Abstract
In the past the successful application of PLD for X-ray multilayer synthesis has already been demonstrated for C-sparce systems. Recently the method has been tested also for Mo/Si layer stacks. An UHV-coating machine has been used to prepare X-ray mirrors on 4" substrates. The ablation of both, Mo and Si targets, was carried out by Nd:YAG laser radiation using the third harmonic (λ=355nm) with a pulse energy E_p=550mJ and a pulse width τ=4...6ns. Multilayers of 10...50 periods have been synthesized. Soft X-ray measurements in the EUV-range at near normal incidence show reflectivities R of typically 60%. From HRTEM a high stack regularity and minimum interface roughness can be deduced. In contrast to conventional technologies (coating by sputtering or e--beam evaporation) the formation of a Mo/Si-face interface layer happens only for deposition of Mo on Si.

EUV reflectivity measurements
Measurement of absolute reflectivity as a function of EUV wavelength and angle of incidence α was made using synchrotron radiation from BESSY (PTB, [2]). Main results of the measurements:
• Reflectivities R of 60% can be observed at different substrate types (ULE, zero dur, silicon, sapphire) at the Si-L-edge (photon energy E=99eV), Fig. 6
• Near normal reflectivities (α=1.5°) at λ=13nm are typically 2% lower compared to the values obtained at 99eV (corresponds to λ=12.52nm), Fig. 7

Coating uniformity
Determination of the coating uniformity by Cu-Kα and EUV-reflectometry. With both methods relative standard deviations of period thickness <0.5% were observed (Figures 8-10).

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References

Mo/Si-multilayers for EUV applications prepared by Pulsed Laser Deposition (PLD)
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Multilayer preparation
Large area pulsed laser deposition (PLD) [1] enables thin film synthesis with high reproducibility. A schema of the PLD principle is shown in Figure 1.

Fig. 1: Principle of thin film deposition by large area PLD method.

HRTEM investigations
Conclusions from HRTEM investigation (Fig. 2):
• very good regularity of the multilayer stack
• extremely smooth interfaces between the different layers
• different interfaces Mo on Si and Si on Mo, for Mo on Si formation of transition layers with sharp interfaces to adjacent layers
• in contrast to sputtered (Fig. 4 and 5) or e-beam evaporated Mo/Si multilayers having polycrystalline Mo-layers no lattice fringes are found, all individual layers are amorphous

Fig. 2: HRTEM cross section of a PLD-prepared Mo/Si multilayer. Coating direction: from bottom to top.

Fig. 3: Structure model of PLD-prepared Mo/Si multilayers

Fig. 4: HRTEM cross section of an ion beam sputtered Mo/Si multilayer.

Fig. 5: HRTEM cross section of a magnetron sputtered Mo/Si multilayer.

On the basis of HRTEM results a structure model for PLD-prepared Mo/Si multilayers is proposed:
• multilayer period consists of three layers
• absorber and its supporting spacer are separated by an amorphous interlayer
• a MoSi2 composition is suggested for this interlayer

By variation of Si and Mo contents of absorber and spacer, resp., the model was adapted to the measured data of Cu-Kα- and EUV-reflectivities. The best fitting result is shown in Figure 3.

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Fig. 6: EUV reflectivity of sample V414 as function of angle of incidence α.

Fig. 7: Near normal incidence EUV reflectivity of sample V539 as a function of the wavelength.

Coating uniformity
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Fig. 8: Cu-Kα reflectographs of a 10-period Mo/Si multilayer (V628) at different sample positions (4" substrate).

Fig. 9: Period thickness as function of sample position of multilayer V628.

Fig. 10: EUV-peak positions and reflectivities as function of sample position (50 period multilayer, plane 4" substrate).

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References