Thermal stability and mechanical stress of B-based multilayers

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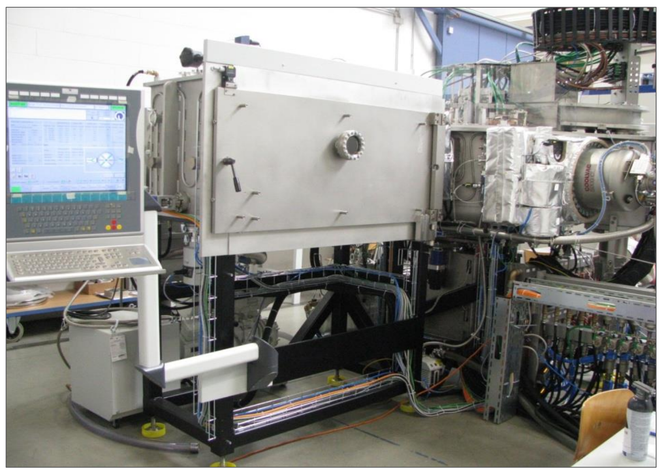
Motivation

- high reflective B-based multilayer mirrors (R > 70 %) are necessary for many applications (next generation of EUV-lithography (λ = 6,x nm), solar spectroscopy, …)
- change of physical properties under high thermal loads should be studied
- mechanical stresses in coatings lead to substrate deformation and film delamination

➢ reduction of the residual stress necessary

Sputtering system Nessy 3:

- base pressure: 10^{-8} Torr
- work pressure: 6×10^{-4} Torr
- optics size: D < 200 mm
- 6 magnetrons: dif. barriers
- thickness unif. 0.1% on 200 mm

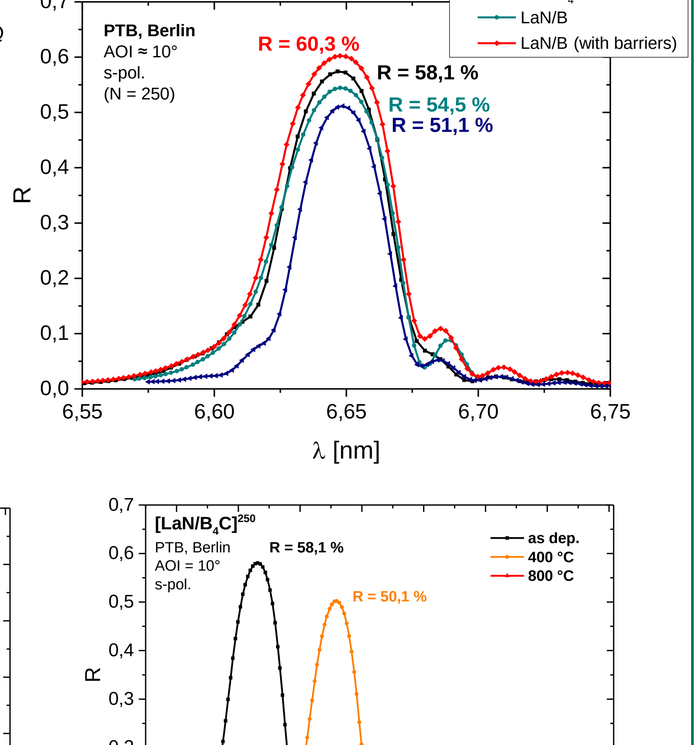


Characterization

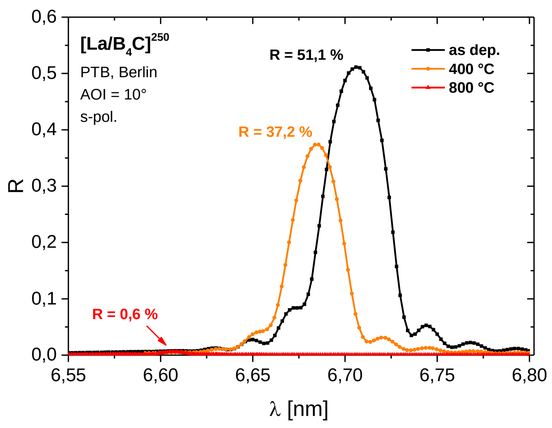
- XRR & XRD (λ = 0,154 nm)
- EUVR (PTB, Berlin) (λ = 6,5 … 7 nm)
- TEM, EDX (Fraunhofer IMWS)

Evolution of EUV optical performance of B-based MLs up to 800 °C

- peak reflection increased to R > 60 % @ 6,65 nm
- new materials investigated
- interface engineering is the key technology to reach high optical performance



Effects of annealing on EUVR:



Reduction of the mechanical stress

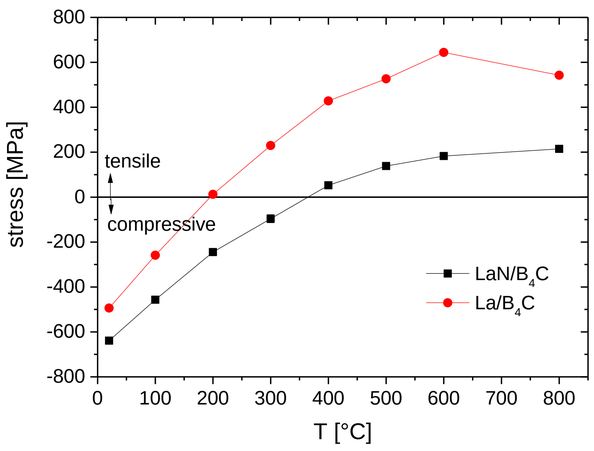
- high values of residual stress in B-based MLs of ~ 0,5 … 1,0 GPa
- reduction of the stress by post annealing of the ML

La/B_4C:

- σ = 0 MPa @ 200 °C
- ΔR = - 4,9 %
- high tensile stress due to grain boundaries of LaB_6 crystallites

LaN/B_4C:

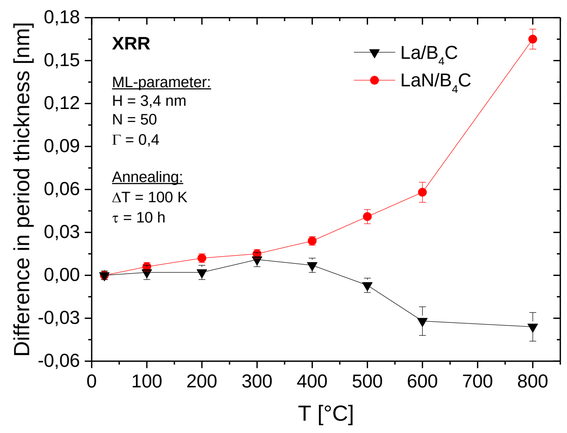
- σ = 0 MPa @ 400 °C
- ΔR = - 8,0 %



Thermal stability

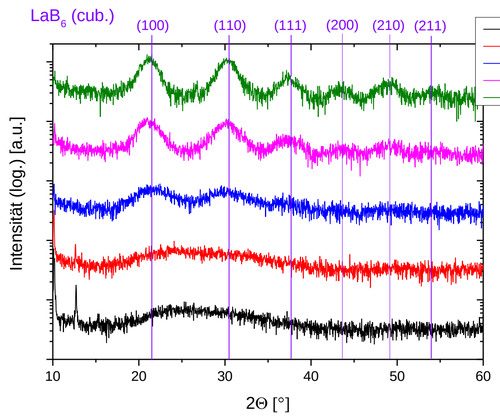
Period thickness changes (XRR):

- **decrease** in **La**/B_4C-MLs (formation of LaB_6)
- **strong increase** in **LaN**/B_4C-MLs (formation of BN)



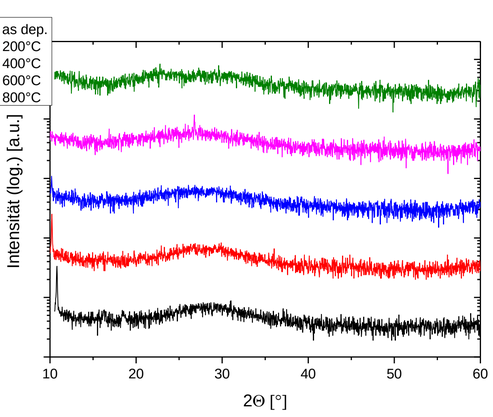
XRD-study:

La/B_4C – ML:



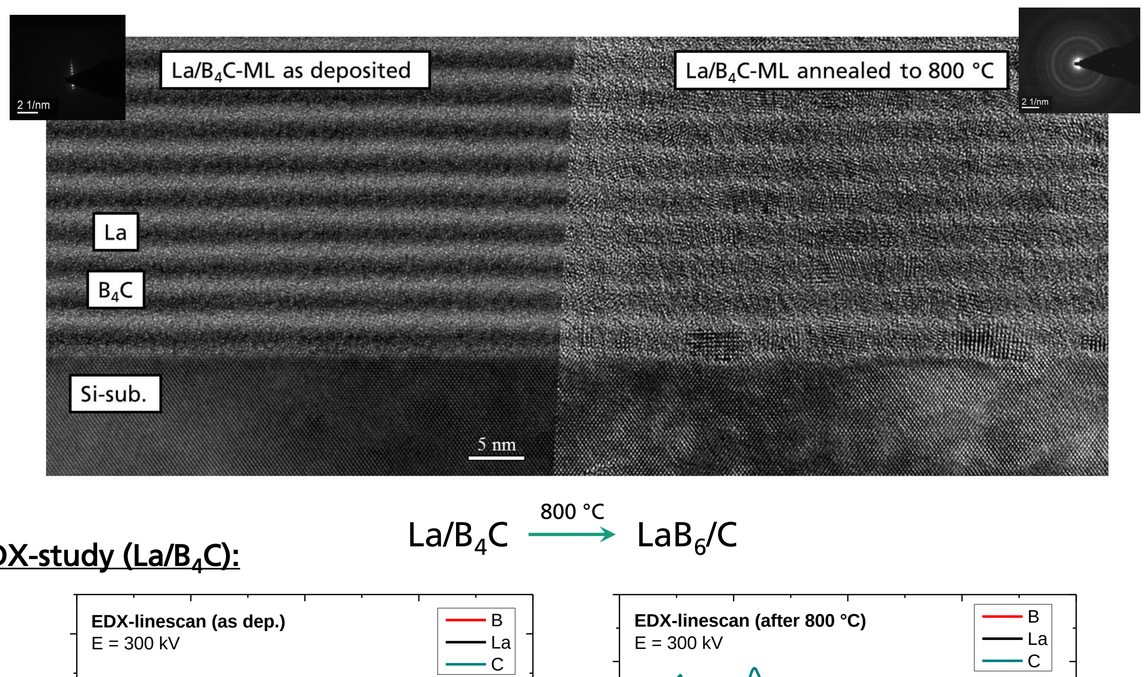
➢ crystallization of LaB_6 at T = 400°

LaN/B_4C – ML:



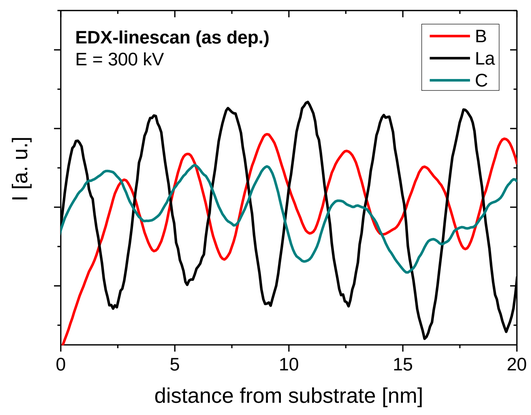
➢ no signs of any crystallization up to T = 800°

TEM-study (La/B_4C):

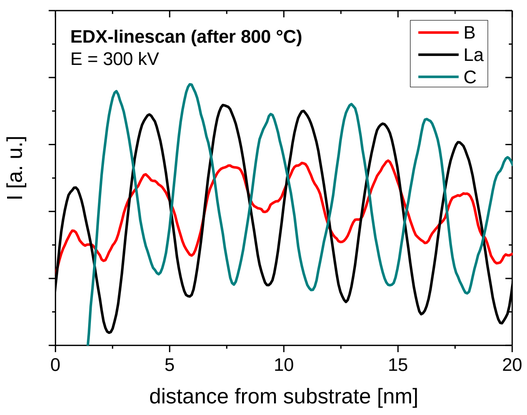


La/B_4C $\xrightarrow{800\ °C}$ LaB_6/C

EDX-study (La/B_4C):



➢ **B** and **C in phase**, **La** in between



➢ **B** and **La in phase**, **C** in between

Summary

- peak reflection increased to **R > 60 % @ *6,65 nm*** with **FWHM = 0,05 nm**
- thermal resistance studied up to **800 °C :**

La/B_4C:

- period shrink (-1 % @ 800 °C) due to LaB_6 formation
- loss of EUVR ($R_{800°C}$ = 0,6 %) due to rougher interfaces caused by crystallization of LaB_6

LaN/B_4C:

- period expansion (+ 5 % @ 800 °C) due to BN formation assumed
- higher thermal stability of EUVR ($R_{800°C}$ = 12,5 %)

- post annealing **decreases residual stress** (T = 200 °C @ La/B_4C and T = 400 °C @ LaN/B_4C for σ = 0 MPa)

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