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Mass Analysis of Ballistic Electron Spectra

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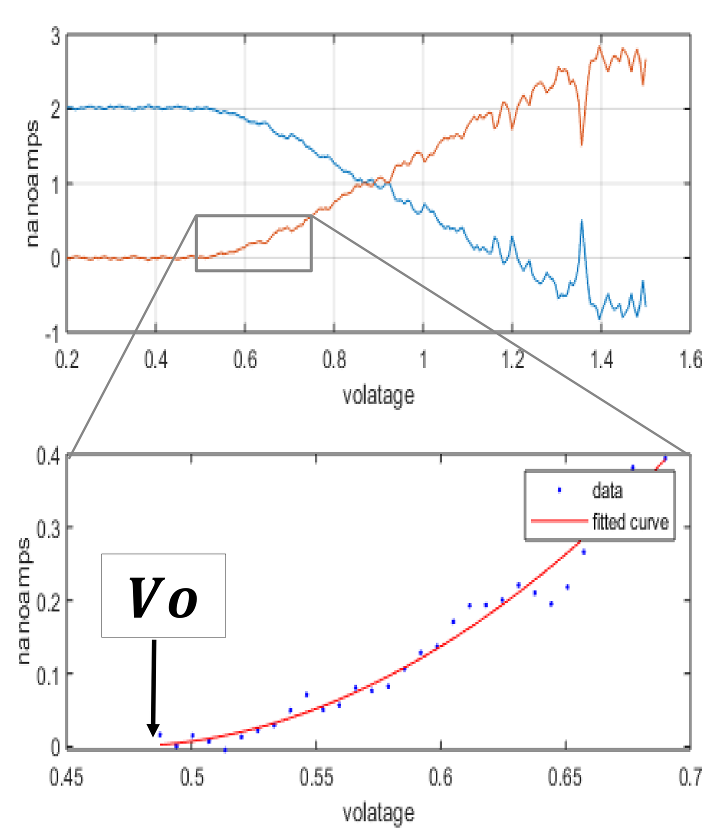
Abstract

The metal/semiconductor interface is of vital importance to a number of electronic devices. The energy barrier that forms at this interface can dominate the overall electronic properties of a device. A poor interface can prevent a device from reaching its full potential. Thus, a better understanding of the mechanisms that determine this barrier could aid in the optimization of an interface for a particular application. For the current project, electrons were shot into gold films deposited on a molybdenum disulfide (MoS_2) semiconductor at different voltages using a scanning tunneling microscope in a ballistic electron configuration. The number of electrons entering the MoS_2 as a function of voltages can be used to determine the energy barrier, or threshold voltage, at this interface by fitting individual spectrum to the theory. For this project, spectra were taken in a grid fashion (10x10) to examine the energy barrier at different locations on the sample to investigate how impurities affect the quality of the interface. To do so each spectrum had to be fitted individually, a time consuming task. To make this process more efficient, a program was written in MATLAB to automate this process. The program was used to prepare the raw data to fit to theory. The fitted data was used to create an energy barrier map of the interface, displaying areas where it is easy or hard for electrons to traverse the interface. This current map lacks the resolution to identify impurities. However, in the future a 500x500 matrix should be sufficient.

Finding the Threshold Voltage



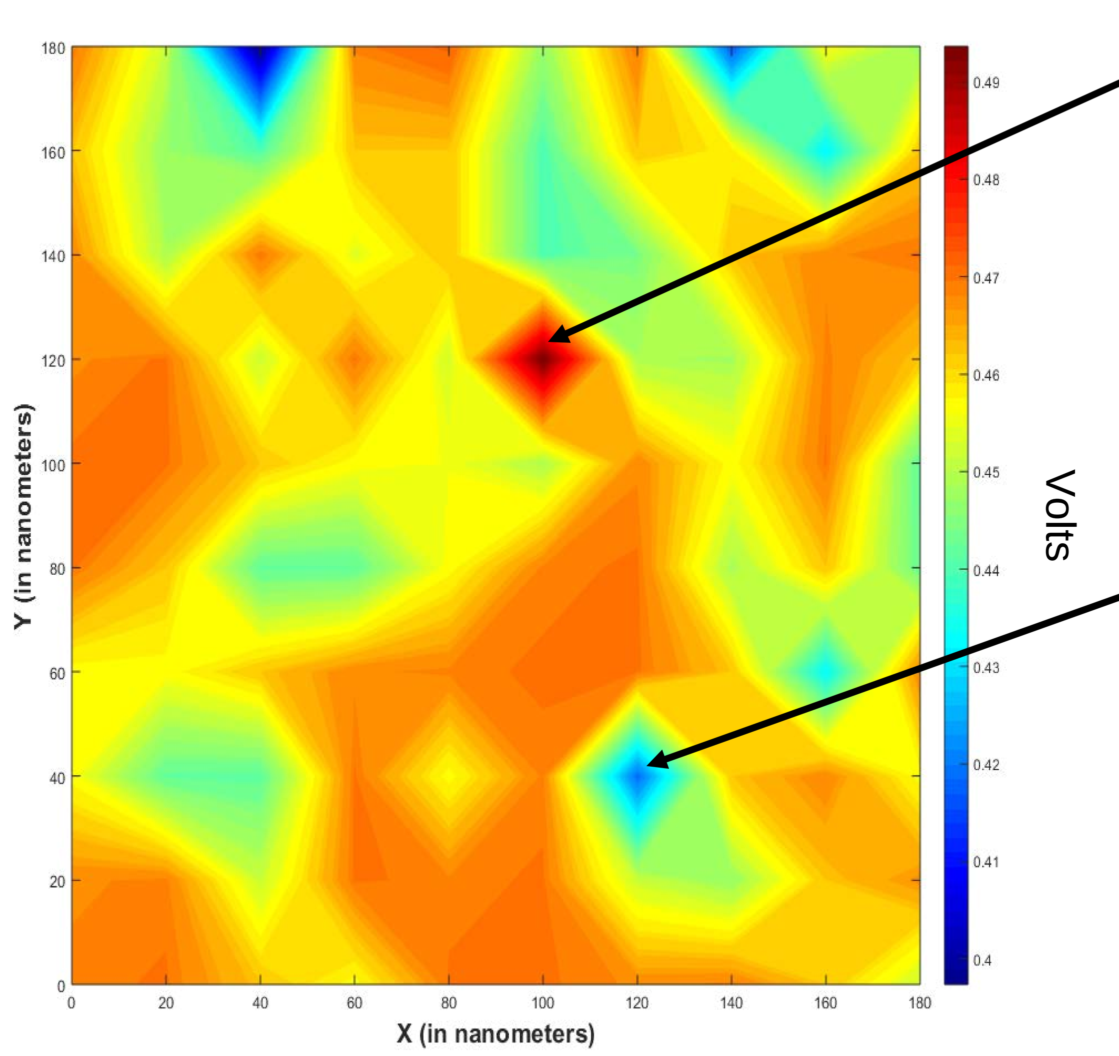
The spectra shown here represents a spectrum taken at a single location on a gold film on molybdenum disulfide.

To fit the data, we had to first flip and shift the original voltage measurements (Blue Graph) to create the data set represented by the Yellow Graph. A fit (Red line) of the transformed data was performed.. The extracted threshold voltage (Vo) is labeled by the arrow in the second graph. The threshold is found by fitting the data to theory:

$$I = A \times (V - Vo)^2$$

I = current
V = voltage
A = amplitude
Vo = threshold voltage

Results

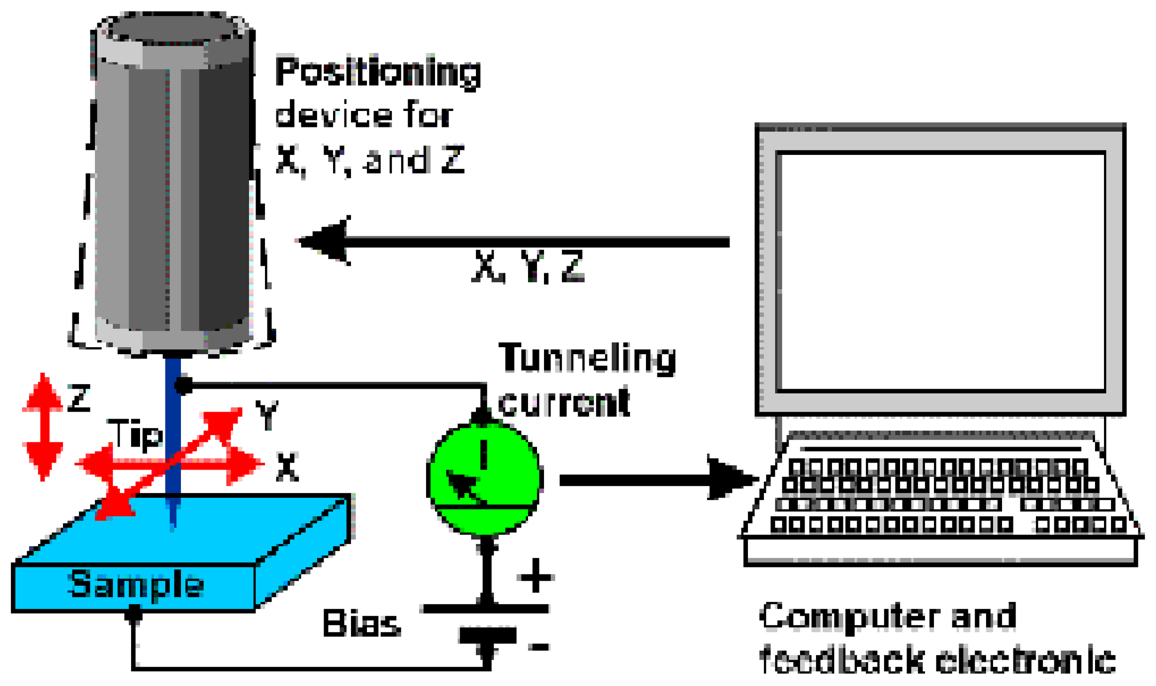


Red represents higher threshold voltages: harder for electrons to pass through.

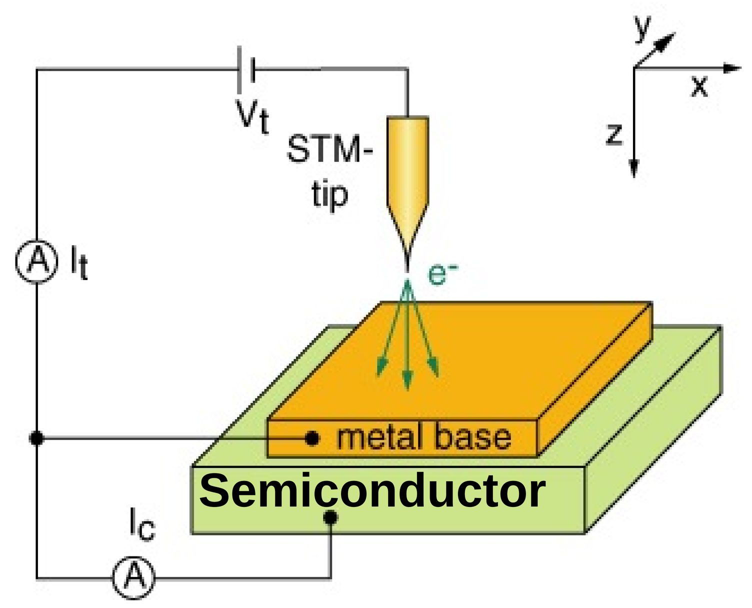
Blue represents lower threshold voltages: easier for electrons to pass through.

Scanning Tunneling Microscope

The Scanning Tunneling Microscope (STM) works by applying a voltage to the tip, which, when brought close enough to the sample, causes electrons to tunnel through the sample creating a measureable current. These current readings can be converted to an image.

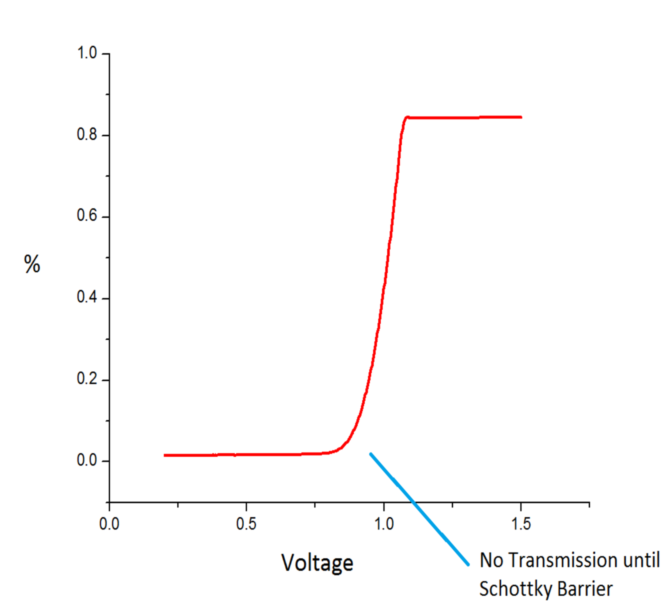


Ballistic Electron Transport



STM-tip shoots electrons into the metal. If the electrons have enough energy to break through the interface, the electrons will enter the semiconductor. This occurs when the voltage is increased; however, there is not transmission until the threshold voltage is reached.

Single ballistic electron spectrum



Acknowledgments

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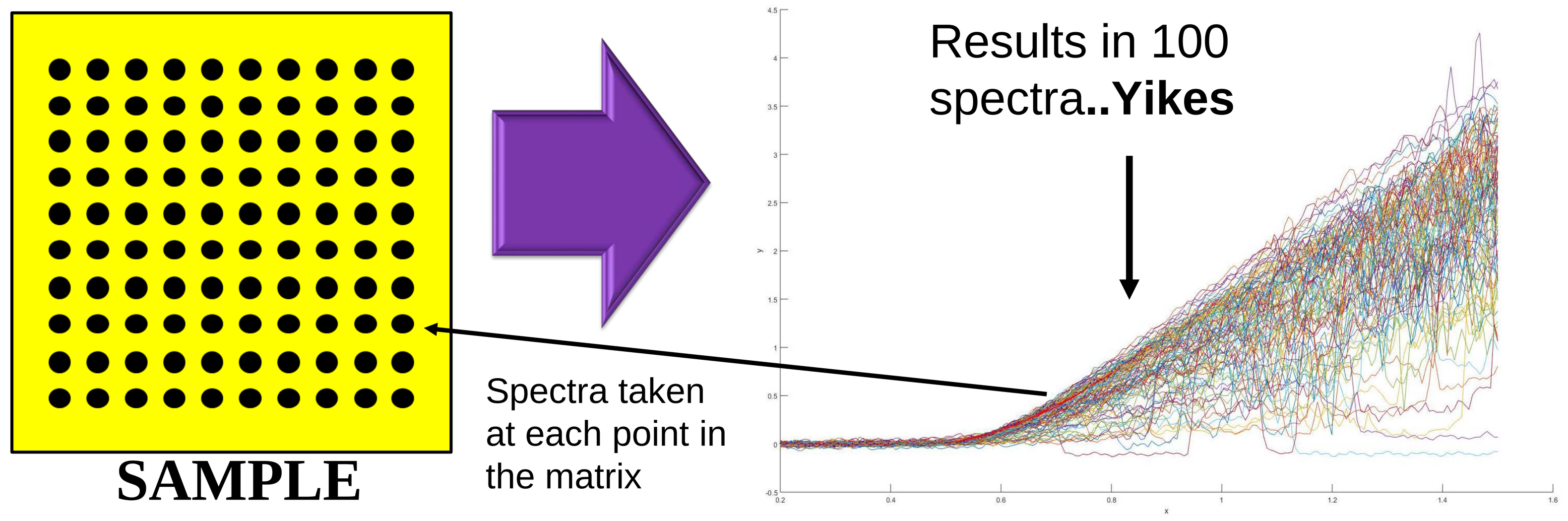
Problem



Spectra can be taken in grid fashion to determine threshold voltage variations. **How can we perform fits to this much data in a reasonable time?**

Procedure

1. Import data into MATLAB into and generate a script to recreate it.
2. Separate the data into groups of 100
3. Prepare for fit to theory. (Flip and zero the data)
4. Prepare fits and extract threshold voltage.
5. Plot the threshold in 3D.

Conclusion and Future Direction

- The script created using MATLAB was able to perform 100 fits in under one minute, thousands of times faster than doing so one at a time in Excel.
- The goal is to increase the spatial resolution of the threshold voltage map by increasing the number of spectra taken in the matrix to 500x500.
- Continue to optimize the automated fitting parameters