Atomically Defined Tips for Force Spectroscopy Experiments

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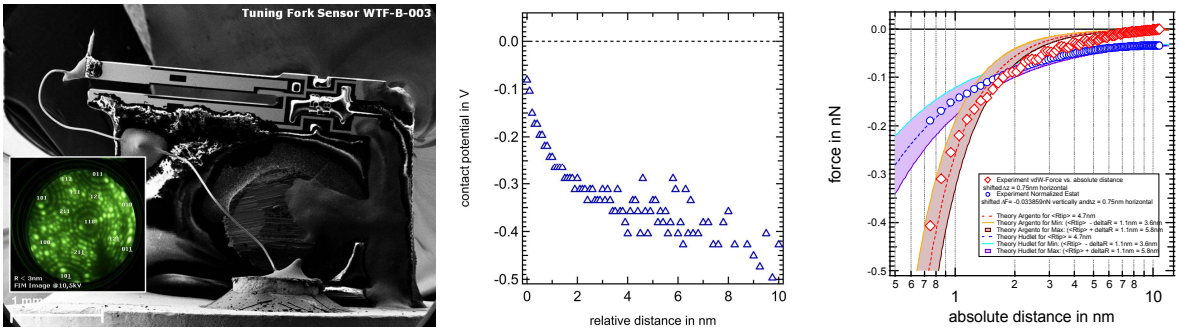
One of the fundamental goals of force spectroscopy experiments in ncAFM is to understand the force interactions between the probing tip and the surface atoms. However, a well-known obstacle is that the precise structure and chemical identity of the probing tip is unknown in conventional ncAFM experiments. Here we combine a dedicated low temperature UHV atomic force microscope based on the quartz tuning fork force sensor in the "qplus" design [1] with an atomic scale tip characterization tool, the field ion microscope (FIM). We attach electrochemically etched tips from metal (i.e. tungsten) with ultra sharp apex curvatures of less than R < 5nm to the tuning fork prong, which are FIM analyzed before and after force spectroscopy experiments (left image) on a Ag(111) surface.



Force interactions are measured in a wide distance range from 0.5nm to 10nm, as a function of tip bias from -2V to 2V. This data set allows us to identify all individual force contributions, e.g. the contact potential (CP), the bias-induced electrostatic forces and the van der Waals forces. Since in our experiments we know the precise tip shape, we can make quantitative comparisons to theoretical force models for the tip-plane geometry [2,3]. The bias-induced electrostatic forces are found to be in quantitative agreement with the theory [2]. Further we show that the only open fit parameter is the absolute distance offset z_0, which can extracted from our comparison between theory and experiment. Secondly, we find that the CP shows an unexpected distance dependence (middle image), which questions the common practice in ncAFM experiments to compensate the CP by a constant compensation voltage. Surprisingly, a comparison to the van der Waals force models shows good agreement only in the short distance regime below 1.5nm. We thus conclude that at larger tip sample distances, i.e. above 1.5nm absolute distance, an additional force contribution must be present, which has not been quantified in previous studies so far.

References

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