High Resolution and High Flux Multilayer Monochromators for Synchrotron Application

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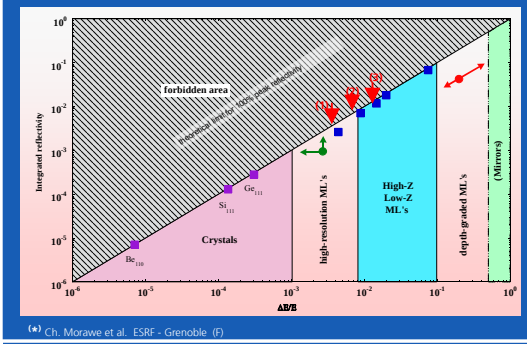
Motivation

Depending on the application either high flux or high resolution multilayer monochromators are used in synchrotron applications to characterize the structural and morphological parameters of compact materials and thin films. The required beam characteristics which mostly depend on the real sample can be realized by various X-ray optical systems that produce either low divergence (high resolution) or high intensity beams. The actual developments tend to the design of customized systems using one or two dimensional beam shaping multilayer X-ray optics, multilayer monochromators or the combination of multilayer optics with other types of X-ray optics. A close interrelation of design, deposition, characterization and application is required to produce these tailored systems. To fabricate either high reflectance or tailored resolution multilayer X-ray optics both the material combination and the layer stack morphology have to be optimized. In particular high resolution is realized by a combination of low-Z / low-Z materials or by low-Z / high-Z layer stacks having very thin high-Z absorber layers in the sub-nm range. Because the multilayer resolution is determined by the number of active layer pairs, stacks with more than 500 periods have to be deposited, for example. To guarantee maximum performance an optimum high precision deposition technology has to be applied for each specific material combination. To realize these requirements complementary high precision deposition technologies such as magnetron sputtering, large area pulse laser deposition and dual ion beam deposition technologies with a reproducibility and long term stability in the sub-nanometer range have to be installed.

Overview of reflecting hard x-ray optics(*)

Integrated reflection coefficient vs. energy resolution

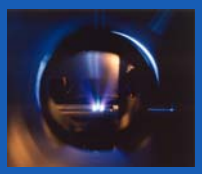


(*) Ch. Morawe et al. ESRF - Grenoble (F)

High Precision Multilayer Deposition Techniques: Combination of Large Area Pulsed Laser Deposition and Magnetron Sputter Deposition

Magnetron sputtering system

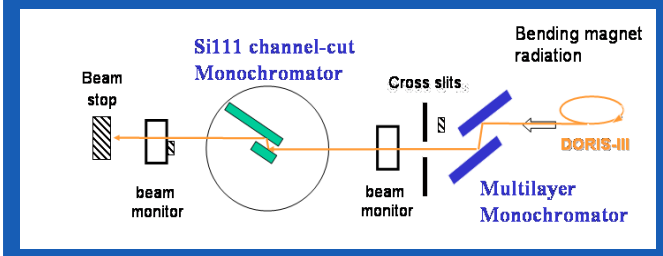
- Homogeneity: 99.9% (6" diameter)
- Cu Kα reflectivity of a Mo/Si-system: R > 60% (Cu Kα / d = 2.0 nm)
- run-to-run stability: 99.9%



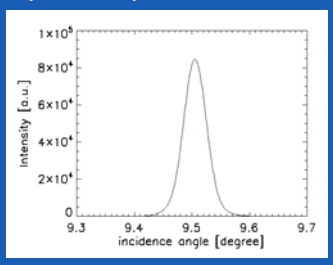
Large Area Pulsed Laser Deposition

- Homogeneity: 99.8 % (80 mm) 99.5 % (40 mm)
- Cu Kα-reflectivity of a Ni/C-Multilayer d = 3.0 nm: R = 68 %
- run-to-run stability: 99.5 %

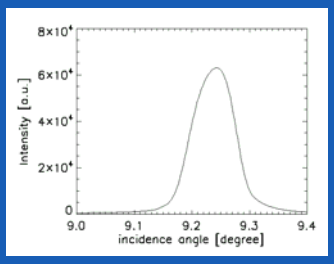
Characterization of a Double Multilayer Monochromators (DMM) by means of rocking scan measurements in the energy range between 8 keV and 21 kev at DORIS: Experimental Setup



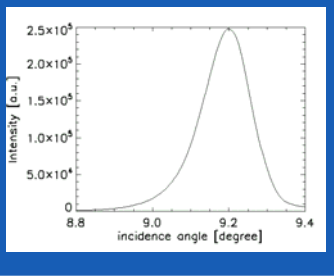
Comparison of spectral resolution of W/B_4C, Mo/Si and Ni/C DMM



1:
W/B_4C multilayer (**)
d = 1.5 nm
E_p = 12 keV
ΔΘ (FWHM) = 0.046°



2:
Mo/Si multilayer
d = 2.98 nm
E_p = 12 keV
ΔΘ (FWHM) = 0.09°



3:
Ni/C multilayer
d = 3.34 nm
E_p = 12 keV
ΔΘ (FWHM) = 0.14°

(**) N. Chkhalo, IPM Nizhny Novgorod

Spectral resolution ($\Delta\Theta/tg\Theta$ in %) of W/B_4C, Mo/Si and Ni/C DMM in the spectral range between 8 keV and 21 keV

	Ni/C	W/B_4C	Mo/Si
8 keV	1.65	0.46	0.96
12 keV	1.70	0.49	0.89
15 keV	1.78	0.56	0.92
18 keV	1.83	0.61	0.95
21 keV	2.13	0.66	1.07

Relative integrated intensity of W/B_4C, Mo/Si and Ni/C DMM normalized to a Si (111) double monochromator in the spectral range between 8 keV and 21 keV

	Ni/C	W/B_4C	Mo/Si
8 keV	40	4.3	7.9
12 keV	20.7	2.4	12.0
18 keV	30.3	4.4	27.6
21 keV	33.5	4.9	9.2

Summary:

- Multilayer monochromators with different spectral resolution in the range between $\Delta\Theta/tg\Theta$ = 0.5% … 2% can be fabricated by means of complementary high precision deposition techniques such as LA-PLD and magnetron sputtering.
- To guarantee an optimum performance special material combinations have to be selected depending on the wavelength and considering the absorption edges.
- The increase of integrated intensity in comparison to Si (111) monochromators corresponds with a decrease of spectral resolution.