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CHEM 475

Module Goals: Adaptions to Scanning Tunneling Microscopy: SP STM, BEEM, PSTM

1. Introduction [1]

- STM is a revolutionary technique to view sample surfaces on atomic level.
- Designed by Binning and Rohrer, who won the 1986 Nobel Prize in Physics.
- Basic introduction to how STM works
- Unaltered STM useful for many things → alteration necessary occasionally for specialized details
- Table 1 → listing traditional methods and three alterations with apparatus set-up, samples, resolution, and limitations

2. Spin-Polarized STM [2]

a. Introduction
   i. Provides detailed information of magnetic phenomena on the single-atom scale
   ii. This is important for accurate measurement of superconductivity and high-density magnetic data storage devices.
b. Device Setup and Sample Preparation
   i. Setup: Tip coated with a thin layer of magnetic material → voltage applied between tip and sample resulting in current → electrons with spins matching the tip's magnetization have a higher change of tunneling → this shows up on the map → Brief discussion about differences between optically pumped GaAs tips and magnetic probe tips
   ii. Samples: thin films, nanoparticles
   iii. Image: Figures 1 (set up of SP STM apparatus) and 20 (SP STM image of Co) from Bode paper
c. Limitations
   i. Can't distinguish between magnetization or space separation → need to combine with conventional STM to get multi-domain structures and/or topological information
   ii. Limit in properties of tip limits usefulness of machine

3. Ballistic Electron Emission Microscopy [3,4]

a. Introduction
   i. Nanometer spatial resolutions of semiconductor interfaces (which is difficult in most conventional surface techniques)
   ii. Can determine interface barrier height and transport across the interface
b. Device Setup and Sample Preparation
   i. Setup: Three terminal technique →Electrons injected from STM tip into Schottky diode (Semiconductor diode with a low forward voltage drop and a very fast switching action)→ a fraction travel ballistically through the metal to the metal-semiconductor interface where they hit Schottky barrier (potential barrier formed at a metal-semiconductor junction with has rectifying characteristics)
   ii. Samples: interfaces, semiconductors
   iii. Images: Adaptation of Fig 1 on page 309 of Stroscio (set up), fig 22 on page 338 of Stroscio (BEEM image of Au compared to STM)
c. Limitations
   i. Sample type – needs to be an interface between two layers

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4. Photon STM [5,6,7]

a. Introduction
   i. STM imaging creates a light due to the electric current → this light can be detected and used to gain more information about the sample.
   ii. Can be used as a measurement of the electromagnetic interaction of two metallic objects in close proximity to one another.

b. Device Setup and Sample Preparation
   i. Setup: Evanescent fields are generated by the total internal reflection of the light at the interface between materials of different optical densities → both planar and point junctions → Protons tunnel from the total internal reflection surface to the tip and get converted to an electrical signal via optical fiber detector. → This allows for calculations of polarization, emission direction and emission time.
   ii. Samples: Fractal Metal Colloid Clusters, Nanostructured materials, single organic molecules
   iii. Image: Figures 1 (set up of PSTM apparatus) and 11 from Reddick paper (PSTM 2)

c. Limitations
   i. Sample needs to be kept a low temperatures for process (cannot be negatively impacted by drastic temperature changes)

5. Conclusion

- Brief written comparison between the three methods
- Review of how specialized each method is
- Brief mention that there are other methods for other specialized applications

References

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4. Kaiser, W.J.; Bell, L.D. Direct Investigation of Subsurface Interface Electronic Structure by Ballistic-Electron-Emission Microscopy, *Phys. Rev. Lett.„* **1988**, *60*, 1406-1409
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