Design and fabrication of double gradient multilayers for a Kirkpatrick-Baez focusing system

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Double gradient multilayer

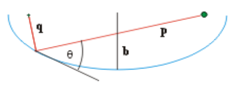
Idea: Figured optics for broad energy bands

- Incident angle variation followed by lateral gradient
- Energy band defined by depth-gradient

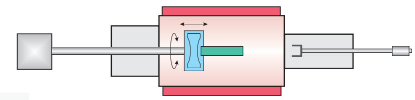
→ Fixed-exit focusing device for variable energies (“micro-spectroscopy”)

Example: Elliptic mirror with $[Ru/B_4C]_{35}$ multilayer coating to be used at energy range 6000-13000 eV with $\Delta E/E \cong 16\%$

Lateral gradient for mean energy $\Lambda = \dfrac{\lambda \cdot m}{2\sqrt{n^2 - \cos^2\theta}}$ $\sin\theta = \dfrac{b}{\sqrt{pq}}$



Deposition system



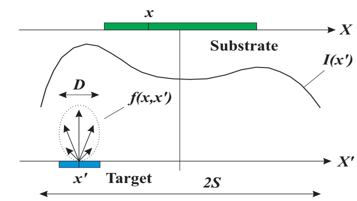
- Ar pressure: $1.3 \cdot 10^{-3}$ mbar
- Polarization voltage: U = -500...-2000 V (DC/RF)
- Particle flux: R = 0.02…0.10 nm/s
- Deposition temperature: $T_{Depo} \approx 100°C$

- Distributed Electron Cyclotron Resonance (DECR) plasma sputtering
- 3 target positions, rotation and linear movement

Thickness control

Basic model assumptions

- Total particle flux ≅ weighted sum of Gaussian (G) + Lorentzian (L)
- Rate R ∝ ion current I at U=const
- Local velocity v ➔ local “exposure time” dt=dx/v
- Integration over total stroke 2S of target movement



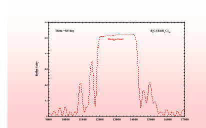
Depth-graded multilayers

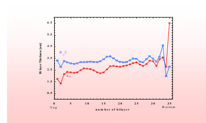
Goal

- Design multilayer with particular reflectivity profile
- R = R(θ) for E = const.
- R = R(E) for θ = const.
- Find vertical composition profile : 71 independent layers

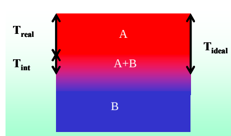
Design method

- Choose appropriate starting solution
- Apply fit algorithm to optimize the structure





Interdiffusion thickness determination

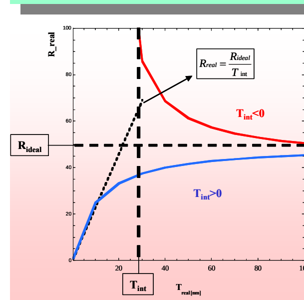


Thickness definition:

$T_{ideal} = T_{real} + T_{int}$

Sputtering rates definition:

$$R_{real} = R_{ideal} * \frac{T_{real}}{T_{real} + T_{int}}$$



Periodic multilayer

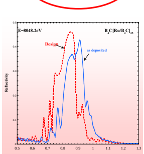
- Ideal speed determination
- Interdiffusion layer for each material

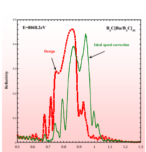
Non perdioc multilayer

- Shift on angle → interdiffusion of B4C
- Braod peak → interdiffusion of B4C

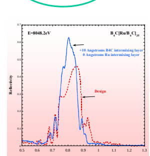
Experimental aspects

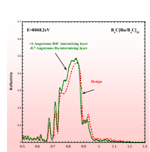
Regular compensation





Interdiffusion compensation added





Tests and calibrations

- At E=8.048.2keV (Lab reflectometer energy)

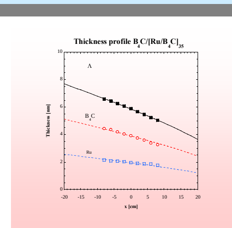
Thickness control

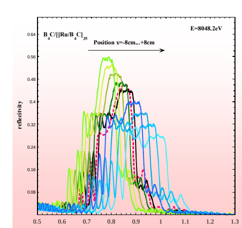
- Depth: variation of exposure time / total speed by analytical function or look-up table
- Lateral: modification of speed profile
- Both depth and lateral gradient possible

Required corrections

- Real film densities
- Layer interdiffusion ➔ variable growth rate
- Machine drift ➔ linear compensation

Lateral gradient - Results





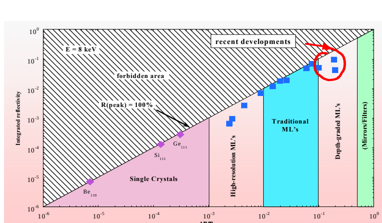
Summary and perspectives

Advantages

- Focusing ML over a broad angle range
- Combination of lateral and depth gradient
- Focusing at fixed distance and variable energies

Future perpectives

- Integration into beamline optics
- Global optimization algorithm for both gradients



Double graded multilayers – Energy Dispersion

Bragg equation: $E = \dfrac{h \cdot c}{2 \cdot \Lambda \cdot \sqrt{n^2 - \cos^2\theta}}$

Elliptical mirror: $\sin\theta = \dfrac{b}{\sqrt{pq}}$

$$E = \frac{h \cdot c}{2 \cdot \Lambda \cdot \sqrt{n^2 - 1 + \frac{b^2}{pq}}}$$

→ Dispersion “along ML mirror”