11th International Conference
on Advanced Materials

ICAM 2009

Rio de Janeiro Brazil
September 20 - 25

Nanoindentation of Au(111) with atomically defined W(111) and (110) indenters using simultaneous Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM)

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Abstract – Contact formation and nanoindentation is investigated at the atomic scale with simultaneous scanning tunneling microscopy (STM) and atomic force microscopy (AFM) techniques. The correlation between pop-in and pop-out events and jumps in conductance is studied during approach and retraction cycles with atomically defined W tips and a Au(111) surface. The unique STM-AFM study performed in ultra high vacuum (UHV) also incorporates *in situ* field ion microscopy (FIM) imaging of the W tips in order to provide full atomic characterization.

The experimental setup allows for the simultaneous detection of tunneling current (STM) and force (AFM) during nanoindentation [1] and contact formation experiments [2]. The combination of these techniques is used to elucidate the interplay between forces and conductivity during contact formation and indentation. Optical interferometry is used to measure the force and tip-sample separation with exceptionally high resolution. We present results from recent contact formation and indentation experiments using etched W tips on atomically flat Au(111) samples. In these experiments, the pop-in and pop-out events that are observed in approach and retraction curves are correlated with jumps in conductance, illustrated in Figure 1. This technique can be extended to other sample materials such as Al.

The detailed determination of tip structure is a common hurdle in the interpretation of scanning probe microscopy data, and contact geometry plays a key role in understanding tunneling junctions, molecular electronics junctions and dissipation in noncontact AFM [2,3,4]. Tip radius is a key parameter in interpreting nanoindentation results, but is often poorly characterized. With our apparatus, the tip can be atomically characterized *in situ* with FIM. Figure 2 (a) shows a FIM image of a (110) oriented W tip in which bright spots represent atoms at the edges of crystal planes. A three-dimensional ball model can be constructed from the identified crystal planes, illustrated in Figure 2 (b) and (c).

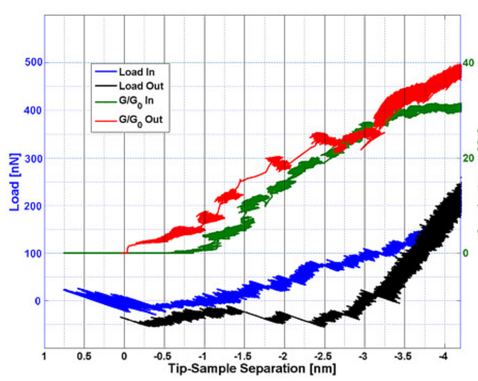

Figure 1: Indentation curve showing force (blue: loading, black: unloading) and conductance (green: loading, red: unloading) for a W tip on atomically flat Au(111).

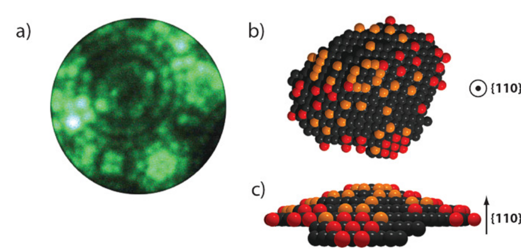

Figure 2: (a) FIM image of (110) oriented W tip; (b,c) 3D ball reconstructions of the tip showing edge and corner atoms in orange and red.

References

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