Large area dual ion beam sputter deposition of nanometer multilayers

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Motivation

Nanometer multilayers are used as mirrors, monochromators or polarizers in numerous applications:

- Extreme ultraviolet lithography (EUVL)
- X-ray diffractometry and reflectometry (XRD, XRR)
- X-ray fluorescence analysis (XRF)
- Synchrotron optics
- Thermal barrier coatings (TBC)

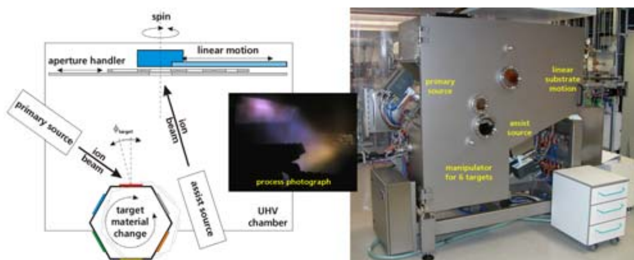
Typical characteristics of popular systems are:

- Materials: Mo/Si, W/Si, Ni/C, Ni/B_4C, Mo/B_4C, La/B_4C, Cr/Sc, Al_2O_3/W
- Number of layer pairs: 50 – 800
- Single layer thickness: d = 0.5 – 10 nm
- Single layer roughness: σ = 0.1 – 0.3 nm

Important specifications of the multilayers are reflectance, resolving power, lifetime or thermal conductivity. The steady need to improve the performance of the coatings requires sophisticated deposition techniques. For an effective industrial use of the techniques, large areas have to be reproducibly coated with uniform coatings.

Ion beam sputter deposition (IBSD) not only offers the possibility to vary the process parameters in wide ranges. With the introduction of rectangular ion beam sources instead of circular ones, also the scalability of the technique to arbitrary substrate sizes is easily possible.

Multilayer fabrication



Left hand side: Schematic view of the arrangement for the large-area IBSD. Two linear electron cyclotron resonance ion sources are used for primary sputtering and layer growth assistance or etching.
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.

Technical data:

Vacuum:
- process chamber: $p < 2\cdot10^{-8}$ mbar
- load lock: $p < 5\cdot10^{-7}$ mbar

Substrates:
- round, up to ∅ = 200 mm
- rectangular, up to L = 500 mm (without spin)

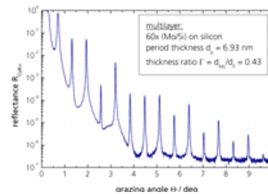
Targets:
- number: 6 pieces
- size: 400 x 200 mm^2

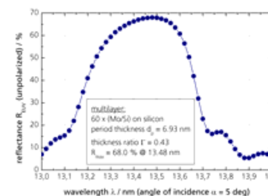
Ion beam sources:
- primary for sputtering
- secondary for assisting and etching
- excitation principle: ECR = electron cyclotron resonance
- grid size: 400 x 200 mm^2
- ion energies: E = 50 - 2000 eV

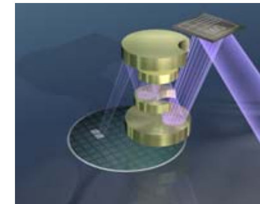
Applications

EUV lithography

Mo/Si multilayers as reflection optics for EUV illumination and projection







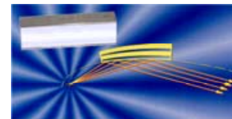
Scheme of the EUVL principle.

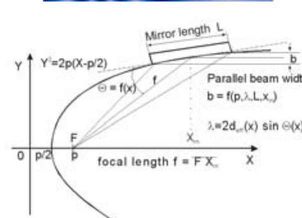
Cu-Kα reflectometry:
- high regularity of the periodic stack
- extremely smooth interfaces

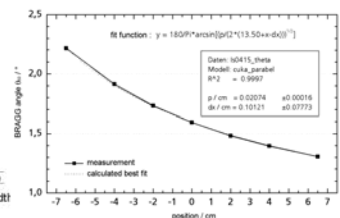
EUV reflectometry:
- R_{max} = 68 % at λ = 13,5 nm

X-ray diffractometry and reflectometry

Multilayers with linear thickness gradients as X-ray collimators



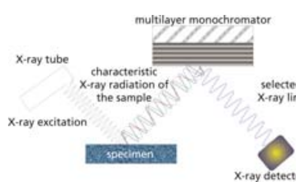




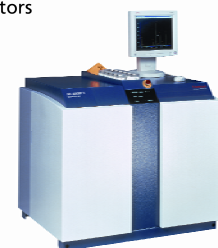
Cu-Kα reflectometry:
- R > 80 % for $d_P \geq 2.5$ nm
- thickness deviation from the ideal case: < 0.1 % over ∅ 140 mm

X-ray fluorescence analysis

Uniform multilayers as XRF monochromators



Scheme of the wavelength-dispersive XRF principle.



XRF spectrometer ARL ADVANT'X.

Multilayer materials:
- W/Si, W/B_4C and Mo/B_4C for the analysis of O, F, Na, Mg, Al, Si
- Mo/B_4C and La/B_4C for B
- Ni/C and Cr/C for C
- Cr/Sc for N

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