Characterization of ALD-Deposited Secondary Electron Emission Materials

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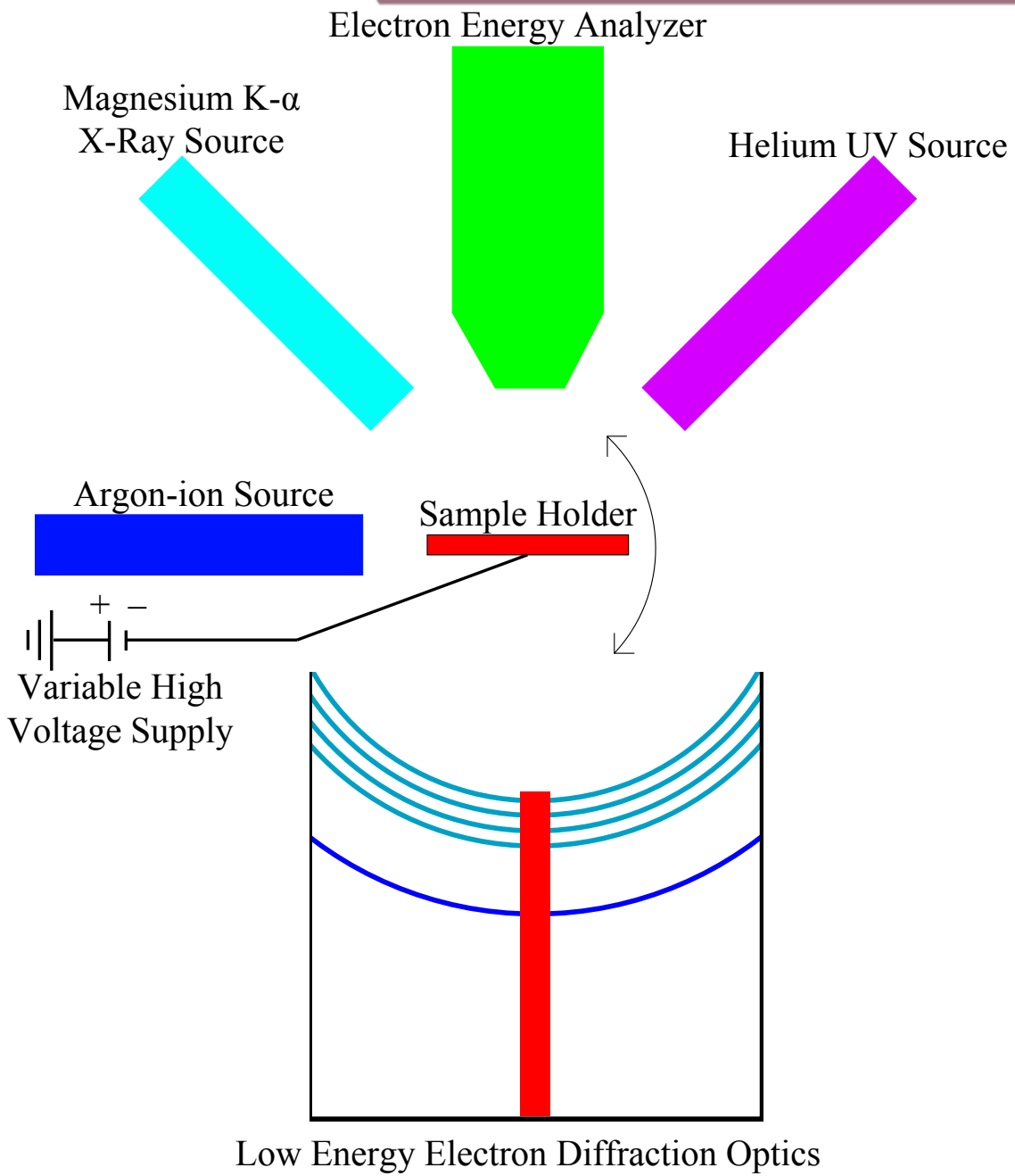
Progress Since February 2010

- Comparative studies of MgO and Al_2O_3
  - Secondary Electron Yield (SEY)
    - Dose Effect (Emission vs. Time or Emission vs. Electron Fluence)
    - Emission vs. Film Thickness (MgO, Al_2O_3 is *in progress*)
    - Sample Charging
- Installed new(er) Low Energy Electron Diffraction (LEED) system onto chamber
  - Easier to enable **pulsed operation** of beam (*in progress)*
    - Minimizes sample charging-related artifacts typical for insulating materials
  - Optimal electron beam size is 50μm
  - Less noise in power supply allows for smaller continuous beam current (10 nA)
- Elimination of major fluorine source in chamber
  - Insulation on wires inside chamber contained fluorine
  - Still see small amounts of fluorine on MgO films (will observe for Al_2O_3)
- CO_2 snow cleaning setup has been tested
  - Studies will be conducted on it's usefulness in cleaning MCPs prior to ALD

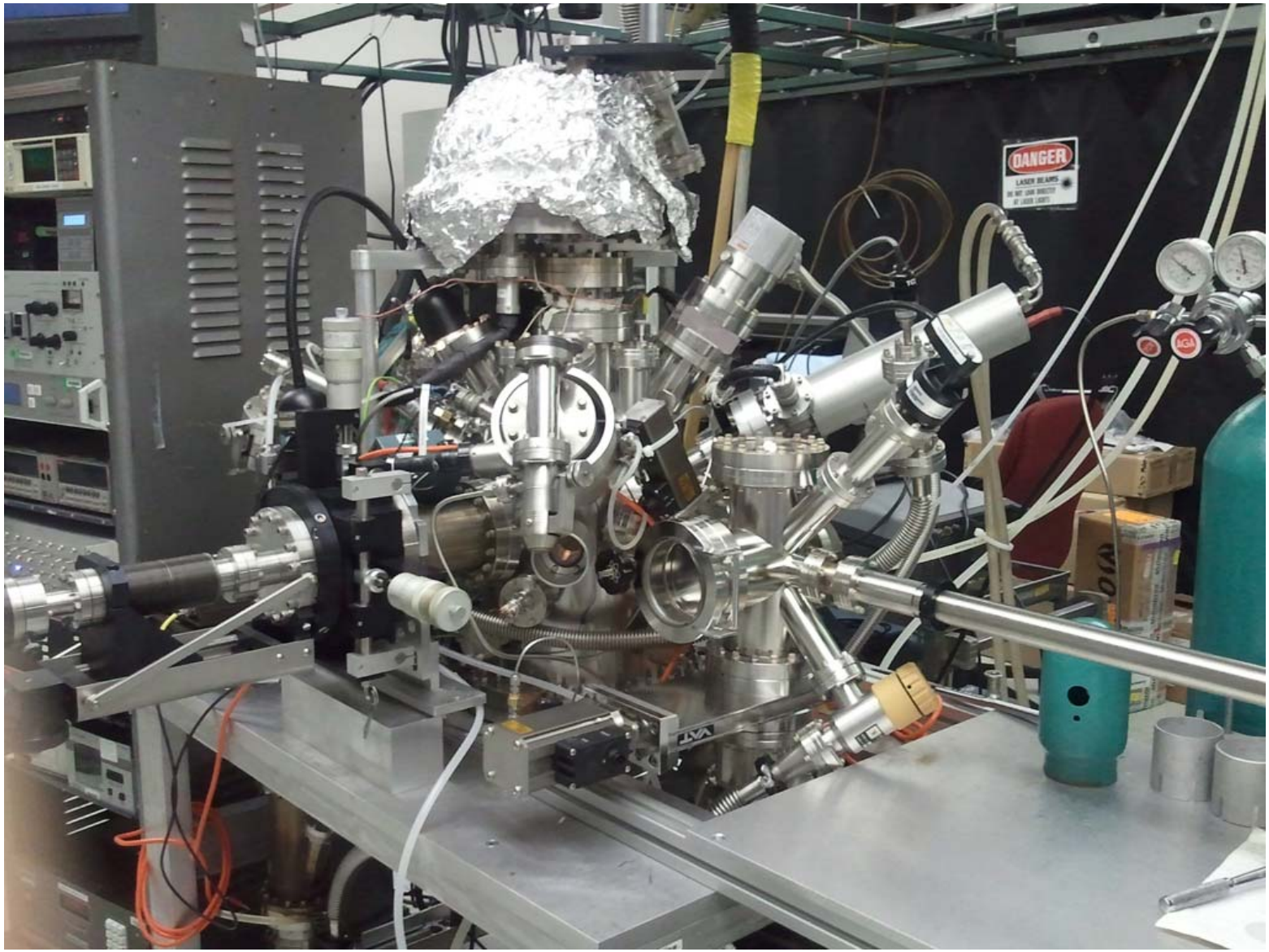
Current Experimental Setup

- X-Ray Photoelectron Spectroscopy (XPS)
  - Mg Kα source of x-rays
  - Hemispherical Energy Analyzer (electron energy analyzer)
    - Maximum resolution of better than 1eV
- Ultraviolet Photoelectron Spectroscopy (UPS)
  - He I (21.22 eV) and He II (40.81 eV) UV emission source.
  - Hemispherical Energy Analyzer
- Secondary Electron Yield (SEY)
  - Fixed energy electrons (typically 950 eV) from LEED system
    - Fixed extraction voltage assures constant electron beam current
  - Wire-mesh and screen portion of LEED system can also be used to collect emitted electrons
    - Applying retarding potential to middle mesh screen allows for determination of kinetic energy distributions of secondary electrons
    - Phosphor screen can be used to determine angular distribution of secondary electrons

Experimental Setup

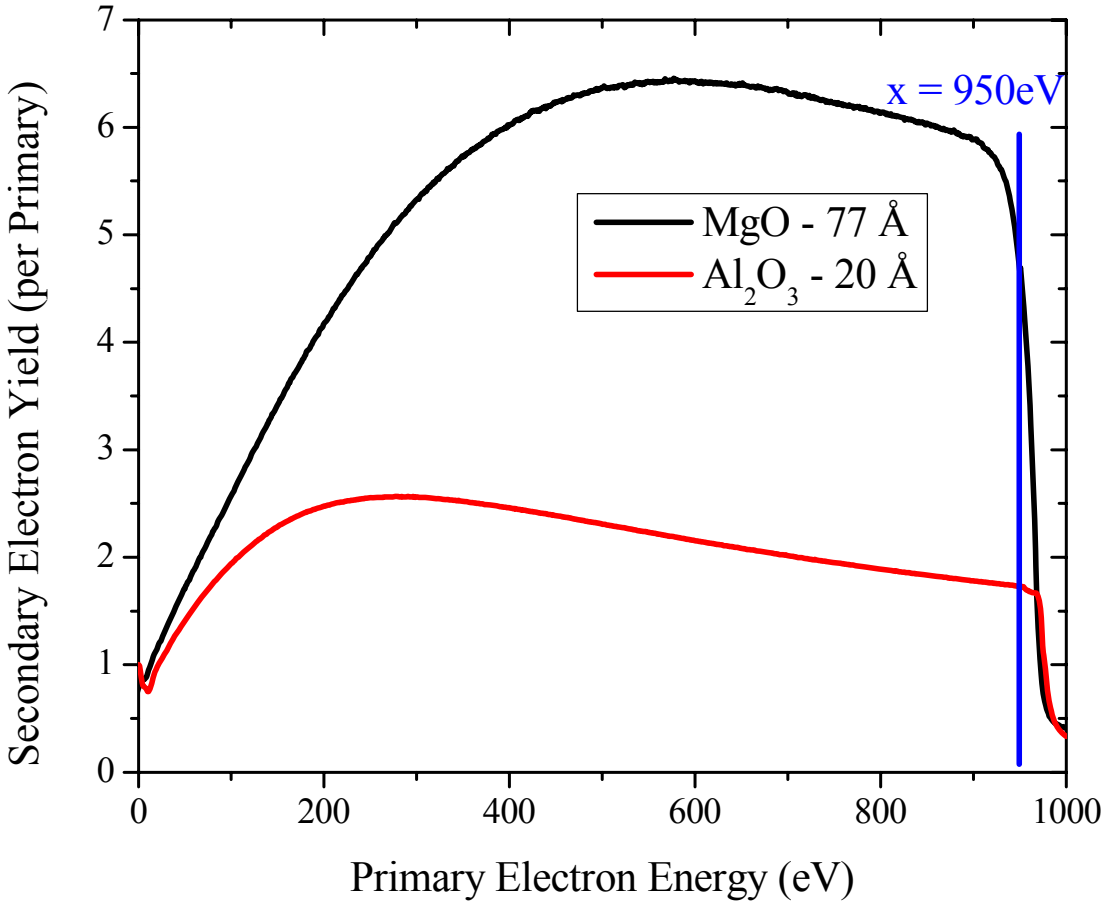


Experimental Setup



Emission of MgO vs. Al_2O_3

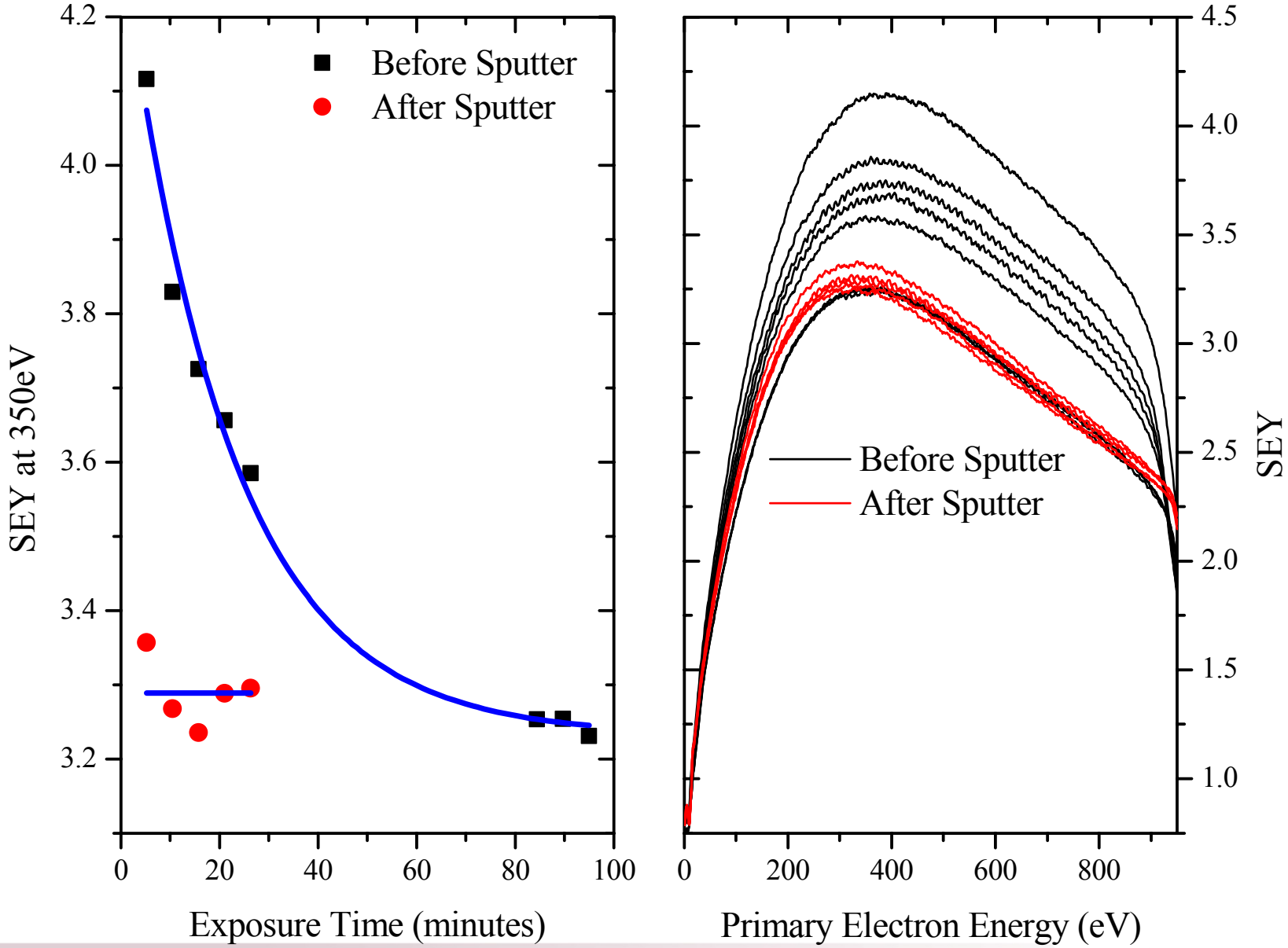
- MgO has a larger secondary emission yield than Al_2O_3



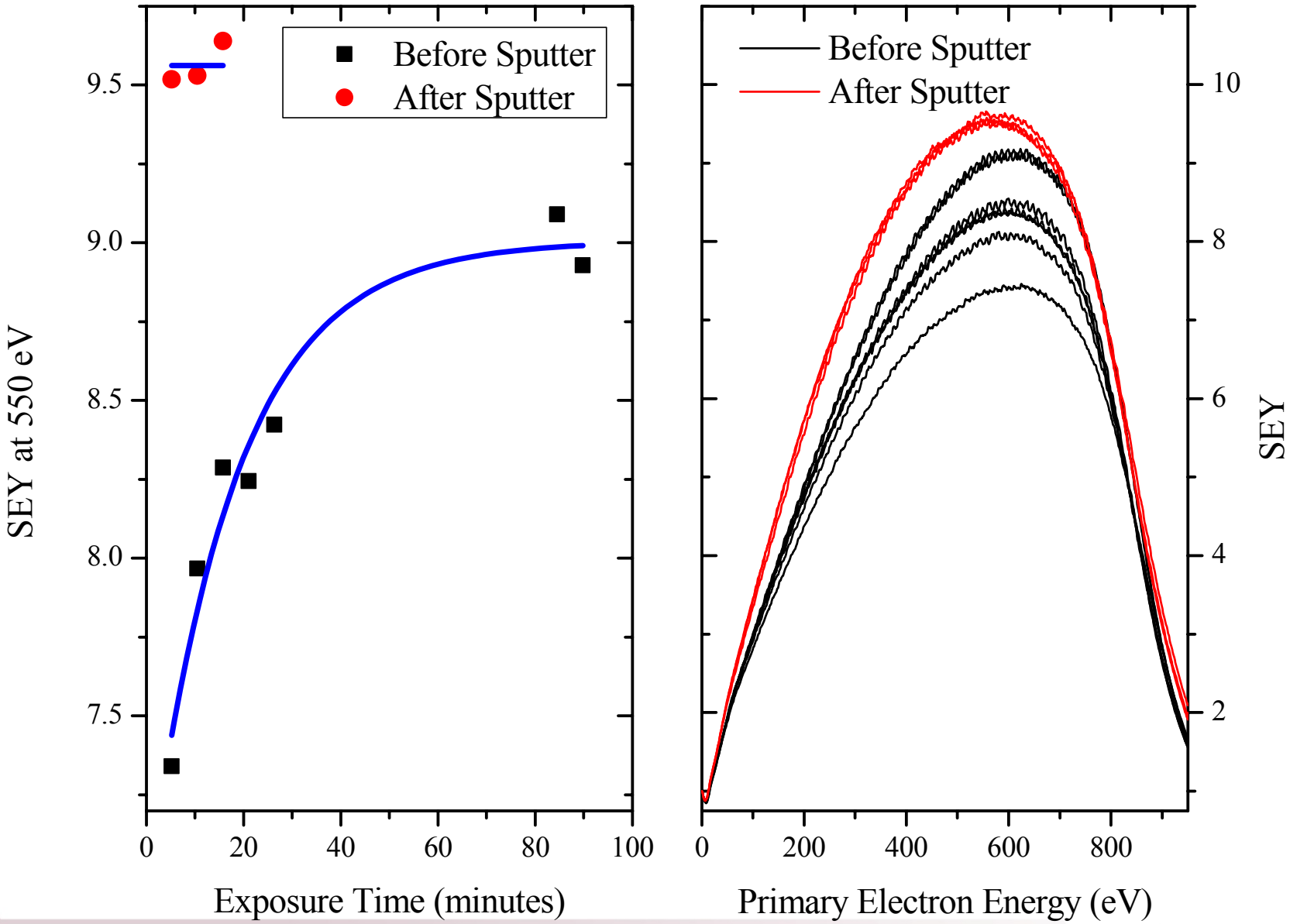
Dose Effect and "Scrubbing"

- We suspect that "Scrubbing" and the dose effect are related
  - The Dose Effect is the change in emission as a function of primary electron fluence.
  - "Scrubbing" is the term that has been applied to exposing an MCP to an electron source until it's emission is permanently stabilized.
- We *hypothesize* that these terms are related to desorption of various surface-bound species that can influence secondary electron yield by
  - Scattering escaping electrons back into material, shielding / blanketing the emissive surface etc…
  - Changing work function of the surface and thus affecting escape conditions for the electrons…
- We want to understand these processes in depth by subjecting the surface to various directed energy fluxes that can cause desorption of surface species.
  - Involves Mass Spectrometry characterization of desorbed species.

Dose Effect for Al_2O_3

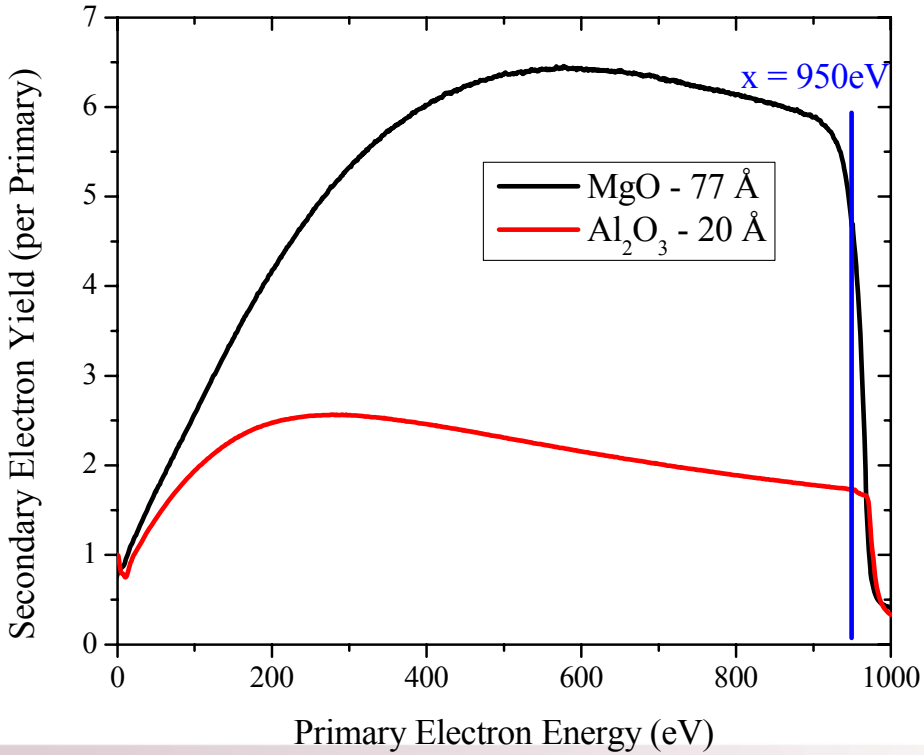


Dose Effect for MgO



Sample Charging

- Cutoff in the yield-curve is expected at the electron-gun's energy (950 eV)
- A net-positive voltage at the sample's surface will result in zero secondary emission
  - Positive charging of the sample's surface will result in a premature cutoff

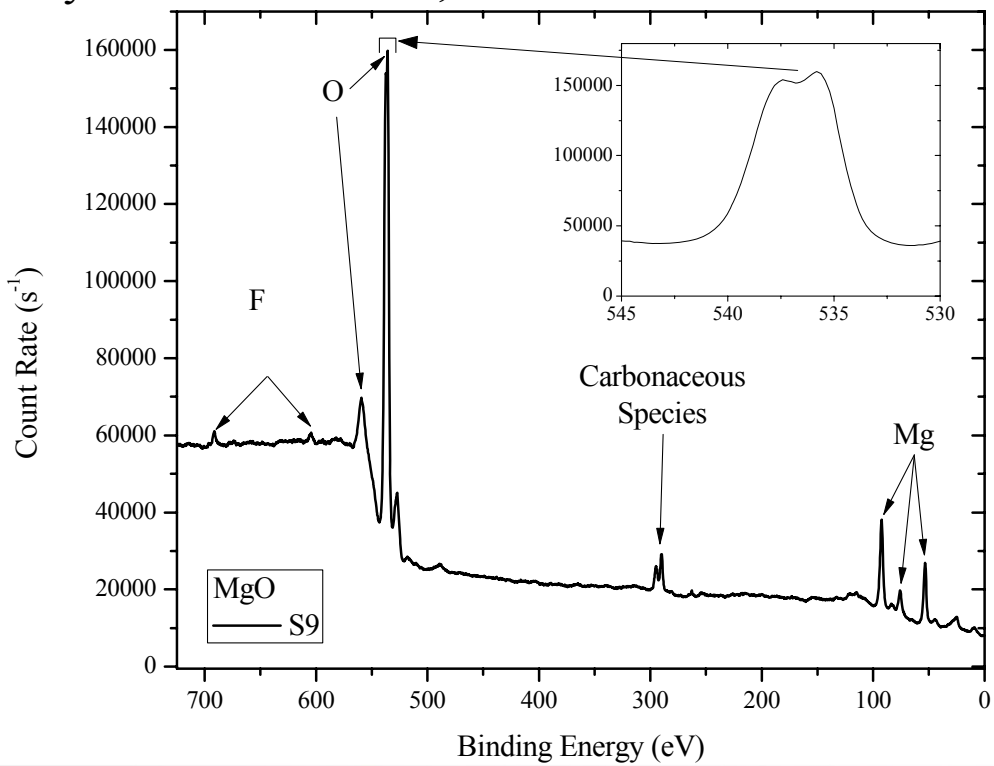


New LEED System

- Original LEED system's power supply was very noisy
  - A short between emission grid and cathode prevented implementation of beam pulsing
- LEED system has been replaced with newer model
  - Lower continuous electron beam currents can be used
    - Decreased current from 70 to 10 nA (I believe lower is possible)
  - Emission grid is much easier to pulse
    - Pulsed electron beam will be used to decrease total electron fluence, sample charging, and electron stimulated desorption.
  - Further experiments with this LEED system will be discussed later

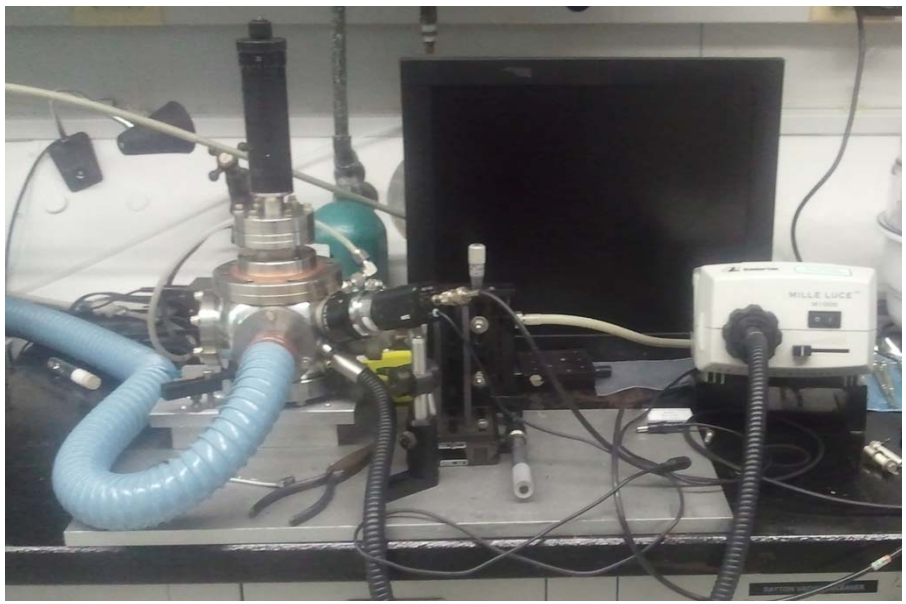
Fluorine Presence in Chamber

- Teflon was found in the insulation of some of the wires used on the inside of the chamber
  - They have been replaced with Kapton
  - Occasionally I still see fluorine, but not in the concentrations observed before



CO_2 Snow Cleaning Apparatus

- CO_2 snow cleaning apparatus for cleaning of NASA Genesis samples has been adapted for MCPs
  - MCPs will be cleaned in this manner prior to ALD deposition
  - Clogged MCP pores will be observed before and after cleaning
  - After ALD, MCP-performance will be compared between MCPs that have and have not undergone CO_2 snow cleaning

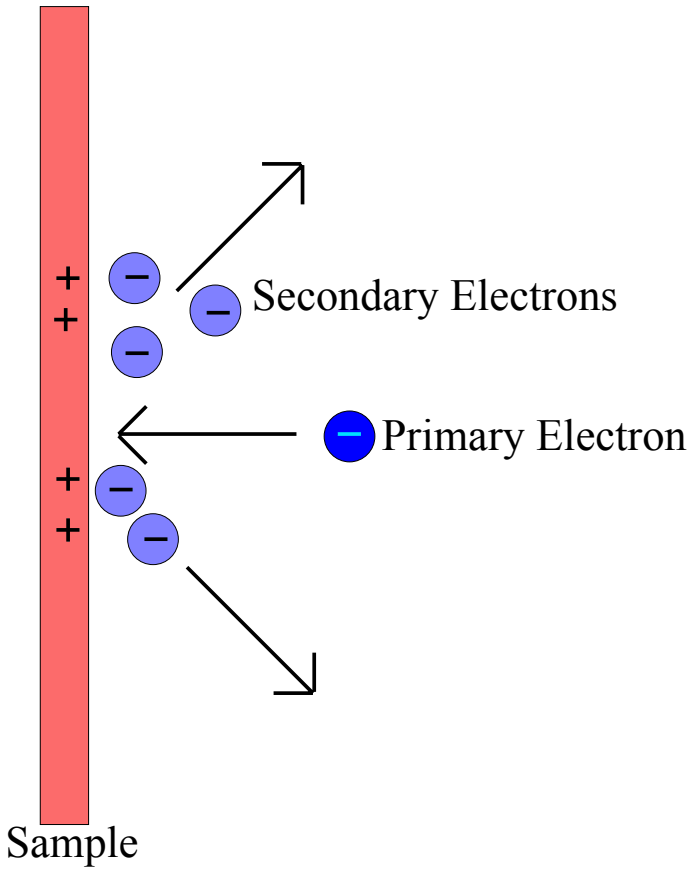


Future Work on Characterization of ALD-Deposited Secondary Electron Emission Materials

- Pulsed electron beam measurements
- Overall comparison of UPS, XPS, and SEY measurements
  - How does surface composition affect band structure (work function) and how does this contribute to the secondary electron yield?
    - XPS (surface composition)
    - UPS (band structure)
    - SEY (secondary electron yield)
- "Scrubbing" of MCPs
  - Mass Spectrometry
    - Temperature-Programmed Desorption (TPD) of surface materials/contaminants
    - Electron and Photon-stimulated desorption of surface materials/contaminants
    - Low energy (< 1keV) ion sputtering
- Emitted electron energy as a function of angle
- Emission as a function of primary electron incident angle
- Mapping Secondary Electron Yield

Pulsed Electron Beam Studies

- Electron Beam Pulsing
  - Limits the sample's electron exposure
    - Decreases charging and electron-stimulated desorption
  - Will allow us to set up a charge compensation procedure if necessary
    - **Negative** Sample Bias – Measurement mode where primary electron energy is retarded by sample bias
    - **Positive** Sample Bias – Charge compensation mode where secondary electron emission is suppressed (samples carry positive charge due to secondary electron emission).

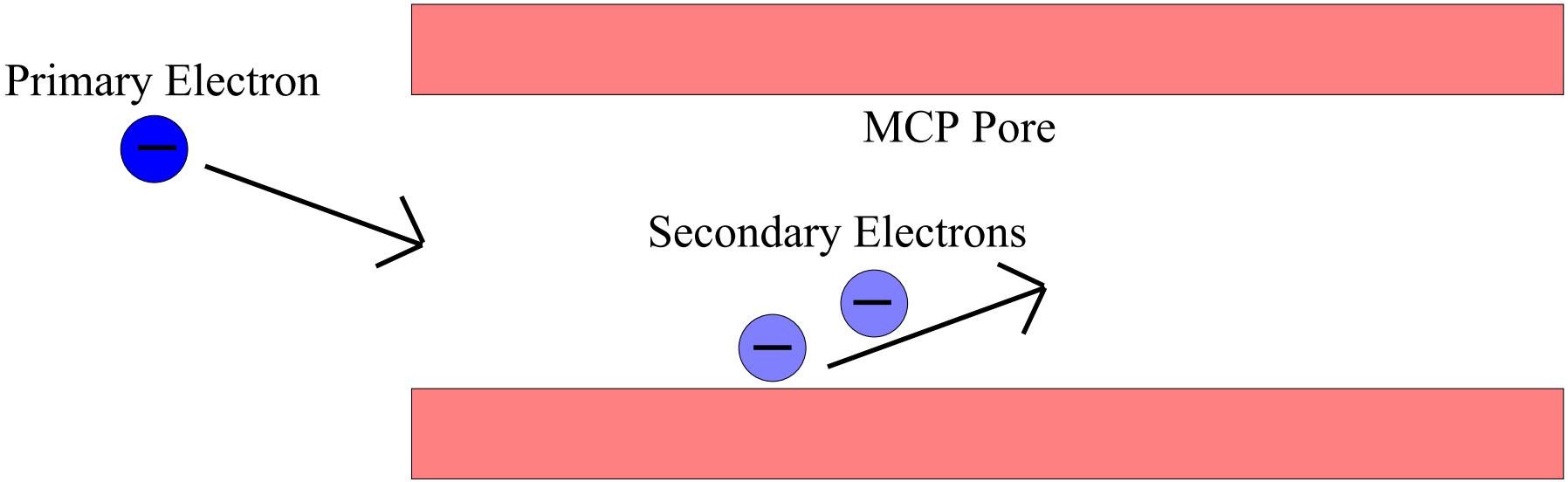


Correlating XPS and UPS with SEY

- X-Ray Photoelectron Spectroscopy
  - It is possible to determine chemical states and bonds from shifts in electron binding energies
- Ultraviolet Photoelectron Spectroscopy
  - Much better at resolving outer electrons with low binding energy
  - Also useful for examining some band structure features
    - Work Function (Valence to Vacuum Transition)
- Secondary Electron Yield
  - Extremely sensitive to surface conditions
  - Even small or low-concentration non-uniformities in the surface can significantly change the band structure or electron scatter cross section

MCP "Scrubbing"

- The scrubbing process involves bombarding an MCP with electrons, allowing a shower of secondary electrons to propagate down the pores.
  - Gain of MCP decreases to a stable value over time
  - We suspect that electron-stimulated desorption of surface material is responsible

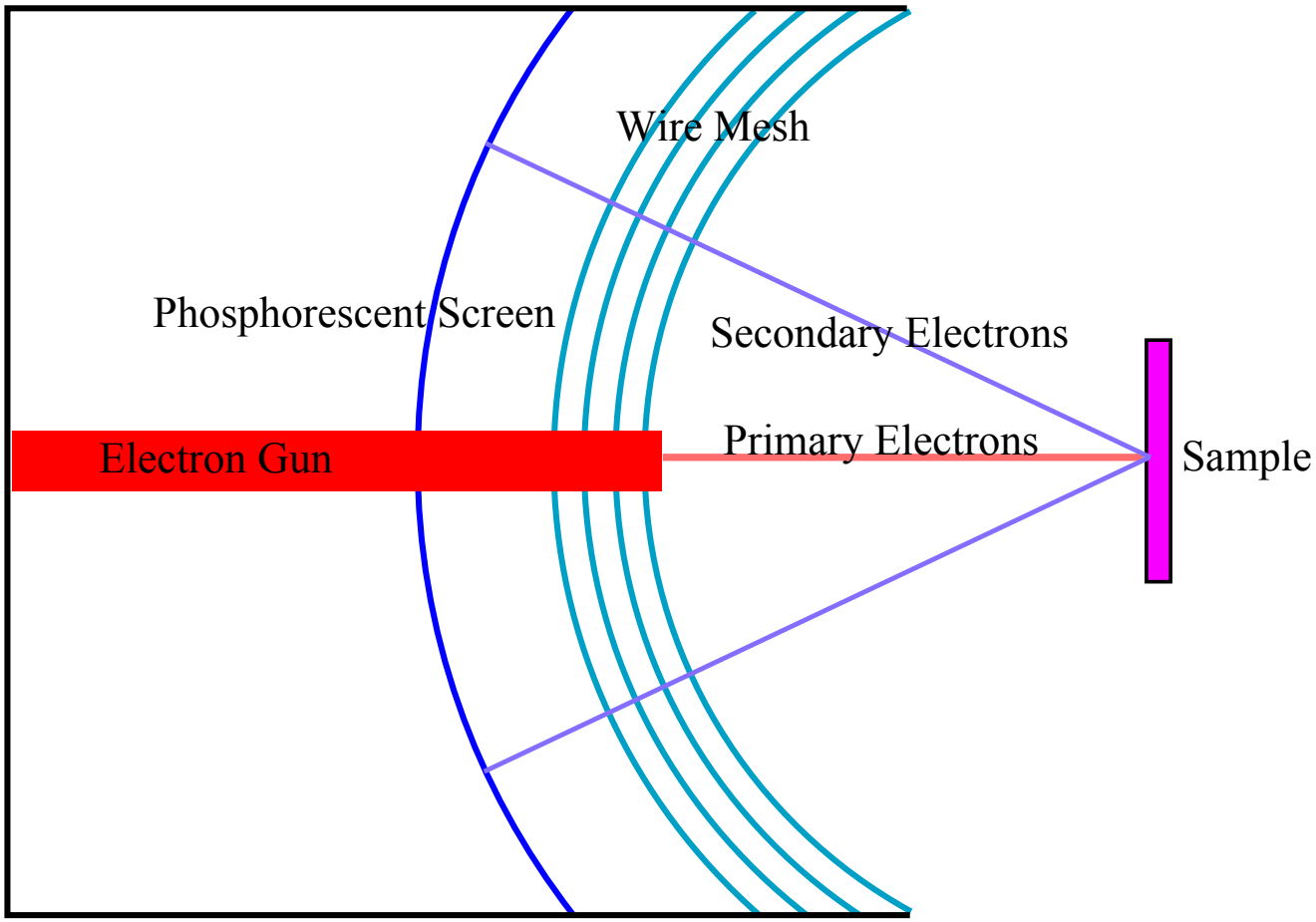


Surface Desorption Studies

- We will test the materials that are used in the MCP pore
- Mass Spectrometry Studies of
  - Temperature-Programmed Desorption (TPD)
    - By observing the temperature dependent desorption rate of all desorbed materials, activation energies can be determined.
  - Electron-Stimulated Desorption and Photon-Stimulated Desorption
    - This will help determine what "scrubbing" does to the inside of the pore
  - Low-Energy Ion Bombardment-Stimulated Desorption/Sputtering
- MS studies will be combined with SEY characterization and XPS/UPS measurements.
  - To understand what species have the strongest effect on emissive properties of materials.

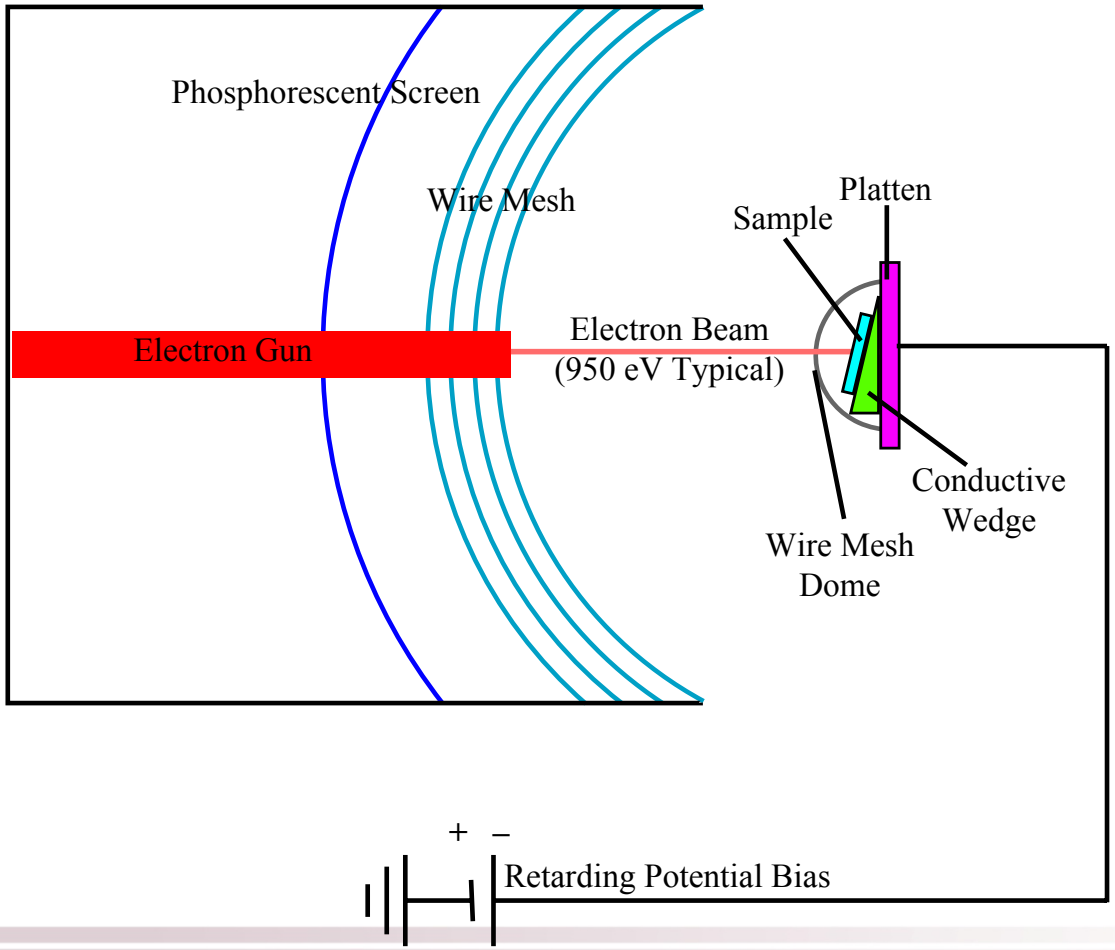
Secondary Electron Energy vs. Emission Angle

- Simulations may benefit from this information



Secondary Electron Yield vs. Primary Electron Incident Angle

- Simulations may also benefit from this information



Mapping of Secondary Electron Yield

- ALD provides a rather uniform conformal coating
  - So far, I have not done a detailed analysis of the entire surface of a sample
  - Automated sample positioning would be required for any meaningful resolution

Summary

- We've been working with Jeff Elam, Qing Peng, and Anil Mane to optimize emissive film properties
- Now that many of the kinks that were slowing us down last year have been worked out of our characterization system, we are now capable of providing better information for all of those involved in the MCP research
- We still have work to do on implementing photocathode research in our characterization system. More on this will be presented tomorrow.