Barrier Heights in Metal-Insulator-Metal Tunneling Junctions

Energy barriers were measured in metal-insulator-metal (MIM) devices. A photoemission measurement system was designed, assembled, and calibrated to yield values for novel MIM structures. This system has advanced materials research in Dr. Conley's group at Oregon State University.

About the Group

Dr. Conley's research interests include atomic layer deposition, high-κ dielectrics, thin film transistors, metal/insulator/metal tunnel diodes, directed integration of nanomaterials and nanodevices, electron spin resonance identification of electrically active point defects, reliability, and radiation effects in novel electronic materials.

Learn more at:
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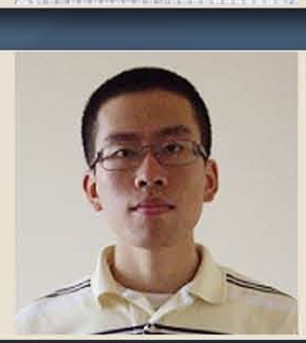

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Dr. John F. Conley, Jr. (Faculty Advisor)
Dr. Conley's current research interests include atomic layer deposition, MIM high-κ capacitors, MIM & MIIM tunnel diodes, memristors, internal photoemission, and directed integration of nanomaterials and devices.
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Engineering Requirements

- ✓ Photoemission Experimental Setup
- ✓ Photoemission Experimental Results
- ✓ Photoemission Analysis
- ✓ Logarithmic Conductivity Experimental Setup
- ✓ Logarithmic Conductivity Experimental Results
- ✓ Logarithmic Conductivity Analysis
- ✓ Thermionic Emission Experimental Setup
- ✓ Thermionic Emission Experimental Results
- ✓ Thermionic Emission Analysis
- ✓ Expected Value
- ✓ Barrier Height Value
- ✓ Final Documentation

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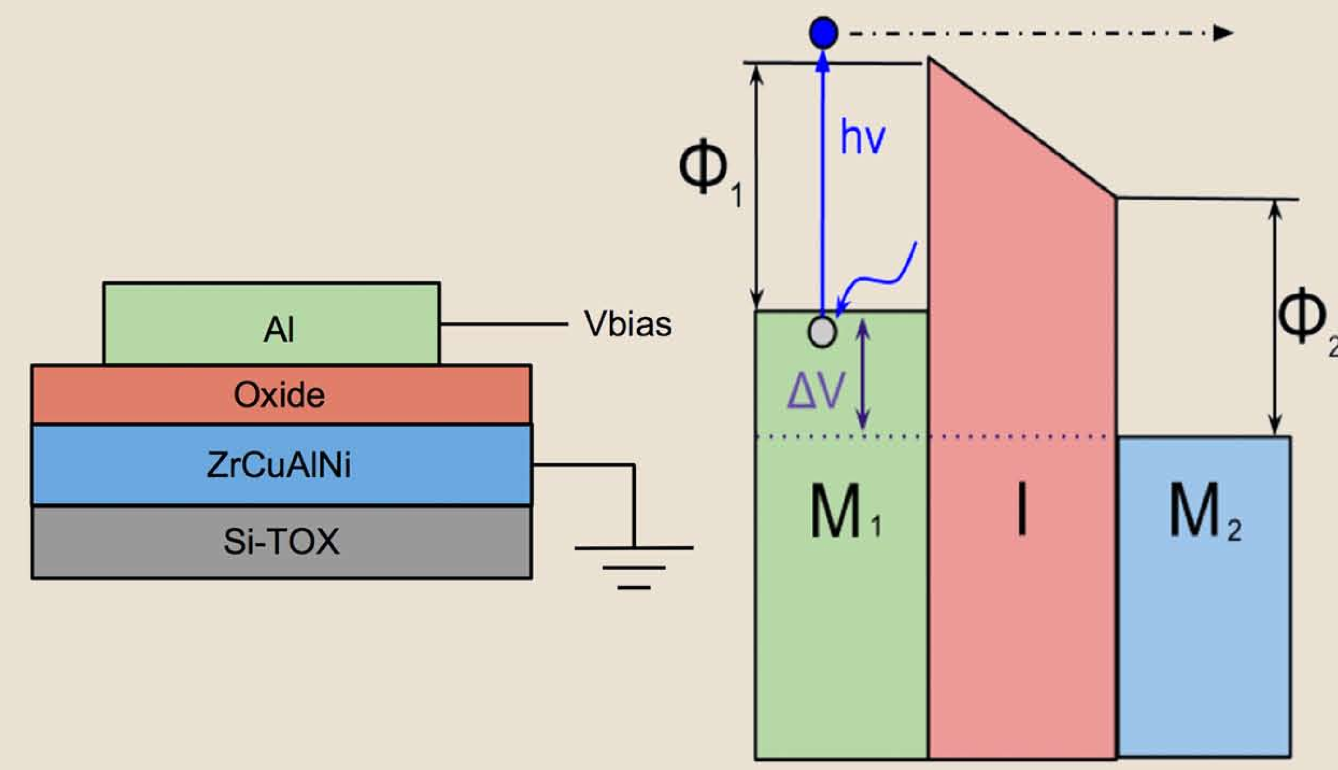
Dr. Plant for advising and lending optical equipment
Nasir Alimardani for his help building our devices
Chris Tasker for advising and troubleshooting equipment

Project Objective

Interface Barrier

For these MIM devices, the barrier heights (Φ_1 and Φ_2 in diagram) of the metal-insulator interfaces have remained a mystery. A three-pronged investigation of logarithmic conductivity, thermionic emission, and internal photoemission spectroscopy was undertaken in order to pinpoint a systemic method of barrier height analysis.

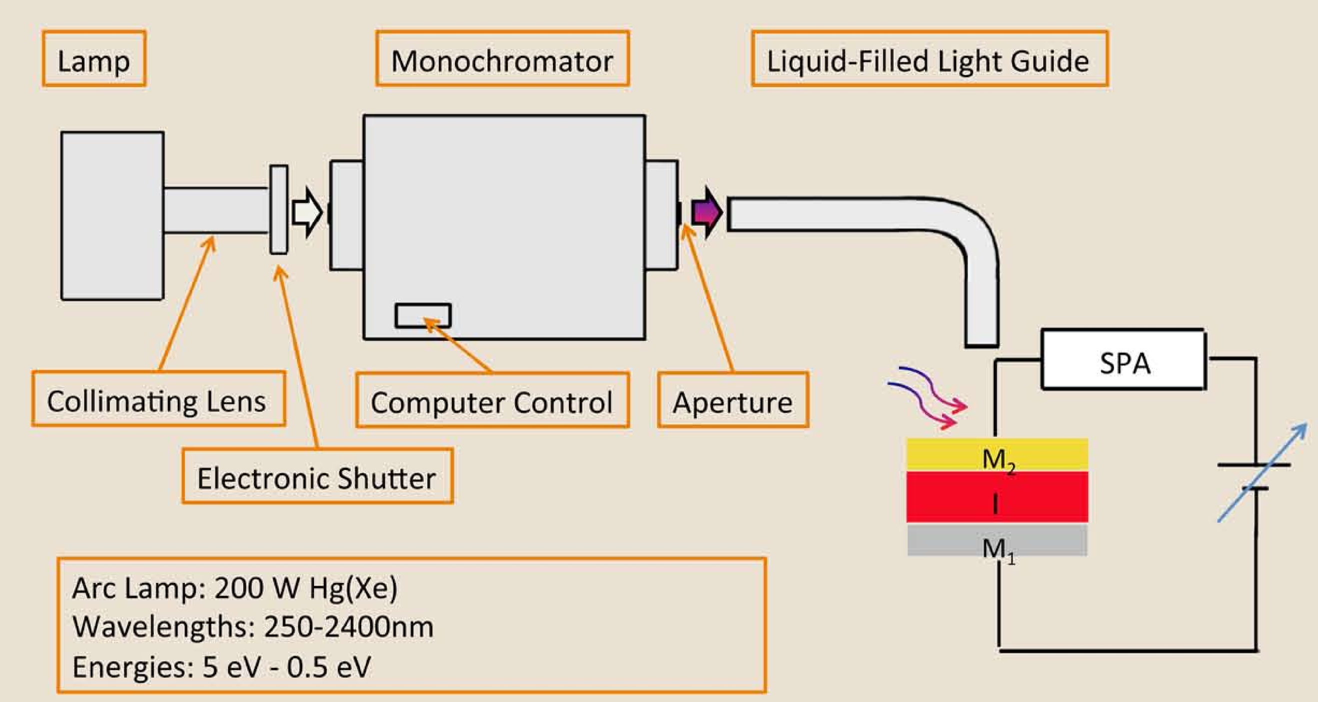


Solution

Internal Photoemission Spectroscopy:

The use of photons to excite electrons which can be used to measure barrier heights.

The I-V response was measured while the devices were sequentially exposed to incident light passed through a monochromator. Field dependent barrier heights were extracted at each bias and then used to determine the zero bias metal-insulator barrier heights.



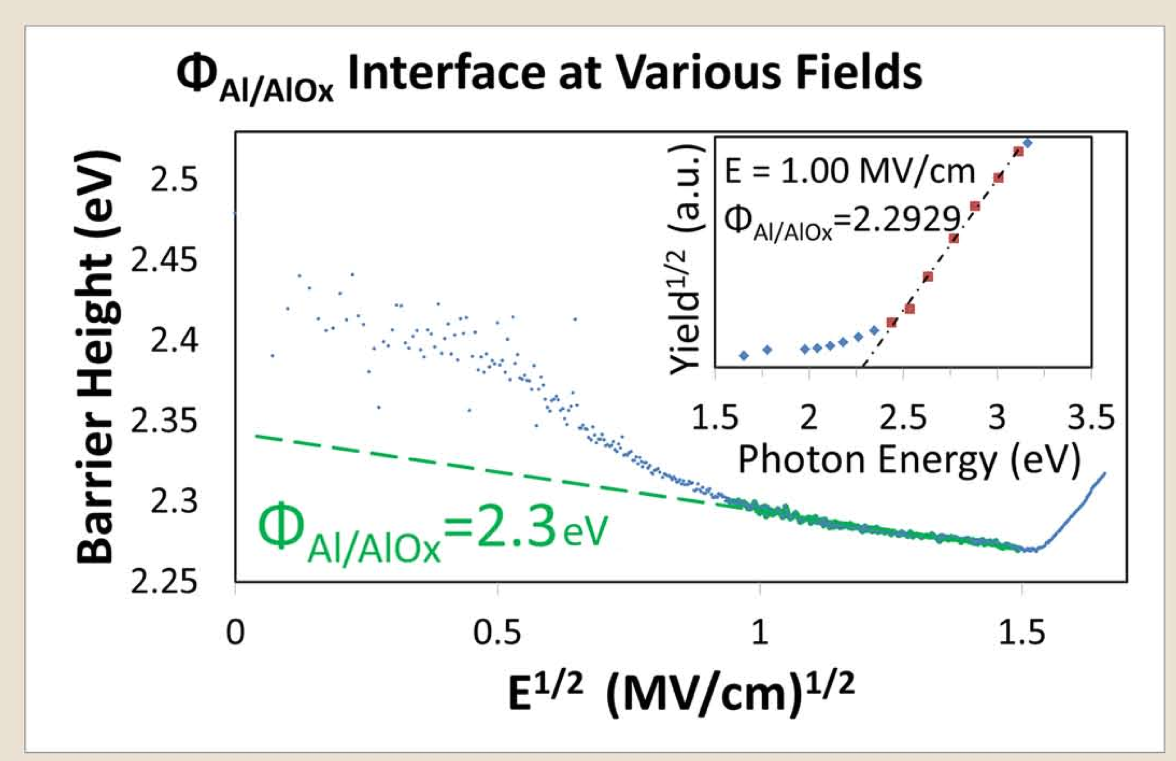
Conclusion

The barrier heights were extracted with photoemission spectroscopy. The barriers of the following interfaces were measured.

Al/Al_2O_3 - 2.3eV

$ZrCuAlNi/Al_2O_3$ - 3.1eV

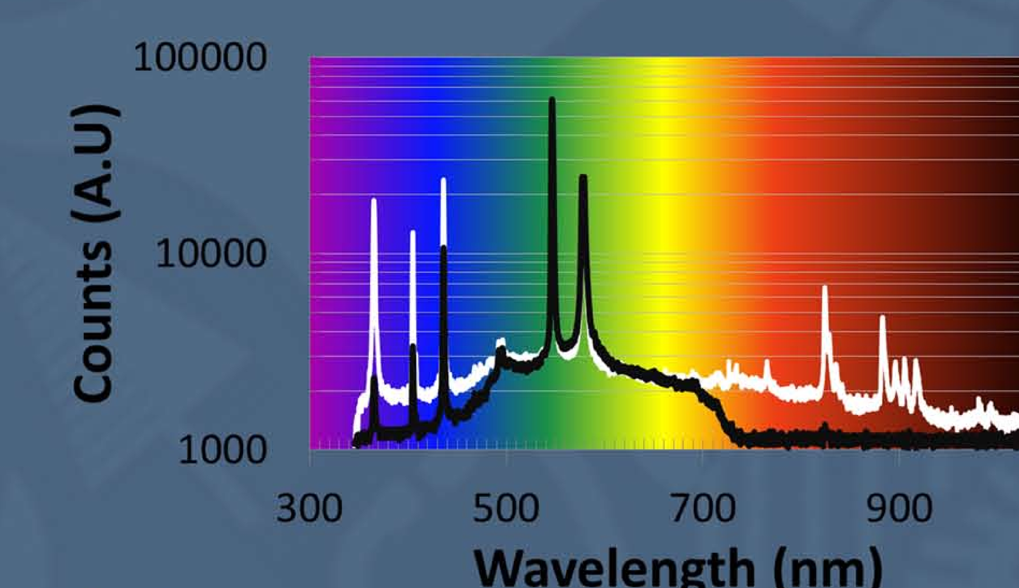
This work has helped further the understanding of MIM tunneling diodes at Oregon State.



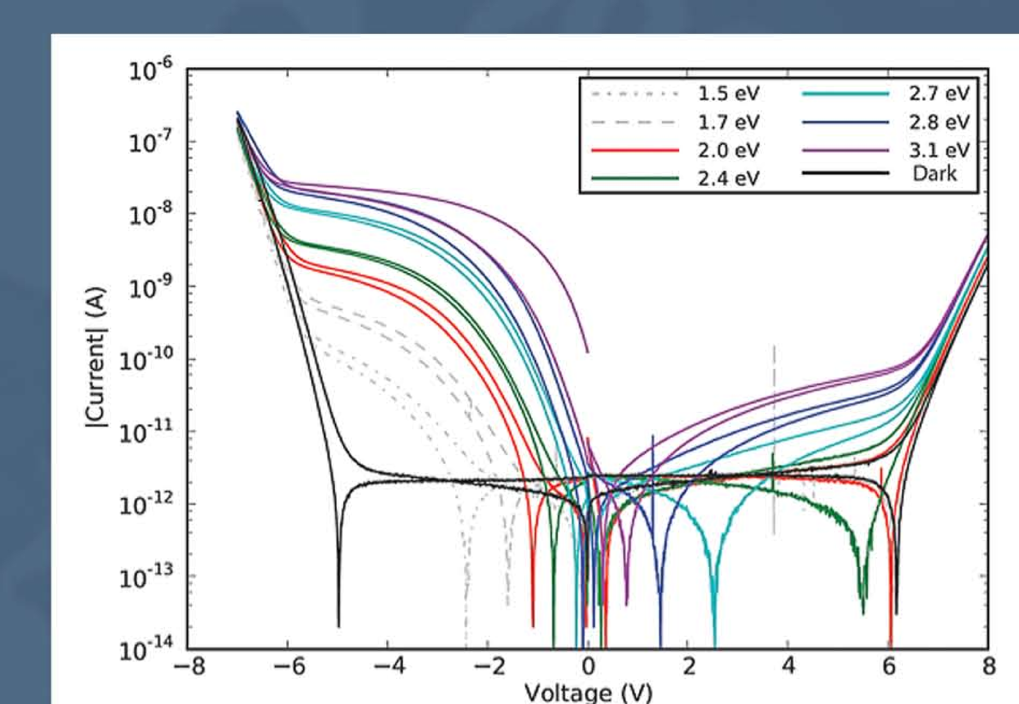
Motivation

Metal-insulator-metal (MIM) tunnel junctions based on Fowler-Nordheim tunneling have been proposed for applications such as hot electron transistors, terahertz operation devices, optical rectennas for IR energy harvesting, and macroelectronics (LCD TV's). Recent work at Oregon State has shown that smooth bottom electrodes improve the performance of these devices. In order to further optimize operation of these diodes for a given application, accurate energy barrier band profiles are necessary.

A device under test in the probestation



Arc Lamp spectra measured with a spectrometer



Typical IV curve of a MIM diode with incident LED light. The deviation is the photo response.

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