Electrostatic characterization of tips for NC-AFM

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The quantitative interpretation of non-contact atomic force microscopy (NC-AFM) results, including images, force curves, potential as well as charge measurements, critically depends on the shape and dimensions of the tip. Here, we address the challenge of a reliable and reproducible characterization of parameters describing the experimental tip-sample system, such as tip radius R_{tip} and absolute tip-sample distance offset δz, taking into account electrostatic interactions. Our approach involves a measurement routine for the capacitance gradient $\partial C_{void} / \partial z_{tip}$. Here the capacitance gradient between a sharp PtIr-coated silicon cantilever tip and metal(-oxide) surfaces as a function of tip-sample distance as shown in figure 1(a-d) and a fit to an finite-difference method (FDM) based electrostatic model is investigated.[1,2] The capacitance gradient is measured from the frequency component at $f_0 \pm 2f_{el}$ when modulating the bias voltage at frequency f_{el}. We discuss approaches to remedy imprecisions that are inherent to this measurement approach. To demonstrate the robustness of this approach, we systematically acquire the distance-dependent capacitance signal on a conducting Cu(111) surface with an ideally infinite permittivity ε_s and a semiconductor TiO_2(101) surface with a moderate permittivity ε_s = 90 F/m, using the same tip. Both measurements yield comparable fit results, with a tip-sample distance offset of 2.0 nm and a tip radius of 7.2 nm for TiO_2 and 7.9 nm for Cu.

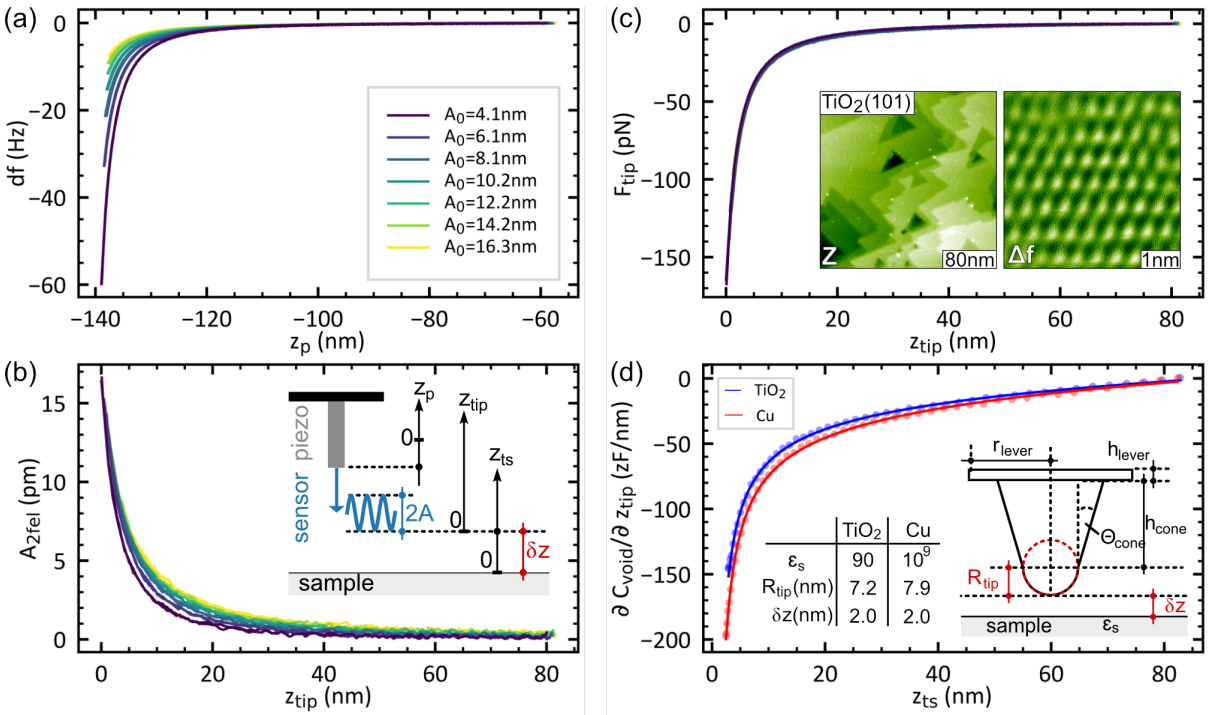

Figure 1. (a,b) Distance-dependent measurements showing the frequency shift and A_{2fel} signal. (inset b) Representation of different z-axis describing the tip-sample system. (c,d) Deconvolved force and capacitance gradient curves, from which the tip radius R_{tip} and the absolute tip-sample distance δz are determined by fitting an electrostatic model to the latter data. (inset d) Tip geometry used in the electrostatic model. Fixed parameters are marked in black, the two fit parameters in red.

[1] Heile, et al. Phys. Rev. B 108, 085420 (2023)
[2] Sadeghi, et al. Phys. Rev. B 86, 075407 (2012)