MTS 723 F97 November 6, 1997

Homework 4

1. This objective of this problem is to determine the current density of a thermionic emitter (thoriated W filament). Note that equations for current densities given in Briggs and Seah give answers in units of A/cm^2 sr (ie, per unit solid angle of view).

a. A thoriated W filament has a work function of 2.5 eV. It operates at 2500 ^oC. Determine the theoretical maximum current density we can expect (in A/cm^2 sr) using the Richardson equation.

b. If the filament becomes coated with C, its work function increases to 4.0 eV. By what factor does the current density change? What temperature would we have to use to recover the current density of the clean filament? Significant weakening of metals occurs above about 2/3 their melting point. Is the carbon coated filament safe to use?

2. The objective of this problem is to compare the acceptance efficiency of a CMA with that of an HSA. Both analyzers only accept a fraction of the total number of electrons emitted from a surface. Assume that the intensity of photoemission from a surface is independent of angle relative to the surface normal and that the event is a point source of electrons.

a. Prove that a CMA "sees" a factor of $2 \sin(\alpha)\ \delta\alpha$ of the total number of electrons emitted from a sample, where α is the input angle and $\delta\alpha$ is the half angle of acceptance into the analyzer. Also, show that an ideally designed CMA with a half angle of acceptance of 6^o accepts about 14% of the emitted electrons from a sample that is placed in front of it and is perpendicular to the axis of the CMA.

b. The HSA has an acceptance angle, θ, defined as the semi-angle at the apex of a cone that is seen by the front lense to the analyzer. Prove that the transmission (the fractional amount of the total emitted electrons the analyzer "sees") of an HSA is equal to $(1 - \cos(\theta))$ (this formual agrees with that given in Briggs and Seah for an HSA where the lens defines the transmission for AES). What is the transmission of an HSA with a nominal half angle of acceptance of 15^o?

3. The objective of this problem is to design a CMA. We want it to have the following specifications:

> the half angle of acceptance at the input should be 5^o
> the CMA must fit comfortably through a flange with a 10 cm inner radius

a. What would you propose for the outer radius, inner radius and distance between sample and focal point for your CMA?

b. What is the energy minimum energy resolution we can expect from your CMA?

c. What voltage difference is needed in your CMA between the inner and outer cylinders to focus electrons that have a kinetic energy of 500 eV?

4. The objective of this problem is to analyze XPS survey spectra. The attached spectra are four survey scans from material A through D. One or more of the spectra contain "ghost" peaks.

a. Identify the elements associated with all the peaks. Label all the peaks according to their orbital. Include the jj-coupling terminology where appropriate (for example, if you determine the spectrum shows Au 4f levels, then label the correct peaks as Au $4f_{7/2}$ and Au $4f_{5/2}$).

b. Label the Auger peaks and any "ghost" peaks. What was the x-ray source, Mg $K\alpha$ or Al $K\alpha$? What appears to be the source of any "ghost" peaks?

c. One peak from the survey scan for material A has been expanded (this is NOT a high resolution scan, just an expanded region of the survey scan). Determine the following:

i. The separation between Kα and Kβ lines for the x-ray source.

ii. The total spread introduced by the source and analyzer assuming the inherent line width for the expanded peak is 0.5 eV.

iii. Based on the x-ray source you decided was being used, what is the peak broadening introduced by the analzyer?

Note: Spreading introduced by a non-ideal source or analyzer is a convolution process. The same principle we discussed for how noise increases when we co-add spectra applies. When two peaks are convolved in real space, their variances add, NOT their standard deviations (half widths).

d. From your analysis of these four spectra, what two elements would you say are ubiquitous on sample surfaces.

5. The objective of this problem is to analyze XPS high resolution scans. The attached peaks from an oxidized titanium sample were taken with a Mg Kα source.

a. Estimate the peak half-widths for the attached peaks. Prove that, to a reasonable approximation, absolute resolution is constant whereas relative resolution clearly changes (increases or decreases) as we expect. Be careful how you handle the overlapping peaks (as in the O 1s spectrum).

b. Determine the relative atomic concentrations using peak heights as a measure of intensity. The sensitivity factors are given below.

c. Estimate the peak areas and determine relative atomic concentrations of the elements from them. I will post the raw data as time permits. One accurate way to determine “peak area” without software is to cut out the peak and weigh it on a balance. Be sure to calibrate the weight of the paper against a measure of actual area (in units of c•eV/s) for each peak because the plot scales are not the same. A rough estimate of peak area can also be obtained by fitting triangles to the peak. You should be able to include an estimate of your measurement error for this part.

d. Comment on any differences between these results and those you determined in part b. Under what conditions should the two calculations (using peak height versus peak area) give exactly the same results for relative atomic concentrations?

e. Do you see any evidence for Ti metal on this sample? What about other oxidation states of Ti?

f. What is the value of x in the formula TiO_x for this sample?

Relative Sensitivity Factors

Ti - 2.001 (using both peaks) 1.334 (using Ti $2p_{3/2}$ only)

O - 0.711

C - 0.296