EUV LITHO, INC.
EUV Litho Workshop
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Investigating electron-driven EUV chemistry

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CXRO THE CENTER FOR X-RAY OPTICS
BERKELEY LAB Lawrence Berkeley National Laboratory

Motivation

- Fundamental understandings of EUV electron driven chemistry is needed for targeted material engineering
- Tools for interrogating the energy spectrum of electrons of EUV materials are needed
- Tools for predicting the electron energy spectrum is needed to speed up material development

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Objectives

- Enables direct measurement of photoelectron energy spectrum of underlayers with condensed phase photoemission experiment
- Develop the capability to extract internal electron energy spectrum from photoemission spectrum
- Predict primary electron spectrum prediction
- Understand EUV induced chemical alterations during photoemission experiment

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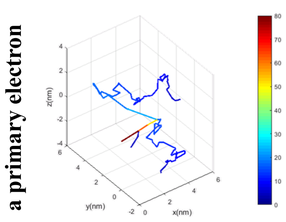
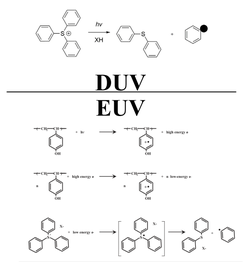
The Problem

Simulated trajectory of a primary electron



PAG activation



- EUV radiochemistry is electron driven
- Electron processes are yet to be understood
- Electrons' propensity to interact results in a broad spectrum of electrons in materials
- Difficult for scientific investigation or material engineering

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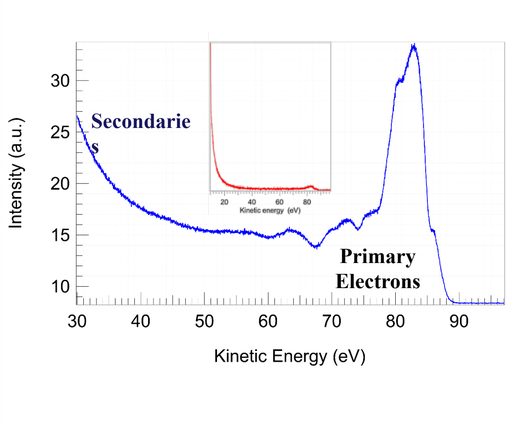
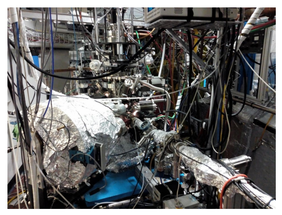
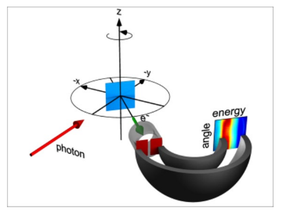
Condensed phase photoemission







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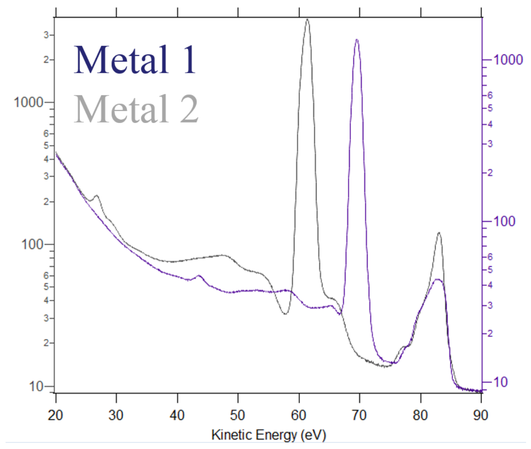
Photoemission—underlayers



Ability to engineer primary electron spectrum is demonstrated

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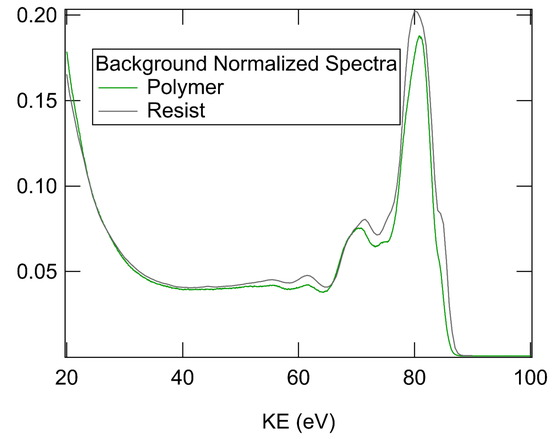
Photoemission—resists



Photoelectrons are mostly from polymers

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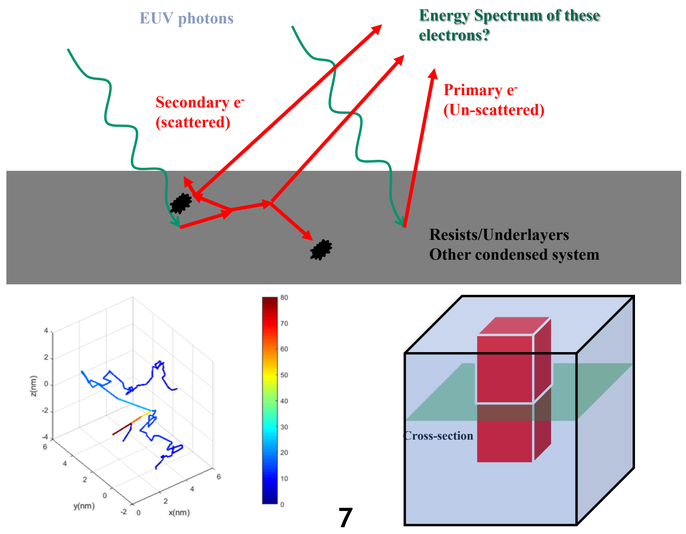
Internal spectrum vs photoemission



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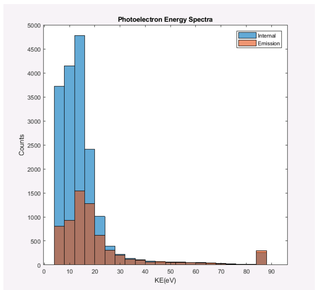
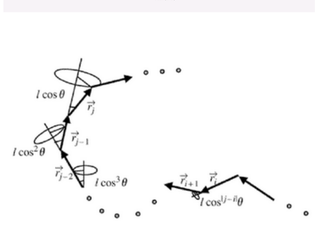
Forward-dominant scattering

- The internal and photoemission spectra don't match
- Previous solution: division by scattering mean free path
  Henke, B. L., Smith, J. A., and Attwood, D. T., *Journal of Applied Physics* 48(5), 1852-1866 (1977).
- The outcoming direction of scattering events can be correlated with the incoming one
- That results in a longer directional memory
- Effectively a longer mean free path





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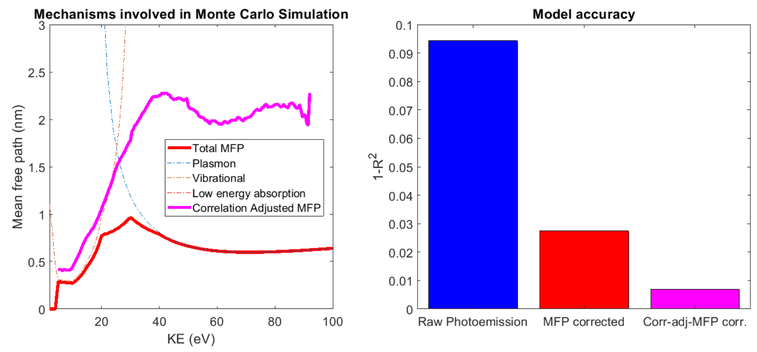
Dividing photoemission spectrum with correlation adjusted mean free path



We're able to recover the internal electron energy spectrum from photoemission data

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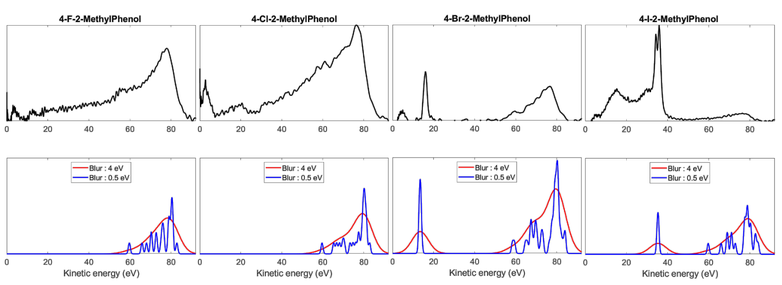
Modelling photoemission spectra

Photoemission spectra of prototypical monomers for EUV resists were measured

Kostko, Oleg, et al.
The Journal of chemical physics
149.15 (2018): 154305.



Using Hybrid-DFT calculations, the peak positions are well predicted

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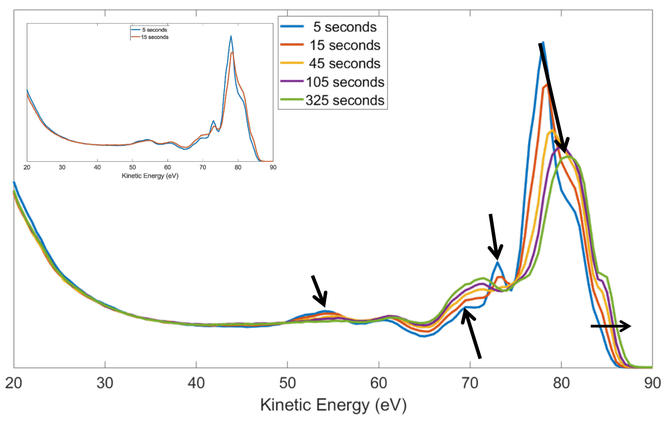
Avoiding cross-linking



Things happen in tens of seconds

A 10 second scan preserves the sample reasonably well

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Future Goals

- **Further understanding of EUV radiation chemistry through EUV-induced photo-electron spectroscopy**
  - Additional spectroscopic techniques will be explored
- **Explore chemical yield/cross-sections as a function of electron energy in EUV resists**
  - A two pronged computation/spectroscopy approach will be employed in collaboration with staff at CSD, MSD and Molecular Foundry

Acknowledgment
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