Mechanisms of SWNT Probe-Sample Multistability in Tapping Mode AFM Imaging

Santiago D. Solares, Maria J. Esplandiu, William A. Goddard III, and C. Patrick Collier

Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, California 91125

δMaterials and Process Simulation Center

When using single-walled carbon nanotube (SWNT) probes to create AFM images of SWNT samples in tapping mode, elastic deformations of the probe and sample result in a decrease in the apparent width of the sample. Here we show that there are two major mechanisms for this effect, smooth gliding and snapping, and compare their dynamics to the case when a conventional silicon tip is used to image a bare silicon surface. Using atomistic and continuum simulations, we analyze in detail the shape of the tip-sample interaction potential for three model cases and show that in the absence of adhesion and friction forces, more than two discrete, physically meaningful solutions of the oscillation amplitude are possible when snapping occurs (in contrast with the existence of one attractive and one repulsive solution for conventional silicon AFM tips). We present experimental results indicating that a continuum of amplitude solutions is possible when using SWNT tips, and explain this phenomenon with dynamic simulations that explicitly include tip-sample adhesion and friction forces. We also provide simulation results of SWNT tips imaging Si(111)-CH$_3$ surface step edges and Au nanocrystals, which indicate that SWNT probe multistability may be a general phenomenon, not limited to SWNT samples.