Appendix

Error Analysis

Assume that F is multiples function of numerical value x, y and z while K, a, b and c is constant. The standard error of function F can be derived by applying the differential method as below:

$$F = Kx^a y^b z^c$$

applying natural logarithms,

$$LnF = LnK + aLnx + bLny + cLnz$$

differential,

$$\frac{\delta F}{F} = a\left(\frac{\delta x}{x}\right) + b\left(\frac{\delta y}{y}\right) + c\left(\frac{\delta z}{z}\right)$$

the magnitude of error,

$$\left[\frac{\delta F}{F}\right]^2 = \left[a\frac{\delta x}{x}\right]^2 + \left[b\frac{\delta y}{y}\right]^2 + \left[c\frac{\delta z}{z}\right]^2$$

1. Refractive Index, *n*

The refractive index of thin film is defined as,

$$n(\lambda) = \left[N + \left(N^2 - n_o^2 n_1^2\right)^{1/2}\right]^{1/2}$$

with $$N = \frac{\left(n_o^2 + n_1^2\right)}{2} + 2n_o n_1\left[\frac{T_{Max} - T_{min}}{T_{Max} T_{Min}}\right]$$

The maximun error in T_{max} *and* T_{min} is,

$$\left[\frac{\Delta T_{Max}}{T_{Max}}\right]=\left[\frac{\Delta T_{Min}}{T_{Min}}\right]=0.01$$

$$\left[\frac{\Delta N(\lambda)}{N(\lambda)}\right]^2=\left[\frac{\delta(T_{Max}-T_{Min})}{T_{Max}-T_{Min}}\right]^2+\left[\frac{\delta T_{Max}}{T_{Max}}\right]^2+\left[\frac{\delta T_{Min}}{T_{Min}}\right]^2$$

$$\left[\frac{\Delta N(\lambda)}{N(\lambda)}\right]^2\approx\left[\frac{\Delta T_{Max}+\Delta T_{Min}}{T_{Max}}\right]^2+\left[\frac{\Delta T_{Max}}{T_{Max}}\right]^2+\left[\frac{\Delta T_{Min}}{T_{Min}}\right]^2=0.0006$$

$$\left[\frac{\Delta n(\lambda)}{n(\lambda)}\right]^2=\left[\frac{\Delta N}{N}\right]^2=0.0006$$

Hence $$\left[\frac{\Delta n(\lambda)}{n(\lambda)}\right]=0.024$$

Since mean $n(\lambda)$ is 2.12, thus $\Delta n(\lambda)=2.12\times0.024\approx0.05$

2. Films Thickness, *d* and Deposition Rate

d is defined by equation as below,

$$d=\left(\frac{m\lambda}{2n}\right)$$

Hence $$\left(\frac{\Delta d}{d}\right)=\left(\frac{\Delta n}{n}\right)=0.024$$

Since mean d is 1023nm, thus $\Delta d=1023\times0.024\approx25$nm

The deposition rate is defined as $R=d/s$, where s is the period in seconds.

Hence $$\left[\frac{\Delta R}{R}\right]=\left[\frac{\Delta d}{d}\right]=0.024$$

Since mean R is 2.67Å/s, $\Delta R=2.67\times0.024\approx0.06$Å/s

3. Optical Energy Gap, E_g

The optical energy gap is determined from the intercept of the linear trends at energy axis of the graph $(\alpha h\nu)^{1/2}$ versus $h\nu$. Thus $E_g = C/m$ where C is the intercept on the energy axis and m is the gradient of the linear portion.

$$\left[\frac{\Delta E_g}{E_g}\right]^2 = \left[\frac{\Delta C}{C}\right]^2 + \left[\frac{\Delta m}{m}\right]^2$$

from the least square method,

$$\left[\frac{\Delta C}{C}\right] = 0.002$$

$$\left[\frac{\Delta m}{m}\right] = 0.01$$

Thus $$\left[\frac{\Delta E_g}{E_g}\right] = 0.01$$

4. Urbach Tail Bandwidth, E_e

The Urbach Tail bandwidth is determined from the gradient of the linear part of plot $\ln\alpha$ versus E near the absorption edge. Therefore, $E_e = 1/m$ where m is the gradient.

$$\left[\frac{\Delta E_e}{E_e}\right] = \left[\frac{\Delta m}{m}\right]$$

from the least square method,

$$\left[\frac{\Delta m}{m}\right] = 0.01$$

Thus $$\left[\frac{\Delta E_e}{E_e}\right] = 0.01$$

5. Surface Roughness

Since the scanning condition of Atomic Force Microscope in this experiment uses the ***Van Der Waals*** force and ***Tapping mode***, the roughness can be determined to an accuracy of 0.001nm. However the accuracy also depends on the scanned roughness and the error is about 1% of surface roughness. The maximum surface roughness in this experiment is 32.076nm, so the maximum error is 0.01 x 32.076nm ≈ 0.3nm.

6. Mean Grain Diameters

Since the mean grain diameter is determined from the average of 20 measured grain diameters, the standard error, R is derived from the statistic method.

$$R = \frac{\sqrt{\sum_{1}^{n}\left(X_n - \overline{X}\right)^2}}{n}$$

where $n = 20$ and $\overline{X}$ is mean grain diameter.