CHEMISTRY 448/548 Winter 2009

Assignment #4 (20 pts)

Due Feb. 20th

SHOW WORKING FOR FULL CREDIT AND ALL WORK MUST BE NEAT AND READABLE OR YOU WILL LOSE POINTS !

1. How thick a layer of Al would one need to reduce the yield of a 1186 eV Auger electron from an underlying Mg subtrate by 90%? (10 pts)
HINTS : i) use Fig. 2.20 in the text to estimate the mean free path of the Mg Auger electron
ii) remember the mean free path actually represents the depth at which the probability of escape is (1/e). Use this fact to estimate the thickness of Al needed to suppress the Mg Auger signal by 90% - keep this simple, no integrals.

Solution :

i) estimating the mean free path from Fig 2.20 is complicated by the log-log scale and the scatter in the plot. For Mg Auger electrons (1186 eV) we can estimate that they travel through the Al with a mean free path of about 1.5 +/- 0.2 nm

ii) consider an Al layer that is one mean free path thick (1.5 nm)

Al 1.5 nm

Mg

The Auger signal from electrons that start from the top of the Mg layer and traverse 1.5 nm of Al will have a probability of (1/e) = 0.368 or 36.8% of emerging from the Al surface. In 3.0 nm the probability will be (0.368)x(0.368) = 0.135 or 13.5%. This is slightly less than a 90% reduction. So in 3.0 nm of Al or a little more, the Mg Auger signal will be reduced by about 90%.

or in a more quantitative way

For an Al layer that is n mean free paths thick the Mg Auger signal will be reduced to a $(1/e)^n$ of its original strength So for a 90% reduction we want

$0.10 = (1/e)^n$ or $n = \log(10) = 2.30$

And the depth corresponding to this is 2.30 x 1.5 = 3.4 nm

2. Imagine performing an XPS experiment on $TiSi_2$. The intensity of a photoelectron peak from a particular atom X in the XPS spectrum will depend upon the photon flux (F), the atom concentration (C_x) and the cross-section for photoionizing the photoelectron in question (σ_x).

$$I_x = F \times C_x \times \sigma_x$$

The cross-section for X-rays of frequency ν is related to the binding energy of the photoelectron from X by :

$$\sigma_x = (7.5 / h\nu) (E_B (X) / h\nu)^{5/2}$$

a) what would be the kinetic energy of the photoelectrons generated by 1490 eV Al X-rays for Ti and Si 2p electrons with binding energies of 453 and 102 eV respectively? (5 pts)

Solution :

The photoelectric equation is

$E(kin) = h\nu - E_B$

So for $h\nu = 1490$ eV

Signal	**E_B (eV)**	**E(kin)**
Ti 2p	453	1037
Si 2p	102	1388

b) what ratio of Ti(2p) / Si(2p) peak heights would you expect from a $TiSi_2$ surface (assume surface stoichiometry is the same as bulk)? (5 pts)

Solution :

The peak height for an element (actually it is better to use the area) will depend on the product

(photon flux) x (atom conc) x (cross-section)

The photon flux is the same for both elements, and the cross-sections differ only in the values of the binding energies

$\sigma = (7.5 / h\nu)(E_B / h\nu)^{5/2}$

The mean free path of the photoelectrons (~ 1000 eV kinetic energy) will be ~ 1.5 nm. So the XPS signal will be averaged over a depth of 2 nm or more. Assuming no massive segregation or depletion at the surface, the peak intensities shoudl reflect the bulk stoichiometry of $TiSi_2$ and will be

Ti 2p / Si 2p = σ (Ti 2p) / 2 σ (Si 2p) = $(453 / 102)^{5/2} / 2$

= 20.8 (pretty high!)