Pulsed Laser Deposition of Ni/C- multilayers used for hard and soft X-ray optics

R.Dietsch, Th.Holz, H.Mai, C.-F.Meyer
Fraunhofer Institute Material and Beam Technology
Winterbergstrasse 28, D-01277 Dresden, Germany, Tel: +49 (0) 351/2583-249,
Fax. +49 (0) 351/2583-300, e-mail: dietsch@iws.fhg.de
R.Scholz
Max-Planck-Institute for Microstructure Physics Halle,
Weinberg 02, D- 06120 Halle / Saale, Germany, Tel.: +49 (0) 345/5582-626,
Fax: +49 (0) 345/5511223, e-mail: roscholz@mpi-halle.mpg.de

The development of multilayers of optimum quality causes extremely high demands for the precision of the appropriate preparation technologies. In this connection pulsed laser deposition (PLD) offers a couple of advantages since a precise adjustment of average layer thickness can involve either an excellent thickness uniformity or tailored thickness gradients as well as smoothest interfaces over the entire layer stack.

To realize high quality multilayer stacks on large areas a double-beam PLD-source consisting of two pulsed Nd:YAG-lasers, a computer-controlled target- and substrate-handling system and in-situ thickness control units (quartz oscillators / ellipsometer) was integrated into a commercial MBE system [1].

Optimization of ablation conditions and film growth regime, resp., for various kinds of multilayer systems has been realized by a reproducible variation of pulse energy and repetition rate of each of the two Nd:YAG-lasers using a LabView-virtual instrument. In addition the lasers can be independently controlled by a predetermined pulse delay.

Laterally graded Ni/C-multilayers showing X-ray optical activity were synthesized with optimized deposition parameters in the period thickness range from 3 through 5 nm having average values of thickness gradients typically 0.1...1 nm/cm across 4“ substrate length.

Stability and reproducibility of the PLD technology is demonstrated by X-ray reflectometry results for Cu Kα- and C Kα- radiation applied to 50- and 75- period Ni/C gradient multilayers.

A reflectivity R > 90% was measured for λ = 0.154 nm at a 50 period gradient multilayer at a substrate location with a mean period thickness t = 4.71 nm. High reflectivities in BRAGG peaks and small deviations in the intensities of Kiessig fringes indicate a nearly ideal layer stack.

Ni/C gradient multilayers with mean period thicknesses in the range between 3 nm < t < 4 nm are measured in the soft x-ray region at λ = 4.47 nm [2]. For t= 3.16 nm a reflectivity R = 18.8% was measured at Θ = 45.05° and for t = 3.91 nm a reflectivity R = 23.4% was measured at Θ = 34.85°. Reproducibility of single layer thickness across entire layer stack and low interface roughness is demonstrated by HREM investigations of the total layer stack too, where period thickness variations and interface roughnesses in the order of $\sigma_{t,R} \leq 0.1$ nm are confirmed by image analysis of HREM micrographs.
These Ni/C-gradient multilayers are used as Göbel Mirrors for parallel beam optics in X-ray reflectometry and diffractometry [3]. In the soft X-ray region they can be used as monochromators, mirrors, analyzer crystals and polarizers for C Kα-radiation.

The work was supported by the Federal Ministry of Education and Research of Germany under Grant No. 13 N 6487.

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[2] Measurements carried out at PTB Lab / BESSY, Berlin, Dr. M. Wedowski
[3] Th.Holz, R.Dietsch, H.Mai, L.Brügemann, S.Hopfe, R.Scholz, R.Krawietz, B.Wehner, 46th Denver X-ray Conference 1997, accepted for publication in: Adv. of X-ray Analysis, Vol. 41 (1997)