Characterization of Secondary Emission Materials for Micro-Channel Plates

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Secondary Electron Yield

- Testing Technique
  - We have incorporated XPS, UPS, Ar-ion sputtering, and SEY measurements into one high-vacuum system
- Tested Materials
  - Al_2O_3 and MgO for emissive materials
  - Au for calibration of our system
- Electron-Dose Effect
  - Emission changes as a function of electron fluence
  - Exploring different techniques to examine what’s changing
    - Chemistry and composition
    - Morphology
- Discussion and Summary

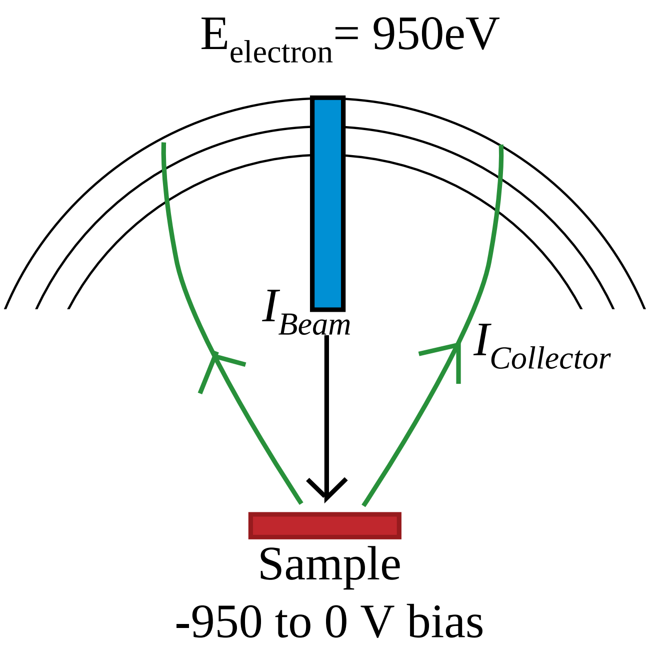
SEY Testing Setup

- Low energy electron diffraction (LEED) setup
  - Electrons are emitted at constant energy (950 eV)
  - Sample is biased using a computer-controlled Keithley Sourcemeter
  - Bias is adjusted to allow for primary electron energy ranges between 0 and 950eV
  - Beam current (I_{Beam}) is determined at beginning of scan and set as a constant

$$Yield = \frac{I_{Collector}}{I_{Beam}}$$

$$I_{Beam} = I_{Collector} + I_{Sample}$$

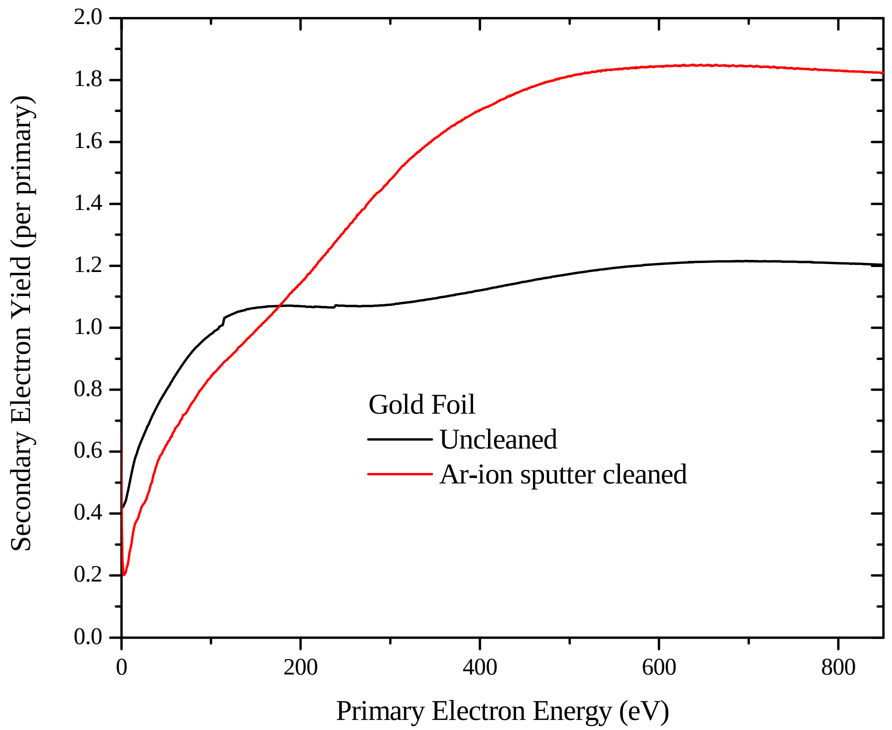
$$Yield(V) = 1 - \frac{I_{Sample}(V)}{I_{Beam}}$$



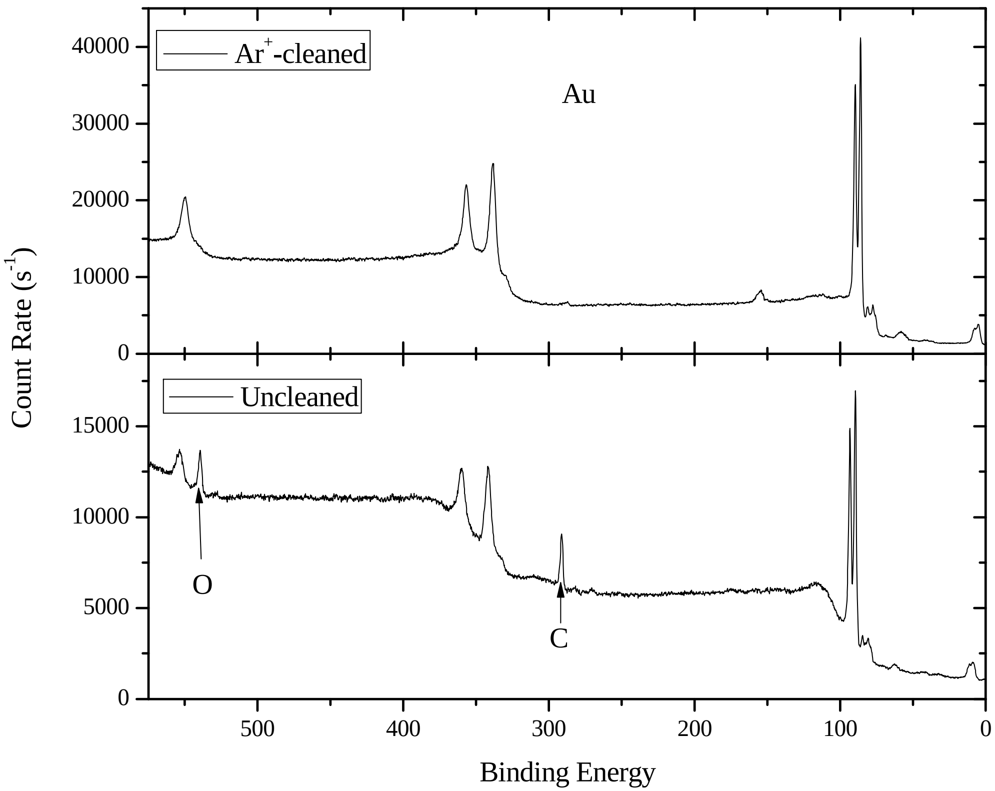
Gold Standard

- Ar⁺-ion sputtering affects both surface composition and morphology
  - C and O, as well as unobserved surface features, may be responsible for the difference in secondary electron yield

SEY of Gold

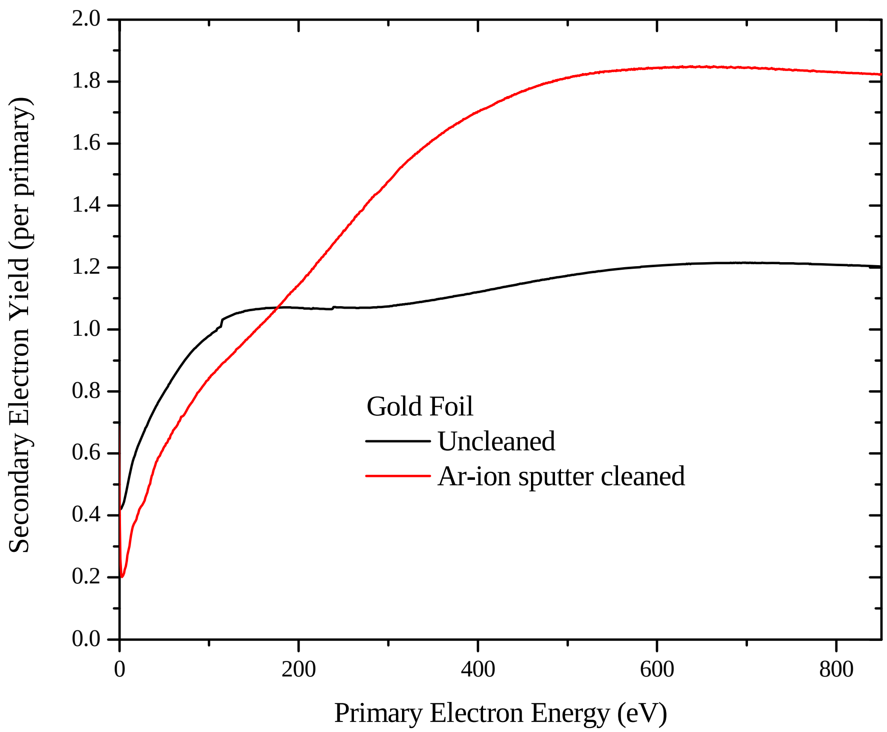


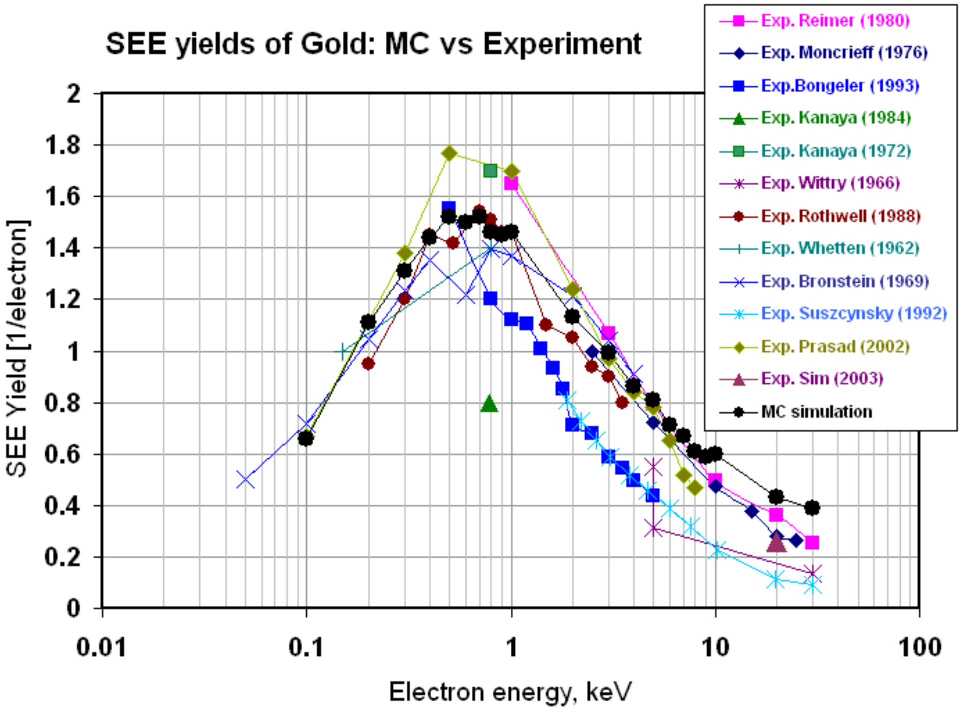
XPS of Gold



Gold Standard

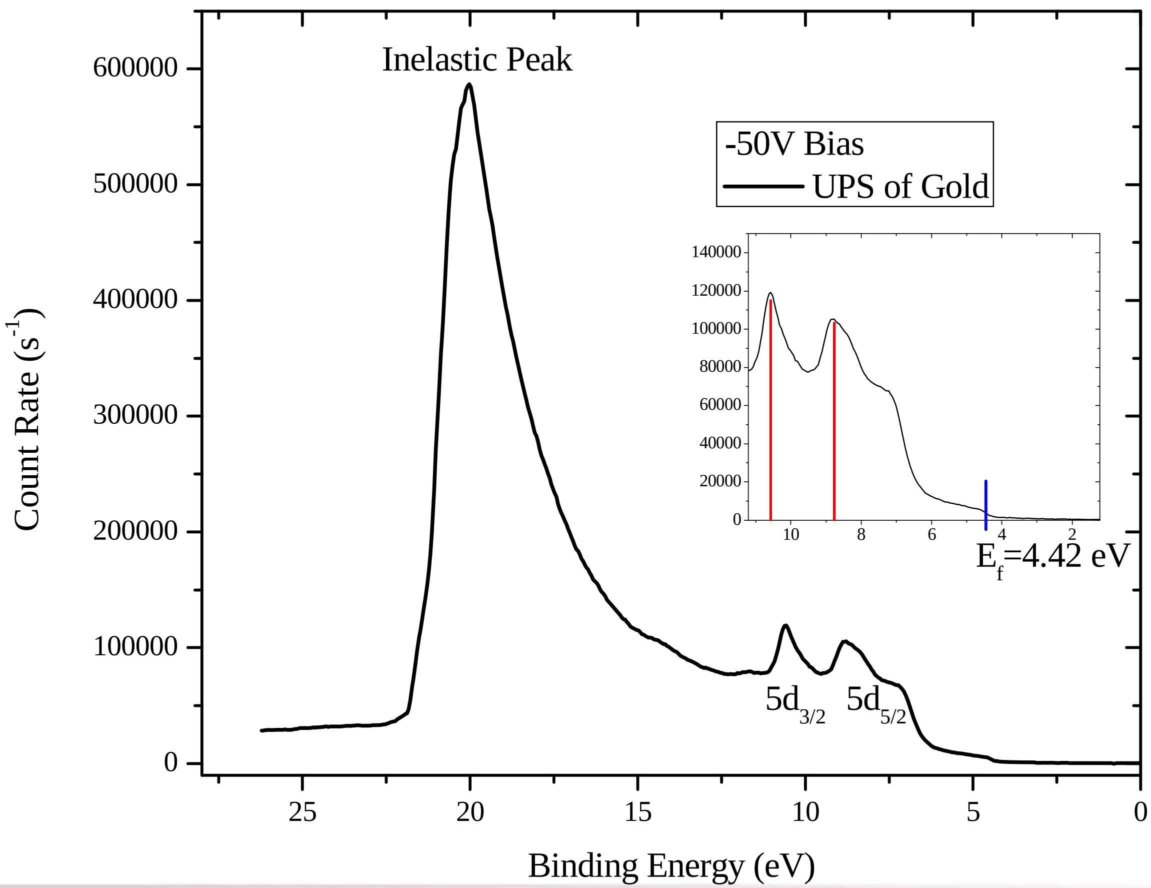
- Results are comparable to literature and calculations





Gold Standard

- UPS spectrum using 21.22 eV helium emission and a -50V sample bias
  - $5d_{5/2}$ located at ~4.3eV binding energy (with respect to E_f)
  - $5d_{3/2}$ located at ~6.1eV binding energy (with respect to E_f)
  - Work function = 4.42eV (does not account for detector 'work function')
  - Previous tests have shown analyzer resolution of about 1eV

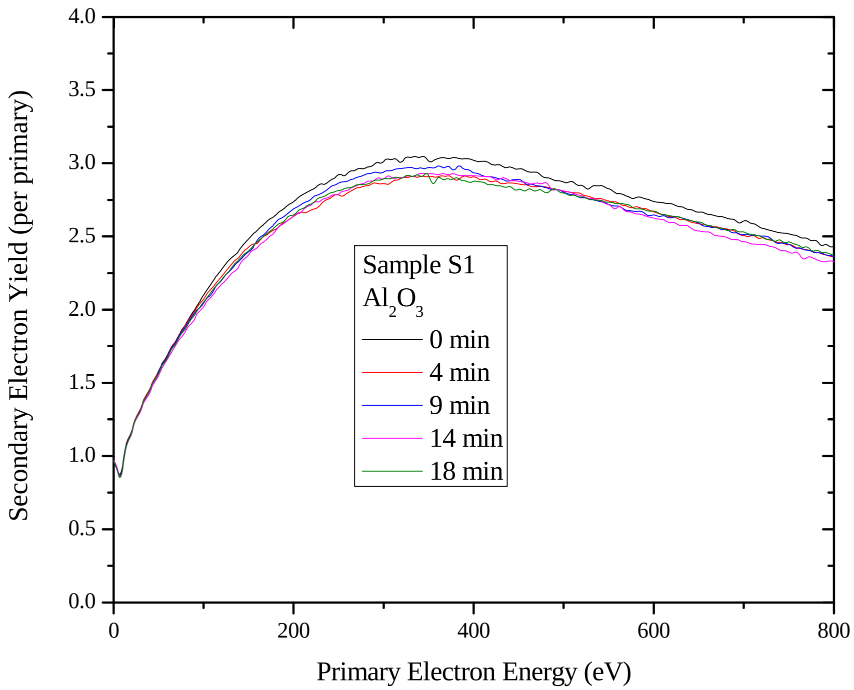


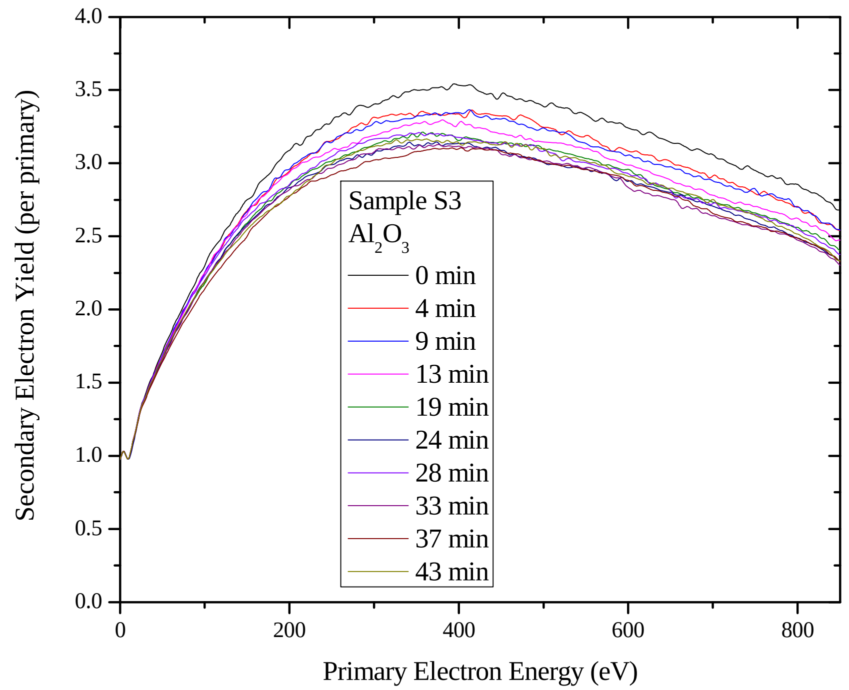
MCP Secondary Electron Emission Materials

- Films are deposited using Atomic Layer Deposition (ALD).
- Deposited on conductive Si substrates.
- Various thicknesses have been and will continue to be studied.
- So far Al_2O_3 and MgO have been tested.

Al_2O_3 Emission vs. Thickness and Electron Fluence

- Al_2O_3 was provided by Jeff Elam's group (Qing, Anil)

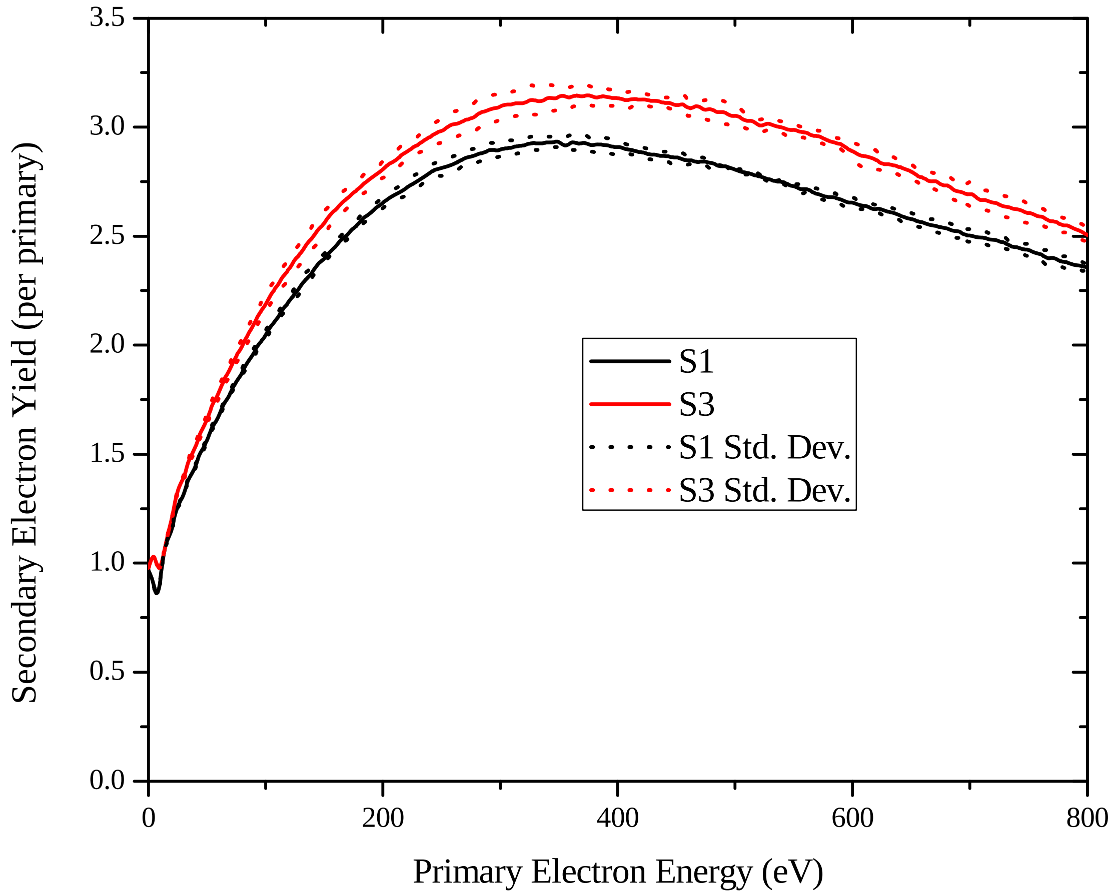




Al_2O_3 Film thickness
S1 – 5.5nm, S3 – 11.3nm

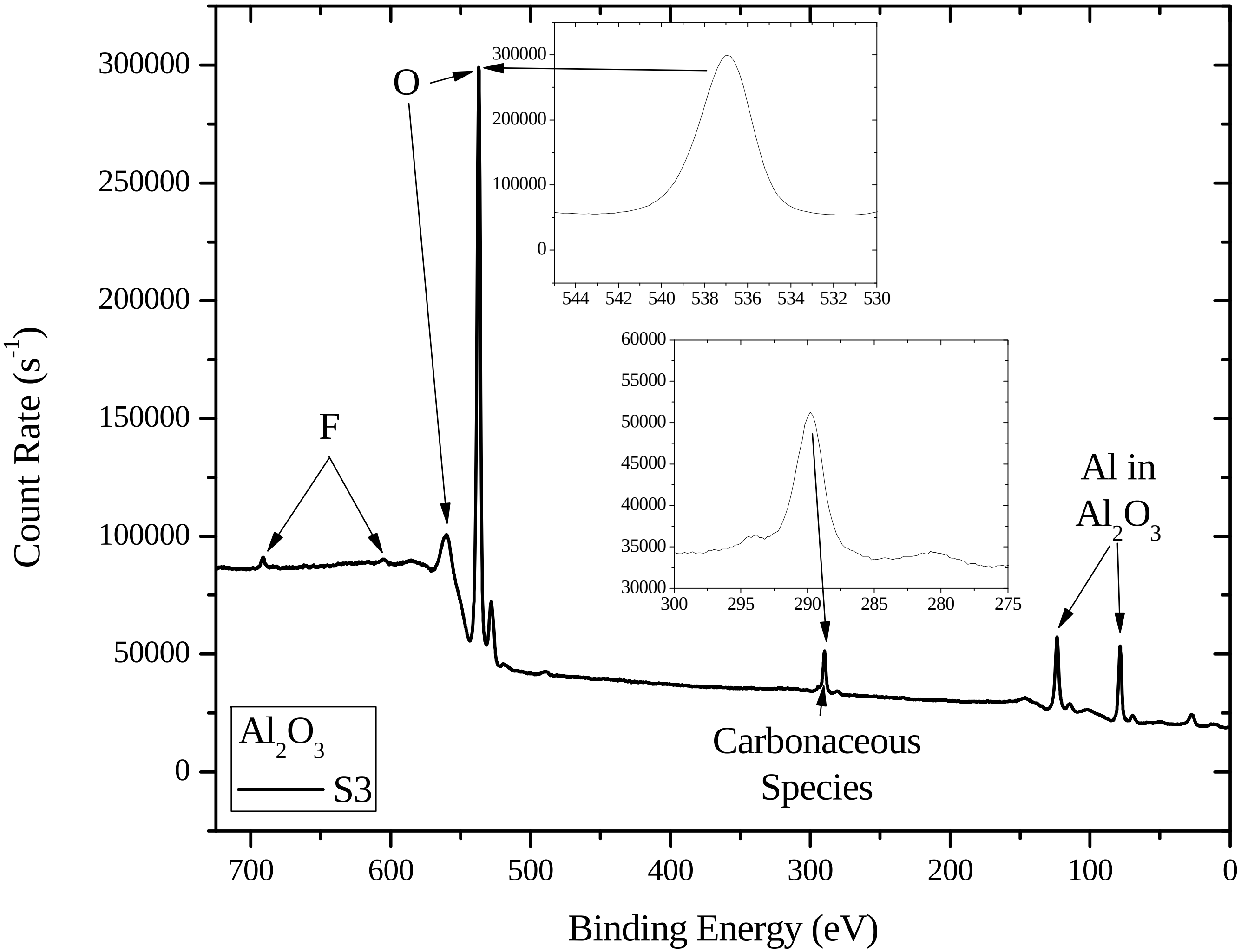
Al_2O_3 Emission vs. Thickness

- Selected Data Averaged
- Si substrate may affect SEY, especially for films less than 10nm
- Long-term monitoring or high-fluence electron exposure will determine the final values of these curves.



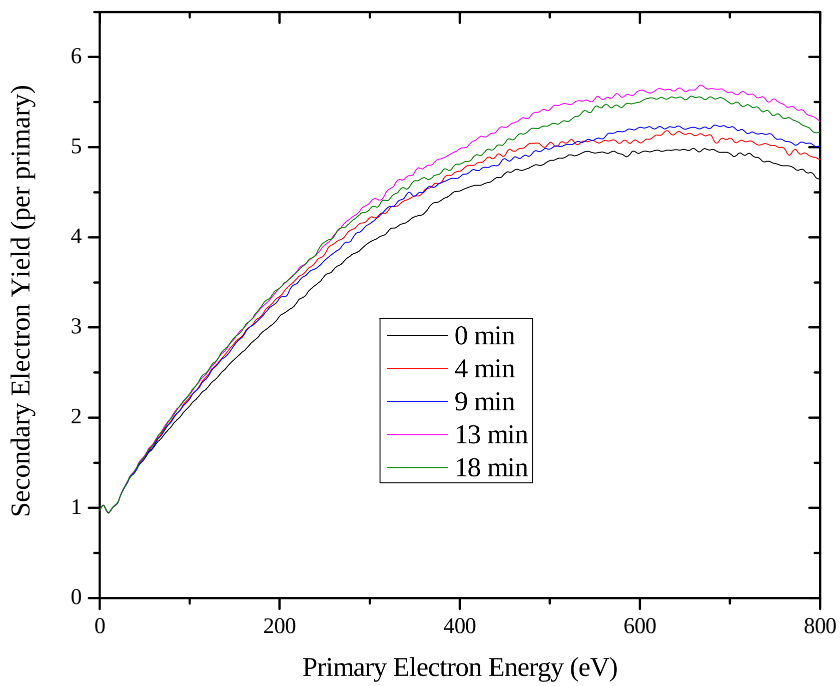
Al_2O_3 Film Thickness
S1 – 5.5nm, S3 – 11.3nm

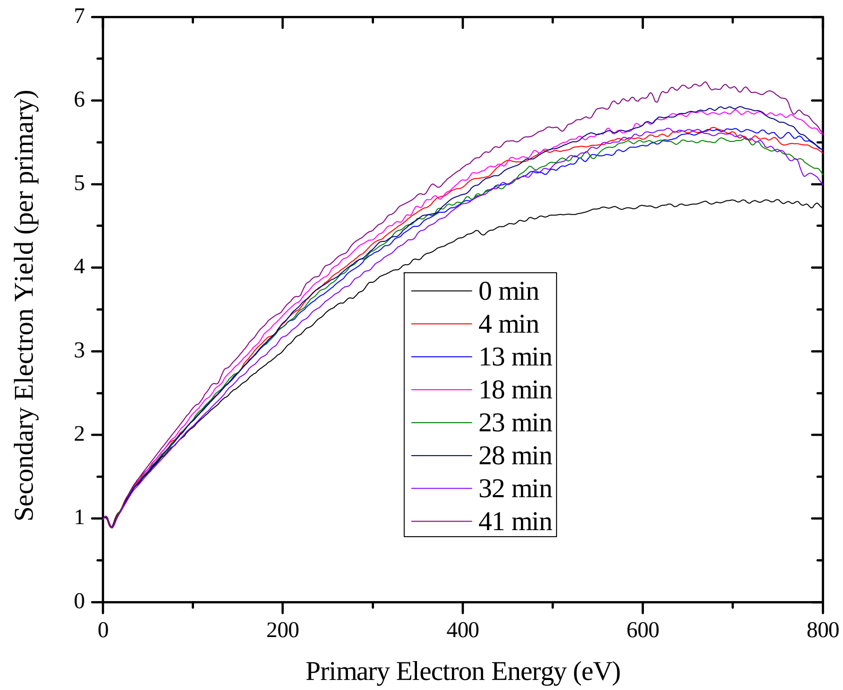
XPS of Al_2O_3



Count Rate (s-1)
Binding Energy (eV)
O
F
Al in Al2O3
Carbonaceous Species
Al2O3
S3
300000
250000
200000
150000
100000
50000
0
700
600
500
400
300
200
100
0
544
542
540
538
536
534
532
530
60000
55000
50000
45000
40000
35000
30000
300
295
290
285
280
275

MgO

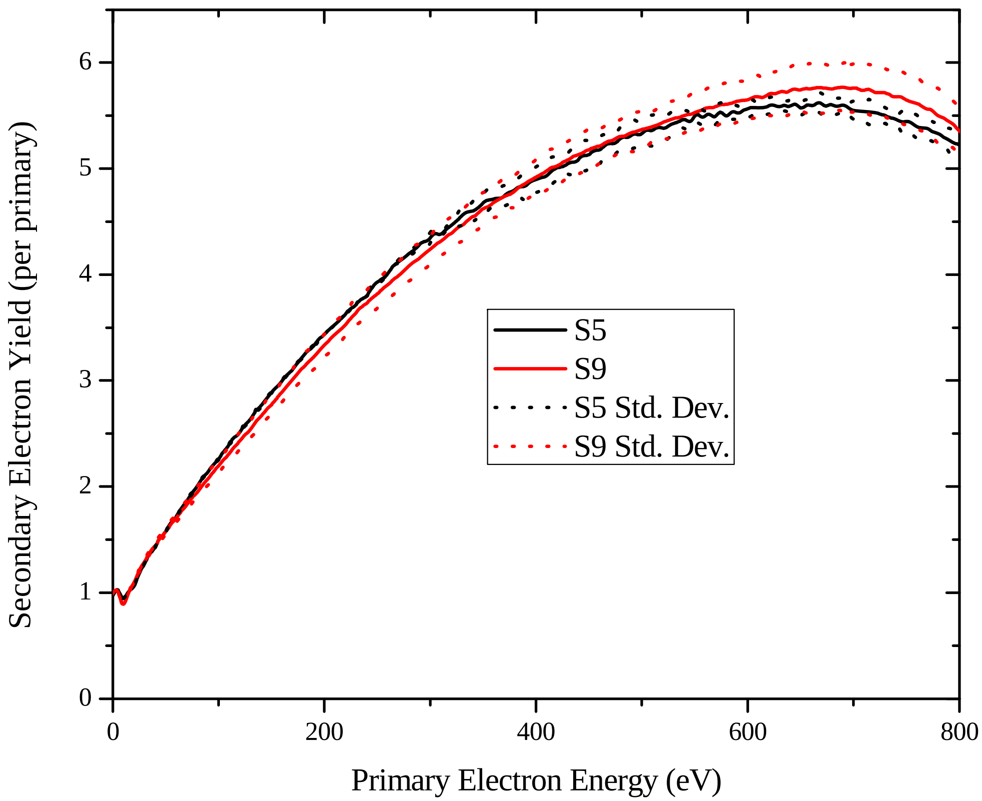




MgO Film Thickness
S5 (left) – 7.2nm, S9 (right) – 14.4nm

MgO

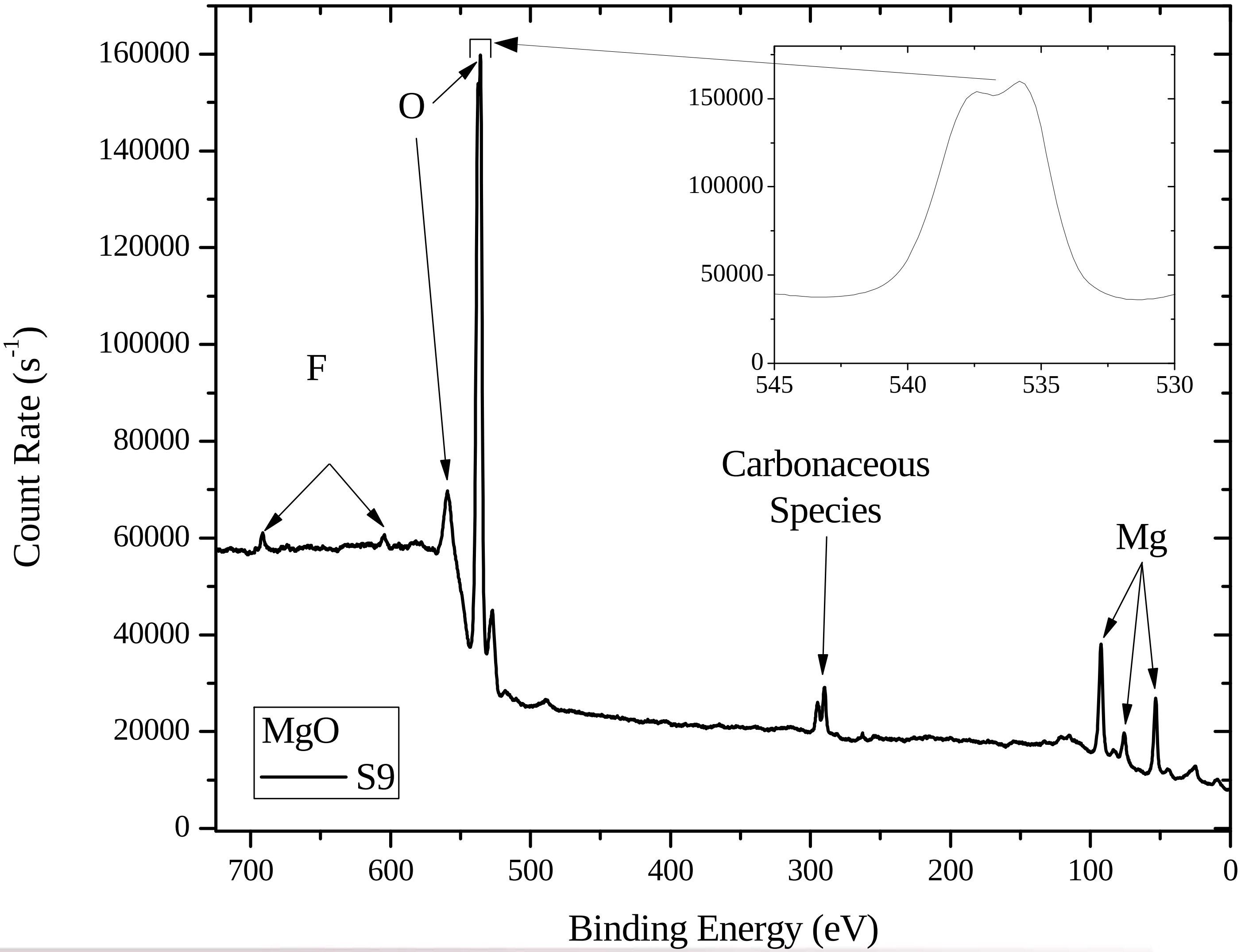
- Not nearly as large of a difference between samples as was seen in the Al_2O_3 samples.
- This experiment should be pursued further to determine if the similarity in emission is real.
- Examining the electron-dose effect may help us here



MgO Film Thickness
S5 – 7.2nm, S9 – 14.4nm

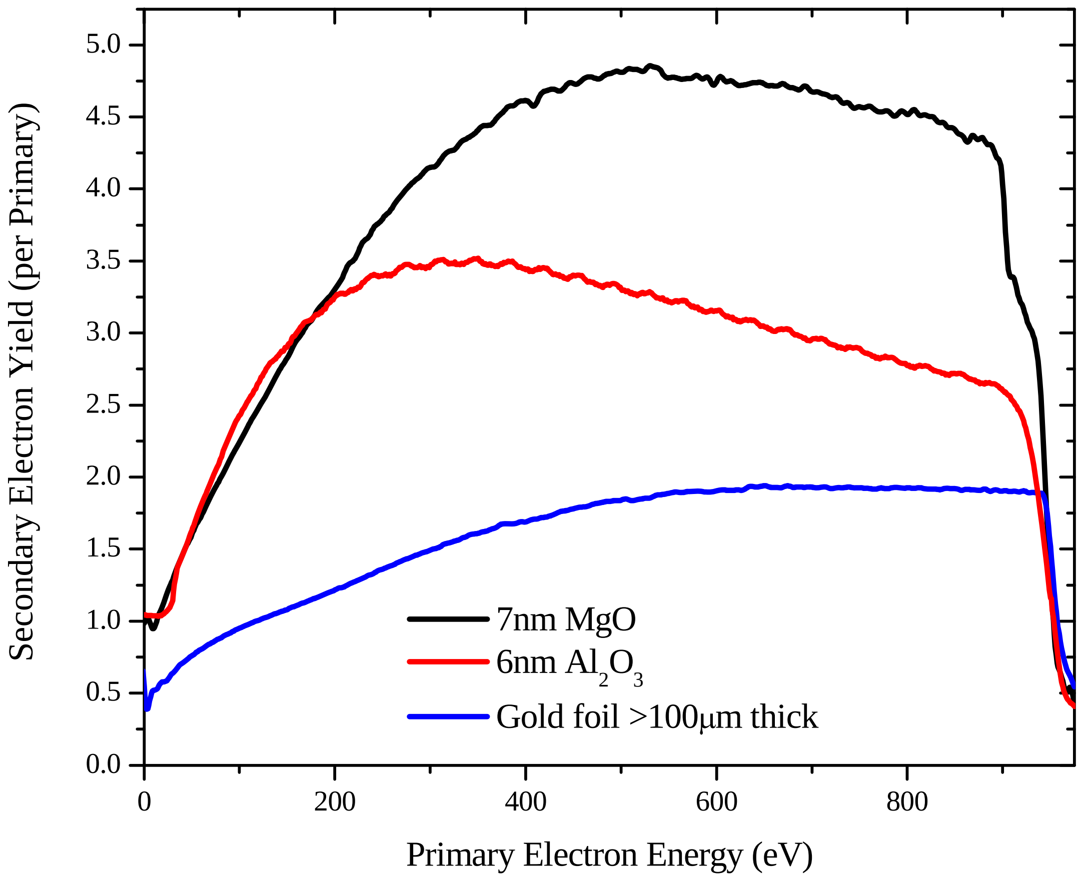
XPS of MgO

- Presence of multiple carbon compounds are evident
  - One is most likely a carboxyl, based on double oxygen peak near 531 eV



Overall Comparison

- MgO is clearly a better emitter, especially for higher primary electron energies.
- With the amount of variation seen in prior samples, MgO is comparable to Al_2O_3 for lower primary electron energies.
- Sample charging appears to occur for MgO and Al_2O_3
  - Increasing temperature will increase sample conductivity

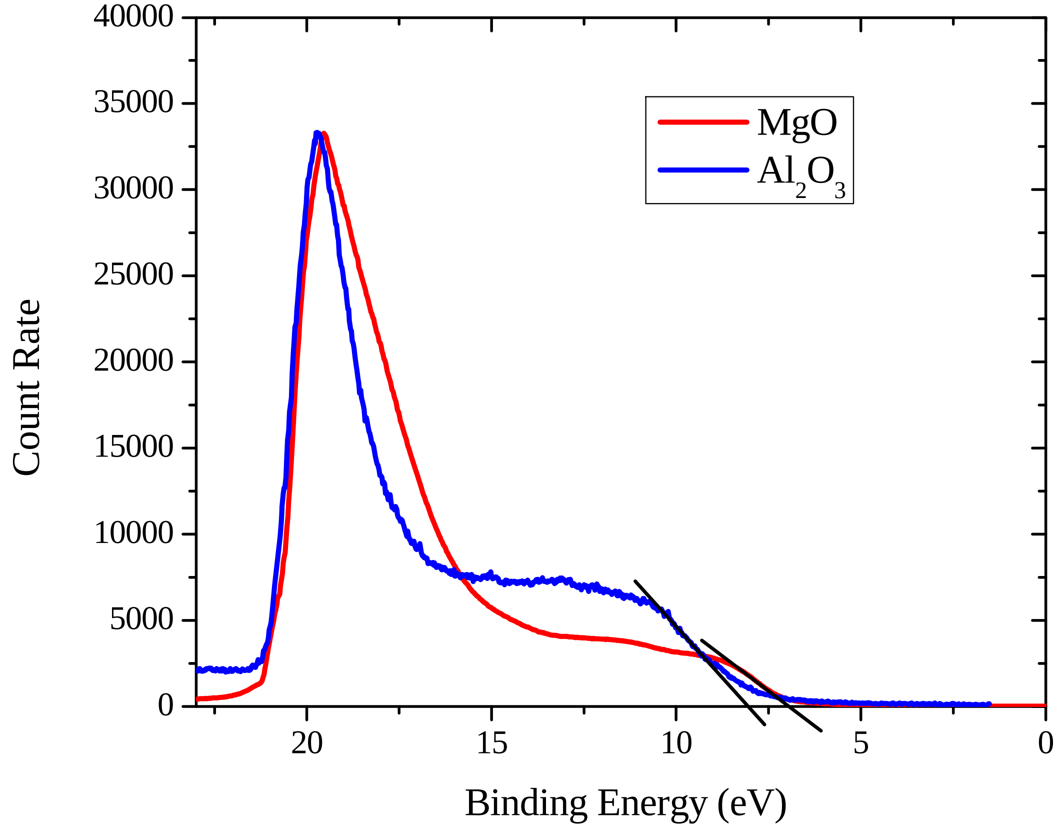


Electron-Dose Effect

- Al_2O_3
  - Emission decreases with increased fluence
- MgO
  - Emission increases with increased fluence
- We will explore why this is the case initially using XPS and SEM
  - Focused electron beam from LEED system does not cover a large enough area for our XPS system to detect any chemical or compositional changes.
  - Defocused electron beam from separate gun has been used.
    - However, an unexpected increase in fluorine is observed in XPS spectra for electron exposure.
- Mass spectrometry should be used to detect material liberated from the sample

Ultraviolet Photoelectron Spectroscopy of Al_2O_3 and MgO

- Valence band edge
  - MgO – 6.97eV
  - Al_2O_3 – 8.04eV



Future Work and Additional Techniques/Equipment

- Preparing for large-area, electron bombardment
  - Monitor and study does effect
- Will monitor SEY as a function of sample temperature
- Writing control software (LabView) to integrate all systems into one control system
  - Ideally, we would like to have complete control over the lens system for the hemispherical analyzer
  - Optimize energy resolution of XPS and UPS
- Designing/preparing new sample holder that is compatible with transmission photocathodes, sample heating, and can hold at least one sample for long term storage (faraday cup)
- Exploring options for Secondary Ion Mass Spectrometer (SIMS)
  - Examining of doping profiles in photocathodes
  - Programmable thermal desorption
  - Electron stimulated desorption