Investigating radiochemistry with EUV photoemission spectroscopy

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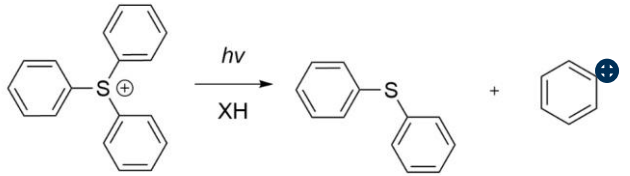
Summary

- Condensed phase photoemission enables direct measurement of photoelectron energy spectrum of underlayers
- Capability to extract internal electron energy spectrum from photoemission spectrum is demonstrated
- Primary electron spectrum prediction is enabled by first principles calculations

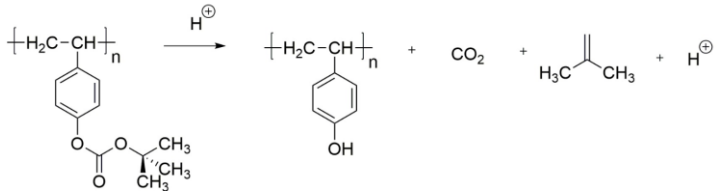
Chemically Amplified Resist in DUV

DUV Absorption by PAG



Acid

Acid Amplification + Deprotection



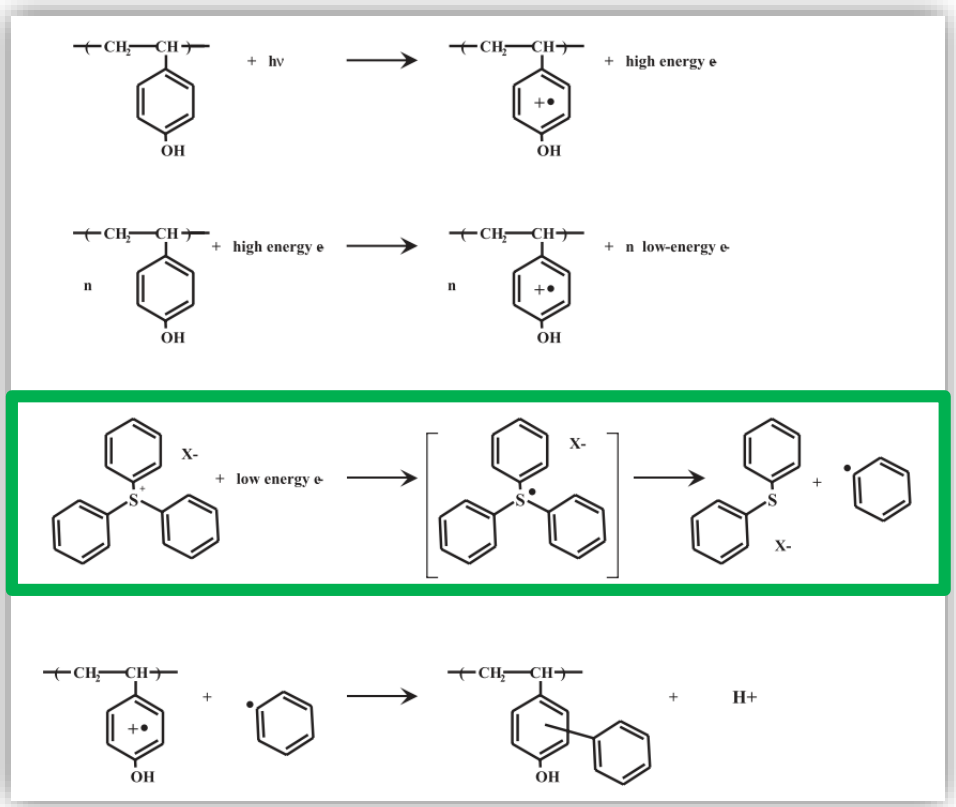
How about EUV?

EUV Absorption by Polymer

DUV Absorption by PAG Photoelectrons

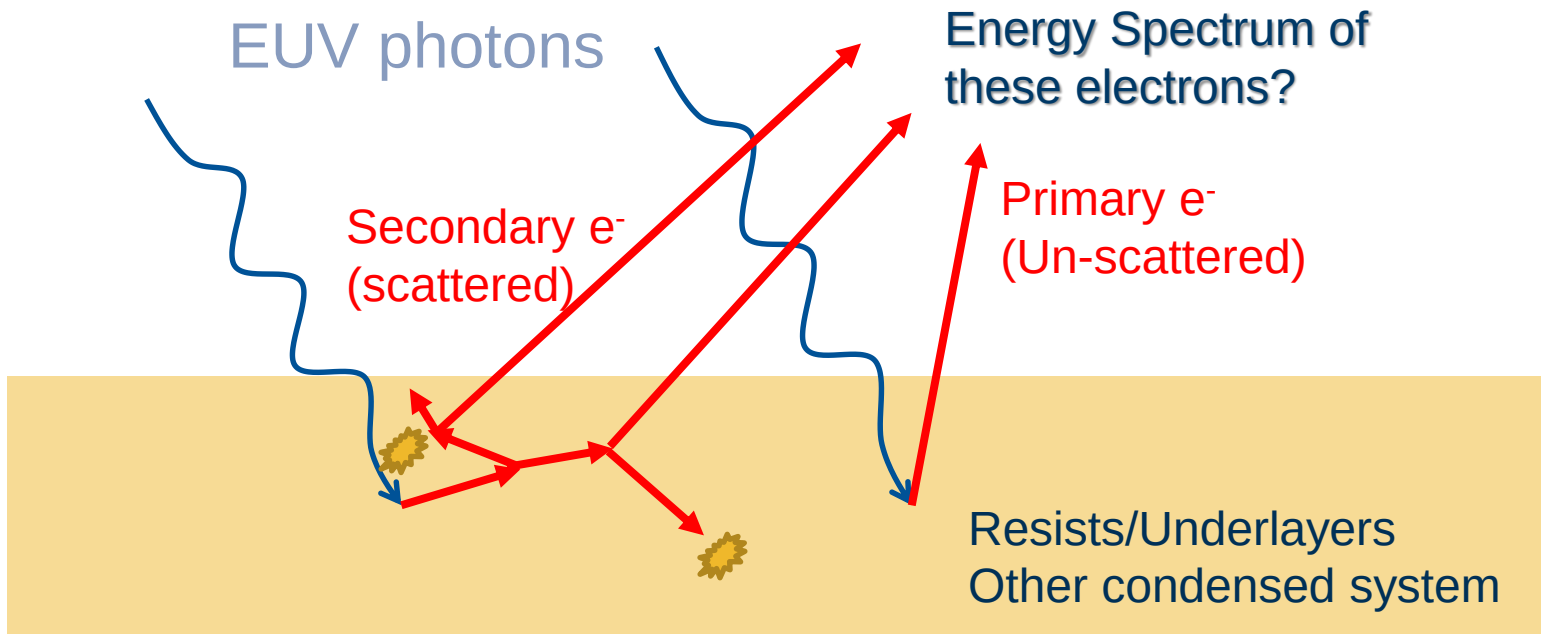
Acid

Acid Amplification + Deprotection



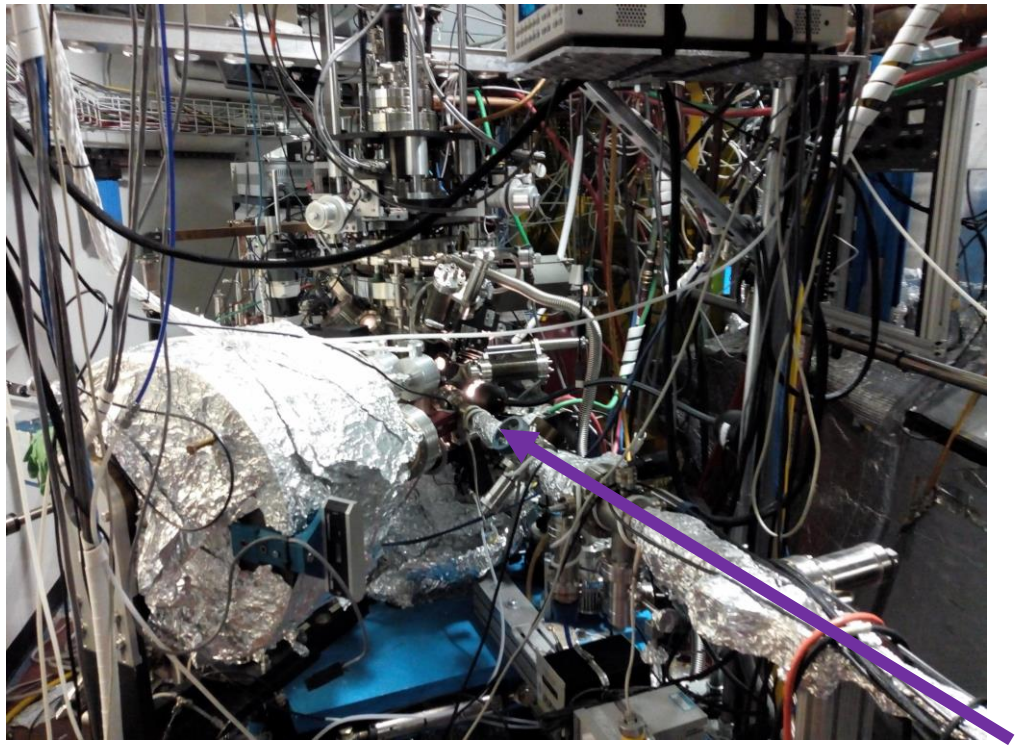
Hinsberg, W. D. and Wallraff, G. M. (2012). Lithographic Resists. In Encyclopedia of Polymer Science and Technology, (Ed.). doi:10.1002/0471440264.pst183.pub2

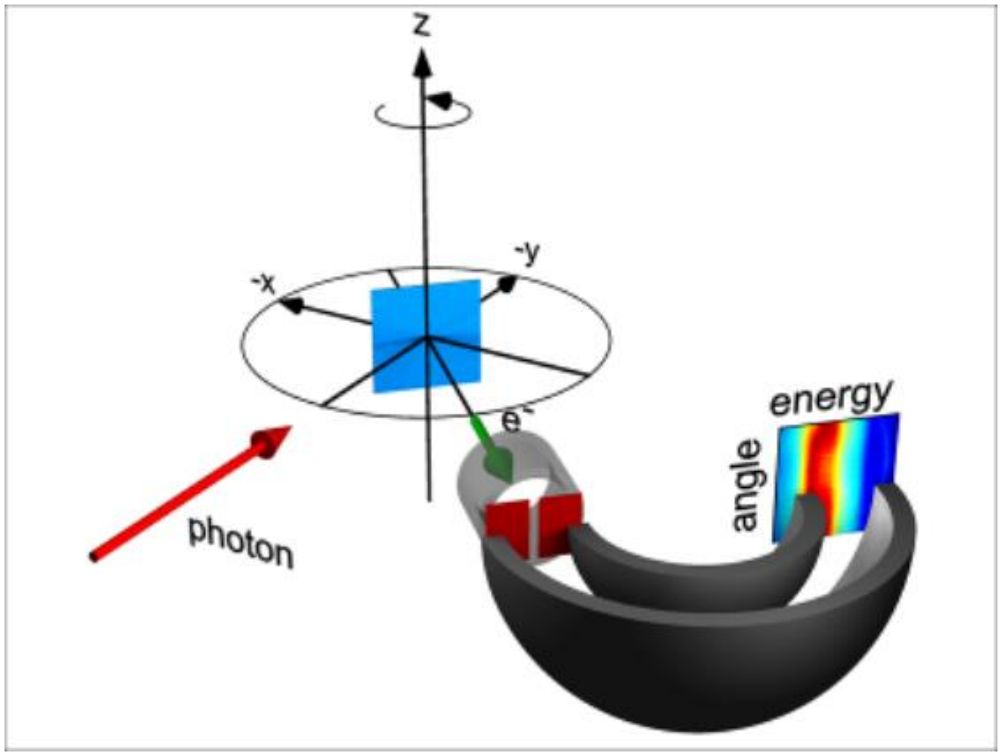
First step: measuring the electrons



We can’t measure those inside but we can measure those escaped

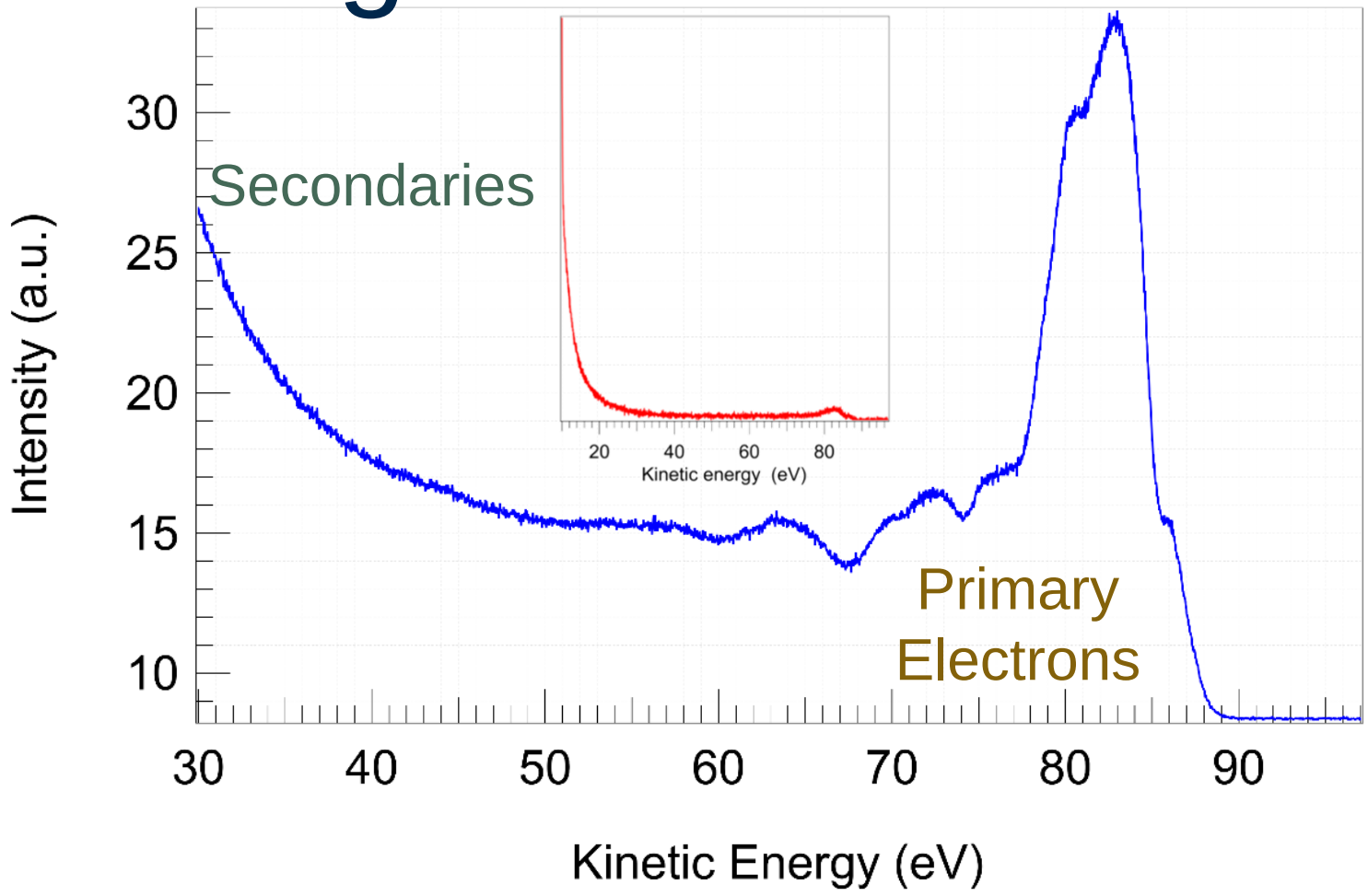
Condensed phase photoemission





http://physics.bu.edu/~ksmith/index_files/Page934.htm

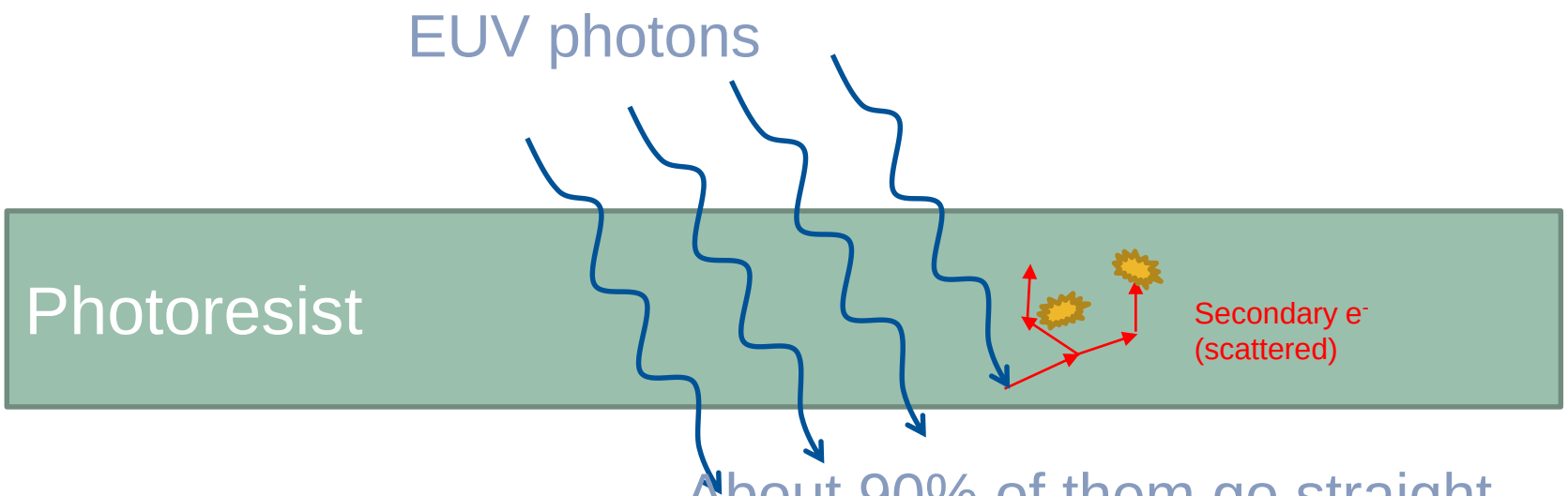
What do we get?



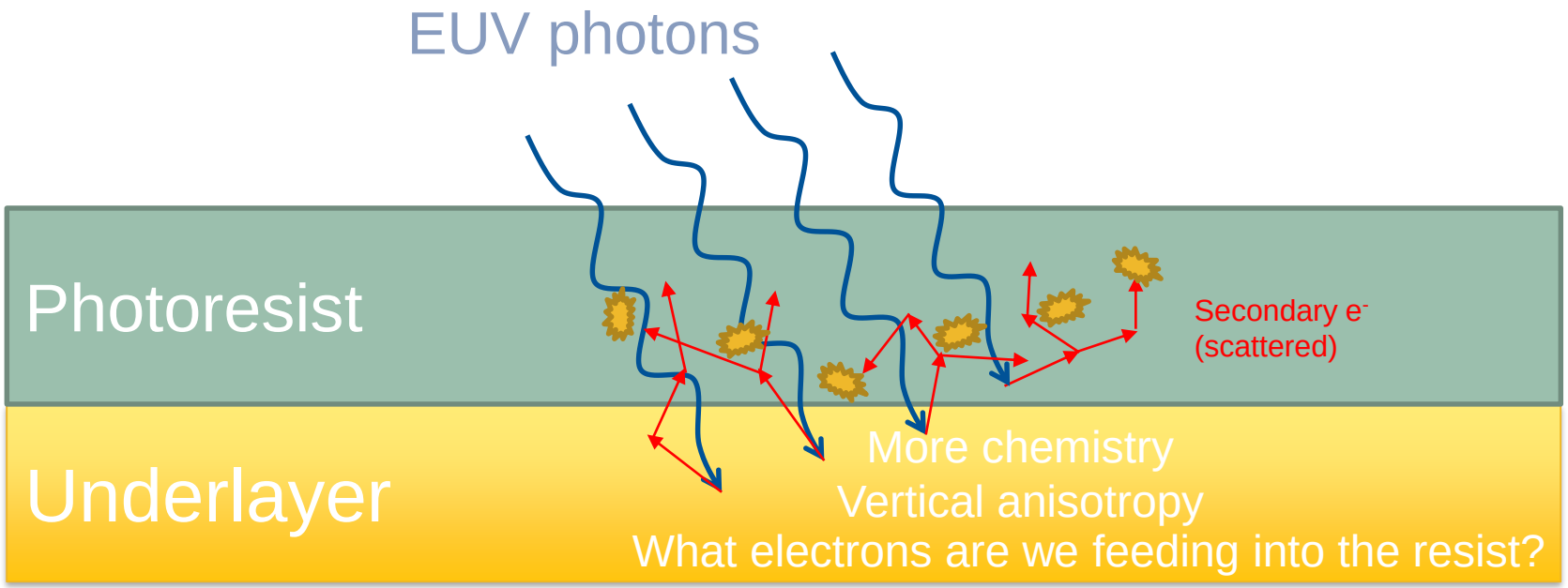
Photoemission of underlayers

And engineering primary electrons

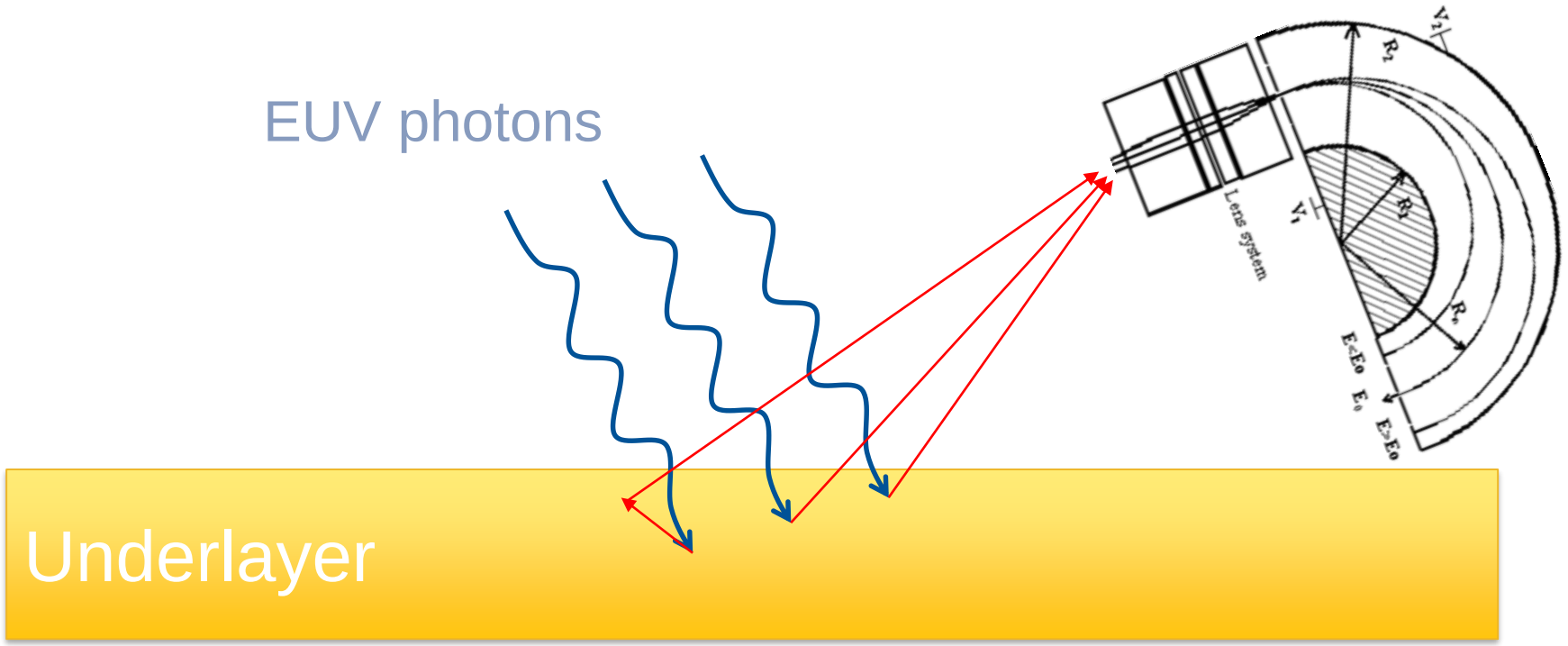
The absorption problem



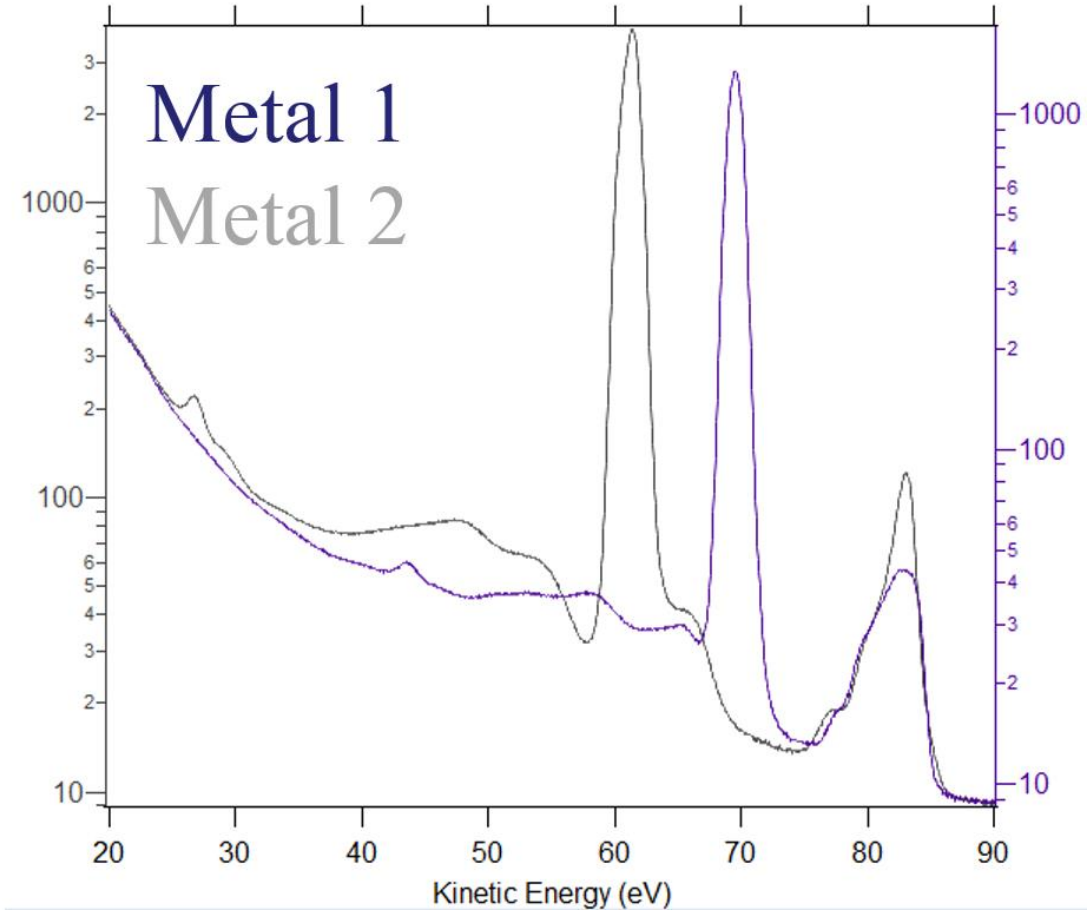
Underlayer as an electron source



Understand what goes into the resist



Primary electron spectra engineering

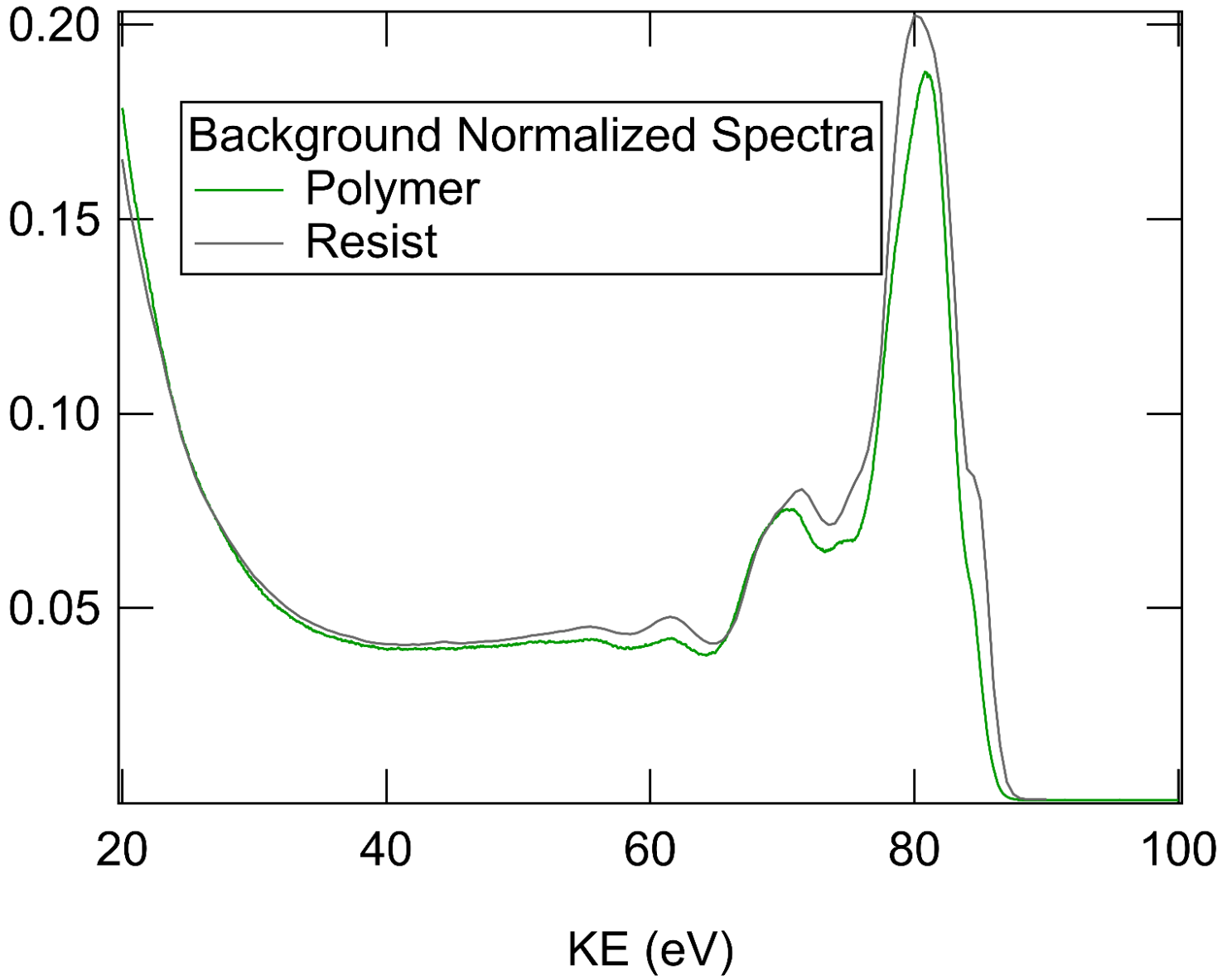


Background normalized photoelectron spectra

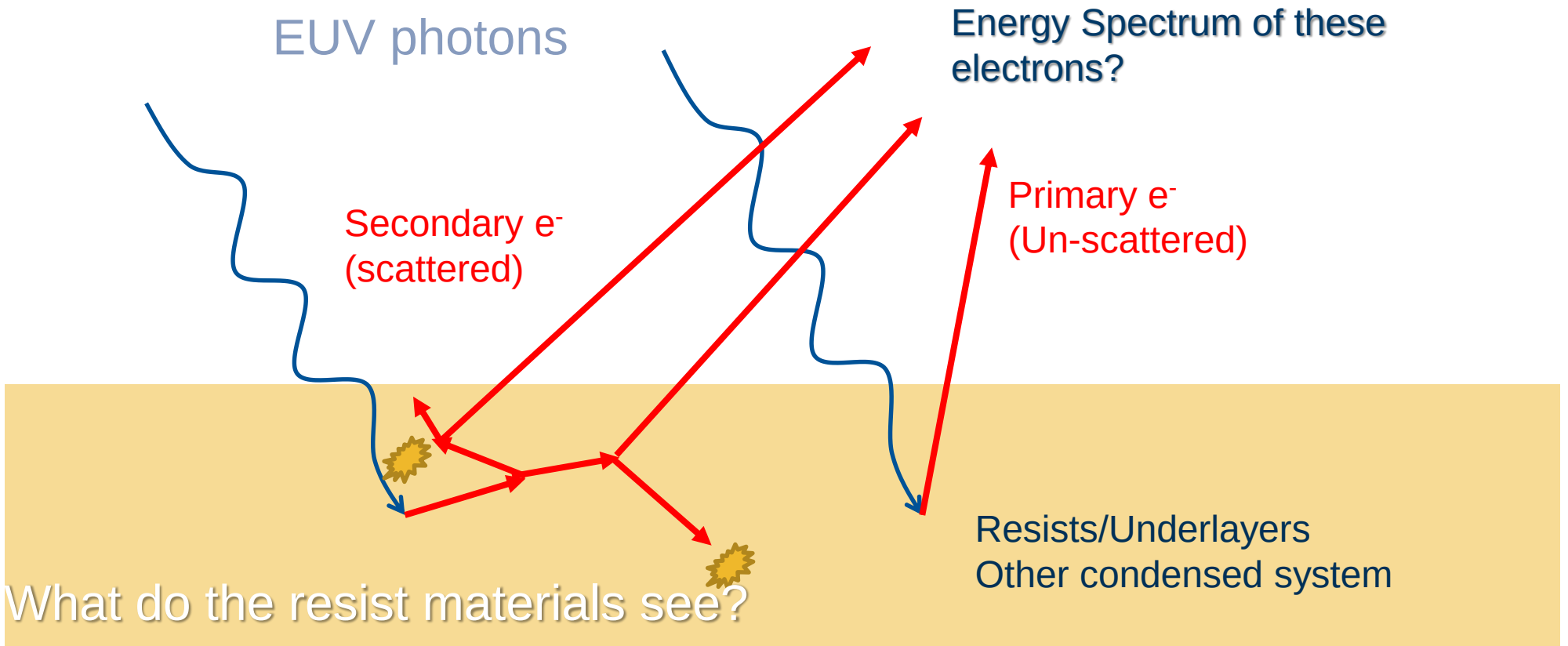
Different metals give different secondary electron generation efficiency

Photoemission of photoresists

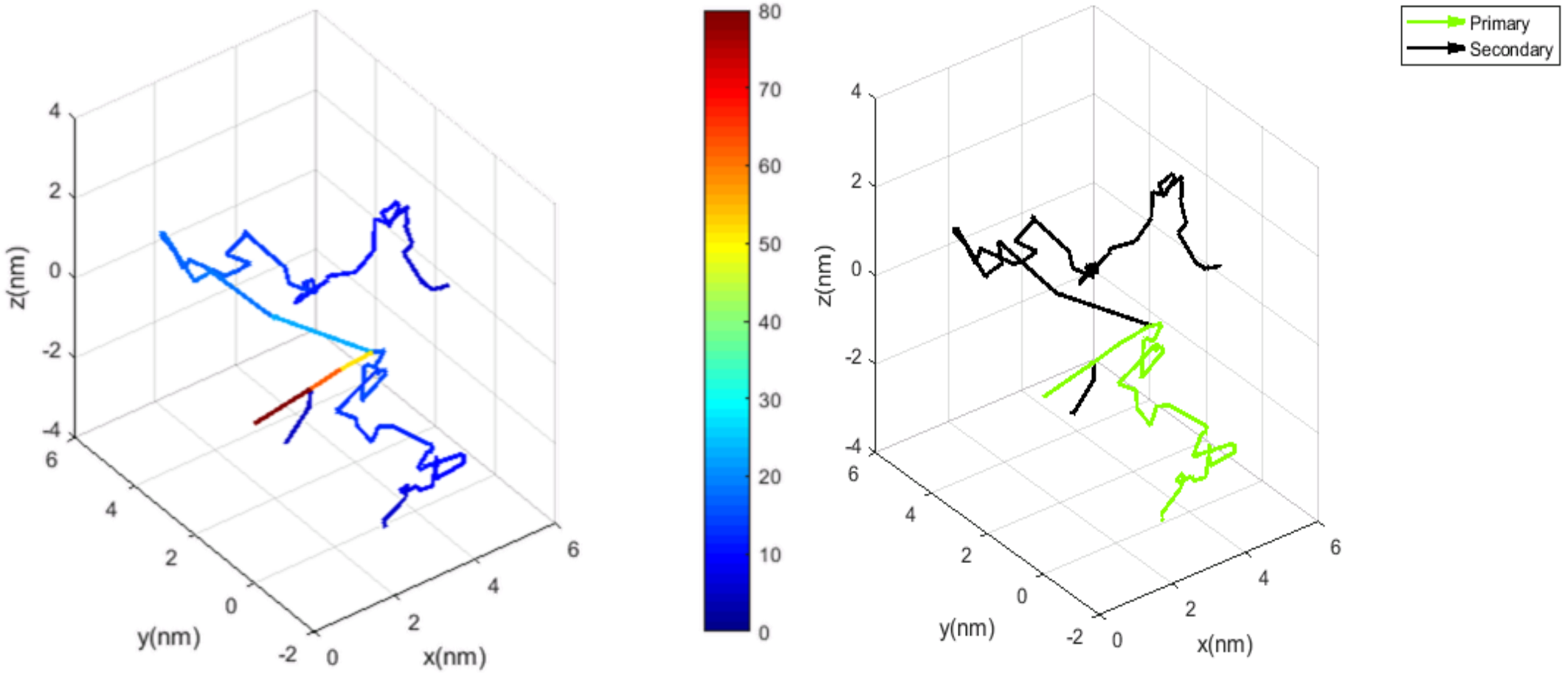
Photoelectrons are from polymers



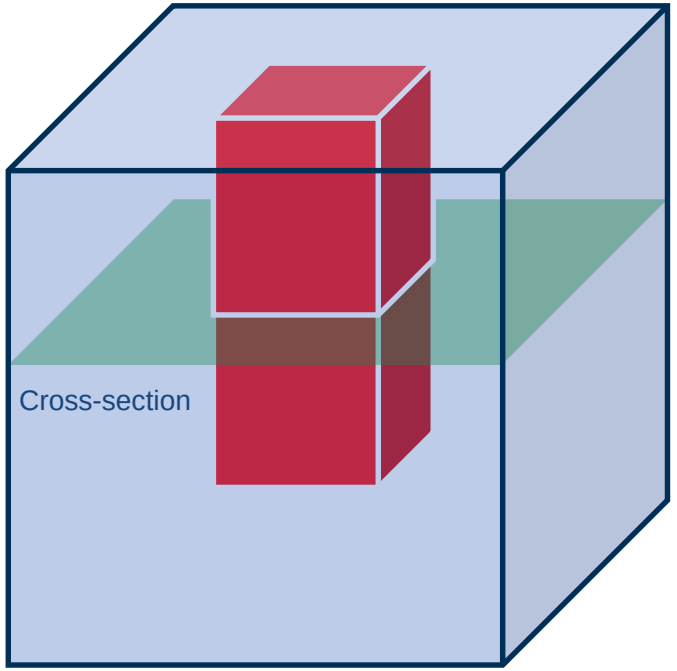
Inside vs outside

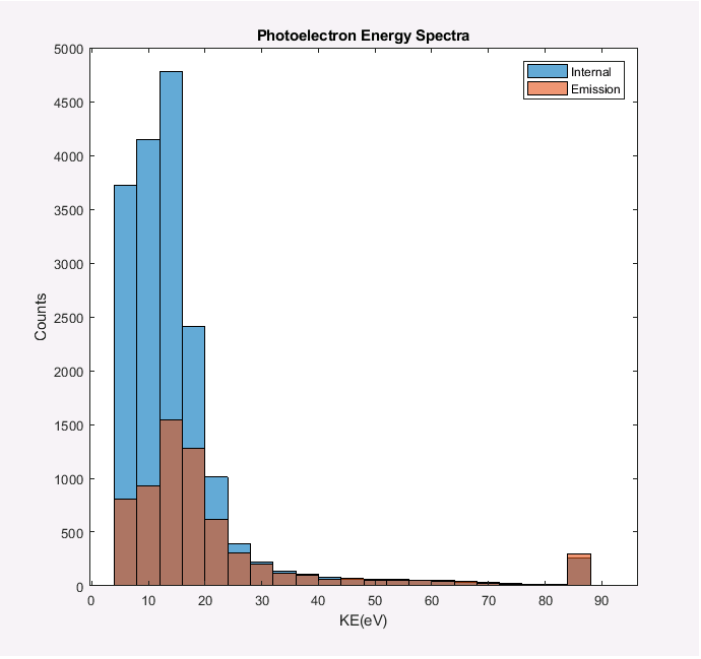


Simulating electron trajectories

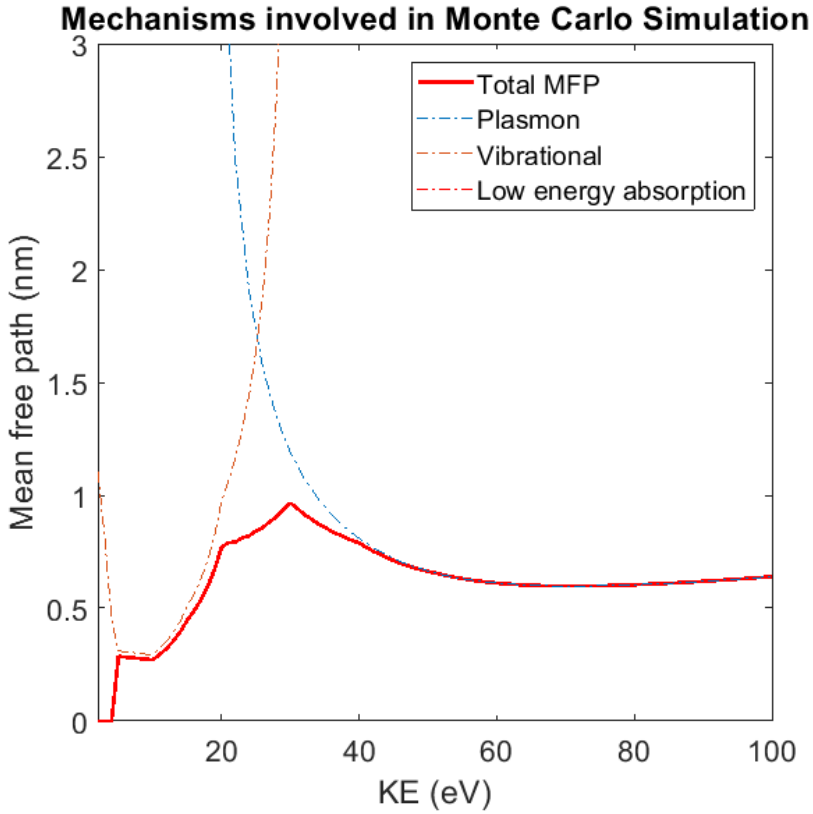


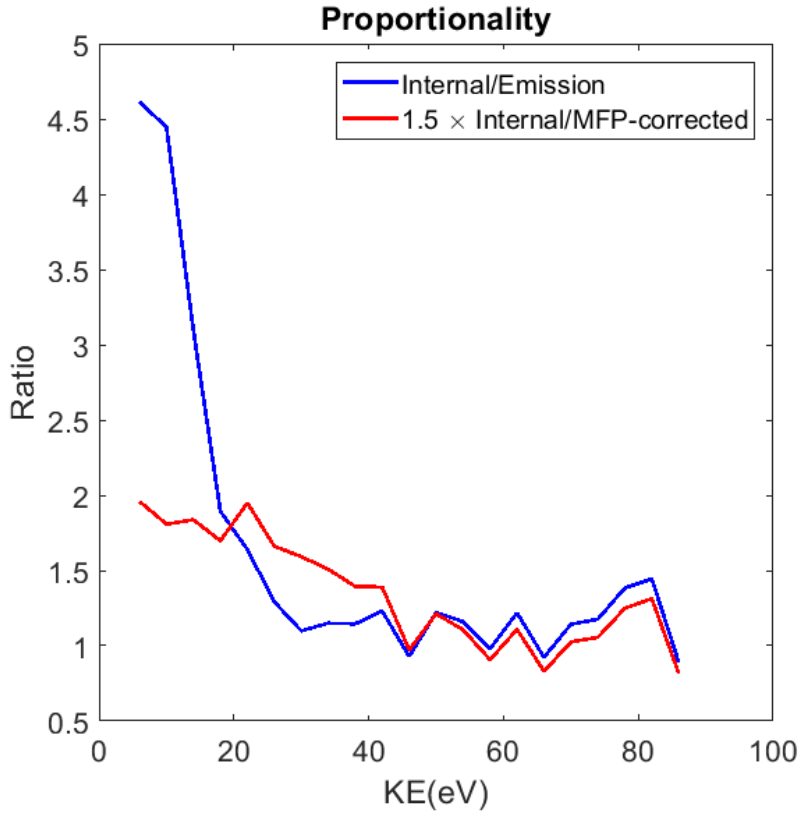
Internal spectrum vs photoemission





Is that the inelastic mean free path





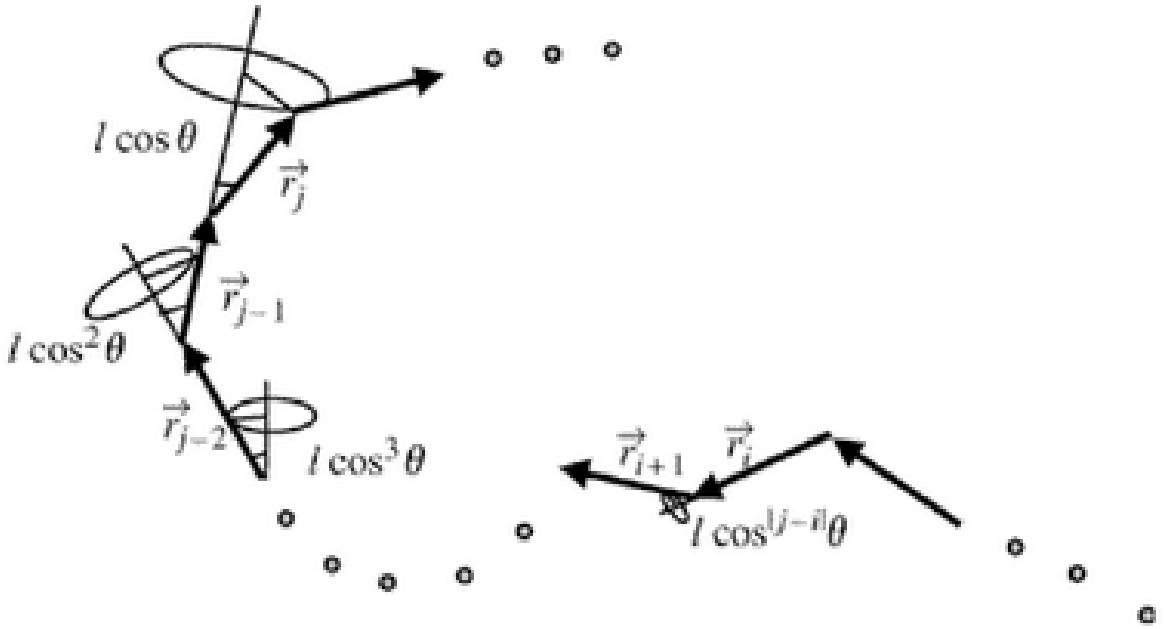
Previous works suggest that correction with inelastic mean free path is sufficient for extracting the internal electron energy spectrum from the photoemission spectrum

Henke, B. L., Smith, J. A., and Attwood, D. T., *Journal of Applied Physics* 48(5), 1852-1866 (1977).

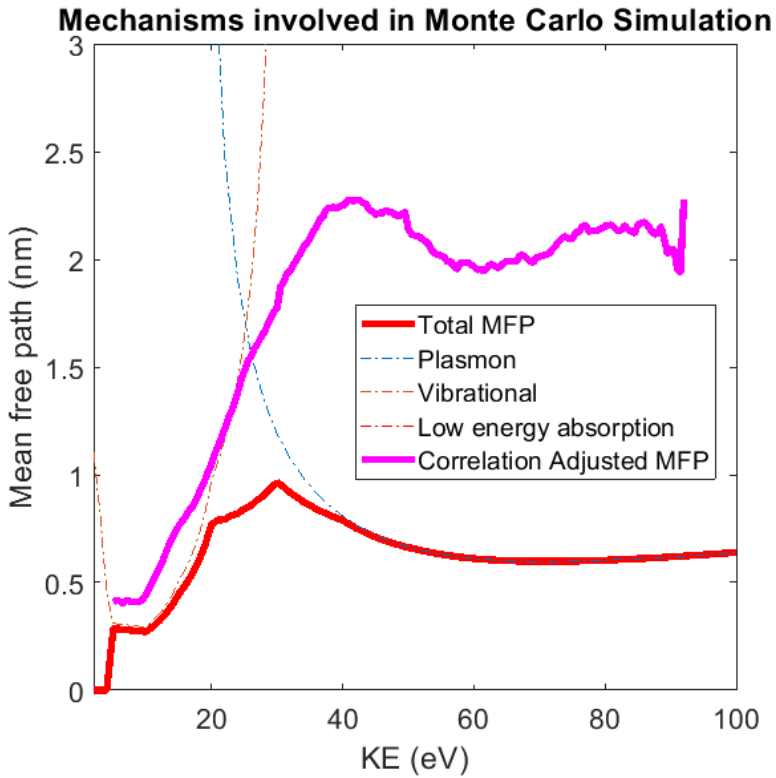
$$\text{Emission} = \underbrace{X(E)}_{\text{Internal Spectrum}} \quad \lambda(E)\left(\frac{E - E_A}{E}\right)\pi$$

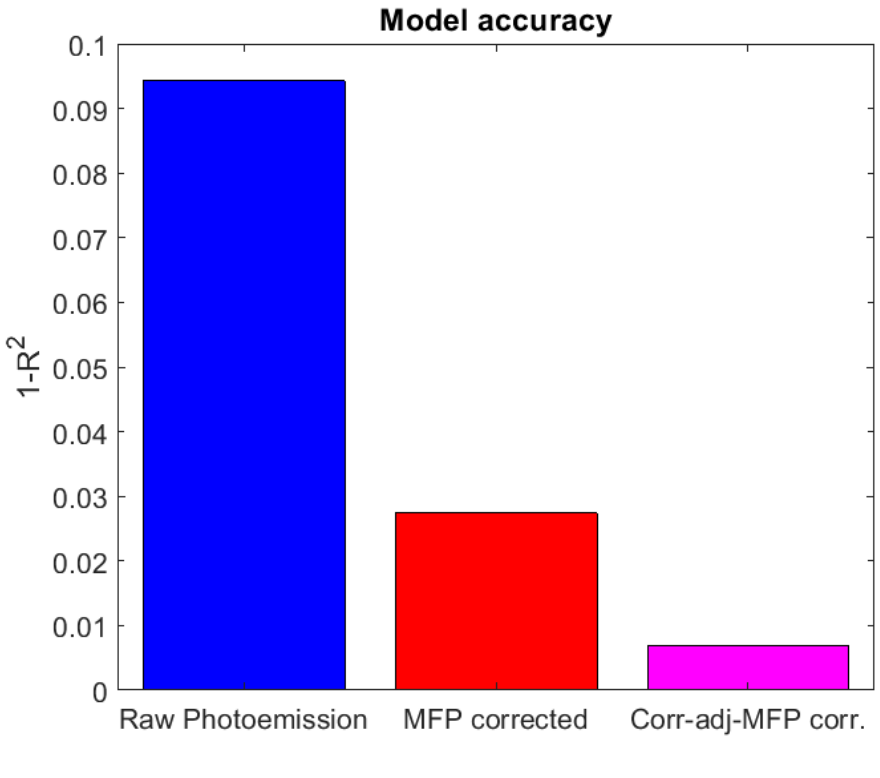
The scattering steps are correlated

- The scattering steps or the outcoming direction of scattering events can be correlated
- That results in a longer directional memory
- Effectively a longer mean free path



Results using correlation adjusted MFP λ

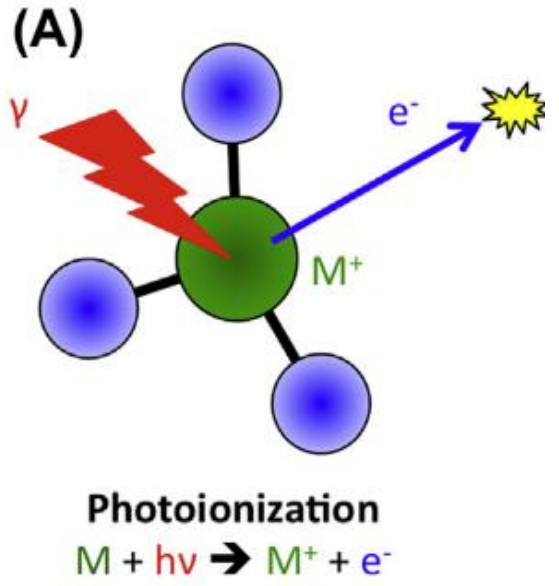


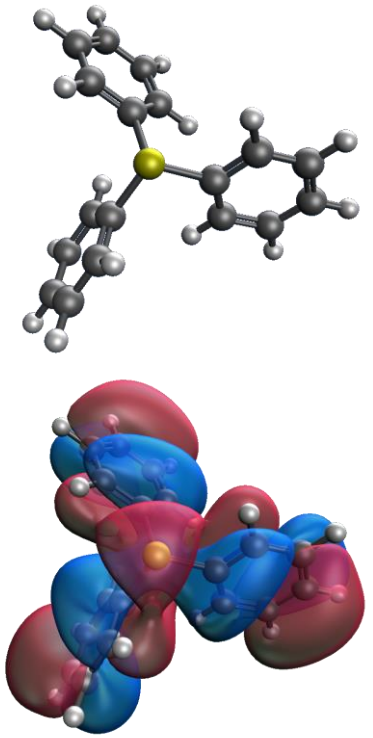


We're able to recover the internal electron energy spectrum from photoemission data

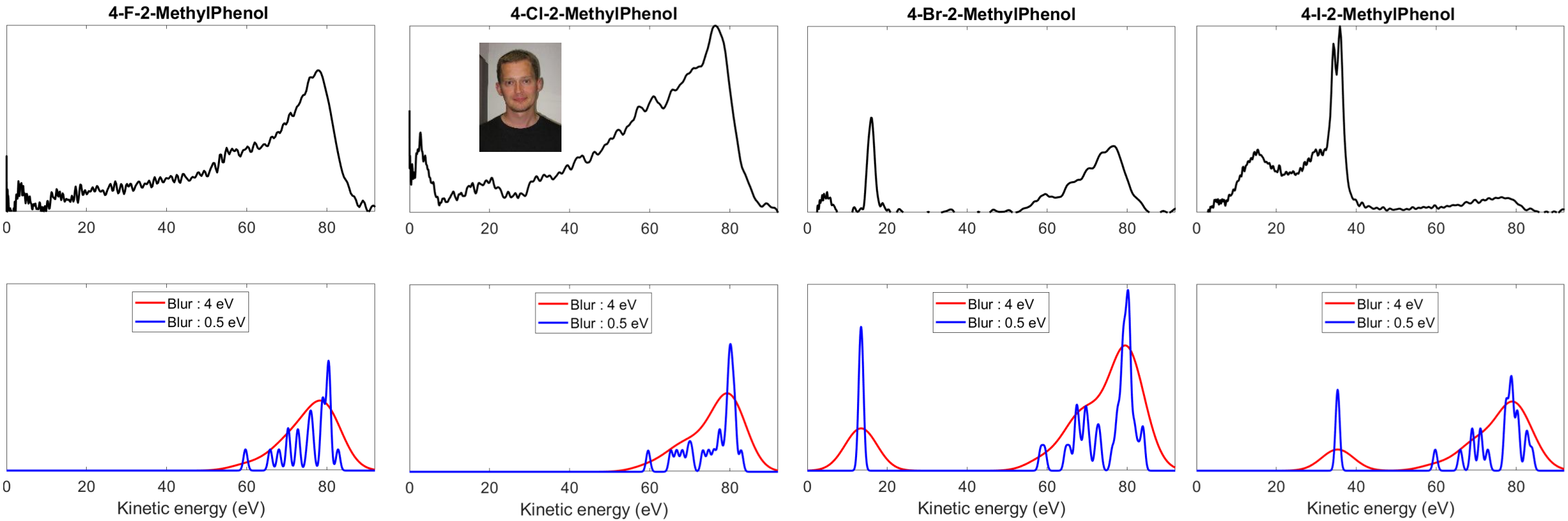
Modelling Photoemission

- Where energy in the photons are converted into electron
- Determines the initial energy spectrum of electrons
- First principle calculations are carried out using Q-Chem





Modelling prototypical monomers



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

Summary

- The primary electron spectrum can be engineered by selecting metallic species.
- The electron energy spectrum inside photoresists can be inferred from photoemission spectroscopy
- Primary electron energy spectrum can be predicted by first principle calculations

Thank you for your attention

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