering-type scanning near-field optical microscopy (s-SNOM) to characterize nickel nanoclusters grown inside single-walled carbon nanotubes (SWCNT). The nanotubes were filled with Ni(II) acetylacetonate and the molecules were transformed into nickel clusters via annealing. The metal clusters give high local contrast enhancement in near-field phase maps caused by the excitation of free charge carriers. The near-field contrast was simulated using the extended finite dipole model, approximating the clusters with elliptical nanoparticles. Compared to magnetic force microscopy, s-SNOM appears much more sensitive to localize metal clusters inside carbon nanotubes. We estimate the quantity of measured nickel atoms to be less than ~ 700 Ni atoms. The spectral near-field mapping also validates the metallic nature of the measured particles. The spectral mapping also revealed nanotube related contrast changes compared to a pure metallic behavior. The induced dipoles in the Ni cluster enhances the week contrast of semiconducting nanotubes which appears in the spectral phase contrast measured above them.