Composition and thickness dependence of secondary electron yield for MCP detector materials

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Motivation

- Large Area Picosecond Photo-Detector Project (LAPPD)
  - http://psec.uchicago.edu
- "Frugal" Micro-Channel Plate (MCP) detectors
  - Modern technologies allow for the construction of MCPs from more cost-effective components and synthesis techniques
    - Porous, non-leaded glass (not effective as MCP on its own)
    - Atomic Layer Deposition (ALD) to functionalize the glass with secondary emissive material (MgO and Al_2O_3)
      - ALD allows for conformal coatings to be placed on any exposed surface (not a line of sight technique)

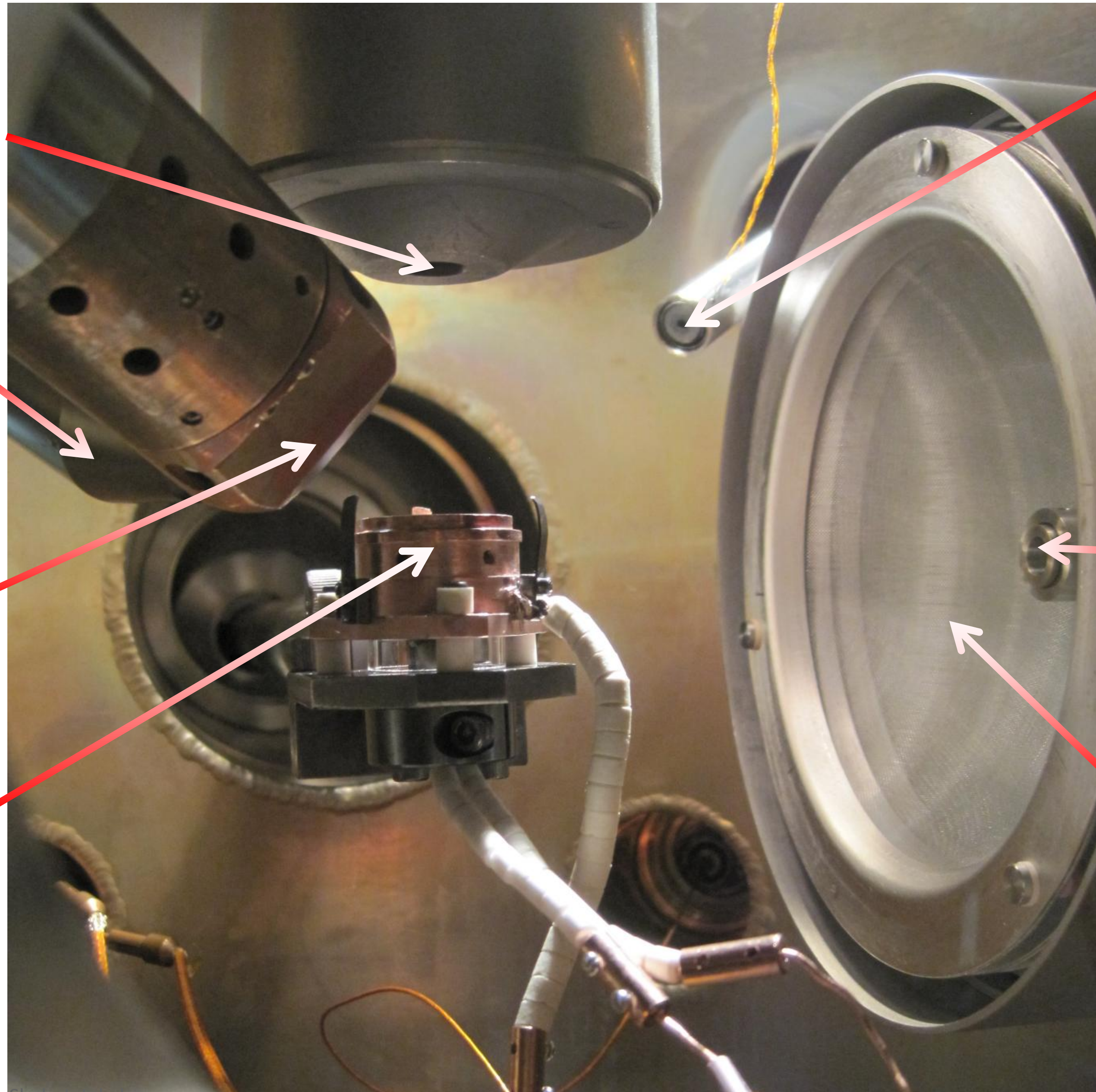
Purpose

- Characterize ALD-synthesized MgO and Al_2O_3
  - Determine how secondary electron emission (SEE) is influenced by:
    - Surface chemical composition
      - Direct effects of elements/compounds on secondary emission
      - Effects that dopants/defects have on secondary emission
    - Surface structure/morphology
      - Effects from electron or ion bombardment

Instrumentation

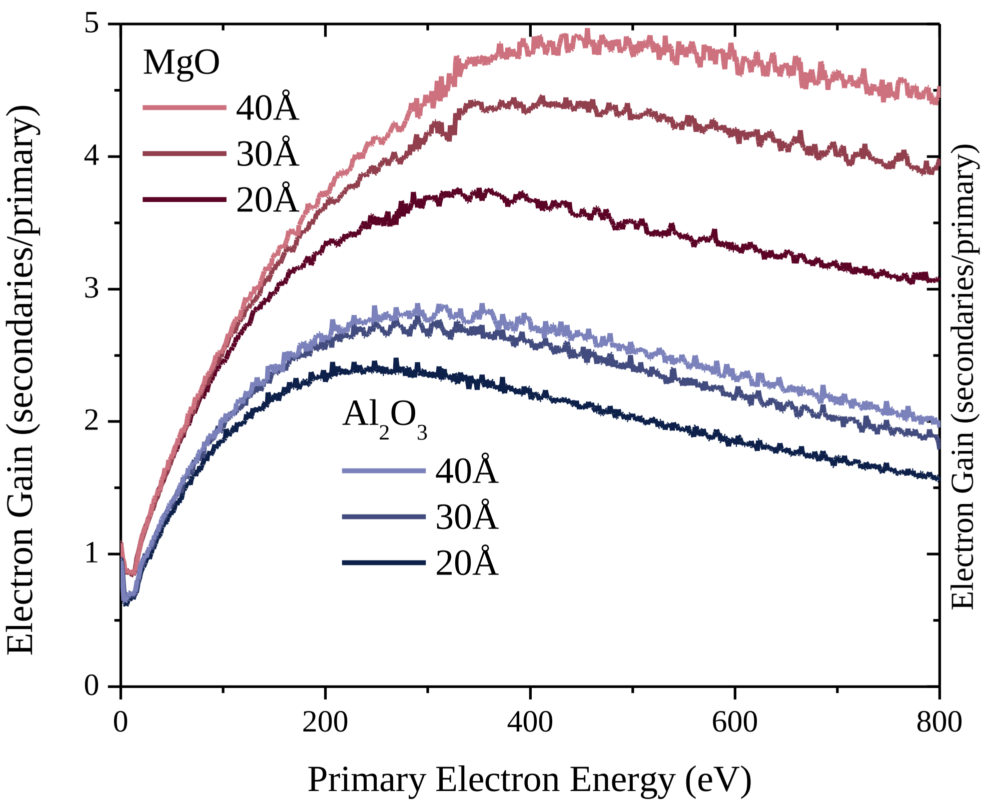
- Repurposed surface analysis equipment
  - Low Energy Electron Diffraction module (LEED)
    - Surface structure/morphology
    - Auger Electron Spectroscopy (AES)
    - Modified for Secondary Electron Emission (SEE) studies
      - Pulsed electron source and secondary electron collection
  - X-ray Photoelectron Spectroscopy (XPS)
    - Mg Kα
  - Ultraviolet Photoelectron Spectroscopy (UPS)
    - He I & He II UV emission
  - Hemispherical Energy Analyzer
    - Acquisition of XPS and UPS electron energy spectra
  - Ar^+ source (up to 5 keV)
    - Surface cleaning and depth profiling

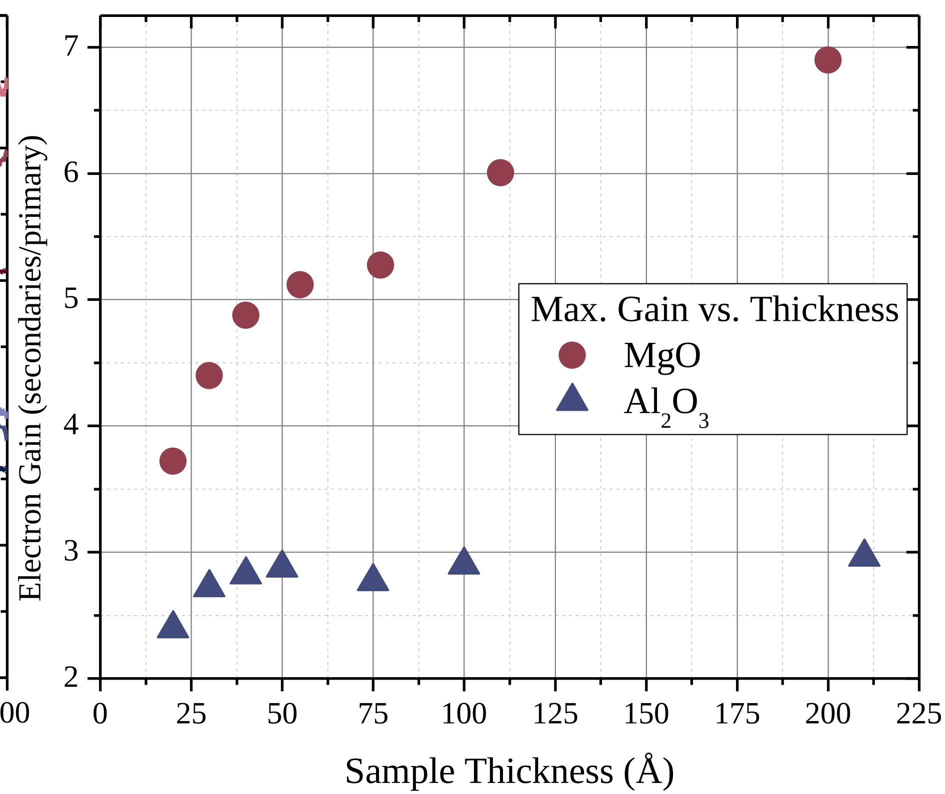
Instrumentation



Study of Secondary Electron Yield vs. Material and Thickness

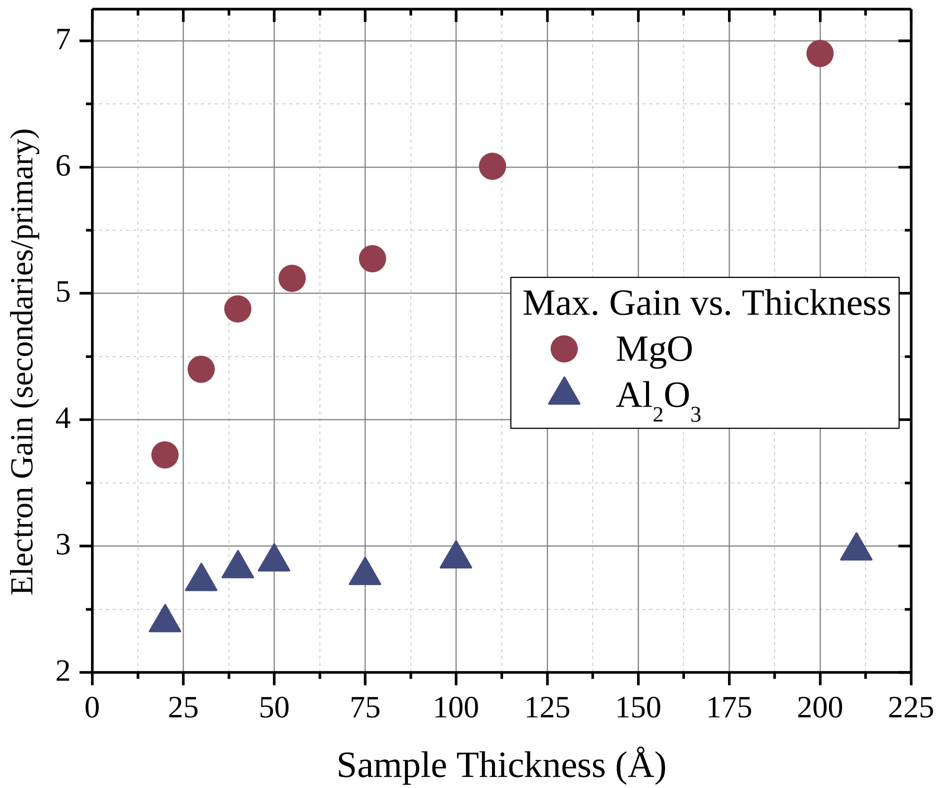
- ALD-synthesized MgO vs. Al_2O_3
  - Maximum gain and its corresponding energy generally increase with thickness





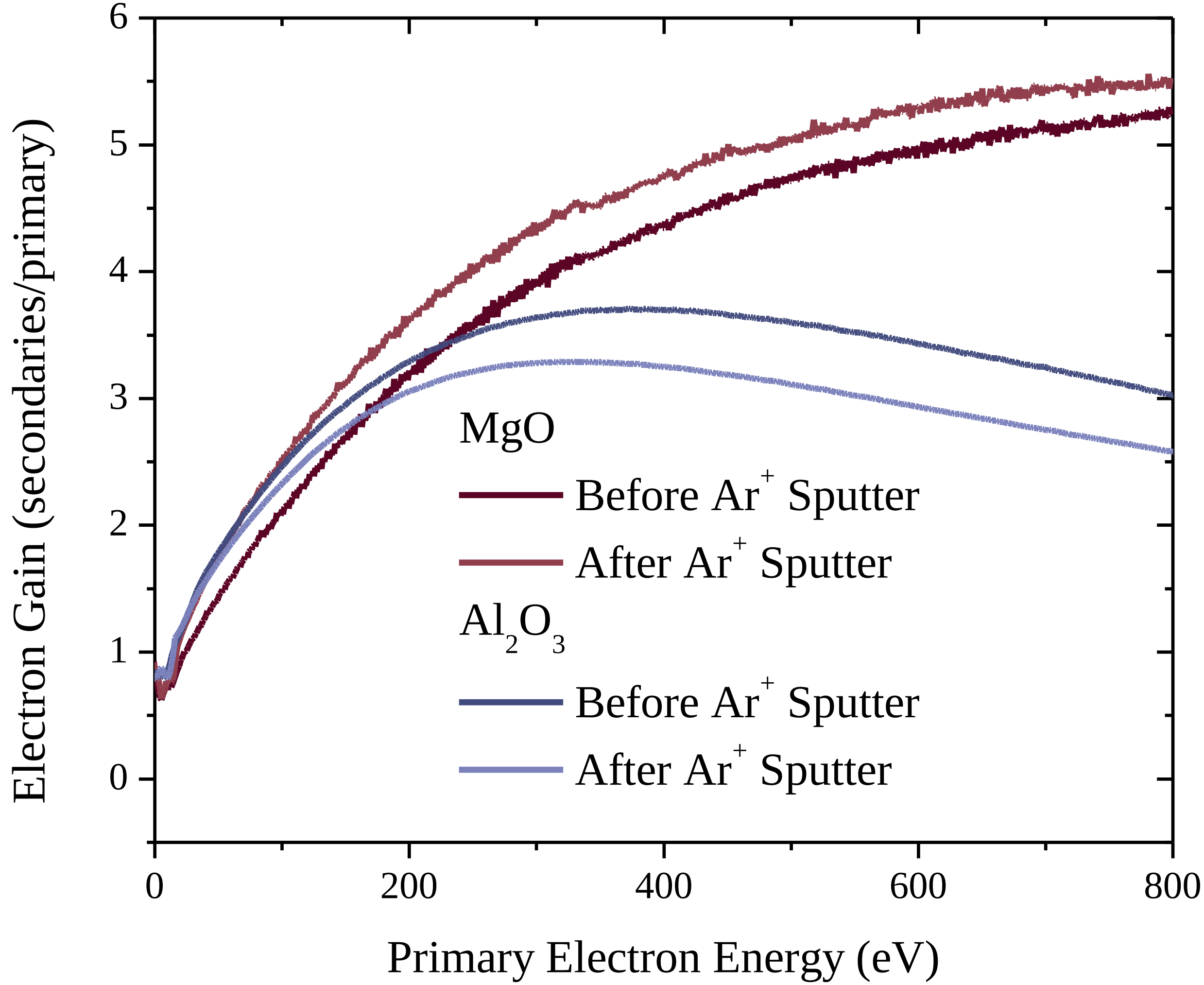
Study of Secondary Electron Yield vs. Material and Thickness

- Maximum in emission vs. thickness
  - Maximum escape length for a secondary electron
- Simulation Effort
  - Parameters from my measurements are used in MCP testing and simulation
    - Matthew Wetstein (ANL)
    - Zeke Insepov (ANL)
    - Valentin Ivenov (FNAL)



Secondary Electron Yield vs. Surface Composition

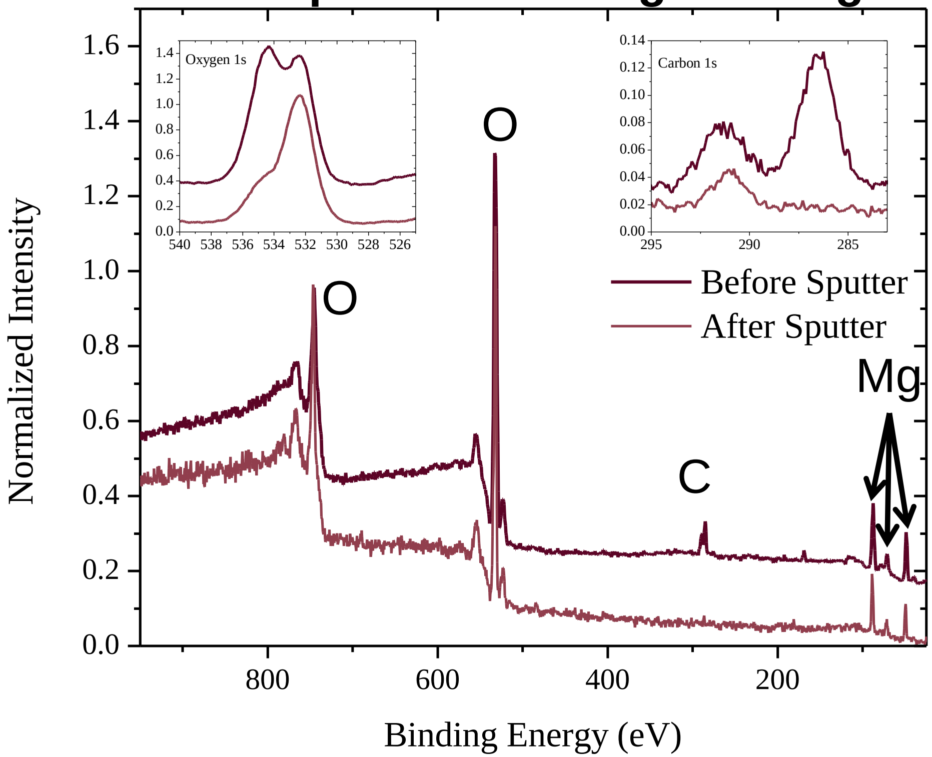
- 5 keV Ar^+ was used to sputter-clean the sample



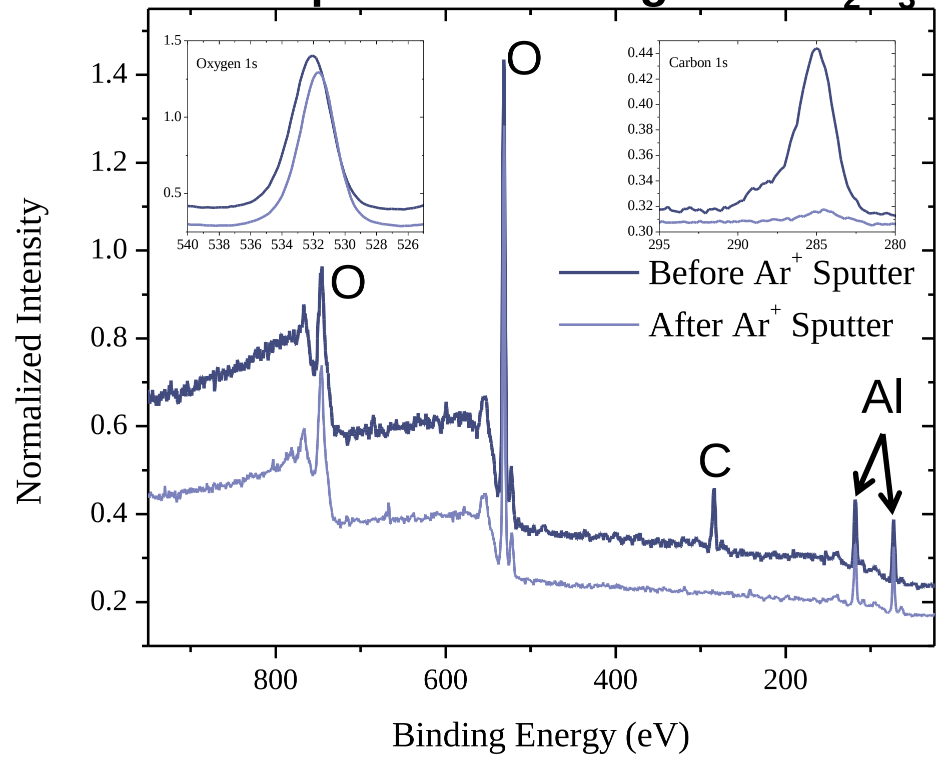
Secondary Electron Yield vs. Surface Composition

- XPS spectra show a decrease in surface carbon
  - Double oxygen and carbon peaks in MgO imply a C-O-type compound

XPS Spectra of ALD-grown MgO



XPS Spectra of ALD-grown Al_2O_3

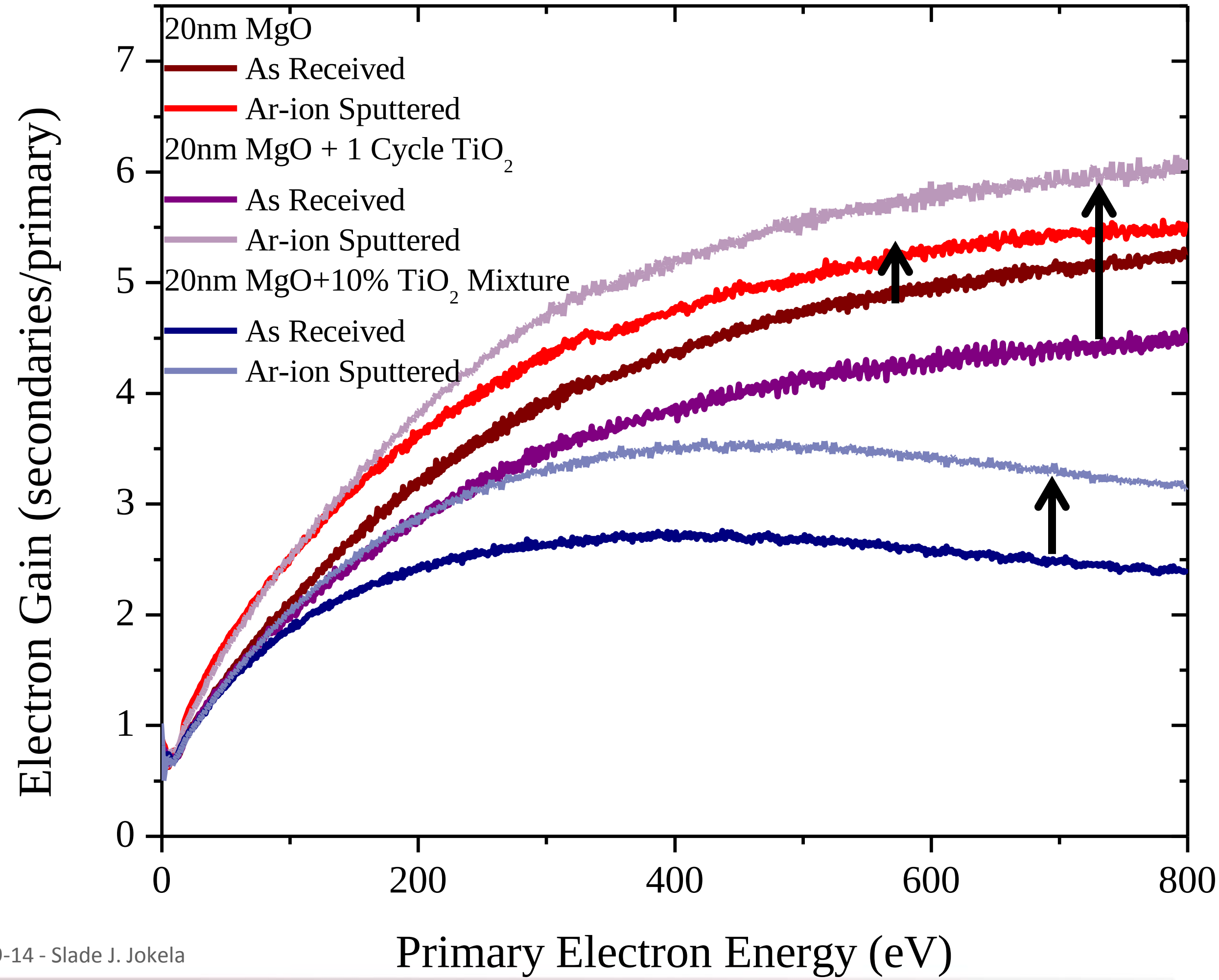


Secondary Electron Yield vs. Surface Composition

- Carbon contamination seems to affect SEY
  - Sources of carbon include atmospheric and remnants of ALD precursors.
  - Emission **increases** when it is removed from MgO
  - Emission **decreases** when it is removed from Al_2O_3
  - The difference can be explained by:
    - Carbon species is less emissive than MgO but more emissive than Al_2O_3
    - The difference in bonding on MgO, as is evident in XPS spectra, results in an increase in work function
    - Surface structure and composition is drastically altered by ion bombardment
      - Preferential ion-sputtering
      - Ion Mixing
      - Recrystallization?

Study of SEY for New Materials

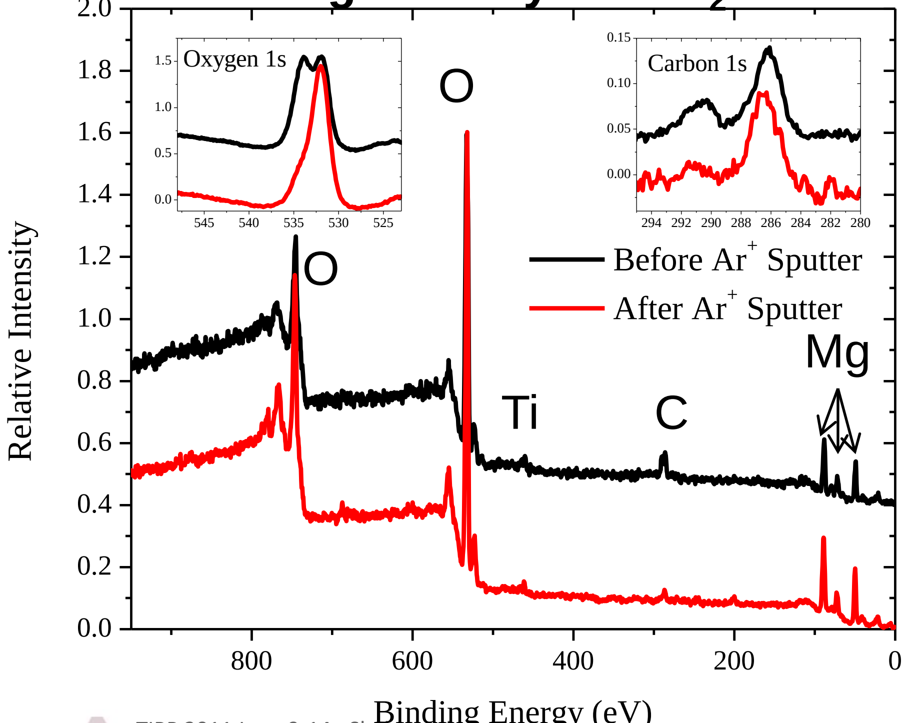
- Increased emission could be beneficial for MCPs
  - Other materials and structures should be considered



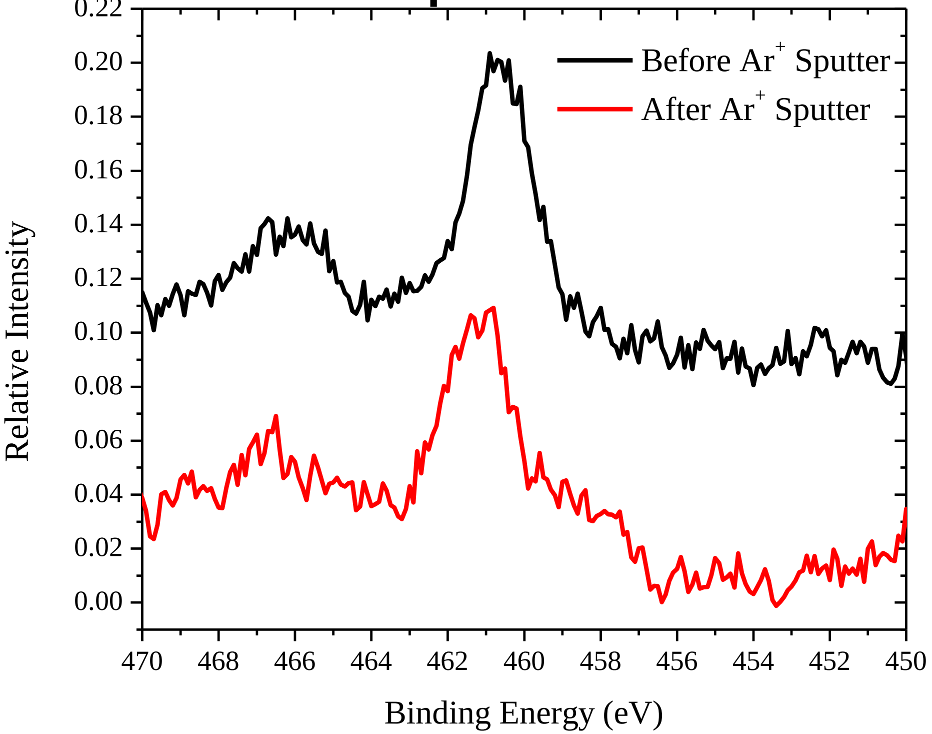
Study of SEY for New Materials

- TiO_2 is reported to have an emission yield of about 1.2
- Ar^+ sputtering will not just remove material, but mix it
  - This Ti could behave as a dopant after mixing, decreasing work function

XPS Spectra of ALD-Synthesized MgO + 1 Cycle TiO_2



Ti 2p XPS Peak



Summary

- MgO clearly has higher emission than Al_2O_3
- Ar^+ sputtering produces different results in the two materials
  - A difference in carbon species on the surface may be responsible
  - Ion bombardment certainly changes surface morphology
- An initial study on MgO and TiO_2 layered materials proved interesting
  - As-synthesized samples showed lower emission than MgO alone
  - After Ar^+ sputtering, all samples showed an increased emission
    - MgO with 1 ALD-cycle of TiO_2 showed the highest emission of all (post-ion-sputter)
    - Ar^+ sputtering induces mixing in the surface components
      - Structural changes or doping could result

Future Work

- Inspection of surface composition and structure vs. electron exposure
  - Ageing in MCPs
- Ion-induced surface reconstruction
  - Ion mixing or surface recrystaliztion (MgO + TiO_2 study)
- Instrumentation for this study (all-in-one)
  - STM
  - SEM
  - Scanning AES (Auger electron spectroscopy)
  - Heated stage for thermal desorption studies
  - Gas exposure to determine effects of atmospheric gasses on “cleaned” surfaces

Thank you

ALD-Synthesis performed by:

Jeff Elam, Anil Mane, Qing Peng (Argonne National Laboratory)

Instrumentation and scientific expertise/support:

Igor Veryovkin and Alexander Zinovev (Argonne National Laboratory)

LAPPD Collaboration

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