Scanning probe microscopy for surface chemical analysis and electrical conduction measurements

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Scanning probe microscopy (SPM), such as scanning tunneling microscopy (STM) and atomic force microscopy (AFM), allows for the characterization of various material surfaces at atomic scale.
First, we will present the chemical identification method by AFM [1-3]. Short-range forces/energies measured by AFM include the information of chemical interaction between tip and sample atoms, enabling us to discern the chemical identity of individual surface [2] and tip [3] atoms. We found that this method also pens the possibility to characterize the electronegativity at atomic scale [2].
Next, we will show in-situ reproducible sharp tips for AFM [4]. The fabrication of sharp tips is crucial to diminish the long-range forces such as van der Waals force, which are the source of background noises in AFM. We made an Ag2S crystal, a mixed ionic and electronic conductor, on a conventional Si cantilever, and were able to grow and shrink the Ag nano-protrusion by changing the polarity of the applied bias voltage.
Lastly, we will report conduction measurements of Si surfaces by multi-probe STM. To assess the electrical conduction properties lateral to the surface two-probe (2P-) and four-probe (4P-) STM has been developed. The measurement of conductance with 4P-STM is generally preferred over 2P-STM as it can eliminate probe-to-surface contact uncertainties by employing two tips to inject current and two additional probes to make a high impedance voltage measurement. Here, we overcame the drawback of 2P-STM by achieving the Ohmic contact between tip and Si surface states. The surface conductivity estimated by 2P-STM was comparable with those obtained by 4P-STM. We also utilized STM lithography to create electronically isolated regions from the otherwise surface area, finding that we can measure their conduction properties correctly.

[1] Sugimoto et al., Nature 446 (2007) 64.
[2] J. Onoda et al., Nat. Commun. 8 (2017) 15155.
[3] J. Onoda et al, Nano Lett. 20 (2020) 2000.
[4] J. Onoda et al., Phys Rev. Appl. 15 (2021) 034079.