DESY Summer Student Project

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Determination period of thickness in multilayers X-ray mirrors by analysing of reflectivity spectrum for grazing incidence

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Abstract

The main result of my work in HASYLAB is a computer programme "MultThick", that is used for analyzing the thicknesses uniformity of X-ray mirrors with one or several multilayers.

My work in DESY

Firstly, my supervisor showed me the lab, the equipment and told me about actual scientific investigations, in which this group specializes. I briefly got acquainted with the magnetron and the procedure of preparing multilayer X-ray mirrors. The quality of samples of these mirrors depends on the deposition conditions and the deposited materials. There still is a problem of producing high quality mirrors with preset properties, because thin film deposition is a very delicate process. To prepare mirrors with good properties we must make very uniform multilayers. Also we must learn more about the interaction between layers of different substances and thin film deposition process. In CFEL lab we produced a few different samples with a single or several multilayers using a magnetron. To measure and evaluate these samples we used X-ray diffraction meter X'Pert PRO and stress map meter MOS Ultra-Scan. We made reflective angle scanning for grazing and high incidents, measured a stress map for a few samples which have about 40 periodic layers of Si and Mo, and a few samples with a single W, or W/B_4C layer above a Si substrate. We annealed one of the mirrors at 100 ^{0}C for a one hour in a vacuum oven and made measurements again after the sample cooled down. We have a challenge to decrease the stress and so we must know more about interdiffusion between two layers. We saw that nothing changed in the reflectivity spectrum and stress map, so we decided to treat it at 200 ^{0}C for one hour and again nothing happened. Slight changes started to be visible after 300 ^{0}C, but this was not enough because the stress remains large and negative.

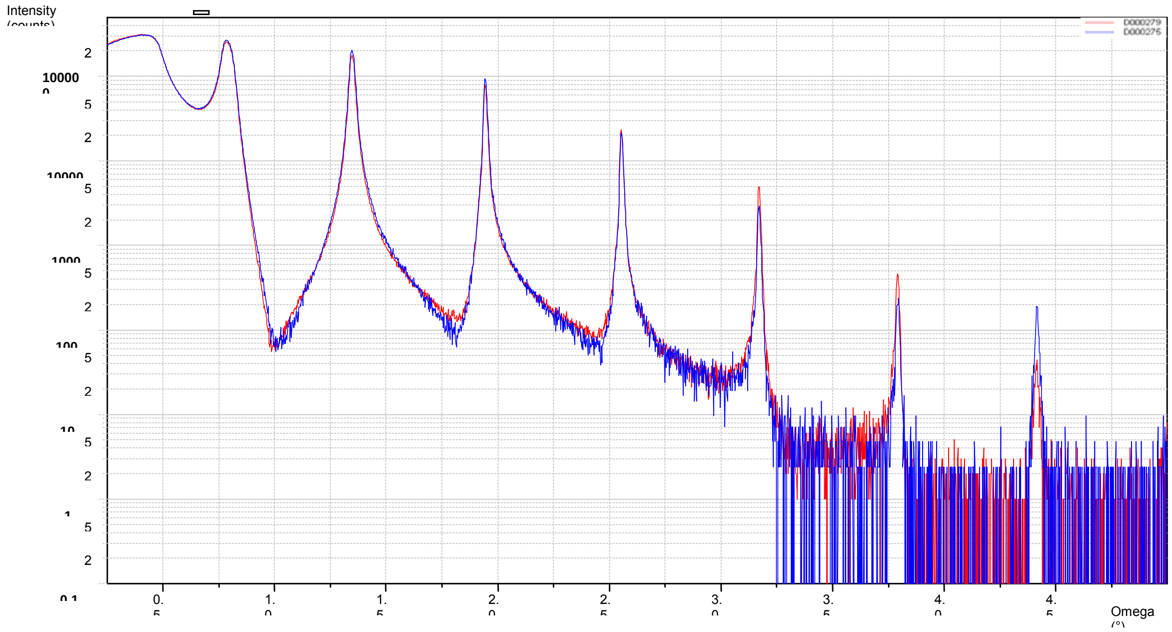

Figure 1. *The grazing angle incidence spectrum of W/B_4C sample. Red line corresponds to the unannealed sample, the blue one was measured after treatment at 300 ^{0}C for one hour.*

We want to have a small and positive stress and appreciable changes of thickness of the layer, so we decided to heat this sample to 400 ^{0}C, but this wasn't done yet.

To define the thickness uniformity one must know the period of each multilayer and how its dependence on the Y-coordinate position at which you are measuring. My supervisor set me a challenge to make a useful soft for analysing the reflectivity spectrum and calculating the thickness of each multilayer. I made this programme, it works well, and we already made calculations for two samples each with one multilayer.

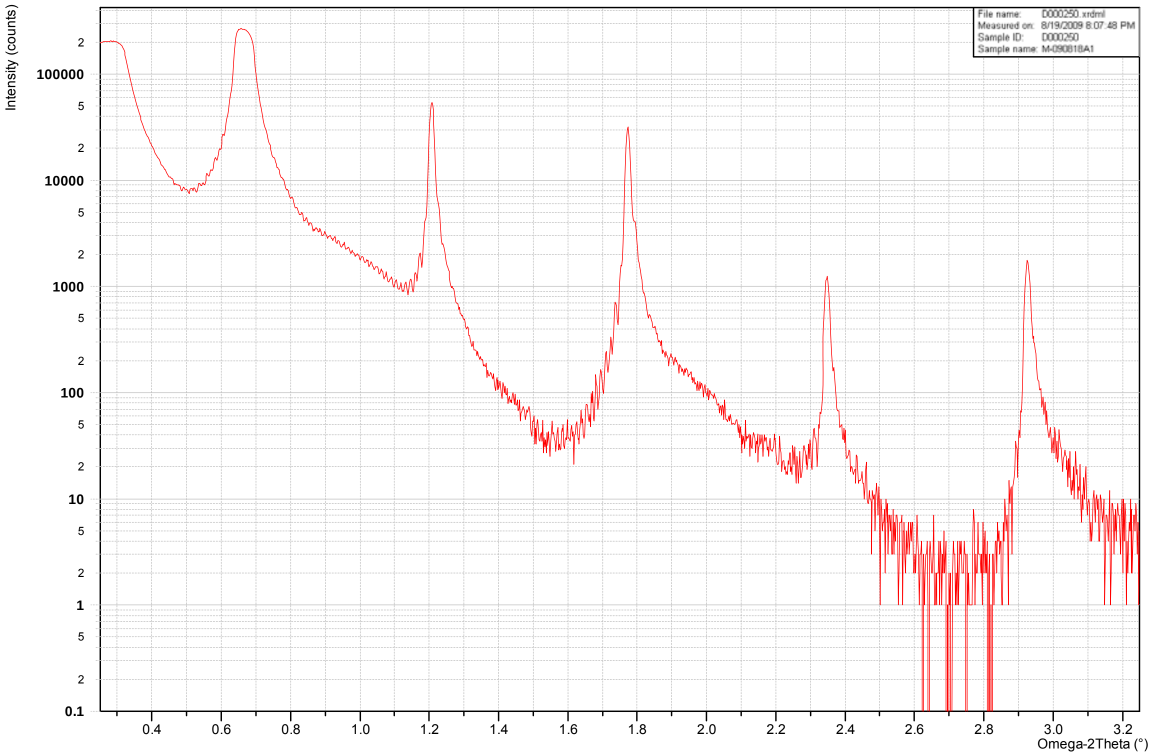

Figure 2. *The grazing angle incidence spectrum of Si/Mo sample, that has 40 bilayers. Calculated thickness Λ= 7.59352 nm ,error S=0.00296 nm. Refractivity index δ=16.03000, error S=0.62702*

This programme can handle complicated spectrums of samples with several multilayers, it is important because CFEL didn't have soft for it before. It uses three methods for calculations:

1) **By modified Bragg equation:**

$$\sin^2(\theta_m) = \frac{(m\lambda)^2}{(2\Lambda)^2} + 2\delta$$

θ_m – angle position of peak, that has order m.
Λ - thickness of multilayer.
δ – refractive index.
λ - wavelength.

Dependence $\sin^2\theta_m$ from m^2 is used for the least square method, that yields Λ and δ with corresponding errors and correlation parameter.

2) **By Spiller equation:**

$$2\delta = \frac{\dfrac{\sin^2\theta_m}{m^2} - \dfrac{\sin^2\theta_{m'}}{m'^2}}{\dfrac{1}{m^2} - \dfrac{1}{m'^2}} \; ; \; \Lambda = \frac{m\lambda}{2\sin\theta_m} * \frac{1}{\sqrt{1-\dfrac{2\delta}{\sin^2\theta_m}}}$$

This method calculates Λ and δ directly without using least square method and therefore has a larger error.

3) **By Henke method:**

$$\Lambda^2_{m,\,Bragg} = \Lambda^2 - \frac{2\delta\Lambda^2}{\sin^2\theta_m} \; ; \; \Lambda^2_{m,Bragg} = \frac{m\lambda}{2\sin\theta_m}$$

Dependence $(\Lambda_{m,Bragg})^2$ from $(1/\sin\theta_m)^2$ is used for least square method, that yields Λ and δ with corresponding errors and correlation parameter.

Input data is the spectrum of reflectivity scan with grazing incidence that usually has about 2000 experimental points. All calculated values are automatically saved in a *txt file.

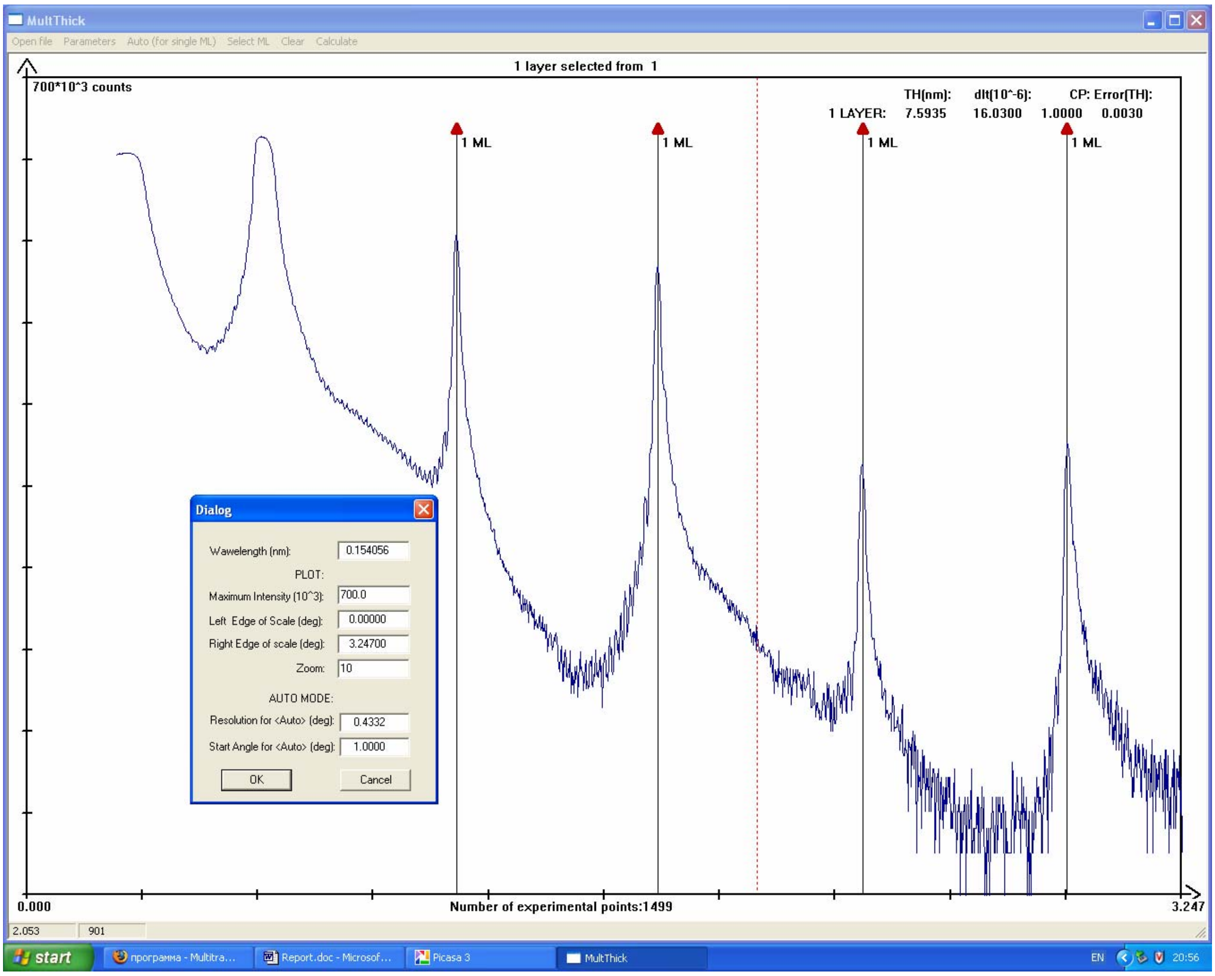

Figure 3. Screenshot <MultThick> programme.

Also I wrote a detailed manual, but I think there is no point in adding it to the report.

Acknowledgement:

I am really thankful to Sasa Bajt for the wise supervising and helpful discussions while performing this project. I was happy to work in CFEL, and now I would like to thank all people that work in this group.