Can STM see below a surface?! Yes!!! Is it really possible? Sure, down to 100 nm!

Exploring a subsurface in metals with STM

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Introduction: Scanning Tunneling Microscopy/Spectroscopy

Topography

Cu(111)

atomic resolution

Resolution
Lateral: atomic, ~0.1nm
Vertical: subatomic, ~0.001nm

Two ways of getting subsurface sensibility:
1. Subatomic variation of the relief
2. Perturbation of surface electron density

In selected points Spectroscopy (STS)

Reflects the Density of States

For each (x,y) Conductance mapping
Mismatch of crystalline lattices of substrate and impurity atoms or embedded nanocluster.

Relaxation of crystalline lattice and interaction of embedded atoms.

Relief variation

Co nanoclusters embedded below Cu(001) surface, 75 x 75 nm².

Ar bubble below Cu(001) surface, 30 x 15 nm².
Buried nanocavities and clusters: TU/e results

Ar-, Ne- or He- filled nanocavities have much stronger scattering effect and therefore they can be detected much dipper than single impurities atoms. The nanocavities are visualized in STM measurements as spots of different contrast above their locations. The contrast oscillates with bias. From the oscillation period the depth can be deduced. Different facets of nanocavities induce different oscillation phase and period. From this the shape and size of the nanocavity can be determined.

\[ d = \frac{\pi \Delta E}{\Delta E \partial k} \]

if \( \Delta E = 0.25 \text{ mV} \) then \( d = 12 \text{ nm} \)
Ultimate depth detection: nanocavities in Cu(110) – 80 nm

Nanocavities vs Nanoclusters

Metallic clusters provide less effective scattering. Nevertheless we can see Co and Fe nanoclusters up to 25 nm deep.

Co nanoclusters in Cu(001)
\( \frac{dI}{dv} @ 900 \text{mV} \) 10 nm of Cu
40 x 40 nm

Fe nanoclusters in Cu(001)
\( \frac{dI}{dv} @ 400 \text{mV} \) 6 nm of Cu
30 x 30 nm

Ar-filled nanocavities in Cu(110)

Depth
- 4.5 nm
- 12.5 nm
- 22.4 nm
- 32.5 nm
- 39.0 nm
- 52.9 nm
- 62.8 nm
- 80.0 nm

Applications

For ITER
Degradation of W or Mo walls by implantation and growth of \( \text{H}_2 \) and He-filled nanocavities: the growth of nanocavities can be visualized

For micro-nanolithography
Ar, Ne, He implantation defects in conducting layers (Al, Cu, Au, Ag, …) during plasma processing or magnetron sputtering deposition

For clean material technology
Study near-surface defects and interfaces directly or by decoration them with He or H nanocavities

For solar cells and nanophotonics
Ge nanoclusters and nanovoids in fused silica

TU/e
Technische Universiteit Eindhoven
University of Technology
Application for ITER: Shape of nanocavity in W

Possible Wulf constructions

Pure tungsten

Tungsten with impurities


R. Jacobs, D. Morgan, and J. Booske ArXiv 1712.05308.pdf

Our experiments

Estimated size ~15 nm

20 x 20 nm

0.22mV ~10 nm


R. Jacobs, D. Morgan, and J. Booske ArXiv 1712.05308.pdf