Initial thoughts on photoemission for electron clouds at CesrTA

K. Harkay, L. Boon, A. Garfinkel

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Annotated with notes from discussions during presentation

Photoemission characteristics we're looking for

- As a function of absorbed photon energy and incidental angle, we want to know the
  - Probability of photoelectron emission
  - Photoelectron energy: a combination of primaries and secondaries
- Surface science field provides datasets for X-ray and UV photoemission spectroscopy for numerous elements (e.g. Casa XPS file from Jim C.)
  - They don't care about the emitted low-energy valence electrons (photons near work function) or about the low-energy secondaries that are always also emitted on photon illumination
  - Data often for monochromatic x-ray source – we have broadband
  - Photoemission from grazing-incidence photons is highly surface-sensitive – angle-resolved photoemission spectroscopy

Photoemission characteristics we're looking for (cont)

- Photon scattering can also involve fluorescence whereby the photon is reemitted at a lower energy – characteristic of the surface material
  - If this effect is important, then the absorbed photons can have lower energy and thereby have a higher probability for photoemission
- Useful website (thanks to Laura) for databases for XPS and fluorescence: http://www.uksaf.org/home.html

Schematic photoemission spectra vs photon energy

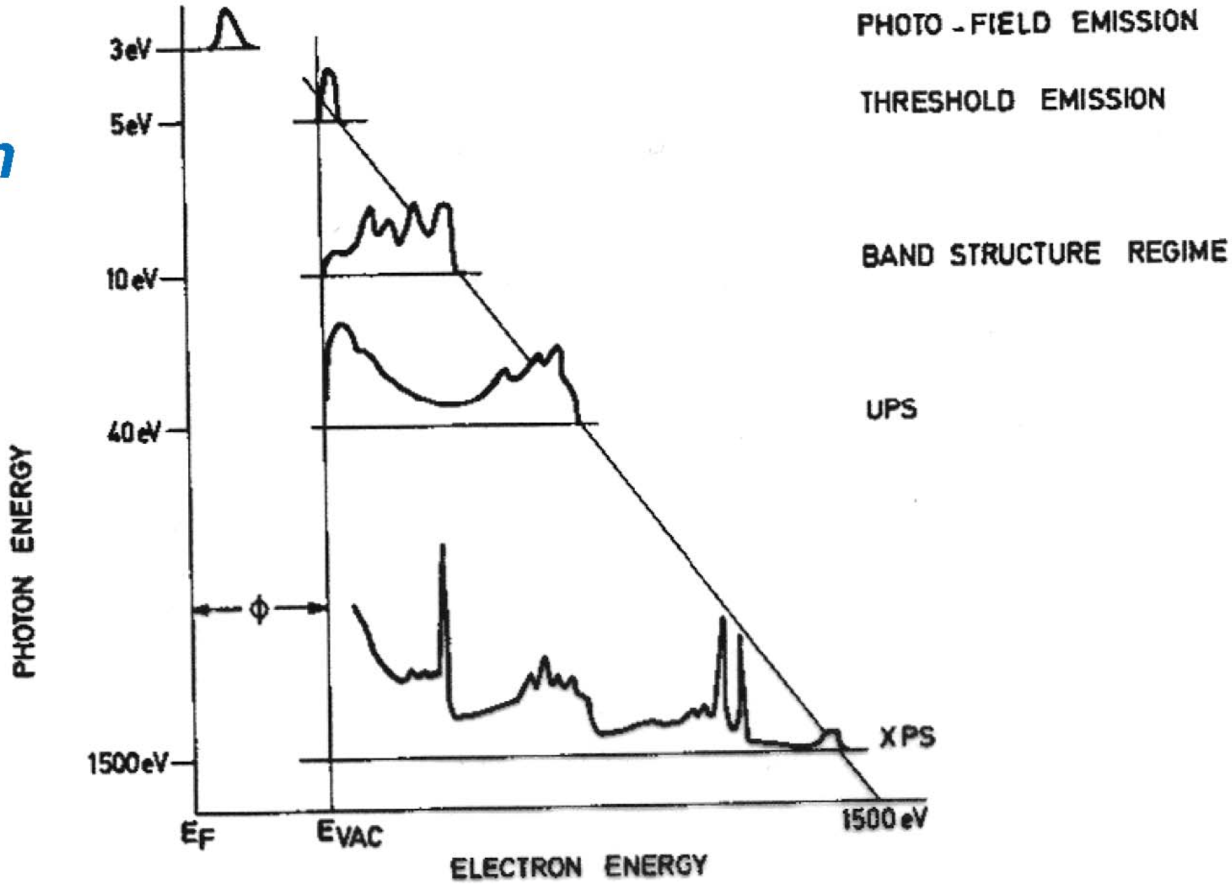
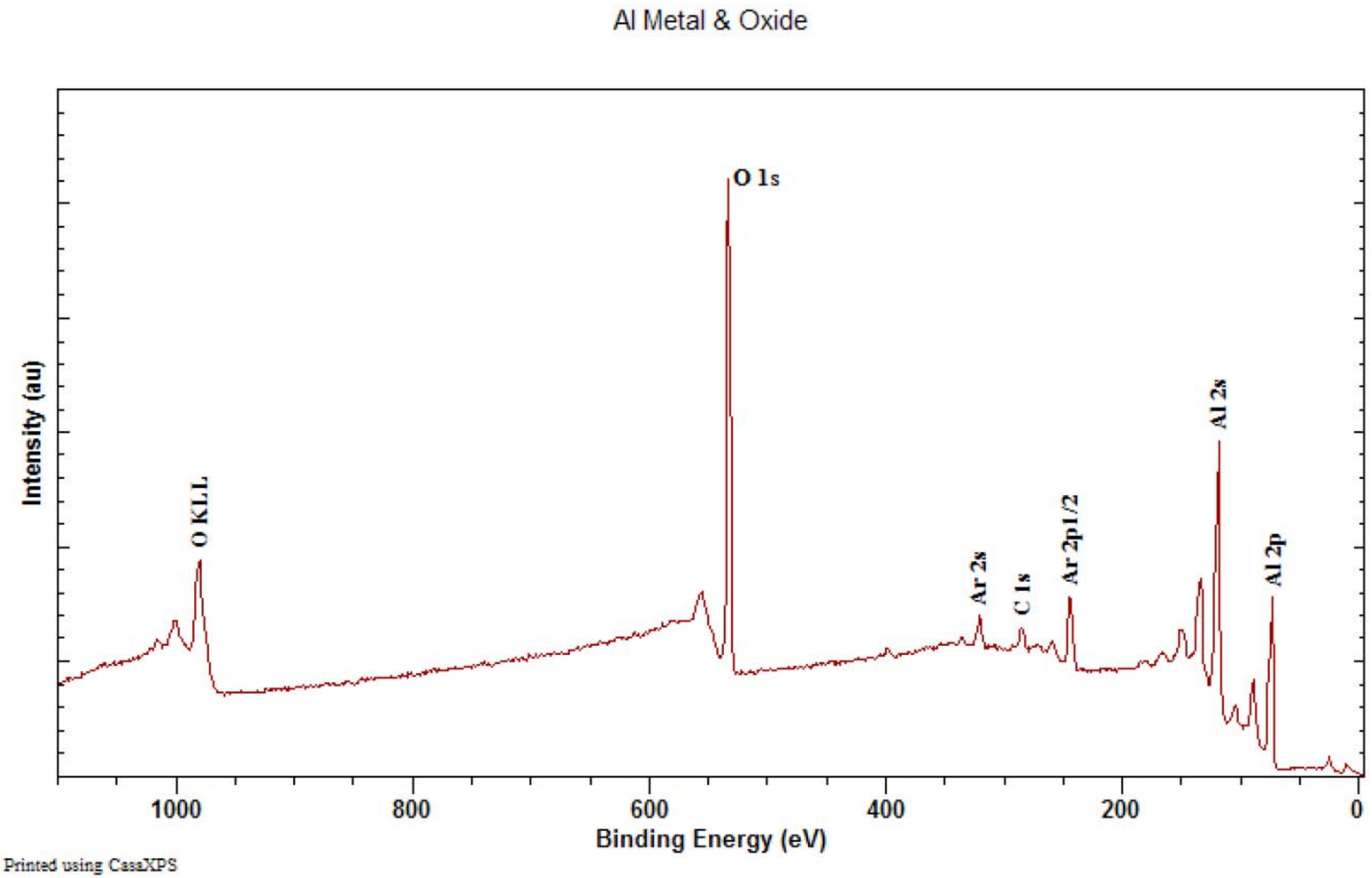


Fig. 5.3 Energy ranges and specialized spectroscopies in photoemission. XPS, excited by soft X-rays, shows spectra of considerable complexity including core level spikes, Auger peaks, valence-band emission and inelastic electrons. UPS has an intrinsically higher resolution and cross section for the valence band. The bandstructure regime, $\hbar\omega \approx 10$ eV, shows sharp structure arising from bulk selection rules. Threshold emission is generally observed without energy analysis. Subthreshold spectroscopy requires additional means to emit photoexcited electrons over the work function barrier ϕ, such as, e.g.,a high electric field

Figure credit: B. Feuerbacher and B. Fitton in "Electron Spectroscopy for Surface Analysis," p. 155 (Springer-Verlag, Berlin, 1977). With kind permission of Springer Science+Business Media.

See also: R. Cimino et al., "VUV photoemission studies of candidate LHC vacuum chamber materials," PRST-AB 2, 063201 (1999).

Reference from Jim Crittendon. Surface-sensitivity of grazing-incidence means we can focus our attention on aluminum oxide Al_2O_3.



Again, metallic aluminium is responsible for the sequence of plasmon loss peaks associated with the Al 2p and Al 2s photoelectric lines not present in the aluminium oxide spectrum. It is worth observing the argon from the ion gun used to reduce the depth of the aluminium oxide layer exhibits plasmon loss structures characteristic of the aluminium metal. Note also that the plasmon loss peaks from the Al 2p transition will interfere with the Al 2s peak, hence the common practice of using the Al 2p line to quantify samples containing aluminium.

Effect of grazing-incidence photon – photoemission spectrum strongly influenced by surface oxide layer

Charles Fadley, “Angle-resolved x-ray photoelectron spectroscopy,” Progress in Surface Science, VOl 16, p 275-388 (1984).

Angle-Resolved X-ray Photoelectron Spectroscopy

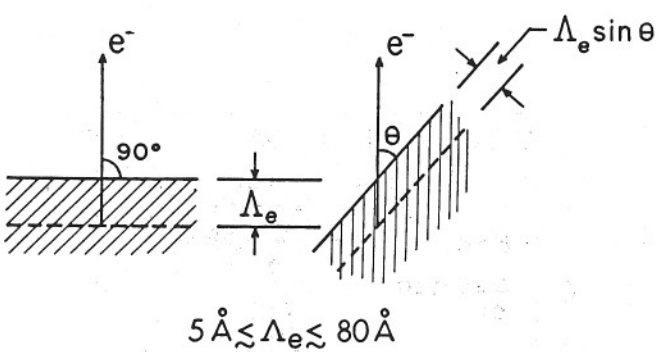


Fig. 5. Illustration of the basic mechanism producing surface sensitivity enhancement for low electron exit angles θ. The average depth for no-loss emission as measured perpendicular to the surface is $\Lambda_e \sin\theta$.

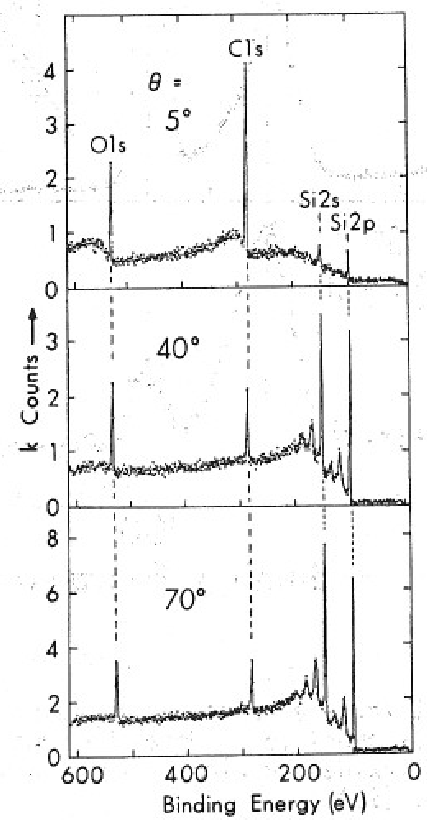


Fig. 6. Broad-scan core-level spectra at three electron exit angles between low and high values for a Si specimen with a thin oxide overlayer (~4Å) and an outermost carbon contaminant layer approximately 1 monolayer in thickness. Note the marked enhancement of the surface-associated O1s and C1s signals for low θ.

Notes added from discussion (also post-discussion*)

- Secondary electron component of the photoemission process clearly observed in R. Cimino et al., PRST-AB 2, 063201 (1999).
- DAPHNE paper [EUROTEV-REPORT-2005-013]
  - Exp. data from Elettra on photon reflectivity and photoelectron yield for photon energies 10-1000 eV – used by Gerry Dugan for synrad3d
  - Photoelectron energy distributions are not included
- ALS should be a good source for XPS and ARPES data at a synchrotron
- Possible fits to the photoemission energy distribution: Bi-gaussian does not work well (Jim Crittendon). Post-discussion*:
  - Cimino paper gives a Lorenztian fit to the Cu white light photoemitted electron energy distribution curves (Fig. 15 in reference given above)
  - APS RFA energy distribs. fit well to Lorentizian for widely-spaced bunches [K. Harkay et al., Proc 2003 PAC, 3183].
- TBD
  - What is the time scale for fluorescence?
  - What references were used for the photoemission distribution in posinst (M. Furman and M. Pivi)?