Today's outline - April 02, 2020 (part A)

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- Angle Resolved Photoemission

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Homework Assignment #06:
Chapter 6: 1,6,7,8,9
due Tuesday, April 14, 2020

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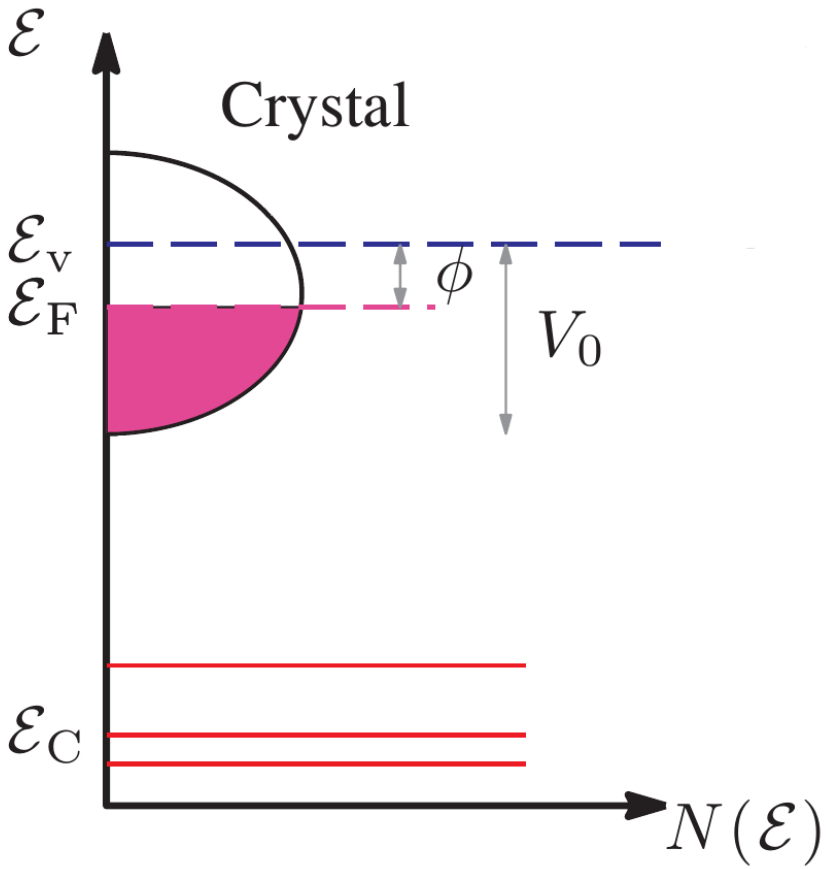
Homework Assignment #06:
Chapter 6: 1,6,7,8,9
due Tuesday, April 14, 2020

Homework Assignment #07:
Chapter 7: 2,3,9,10,11
due Thursday, April 23, 2020

The photoemission process

Photoemission is the complement to XAFS. It probes the filled states below the Fermi level



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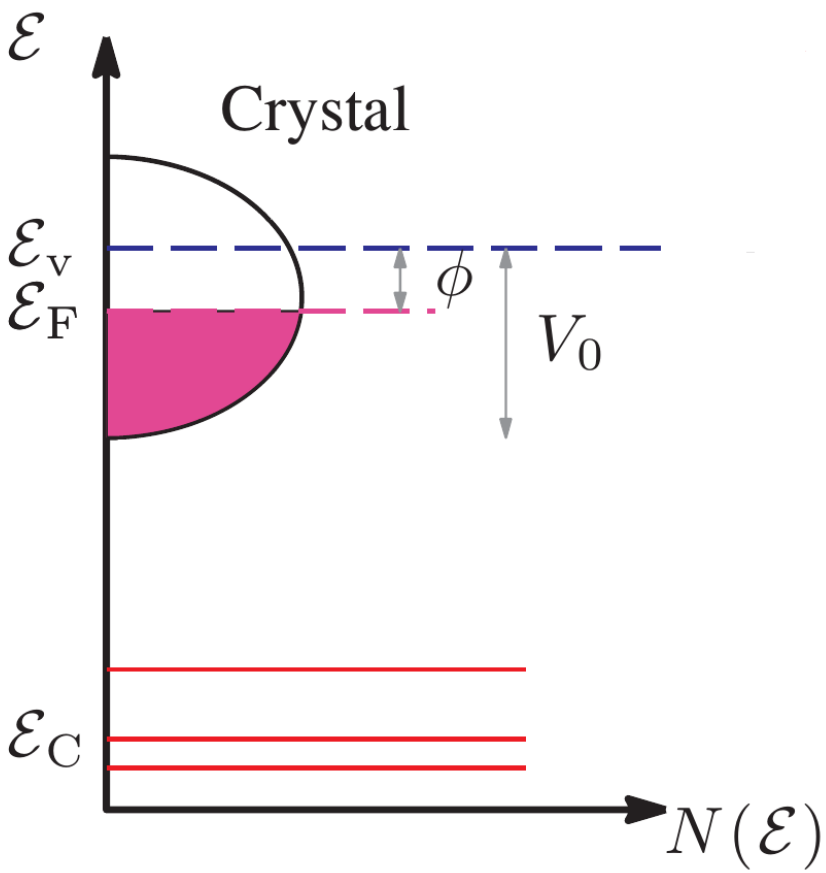

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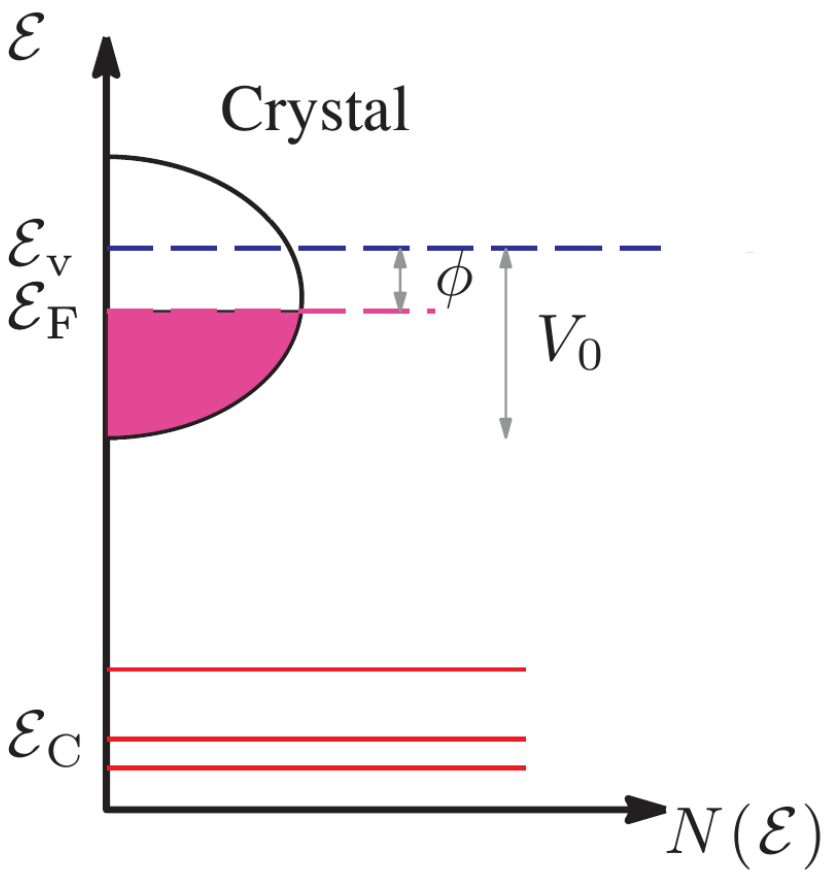

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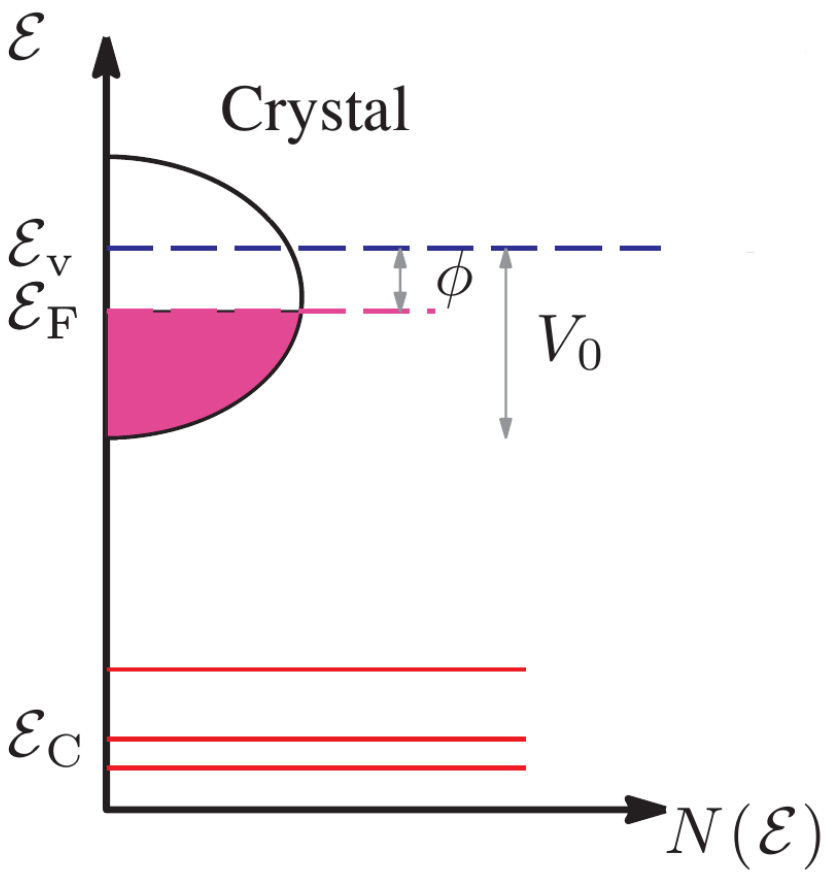

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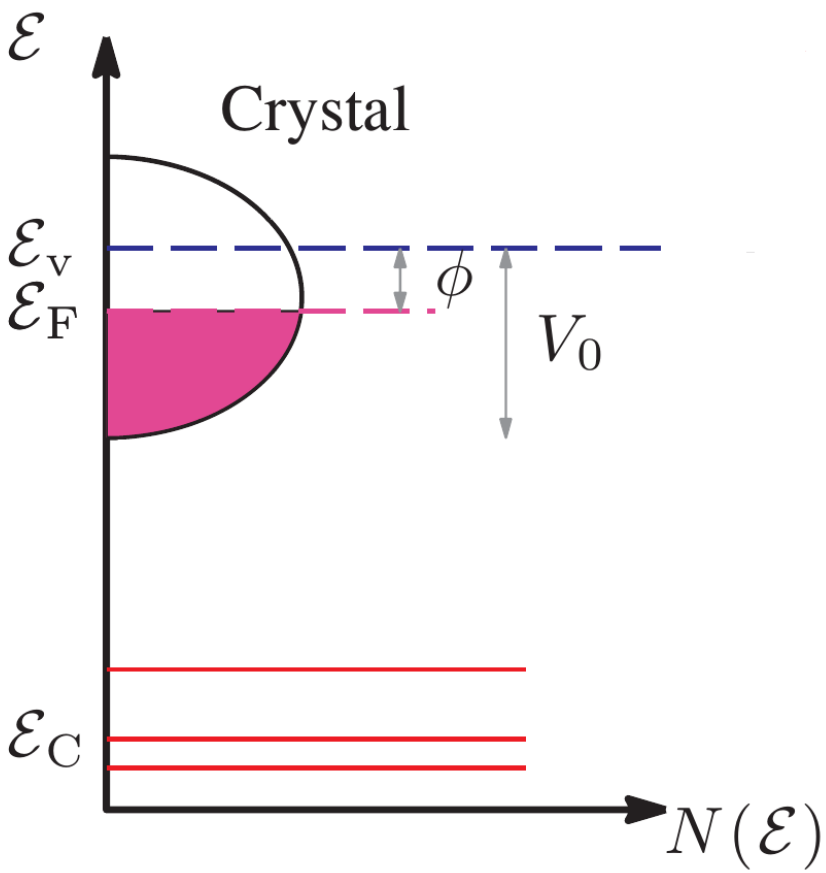

$$\phi = \mathcal{E}_v - \mathcal{E}_F$$

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The work function, ϕ, is the minimum energy required to promote an electron from the top of the valence band at the Fermi energy, $\mathcal{E}_F$, to the vacuum energy, $\mathcal{E}_v$

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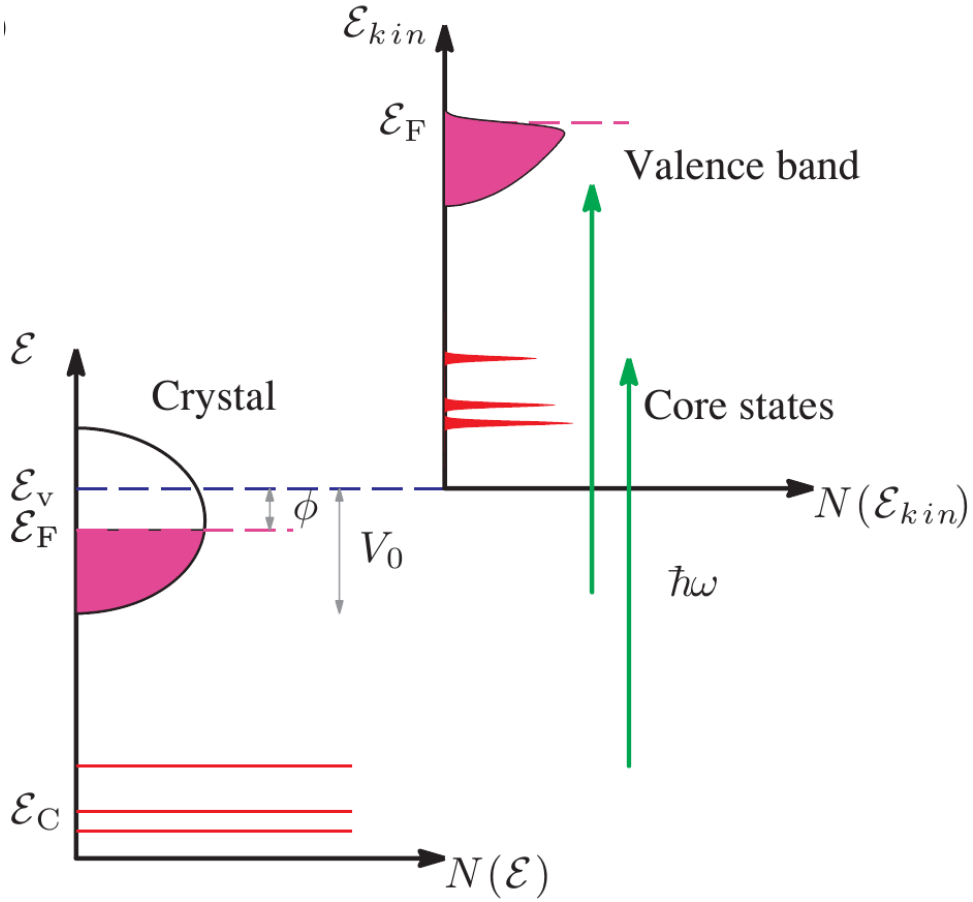
With the incident photon energy, $\hbar\omega$, held constant, an analyzer is used to measure the kinetic energy, $\mathcal{E}_{kin}$, of the photoelectrons emitted from the surface of the sample



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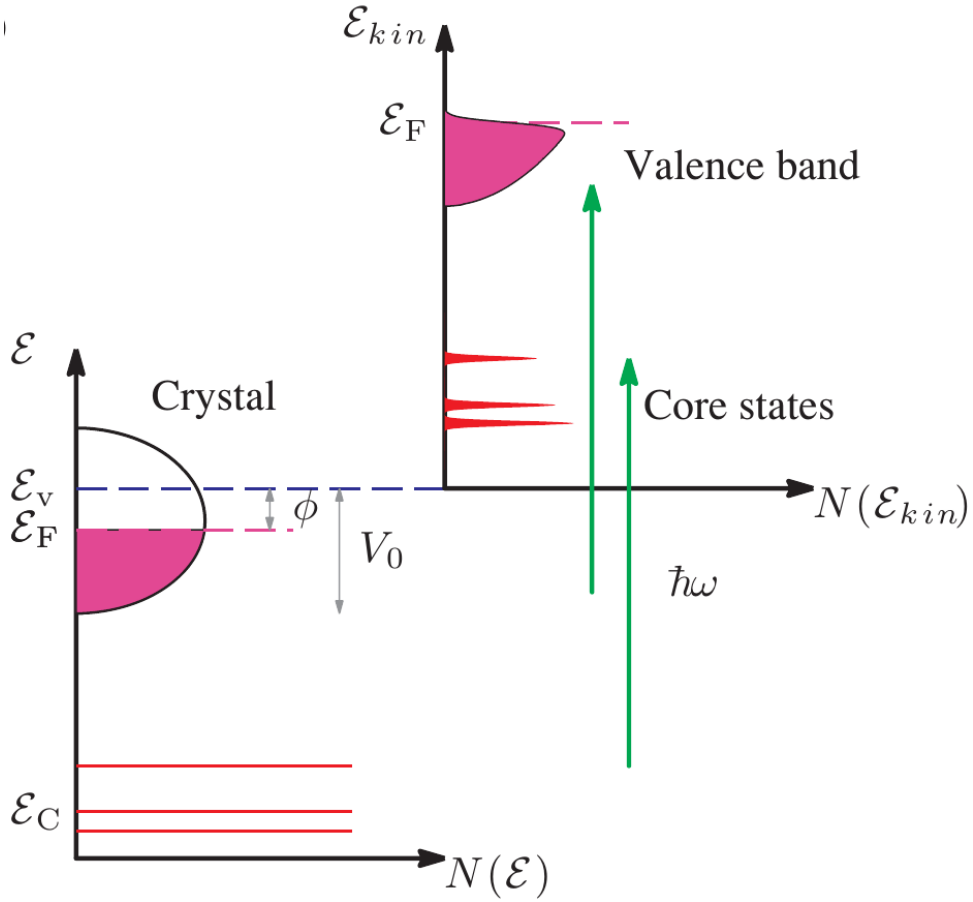

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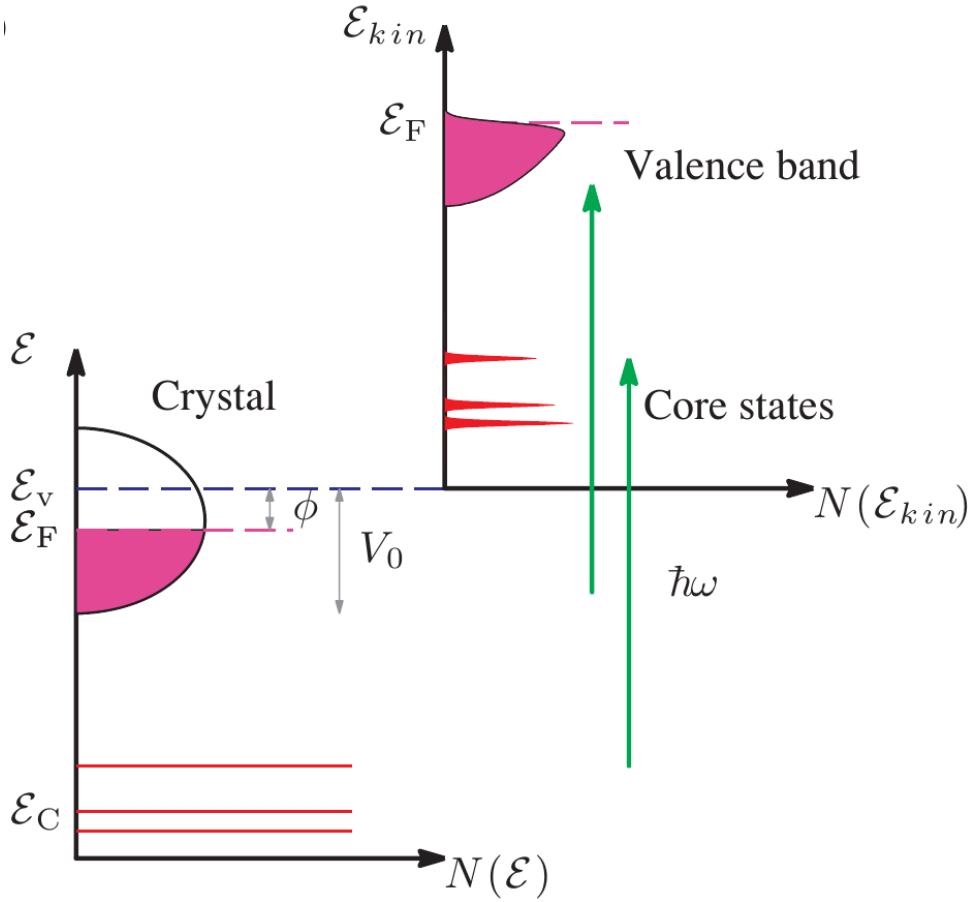

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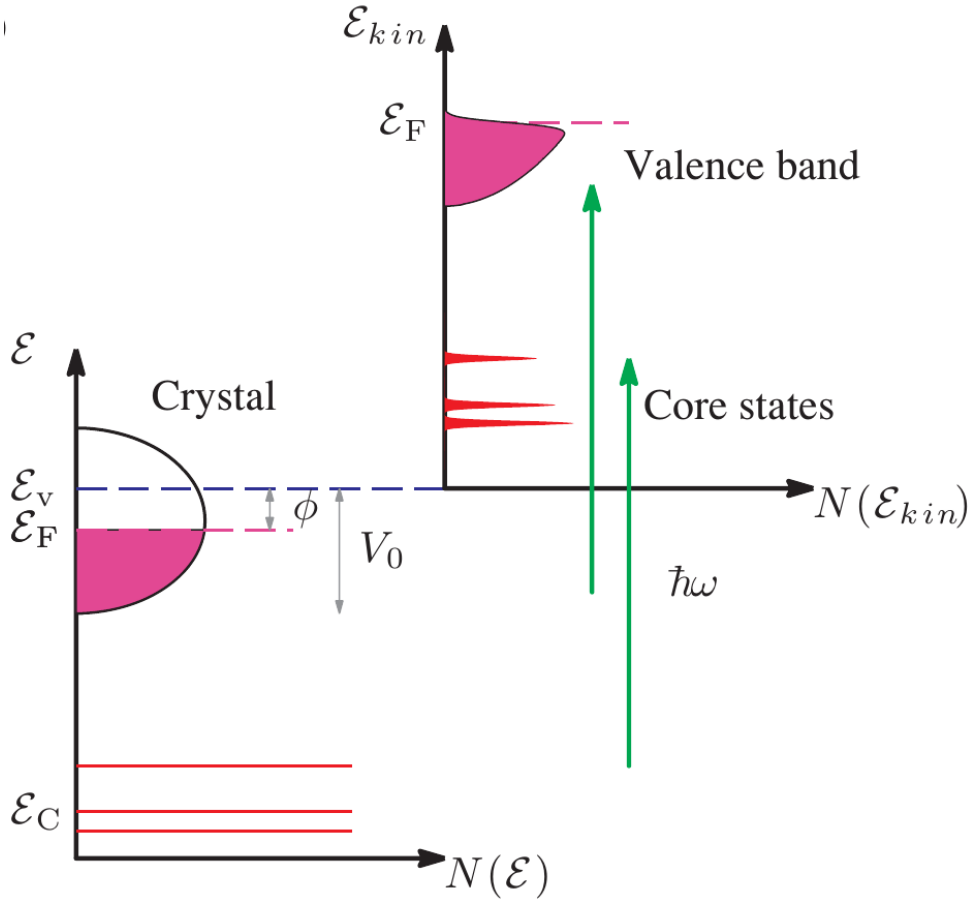

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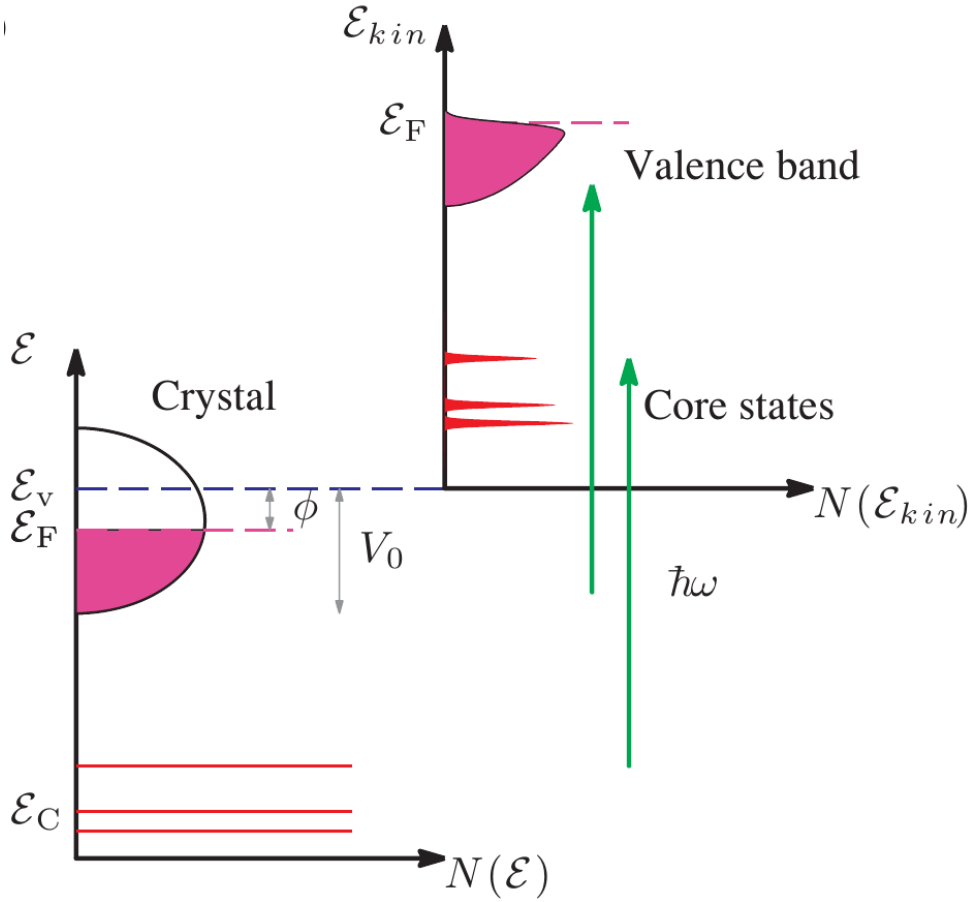

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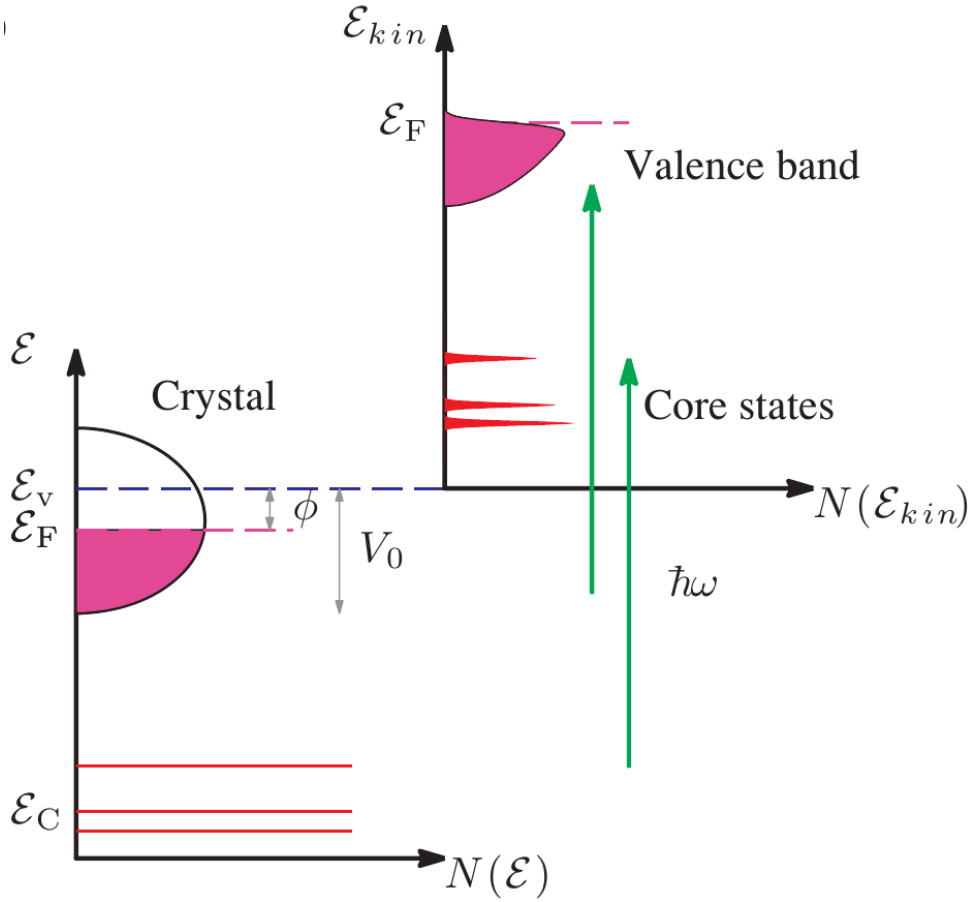

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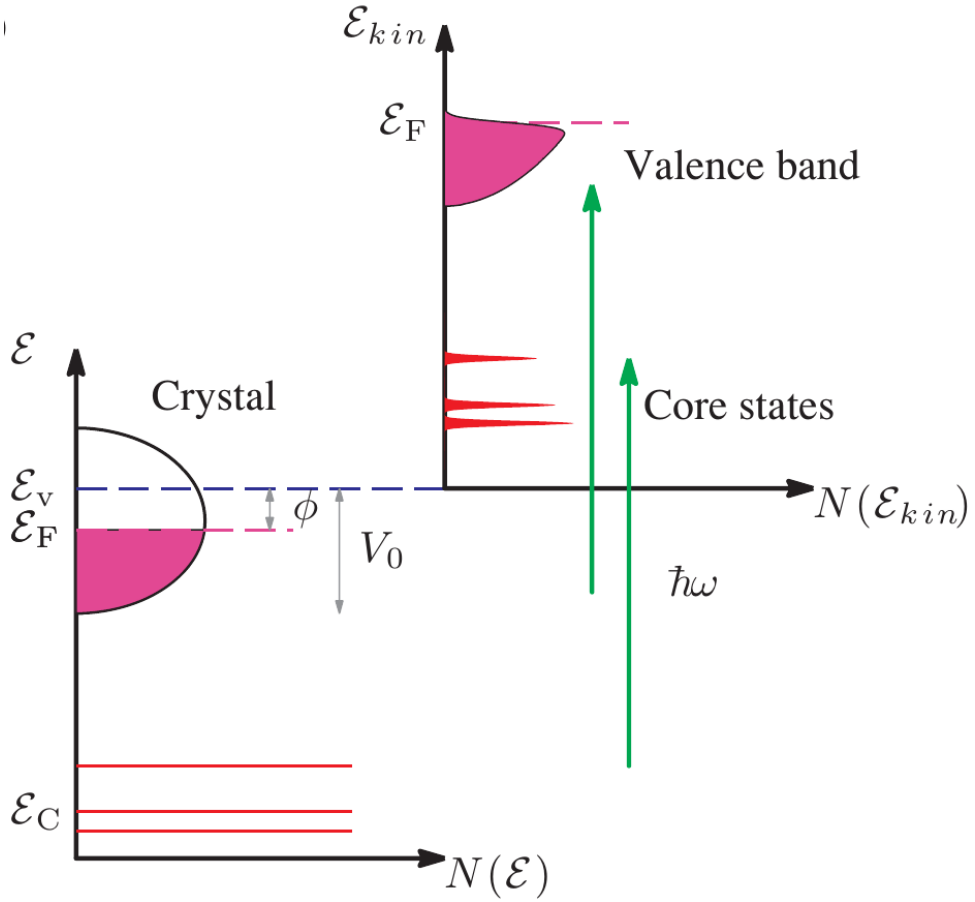

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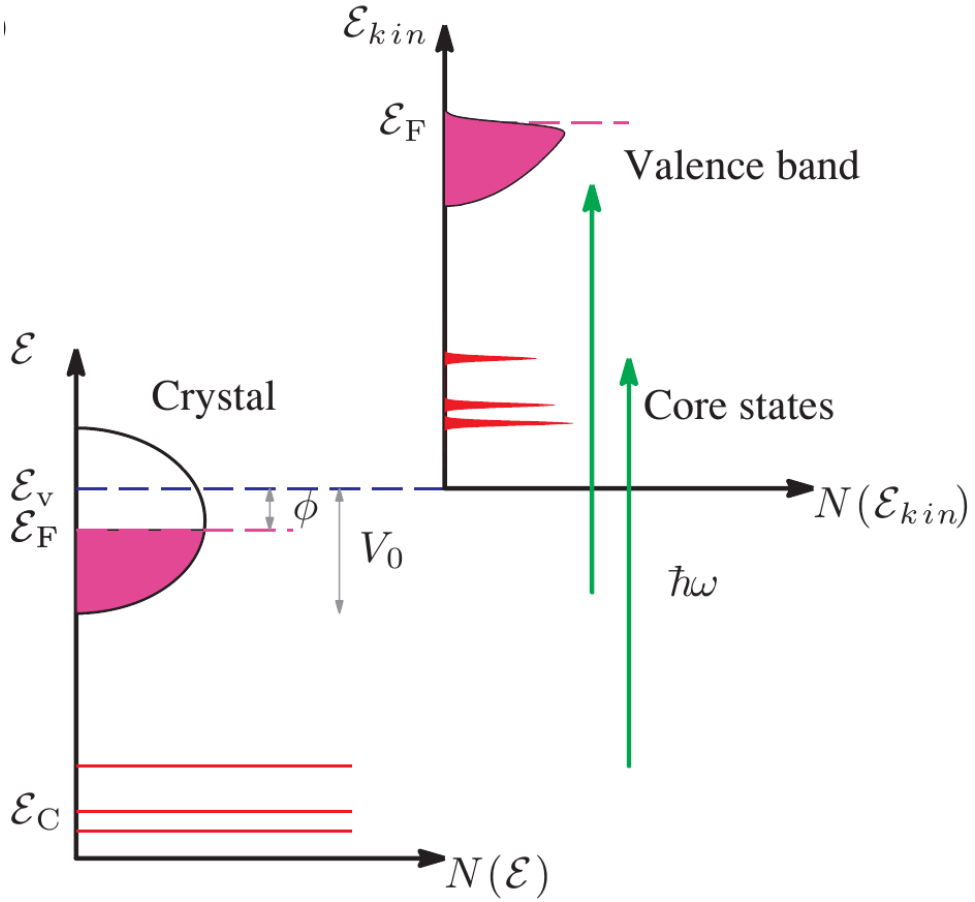

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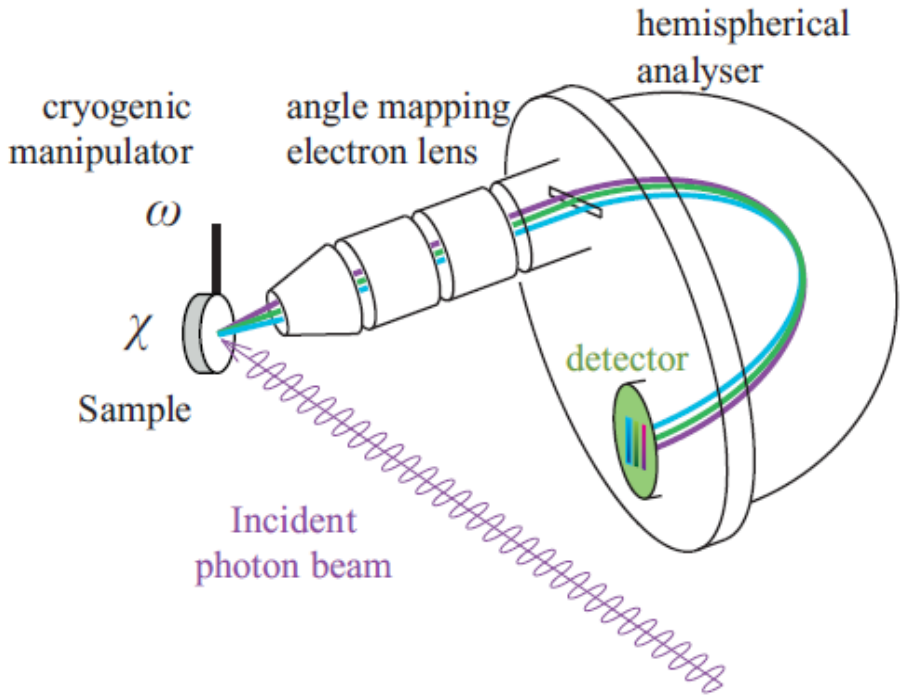
the core states are used to fingerprint the chemical composition of the sample

Hemispherical mirror analyzer

The electric field between the two hemispheres of radius R_1 and R_2 has a R^2 dependence from the center of the hemispheres



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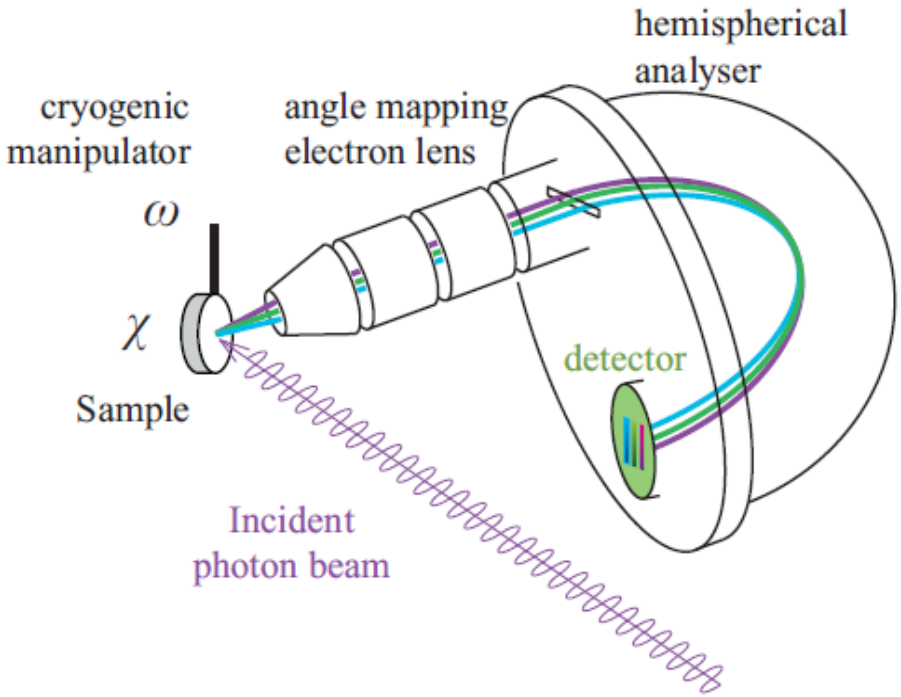

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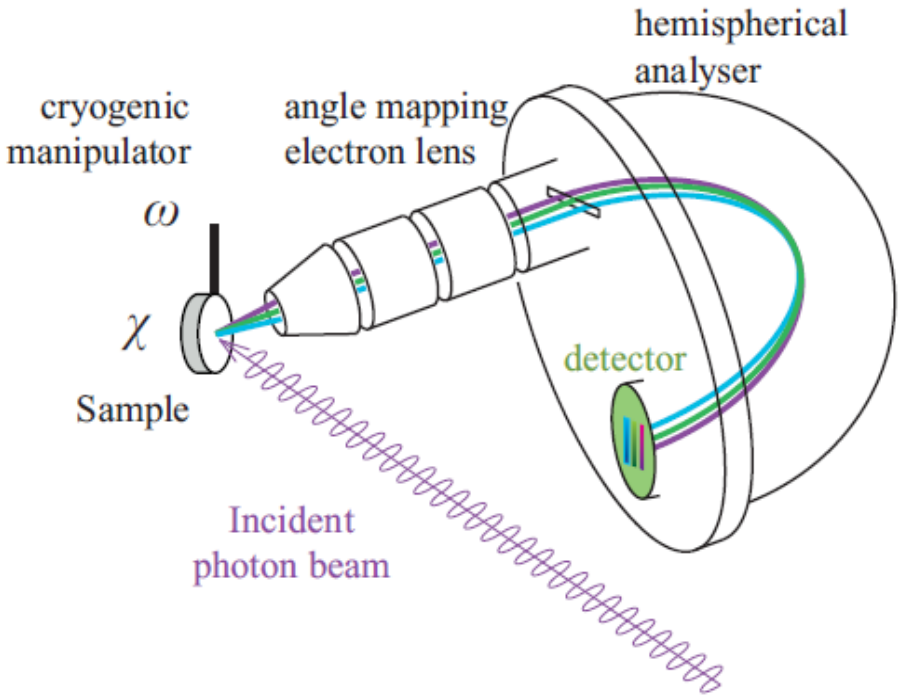

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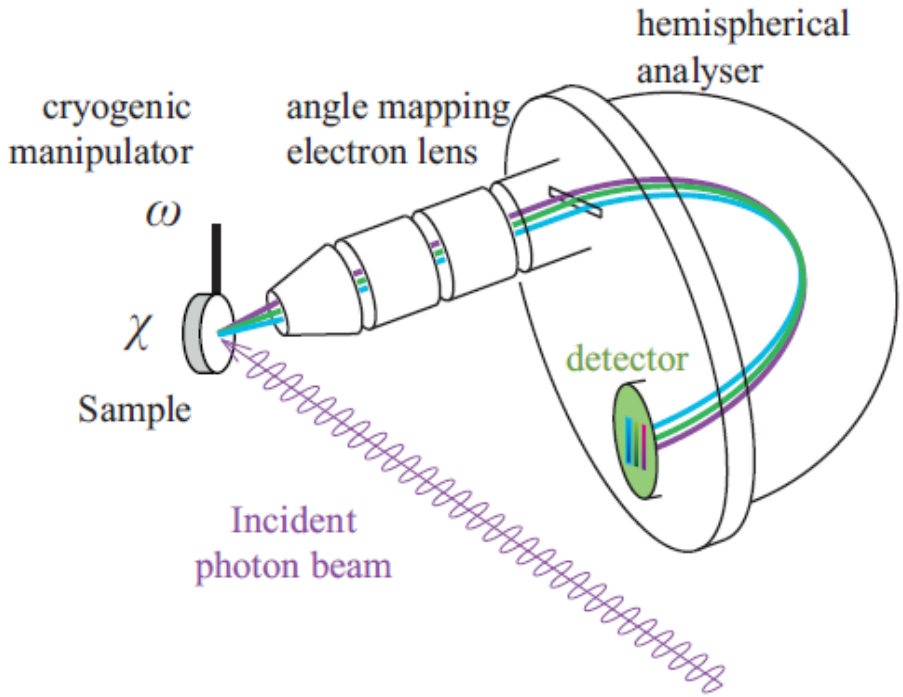

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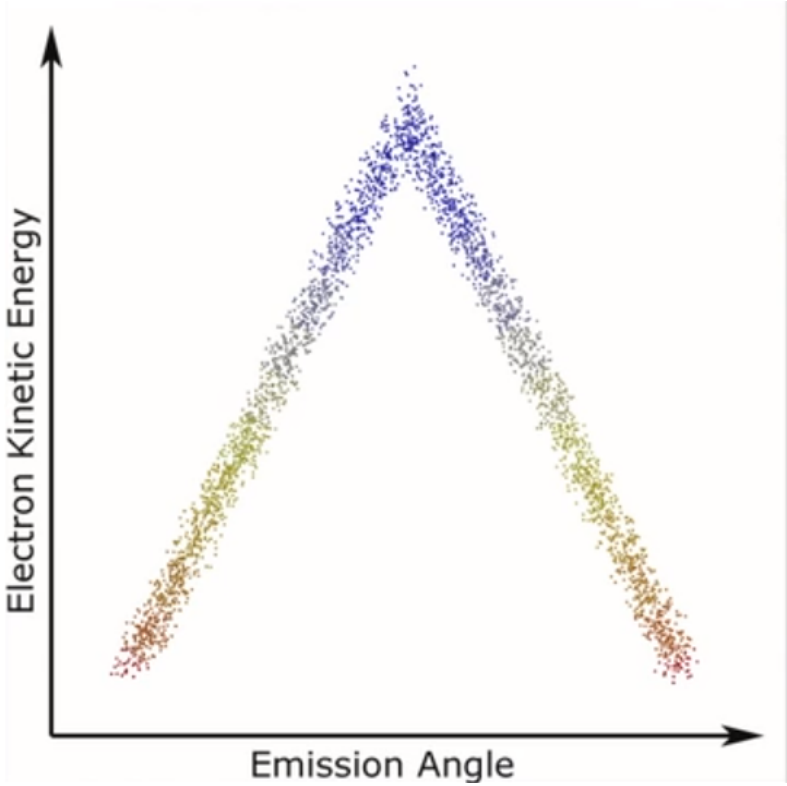

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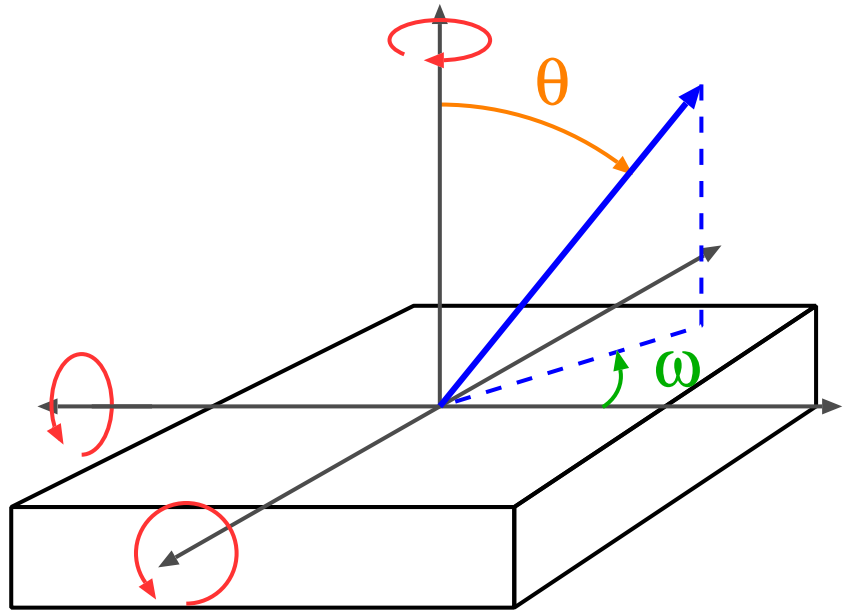
Electrons with different azimuthal exit angles ω will map to different positions on the 2D detector

Photoelectron momentum



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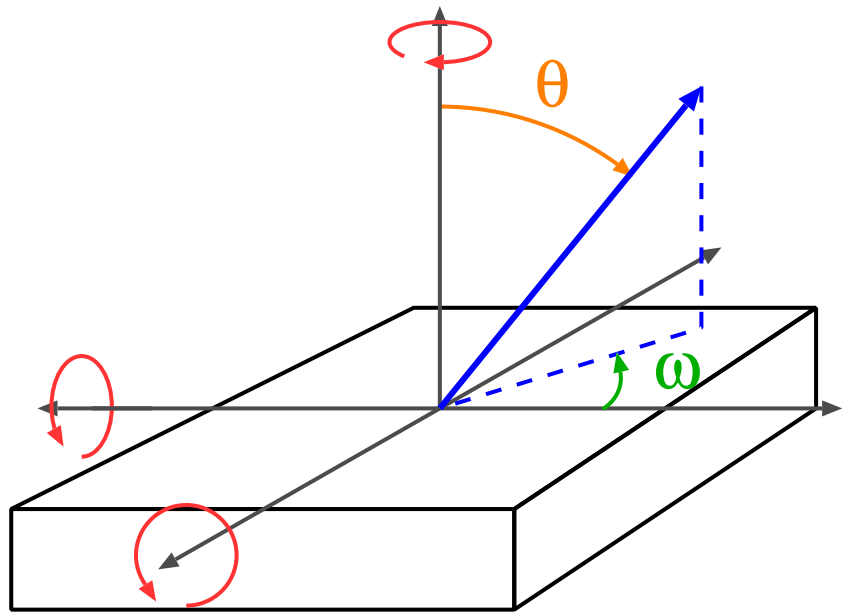

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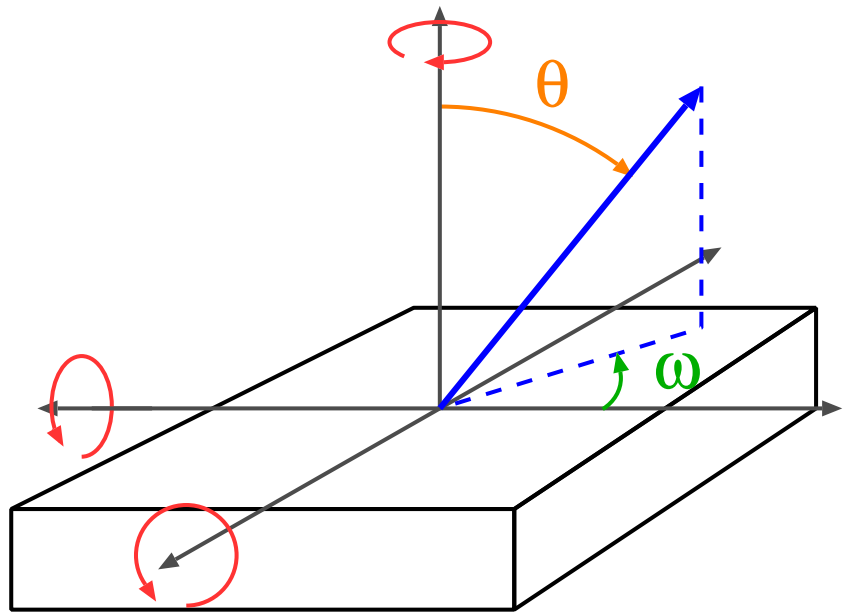

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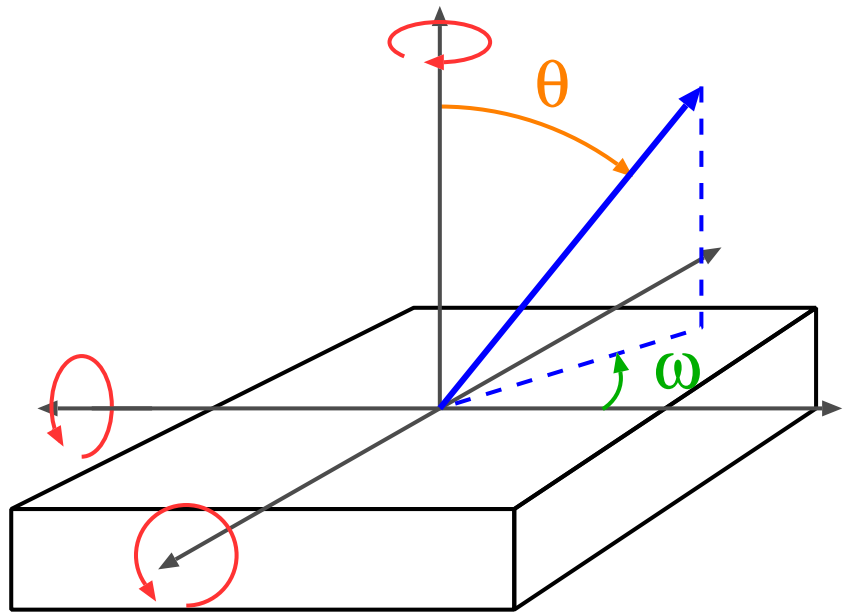

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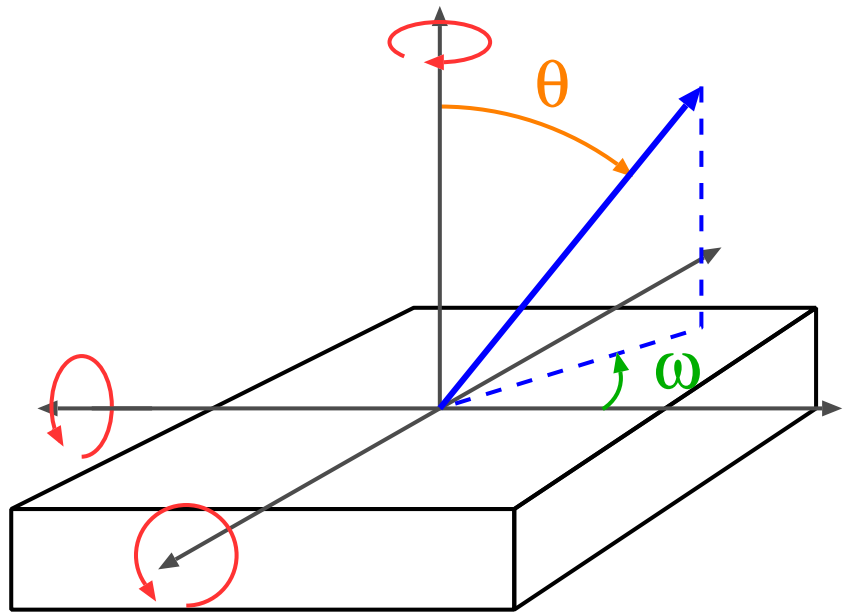

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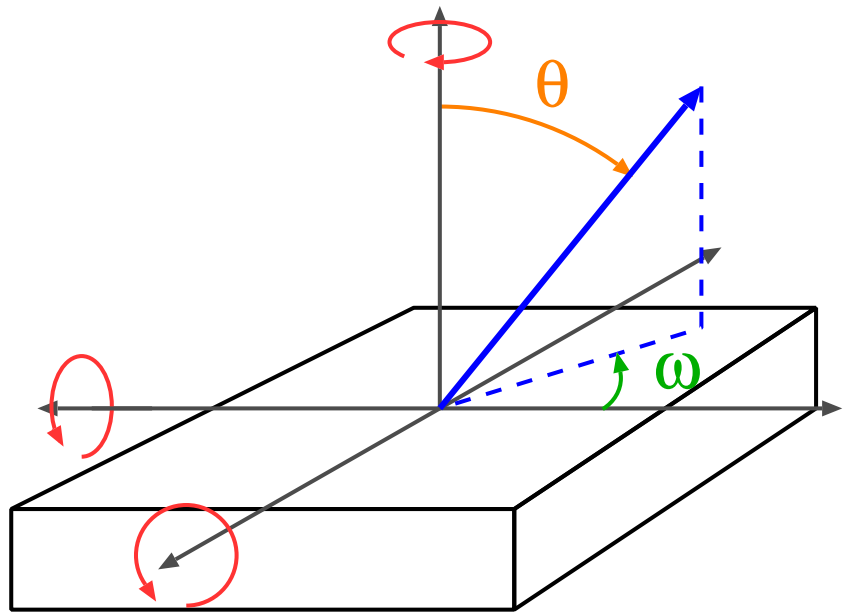

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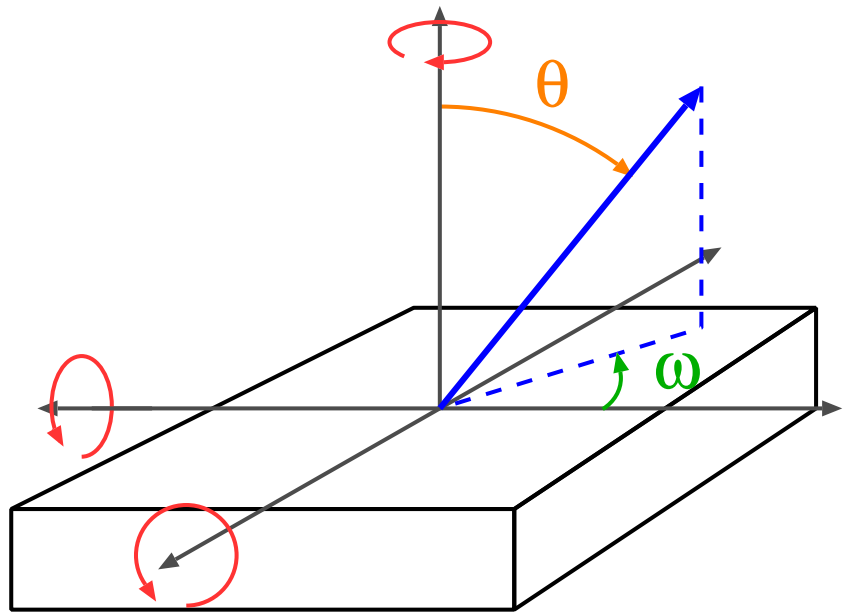

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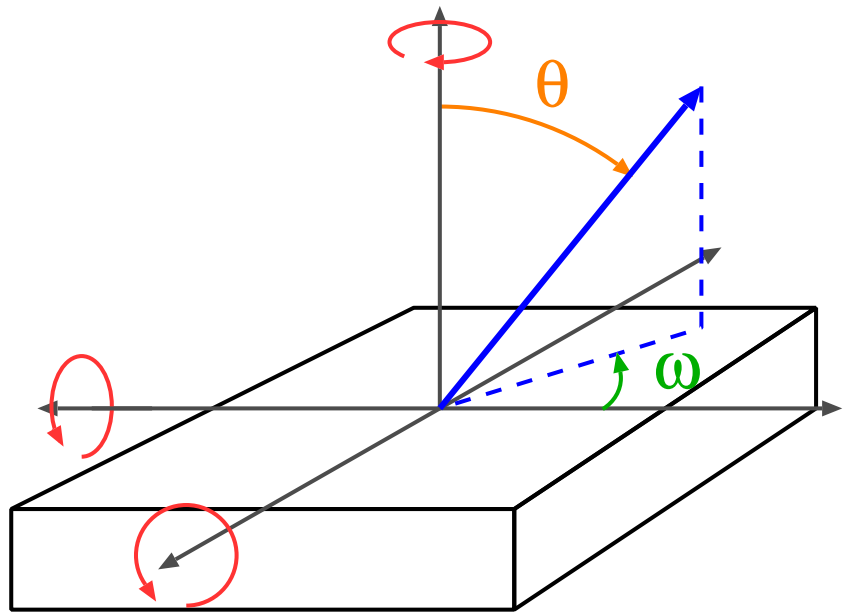

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the electron dispersion curve can be fully mapped by sample rotations

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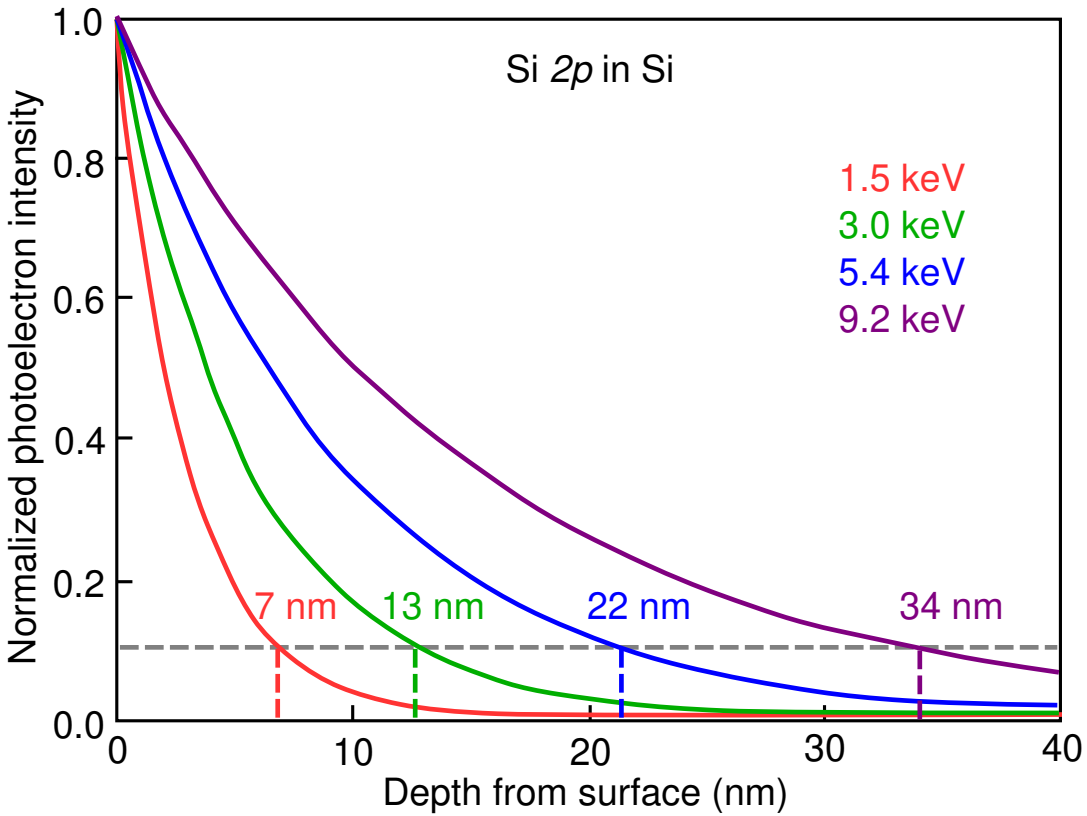

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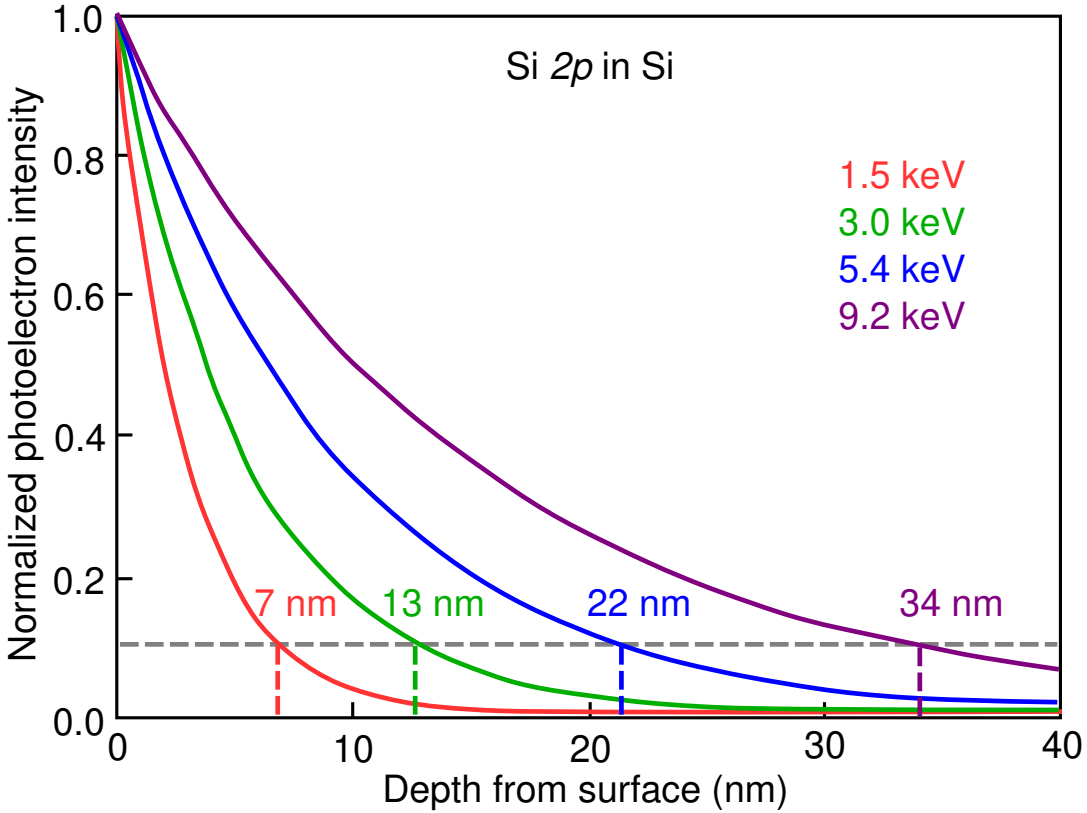

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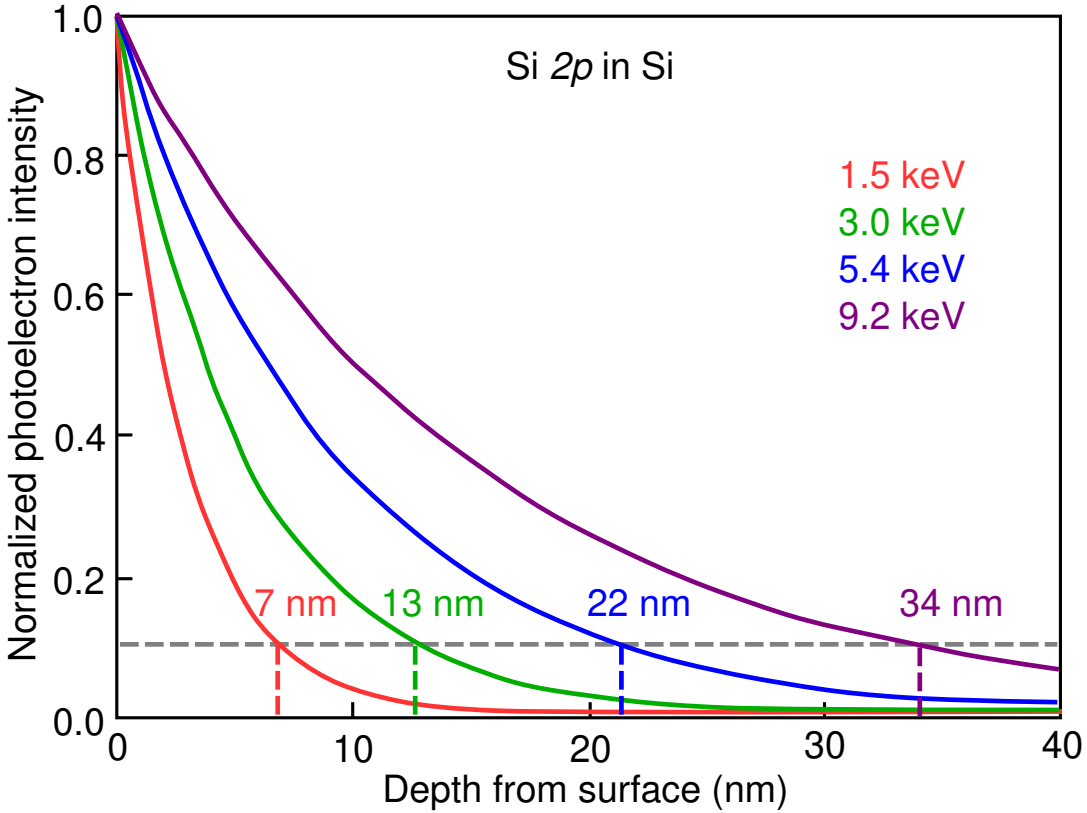

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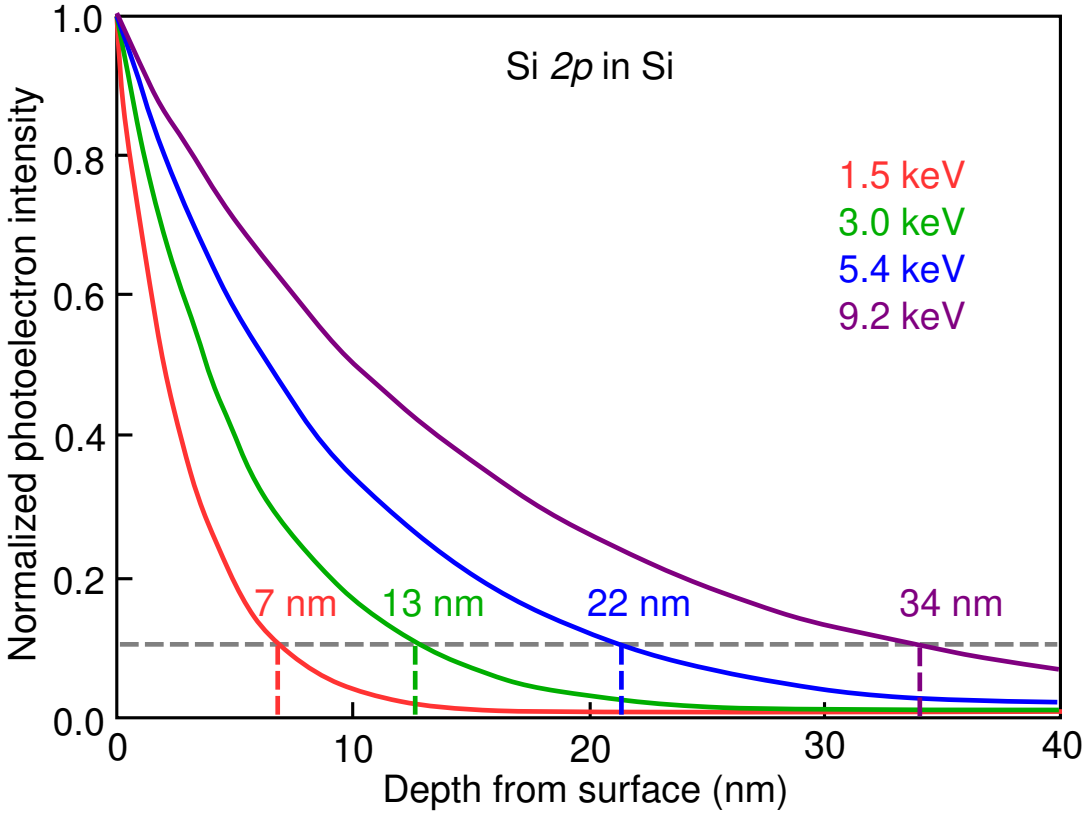

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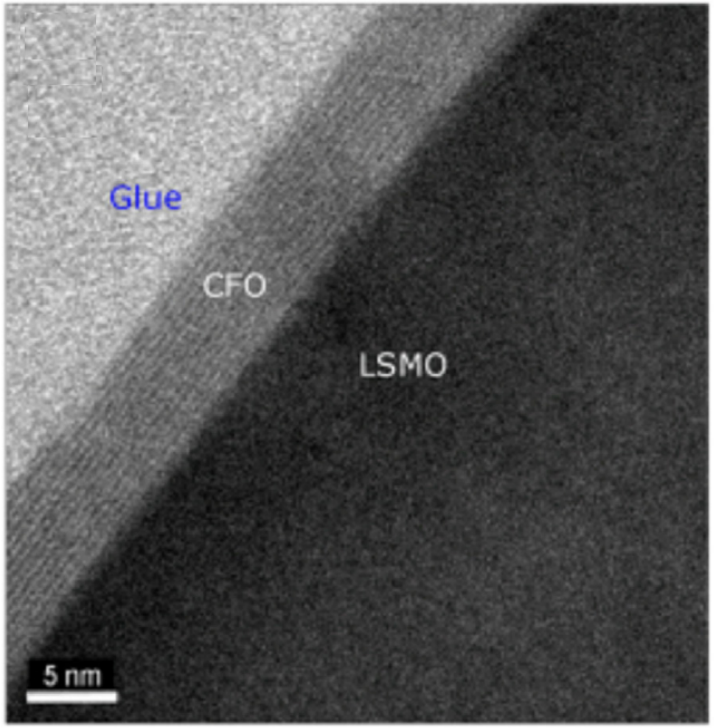
ability to measure bulk photoemission and buried interfaces as well as the surface

HAXPES of buried interfaces

HAXPES is used to probe the thickness of a $CoFe_2O_4/La_{0.66}Sr_{0.34}MnO_3$ heterostructure by varying both angle of incidence and photon energy



The thickness of the $CoFe_2O_4$ overlayer measured as 6.5 ± 0.5 nm by TEM was probed in two ways:

B. Pal, S. Mukherjee, and D.D. Sarma, "Probing complex heterostructures using hard x-ray photoelectron spectroscopy (HAXPES)," *J. Electron Spect. Related Phenomena* **200**, 332-339 (2015).

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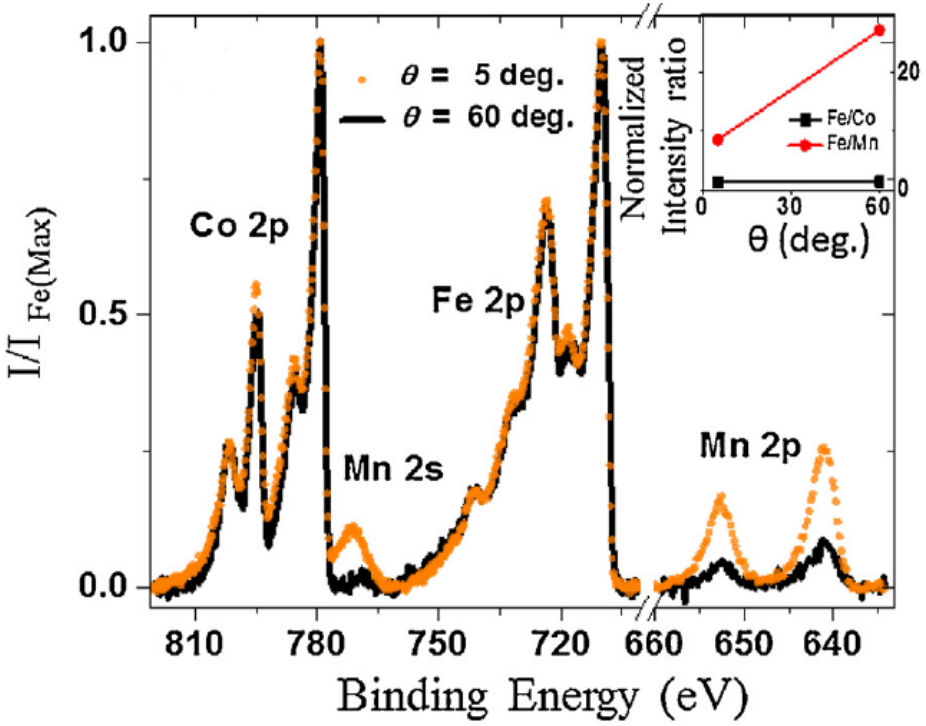

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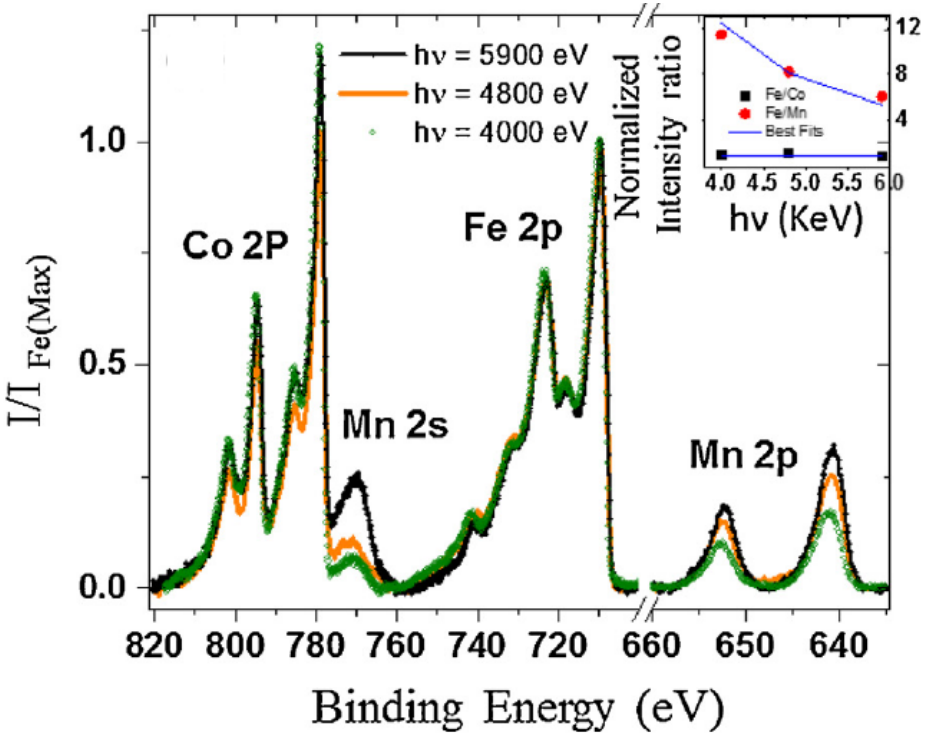

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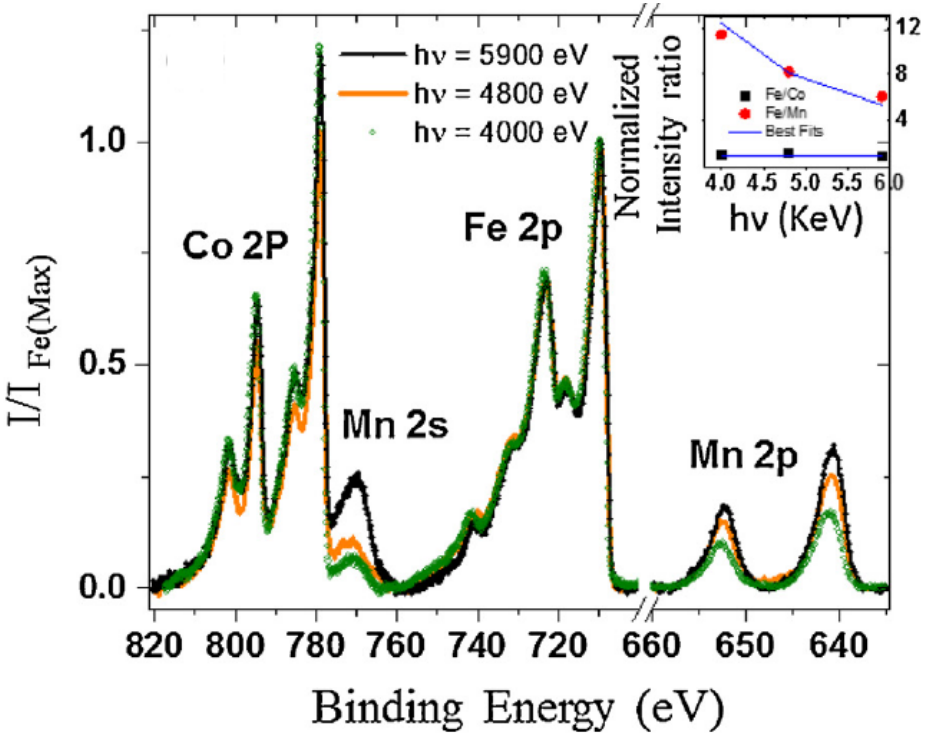
using photon energies from 4.0 keV to 6.0 keV, the thickness was estimated to be 6.8 ± 2.8 nm

B. Pal, S. Mukherjee, and D.D. Sarma, "Probing complex heterostructures using hard x-ray photoelectron spectroscopy (HAXPES)," *J. Electron Spect. Related Phenomena* **200**, 332-339 (2015).

HAXPES of buried interfaces

HAXPES is used to probe the thickness of a $CoFe_2O_4/La_{0.66}Sr_{0.34}MnO_3$ heterostructure by varying both angle of incidence and photon energy



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Both results give consistent results with proper normalization and also show the uniformity of the $CoFe_2O_4$ overlayer

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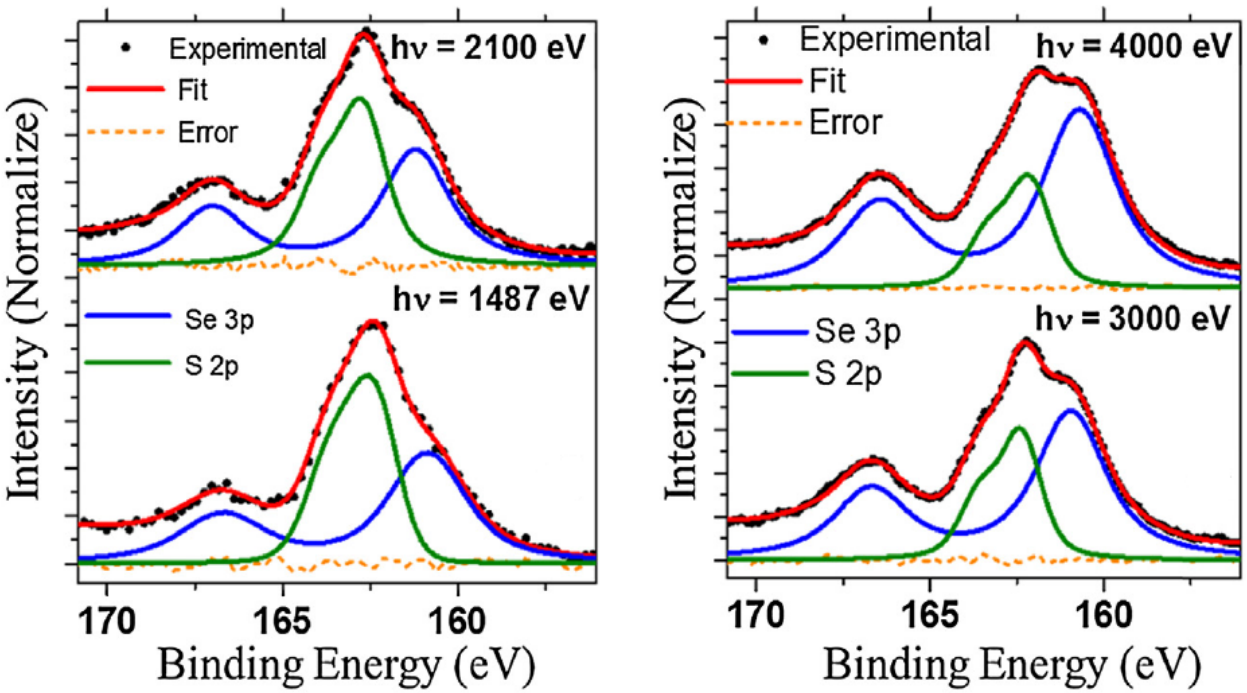
HAXPES of $Zn_{1-x}Cd_xSe_{1-y}S_y$ nanocrystals

With nanoparticles, energy dispersive measurements can provide depth profiling of spherical nanoparticles



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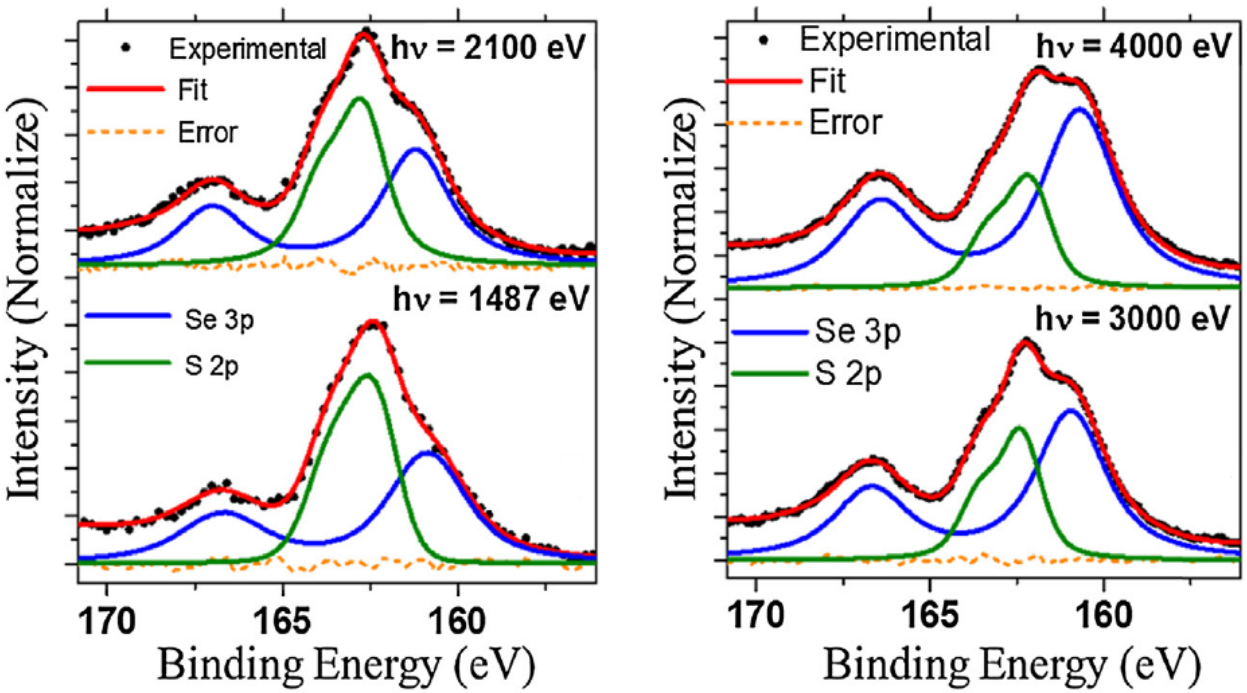

HAXPES at energies ranging from 1.4 keV to 3.0 keV are used to probe the S/Se ratio at varying depths of the 5 nm diameter nanoparticles

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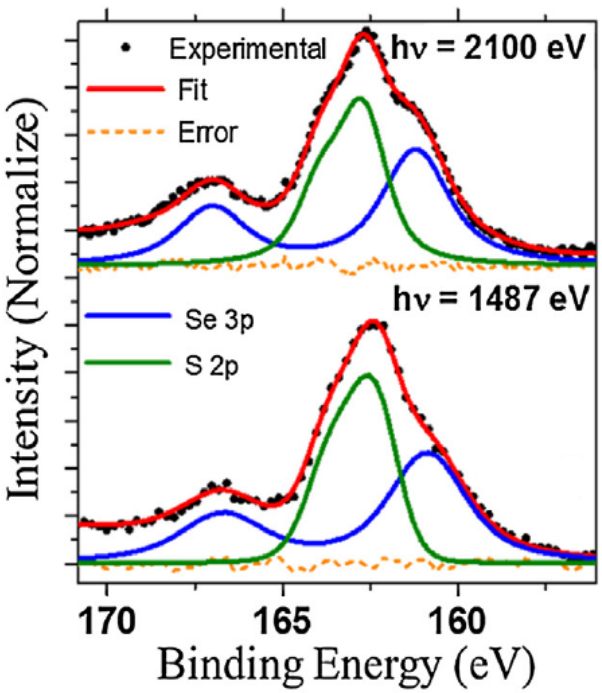

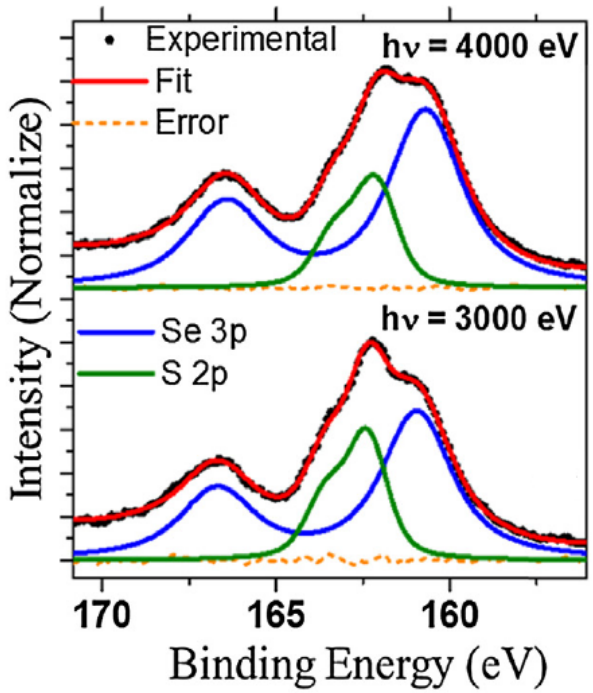

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By fitting the S $2p$ and Se $3p$ photoemission line the structure is revealed to be CdSe at the core and ZnCdS in the outer shell

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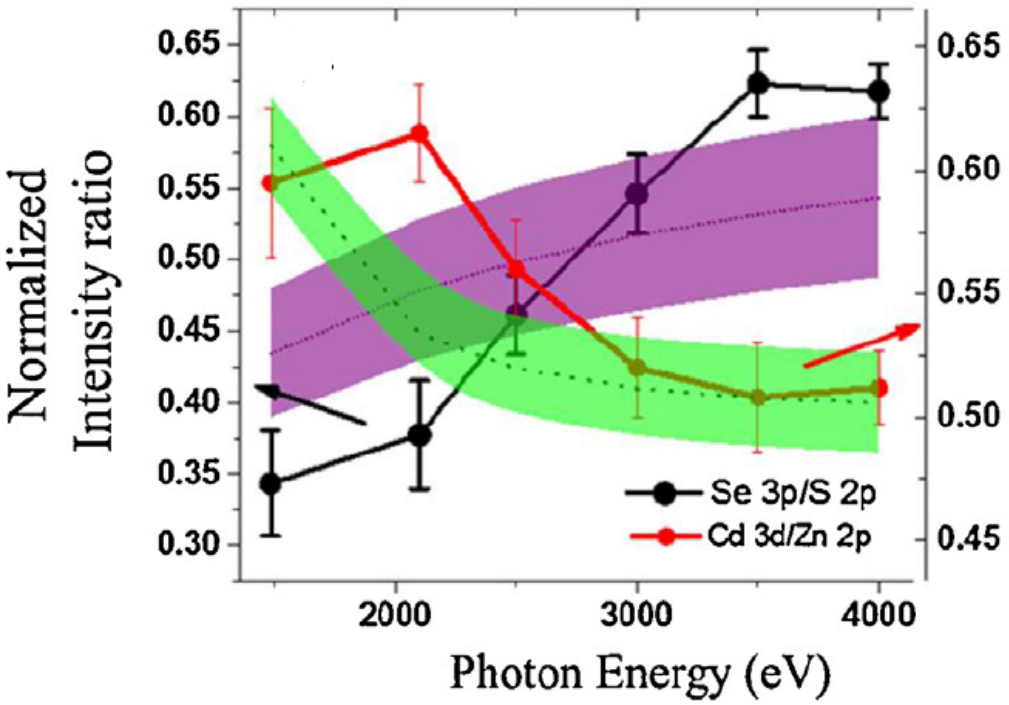

The variation in intensity of the Se/S lines and the Zn/Cd lines suggest that the Se is primarily located in the 2 nm core of the 5 nm particles with the Cd

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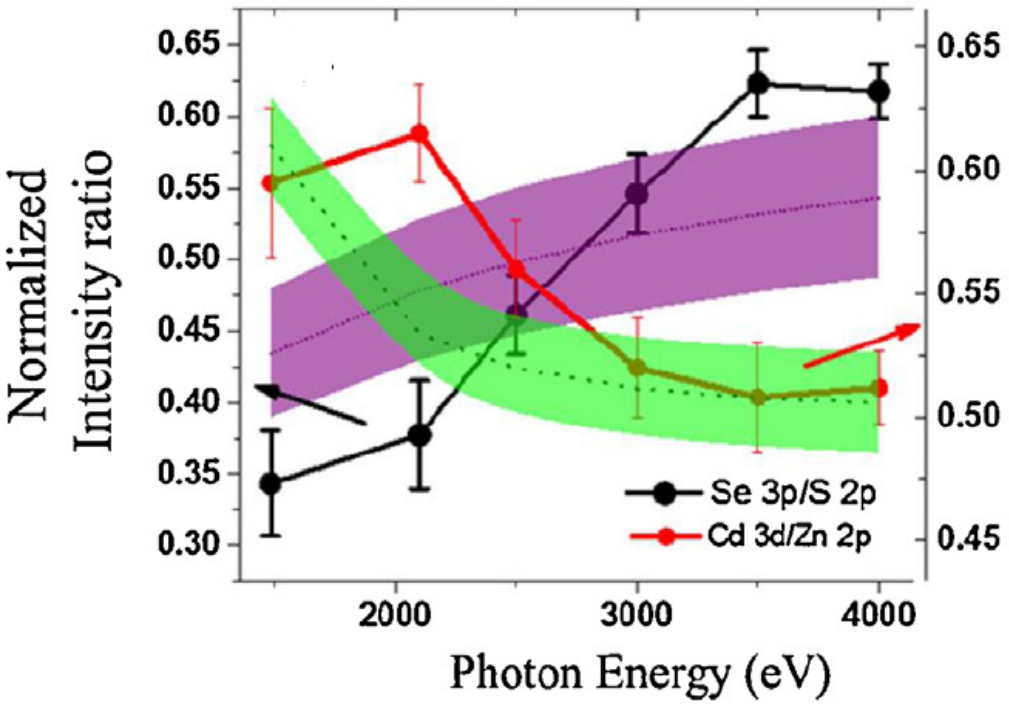

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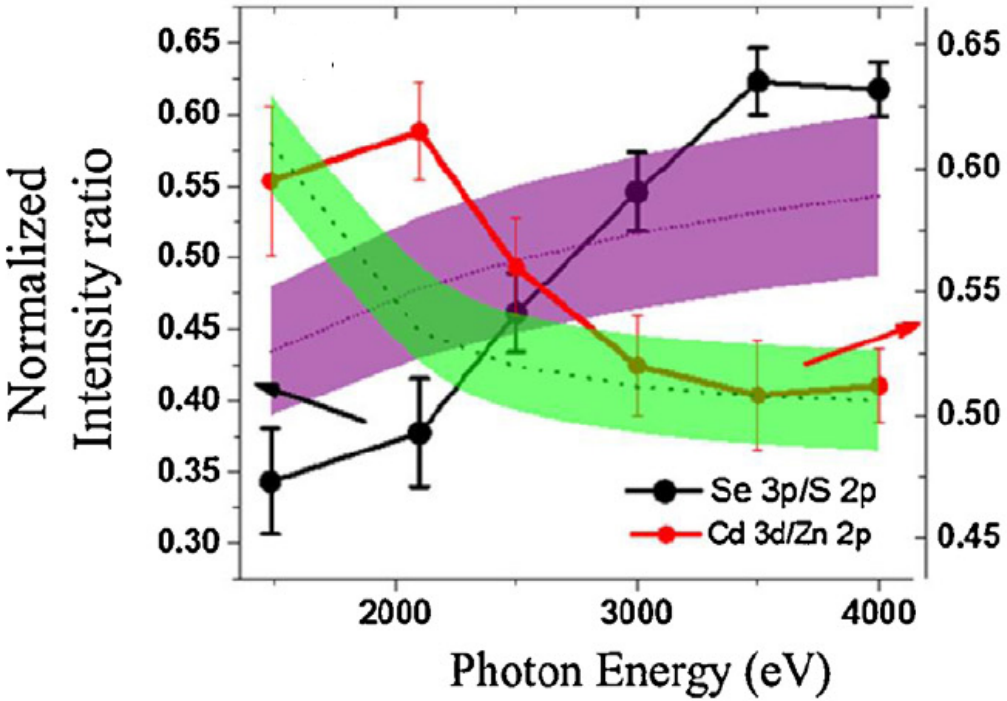

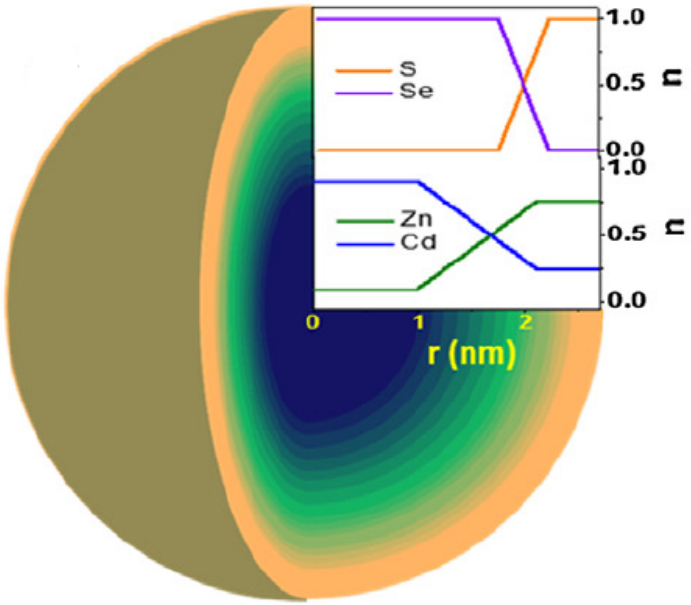

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HAXPES of Si anodes

Si nanoparticle anodes suffer from the accumulation of the SEI layer which reduces performance. The SEI is formed by electrochemical decomposition of the electrolyte at the anode surface.

B.T. Young, et al., "Hard x-ray photoelectron spectroscopy (HAXPES) investigation of the silicon solid electrolyte interphase (SEI) in lithium-ion batteries," *ACS Appl. Mater. Interfaces* **7**, 20004-20011 (2015).

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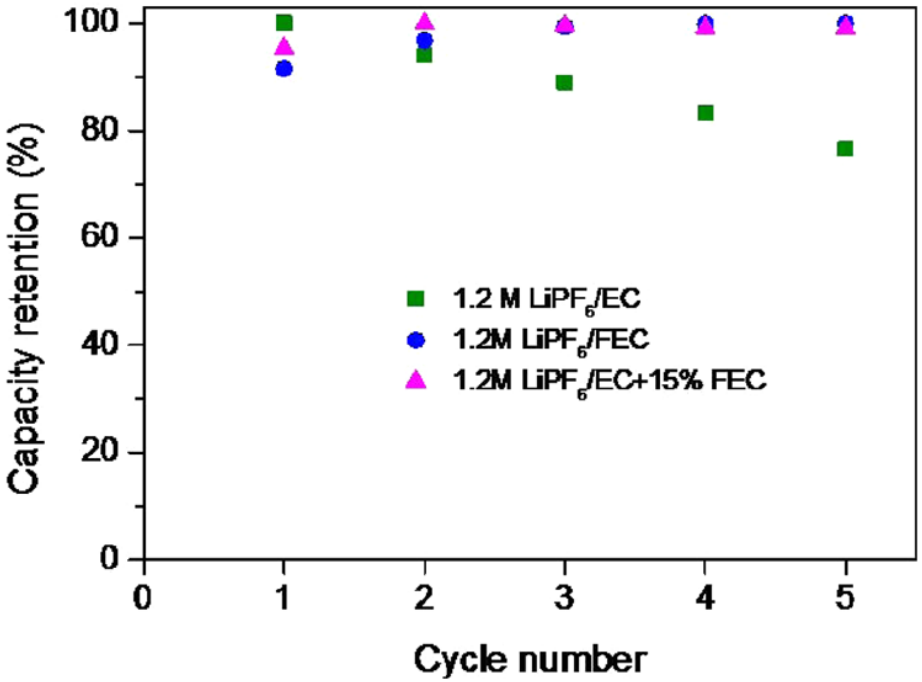

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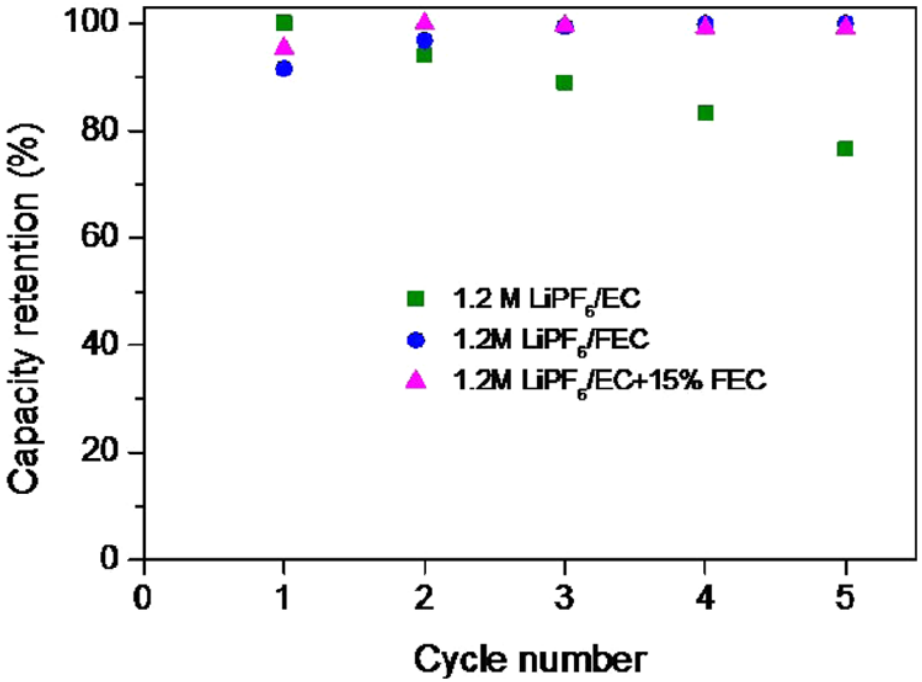

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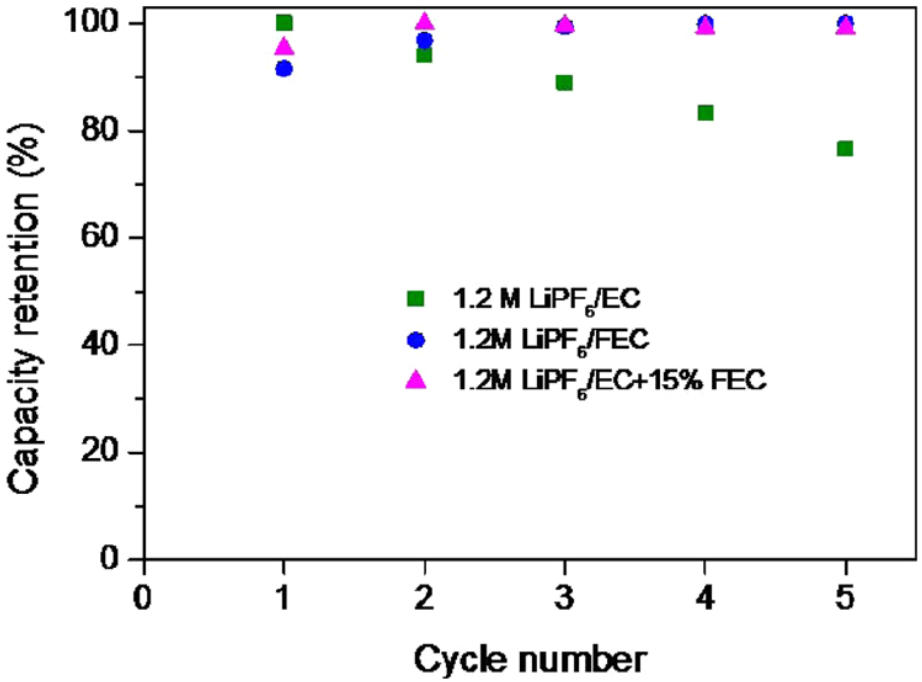

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HAXPES is used to determine the elemental distribution and compounds present as a function of depth in the cycled Si anode.

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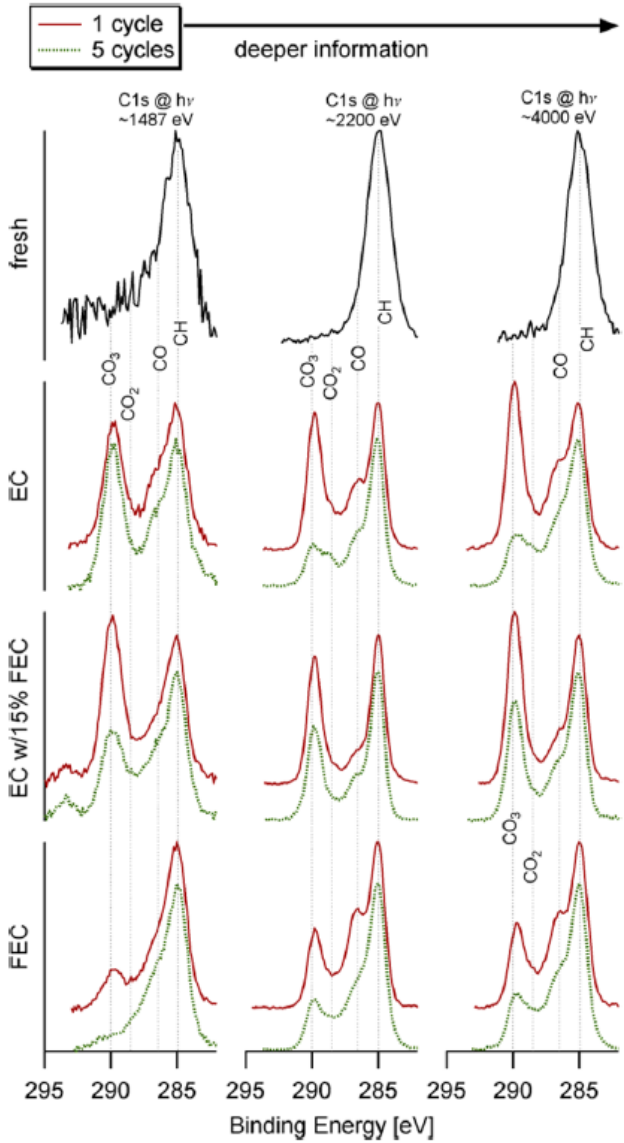

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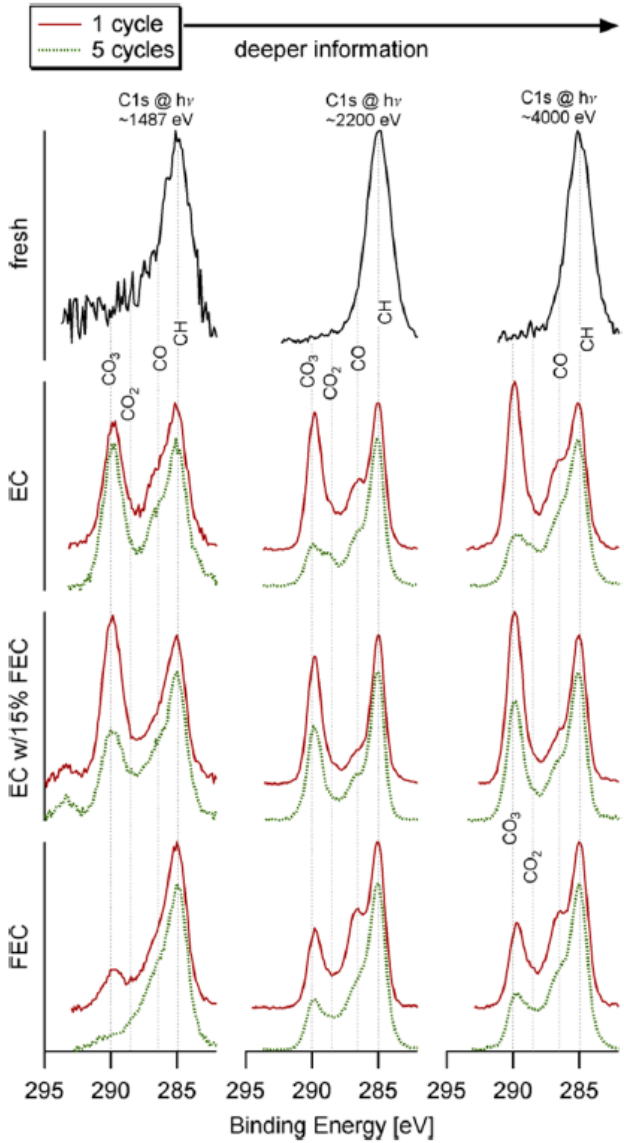

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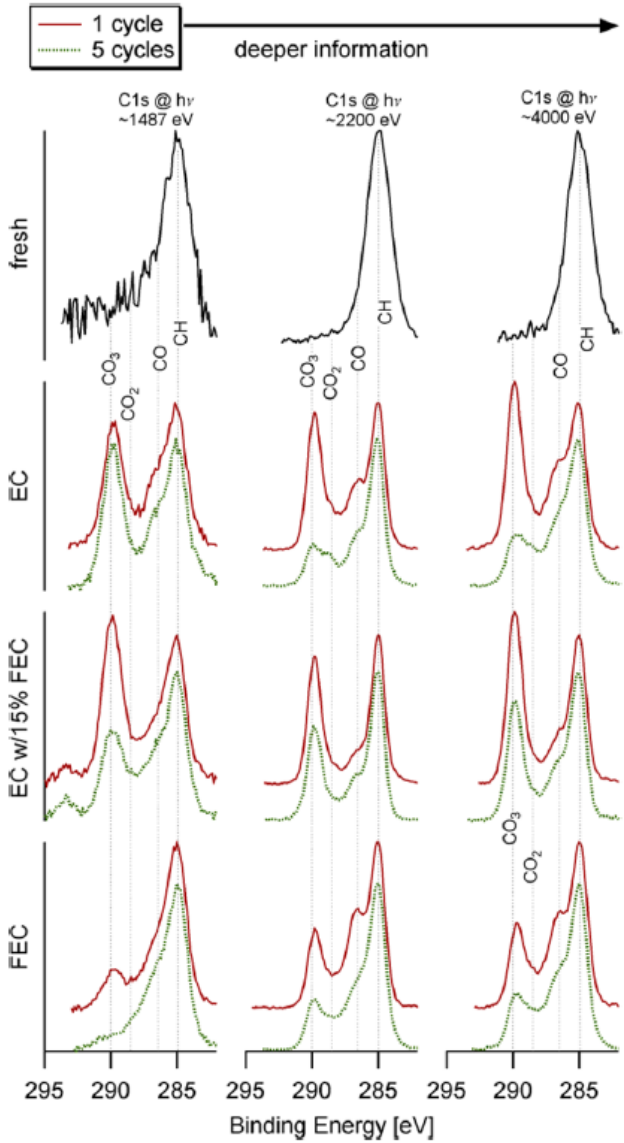

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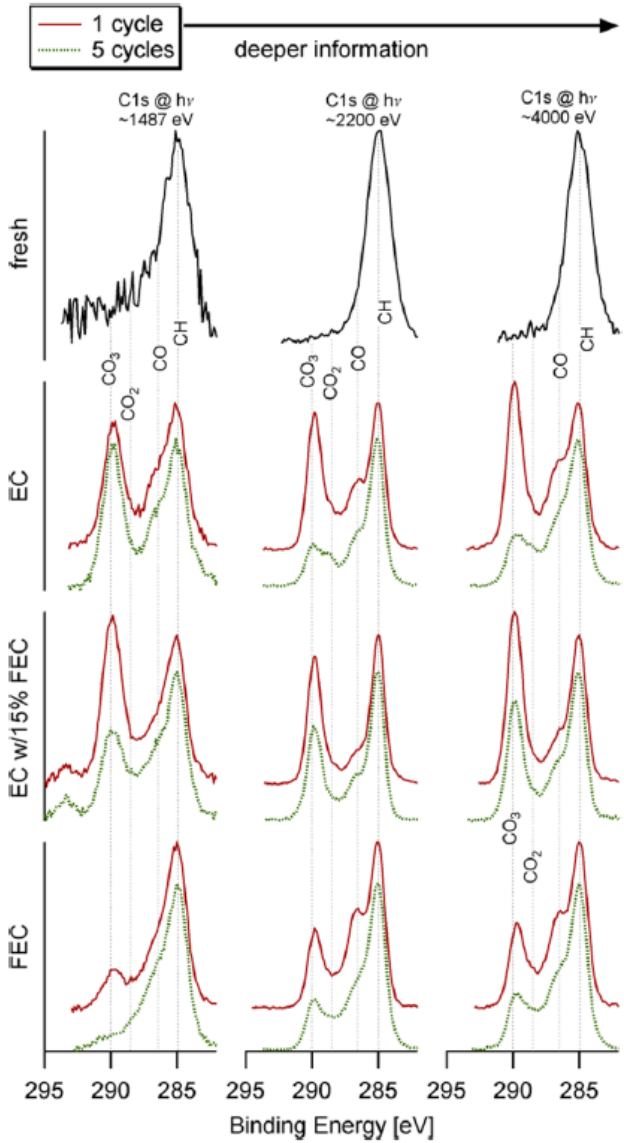

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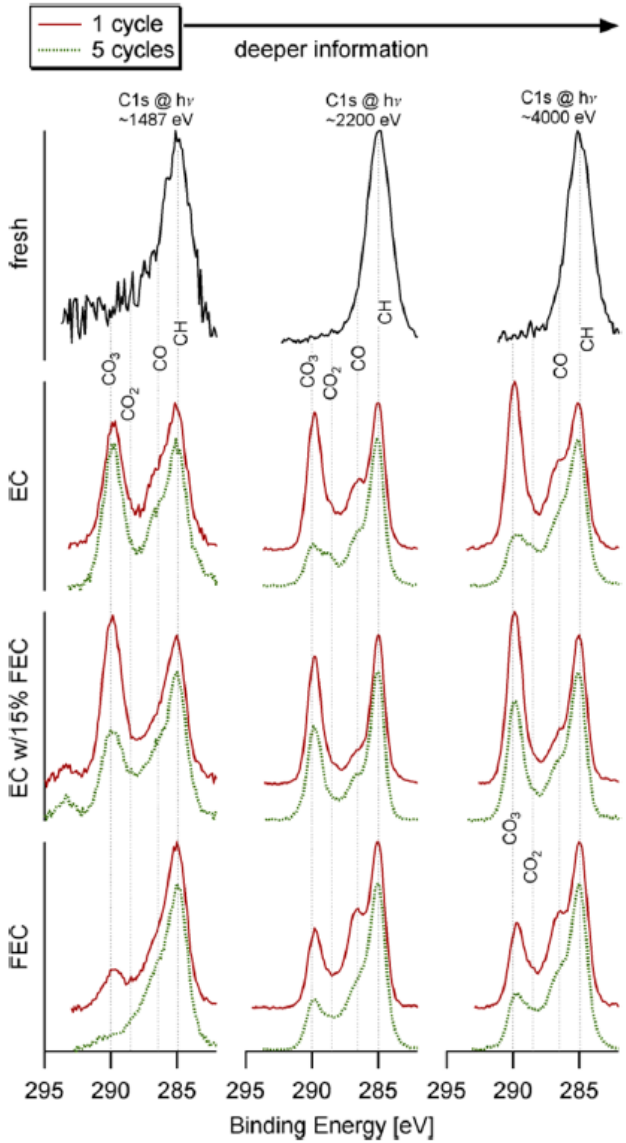

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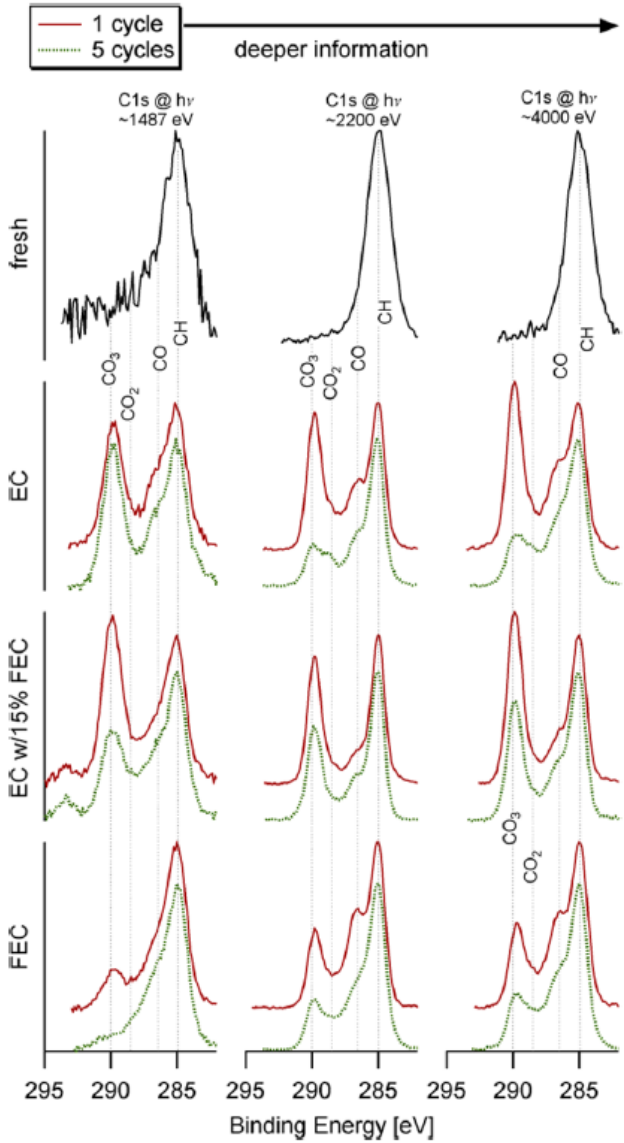

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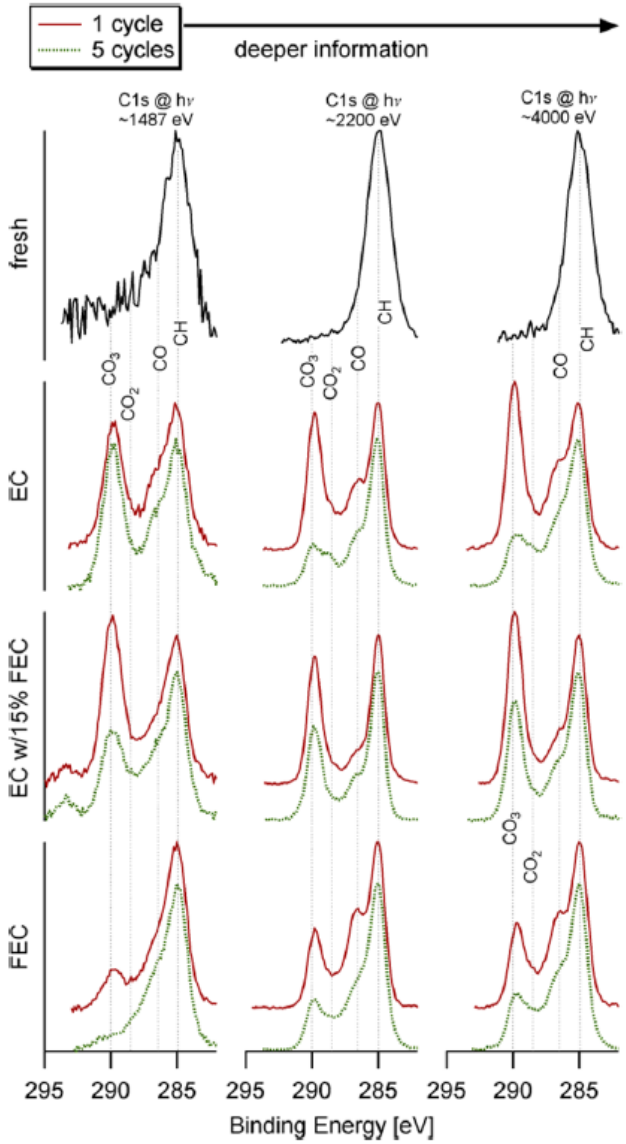

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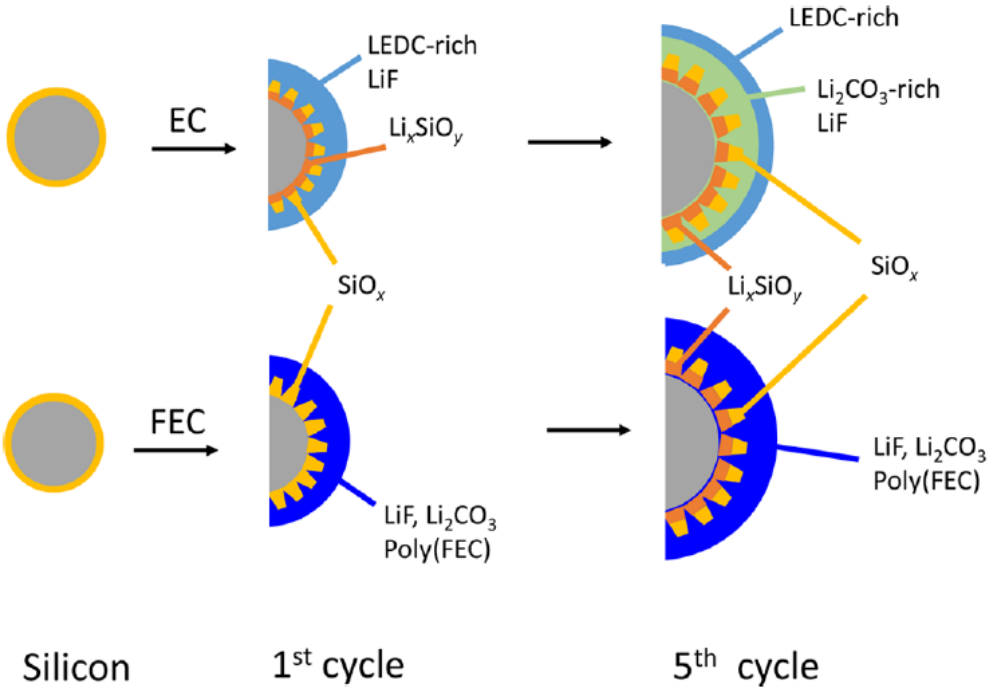

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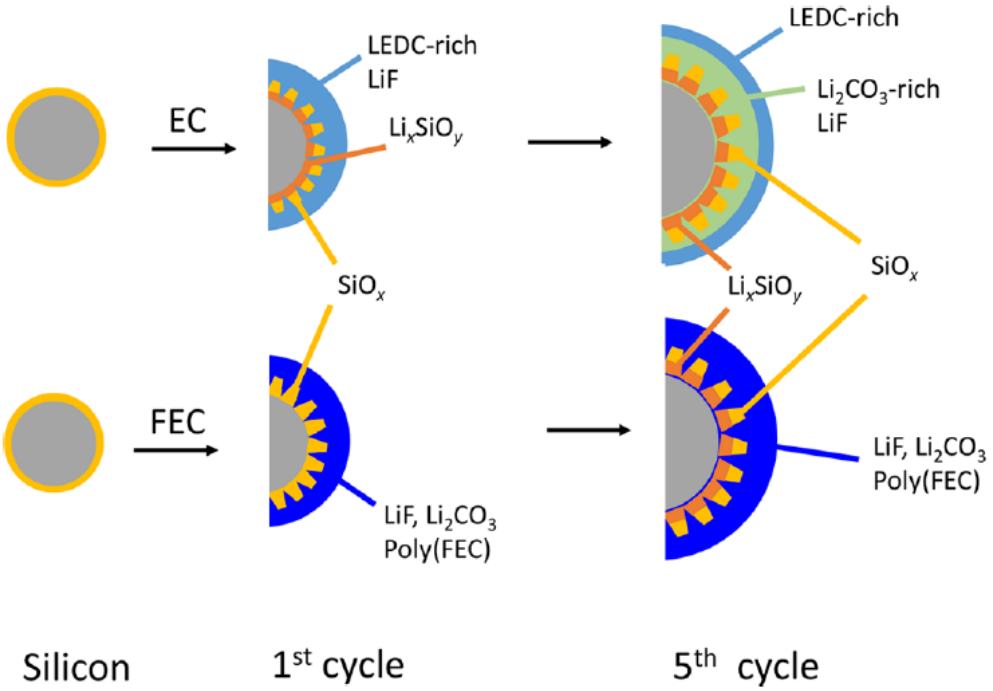

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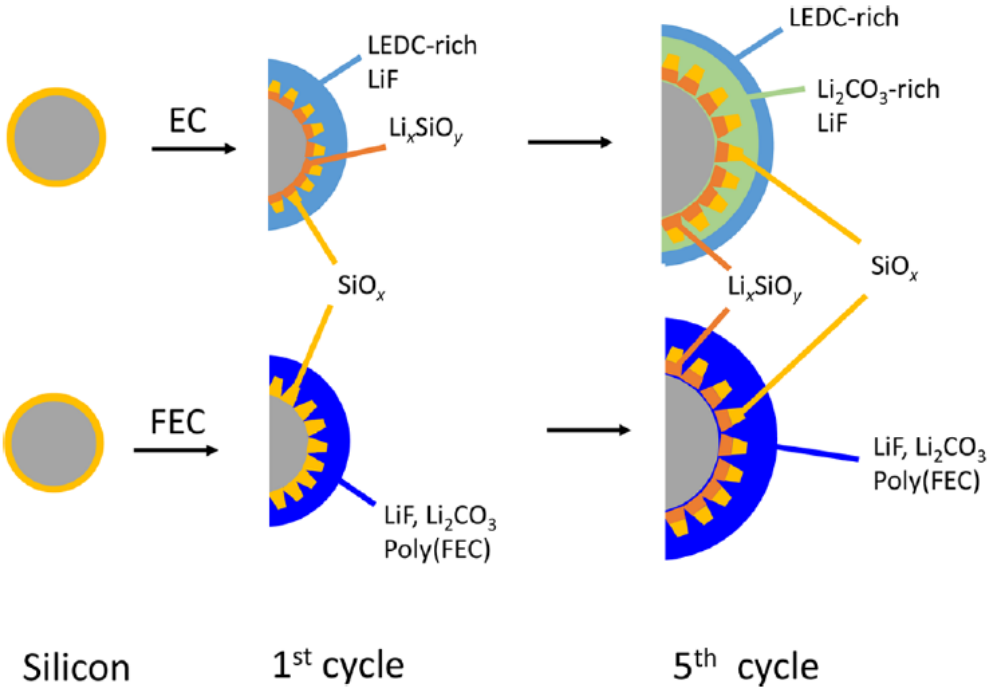

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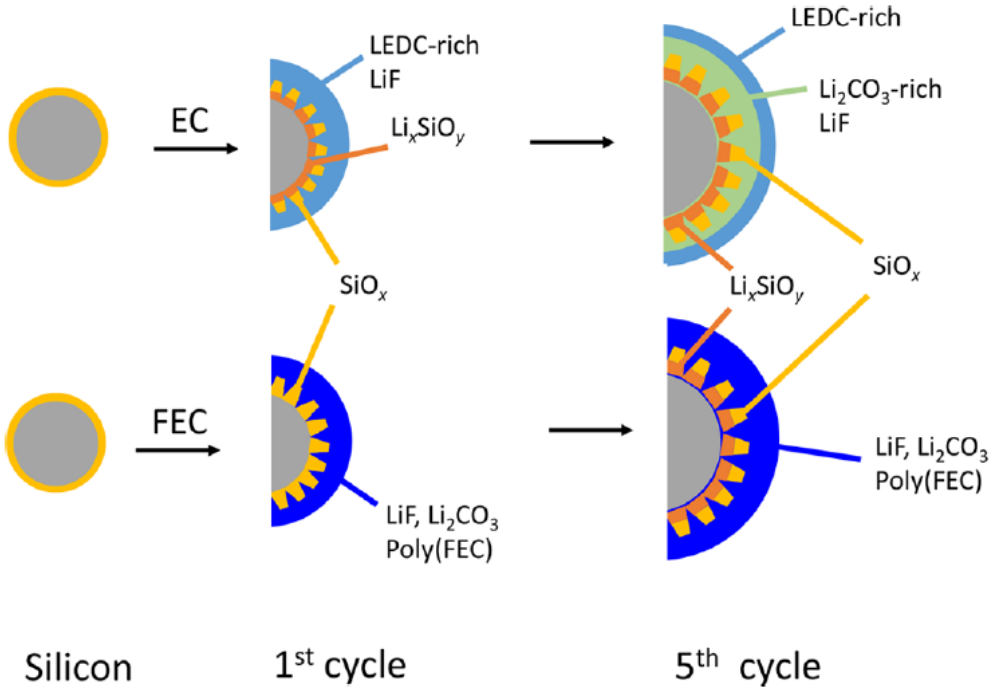

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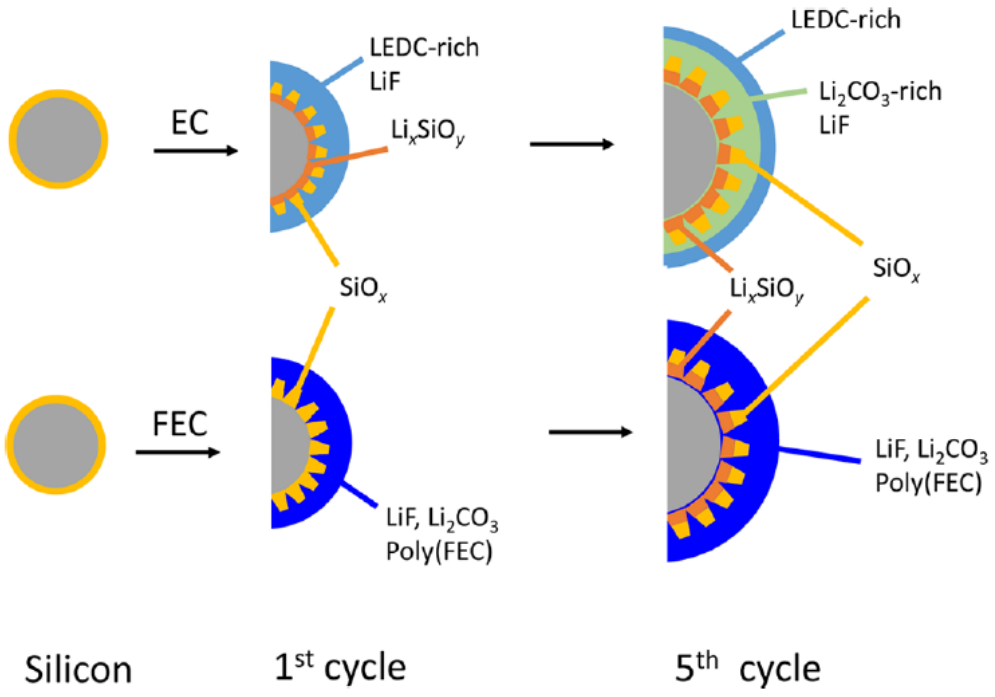

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Official schedule: Tuesday, May 5, 2020 – 17:00-19:00
Proposed schedule: Tuesday, May 5, 2020 – 15:00 CDT

Final projects & presentations

In-class student presentations on research topics

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- Choose a research article which features a synchrotron technique

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