Methods in Force Measurements

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The measurement of tip-sample interaction forces with pico Newton resolution is one of the key capabilities of atomic force microscopy. Joined with the ability to also spatially resolve forces at the pico metre scale, the non-contact atomic force microscope (NC-AFM) is now established as one of the most important surface science tools [1]. The force measurement capability was already swiftly exploited during the early days of NC-AFM by, for example, measuring the formation of a single chemical bond [2], and was soon pushed towards the acquisition of two- and three-dimensional volume data sets [3]. Also, the experimental [4] as well as theoretical [5] framework necessary to perform and analyse dense force volume data has been developed over the last decade.

This lecture will discuss critical aspects of quantitative force measurements using the NC-AFM technique. Starting from fundamental considerations of the relation between frequency shift, force, and potential, the numerical back conversion to forces from measured signals [5,6] will be introduced together with practical considerations. Furthermore, suitable approaches for experimental challenges faced in force spectroscopy experiments will be discussed and methods to determine system parameters necessary for a quantitative force calculation introduced. Finally, an outlook will be given on data analysis steps often taken after calculating the vertical interaction forces.

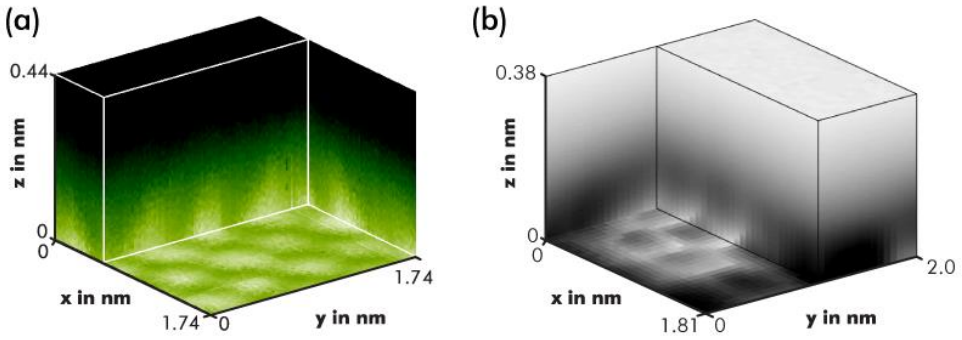

Figure 1: Frequency shift Δf data mapped along three spatial directions on (a) calcite(104) at room temperature [7] and (b) at 77K on an NTCDI molecule adsorbed on Ag:Si(111)-(√3×√3) R30° [8].

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