Carbon / Carbon Multilayer
a new approach in the development of nanometer-multilayer X-ray optics

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For the deposition of C- single and multilayers with low or high sp²/ sp³ bond ratios in the C- films i.e. low and high material densities, established PVD techniques like magnetron and ion beam sputtering, vacuum ARC deposition are mainly used. Because of the wide variability of film growth conditions, the high flexibility of the Pulsed Laser Deposition (PLD) process, the layer-by-layer process control and the UHV-clean deposition conditions, PLD becomes more and more an interesting alternative for the deposition of C- single and C/C- multilayers. The high quality and the long term stability of pulsed laser deposited C- single and C/C- multilayer X-ray optics are demonstrated by investigations of the performance in the soft and hard X-ray regime.

### Performance

#### C- single layers

**Hard X-ray regime**

Measured reflectance at \( \lambda = 1.54 \text{ Å (Cu-Kα)} \) of C- single layers prepared by LA-PLD. The simulations indicate material densities of about \( \rho_{\text{Cu}} = 2.66 \text{ g/cm}^3 \) and \( \rho_{\text{C}} = 2.05 \text{ g/cm}^3 \).

**Soft X-ray regime**

Measured reflectance in the soft X-ray range at \( E_e = 99 \text{ eV} \). For a C-layer with \( d = 41 \text{ nm} \) and \( \rho = 2.52 \text{ g/cm}^3 \) experimental results of \( R = 94.0 \% \) at \( \Theta = 3° \) and \( 87.4 \% \) at \( \Theta = 6° \) are close to the theoretical values. The measurements were done with the new R-VHS soft X-ray reflectometer (see also: Proc. SPIE Vol. 5038 (2003) pp. 12 - 21).

#### C/C- multilayers

**X-ray reflectometry results** \( R (\text{Cu-Kα}) \) for a 100 period layer stack (PL 369): \( d = 7.8 \text{ nm} \), \( R = 6.5 \% \), \( \rho_{\text{Cu}} = 2.4 \text{ g/cm}^3 \), \( \Delta \rho = 0.2 \text{ g/cm}^3 \), \( \alpha = 0.25 \text{ nm}, \Gamma = 0.4 \).

**C/C-multilayers with low period thicknesses \( d \)**

80 period C/C-multilayer \( d = 1.11 \text{ nm} \), \( \Delta \rho = 0.15 \text{ g/cm}^3 \), \( \Delta \rho = 1.3 \% \), \( \alpha = 0.44 \text{ nm}, \Gamma = 0.5 \).

**TEM cross section image (R.Scholz / M.R.Holle) of a C/C-layer stack (PL 307)**: \( d = 3.78 \text{ nm} \), \( N = 100 \), \( \Delta \rho = 0.2 \text{ g/cm}^3 \) (Overview and at higher magn.)

### Deposition: large area PLD

**6" wafer**

- Uniform particle flux
- Target exchange
- Target motion
- Experimental setup of LA-PLD

An advanced large area PLD technique is used to deposit C-single layers and C/C-multilayers showing X-ray optical quality. C-single layers of different material densities show high reflectance both in the hard and in the soft X-ray regime. X-ray optical multilayer showing both high resolution and high reflectivity can be fabricated using only one material – Carbon. Thermal stability up to 600 °C was observed for a C/C- multilayer, at 800 °C a formation of SC was found. C-single und C/C-multilayers show interesting applications as high power X-ray optics and high resolution multilayers.