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2 Task Elektronenspektroskopie

2.1 (Film thickness)

This task is about a thin metal film on a substarte.

a)

We are meant to determine the film thickness, from the measured intensities of I_f and I_s. Therefore we first have to determine the intensities. We start with I_s, which is given with:

$$I_s = I_s^0 \int_0^\infty e^{-\frac{z}{\Lambda_{ss}}} dz \, e^{-\frac{d}{\Lambda_{ff}}}$$

while $I_s^0 \propto n_s \sigma_s$, $\Lambda_{ss} = \Lambda_s (E_s)$ and $\Lambda_{ff} = \Lambda_f (E_f)$. We use the substitution $y = \frac{x}{\Lambda} \Leftrightarrow dx = \Lambda dy$ therefore we get:

$$I_s \propto n_s \sigma_s e^{-\frac{d}{\Lambda_{ff}}} \Lambda_{ss} \int_0^\infty dy \, e^{-y}$$

The integration is simple and only gives a 1:

$$I_s \propto n_s \sigma_s e^{-\frac{d}{\Lambda_{ff}}} \Lambda_{ss}$$

Now we can have a look at I_f, while this one is given with

$$I_f \propto n_f \sigma_f \int_0^d e^{-\frac{z}{\Lambda_{ff}}}$$

which leads to:

$$I_f \propto n_f \sigma_f \Lambda_{ff} \left(1 - e^{-\frac{d}{\Lambda_{ff}}}\right)$$

Now we can get the quotient of the intensities to find d:

$$\frac{I_f}{I_s} = \frac{n_f \sigma_f \Lambda_{ff} \left(1 - e^{-\frac{d}{\Lambda_{ff}}}\right)}{n_s \sigma_s e^{-\frac{d}{\Lambda_{ff}}} \Lambda_{ss}}$$

which can be rearranged to:

$$d = \Lambda_{ff} \ln \left(1 + \frac{n_s \sigma_s \Lambda_{ss} I_f}{n_f \sigma_f \Lambda_{ff} I_s}\right)$$

d therefore depends only on known quantities.

b)

To simplify this expression we assume, that the mean free path will be much bigger than the film thickness, meaning $\Lambda \gg d$. We can simplify the expression, starting with I_s

$$I_s \propto n_s \sigma_s e^{-\frac{d}{\Lambda_{ff}}} \Lambda_{ss}$$

while we now have $d \ll \Lambda_{ff}$ we can expand to first order:

$$I_s \propto n_s \sigma_s \Lambda_{ss}$$

and for I_f

$$I_f \propto n_f \sigma_f \Lambda_{ff} \left(1 - e^{-\frac{d}{\Lambda_{ff}}}\right)$$

while $d \ll \Lambda_{ff}$, we can expand the exponential function (to second order, while first order would cancel the whole term):

$$e^{-\frac{d}{\Lambda_{ff}}} \approx 1 - \frac{d}{\Lambda_{ff}} + \mathcal{O}\left(\left(\frac{d}{\Lambda_{ff}}\right)^2\right)$$

which leads to:

$$I_f \propto n_f \sigma_f d$$

Now we can get the quotient of the intensities again in the simplified form to find d:

$$\frac{I_f}{I_s} = \frac{n_f \sigma_f d}{n_s \sigma_s \Lambda_{ss}}$$

which can again be rearranged to:

$$d = \frac{I_f n_s \sigma_s}{I_s n_f \sigma_f} \Lambda_{ss}$$

2.2 (Yield of photoelectrons in the high kinetic energy regime)

The law for the yield of photoelectrons in the high kinetic energy regime $E_{kin} \approx \hbar\omega$ is given with $Y \propto (\hbar\omega)^{\alpha}$. We are meant to determine the exponent α. We know that

$$\begin{aligned} Y &\propto \int_0^z dz\, I \\ &\propto \Lambda \propto E^{\frac{1}{2}} \\ &\propto \sigma \propto E^{-3} \end{aligned}$$

this means

$$Y \propto E^{-3+\frac{1}{2}} \propto E^{\frac{5}{2}}$$

or

$$Y \propto \sigma \cdot \Lambda$$

We have a look at the figure called "Cross sections vs energy" in the lecture notes. We have three lines there, we will get an average value therefore:

line	σ_e
c1s	$-(2.9 \pm 0.05)$
n1s	$-(3.0 \pm 0.05)$
o1s	$-(2.95 \pm 0.05)$
average	$-(2.95 \pm 0.03)$

Therefore we were able to determine the exponent with $\sigma_e = -(2.95 \pm 0.03)$. This first value seems to fit the expectation of -3 quite well, now the second graph leads to $\Lambda_e = 0.5$, which also fulfills our expectation. We therefore find:

$$Y \propto (\hbar\omega)^{\alpha} \propto (\hbar\omega)^{\sigma_e + \Lambda_e} \approx (\hbar\omega)^{-\frac{5}{2}}$$