Reflectance and resolution of multilayer monochromators for photon energies from 6 000 – 35 000 eV

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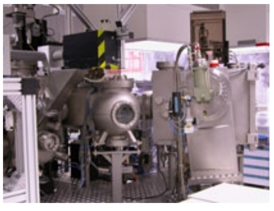
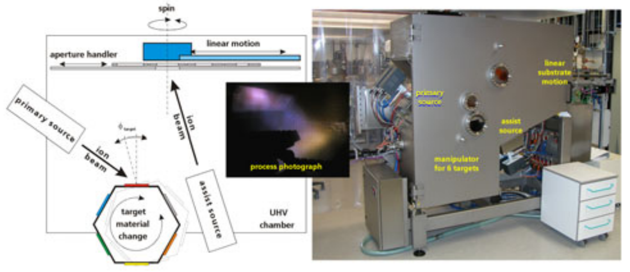
Multilayer fabrication

Nanometer multilayers with single layer thicknesses in the range between 0.5 nm and 20 nm are synthesized using UHV thin film deposition techniques, like sputtering or pulse laser deposition (PLD). Typical values obtained with magnetron sputter deposition (MSD) and ion beam sputter deposition (IBSD) are:

- layer thickness uniformity: ≥ 99.9 %
- run-to-run reproducibility: 99.8 % - 99.9 %
- layer microroughness σ_r (rms): 0.15 nm – 0.25 nm
- multilayer interface width σ (rms): 0.25 – 0.35 nm

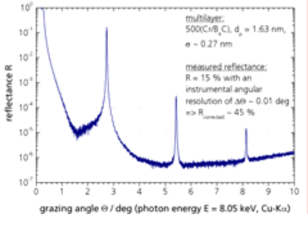


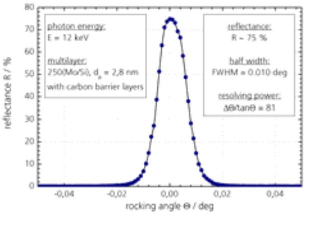
Photograph of the thin film deposition machine "UHV cluster tool" combining two deposition chambers, the handling system, one sample magazine and the load-lock. In both deposition chambers, MSD and PLD, up to four materials can be used in a multilayer period. The typical substrate size is ∅ = 150 mm, the maximum size can be up to ∅ = 250 mm.

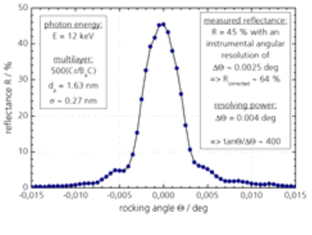


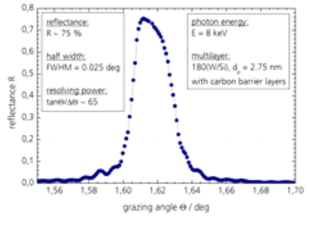
Left hand side: Schematic view of the arrangement for the large-area IBSD. Two linear electron cyclotron resonance ion sources with a grid length of 400 mm are used for primary sputtering and layer growth assistance. Up to 6 materials can be used for one multilayer.
Right hand side: Photograph of the IBSD machine. Substrates with diameters of up to 200 mm can be handled via the load-lock, larger substrates with lengths of up to 500 mm or diameters of up to 450 mm have to be introduced via the front door.

Multilayer examples

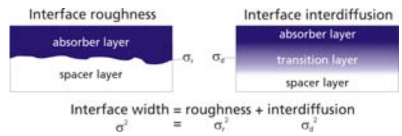


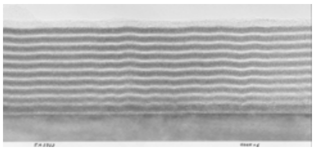




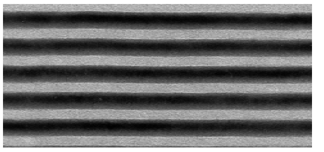


Real structure of nanometer multilayers





Mo/B_4C multilayer showing interface roughness (d_p = 3.38 nm)

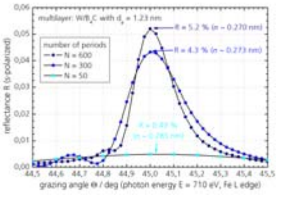


Mo/Si multilayer showing interface interdiffusion (d_p = 6.81 nm)

Reduction of interface roughness:

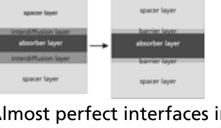
- low-pressure MSD
- ion beam assisted IBSD

=> No roughness increase with increasing numbers of periods even for extremely thin layers

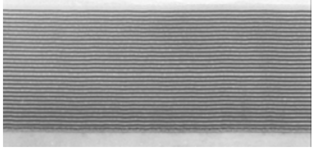


Reduction of interface diffusion:

- application of barrier layers



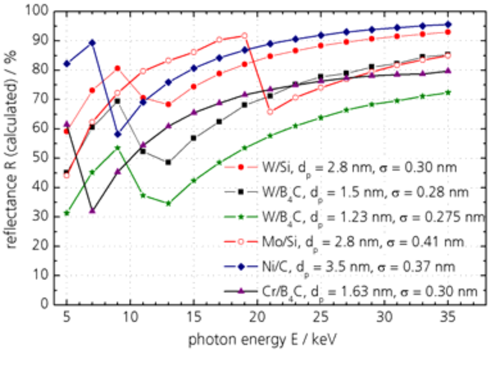
=> Almost perfect interfaces in W/Si (d_p = 3.0 nm, σ ~ 0.29 nm)



Materials selection for E = 6 – 35 keV

Well-understood and preferably applied multilayer systems:

- W/Si, W/B_4C (d_p ≥ 1.0 nm, σ = 0.27 – 0.32 nm): best broadband solution for E = 5 - 35 keV
- Ni/C, Ni/B_4C (d_p ≥ 3.0 nm, σ = 0.35 – 0.45 nm): best solution for E = 5 – 8 keV and E = 20 – 35 keV
- Mo/Si, Mo/B_4C (d_p ≥ 1.5 nm, σ = 0.30 – 0.40 nm): best solution for E = 10 – 19 keV
- Cr/B_4C (d_p ≥ 1.2 nm, σ = 0.27 – 0.30 nm) best solution for high-resolution multilayers



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