Implementation of atomically defined Field Ion Microscopy tips in Scanning Probe Microscopy

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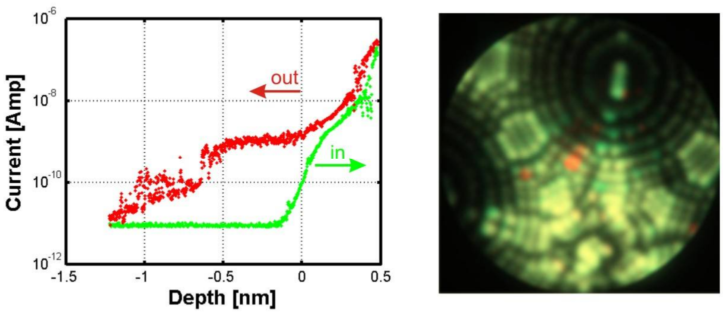
The atomic scale geometry of scanning probe tip-sample junctions is usually unknown. Several groups have investigated combinations Scanning Tunneling Microscopy (STM) with Field Ion Microscopy (FIM) or Atom Probe (AP) methods in order to characterize material transfer during adhesion or tip pulsing in STM experiments, but control over the exact atomic structure of the tip-sample contact has yet to be demonstrated.

We employ FIM to atomically engineer the apex of a tungsten tip which is then used in a combined STM/AFM. In order to preserve the atomic structure of the FIM prepared tip apex, several considerable experimental challenges arise. We have developed techniques to preserve the apex against corrosion by rest gases in UHV over long periods of time, and show that when proper precautions are taken, an atomically defined apex can be approached to tunneling proximity with a sample.

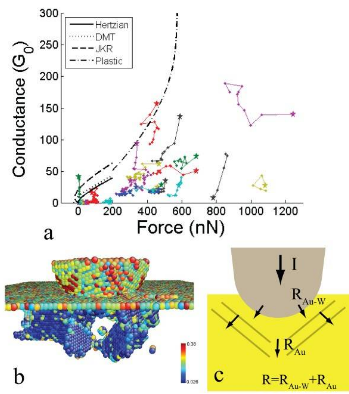
We report results of recent experiments with atomically defined tips from the tunneling to point contact regime performed at room temperature and at 150K on Au(111) and other substrates.

These atomically defined tips are also used in the nanoindentation regime, where a precise knowledge of tip geometry is needed to calculate contact area. From the contact area, we can compute an upper bound for junction conductance based on the maximal conductivity calculated for a W-Au interface, and attribute an additional conductance drop to scattering at defects and disorder in the compressed junction.

(1) Tunneling to Point Contact



(2) Nanoindentation



(1) Tunneling to contact I(z) of W tip with Au(111) surface at 150K; (b) local tip changes (red/green colour for adsorbed/evaporated atoms) due to contact with Au(111) near the center of the FIM image.
(2) Nanoindentation regime where detailed knowledge of tip structure is used to set bounds on junction conductivity (black lines). Supported by molecular dynamics and DFT calculations.

References

[1] A.-S. Lucier, H. Mortensen, Y. Sun & P. Grütter, PRB **72**, 1-9 (2005).
[2] T. Hagedorn, M. El Ouali, W. Paul, D. Oliver, Y. Miyahara & P. Grütter **82**, 113903 (2011).