Controlling interface chemistry in 6.x nm La/B multilayer optics

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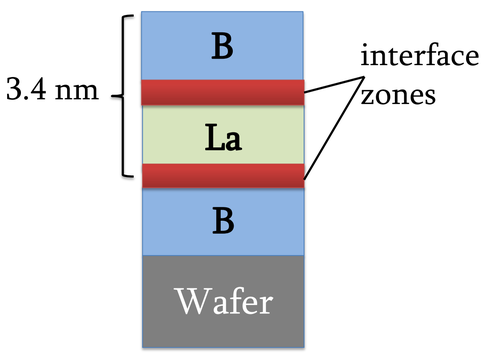
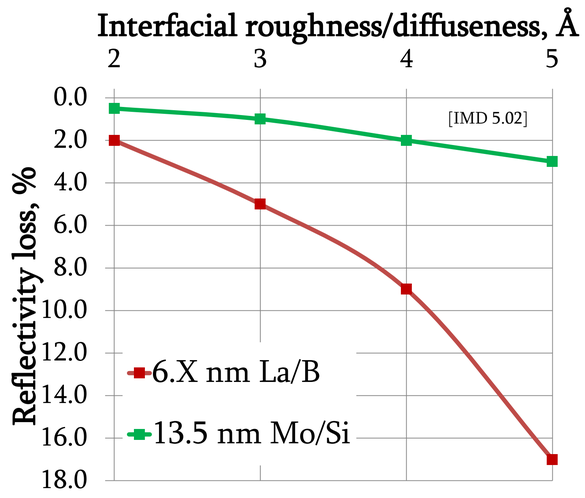
6.x nm multilayers: application-driven motivation

- **EUV photolithography (EUVL):**
  Fabrication of new-generation chip patterns
- **XRF material-analysis:**
  Ultrasensitive detection by X-ray fluorescence
- **EUV telescopes:**
  Space research

6.x nm multilayers: complexity on atomic scale

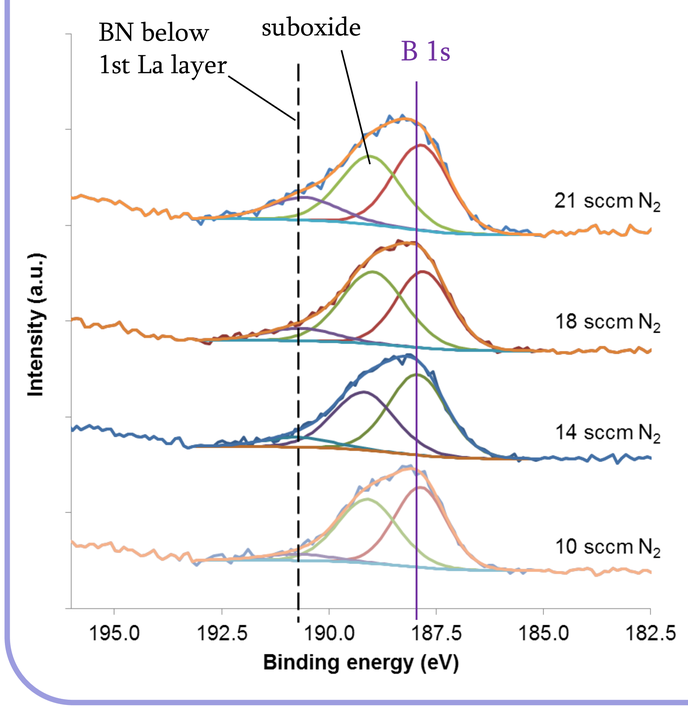
Each layer ~7-10 monolayers!



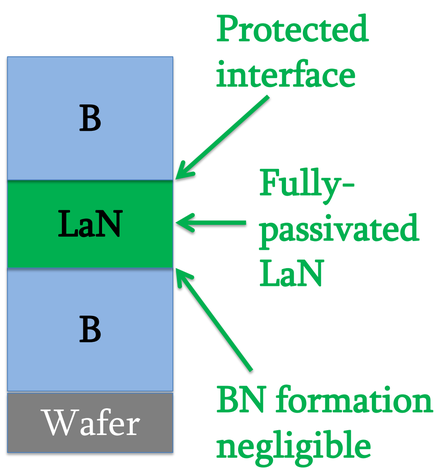


- Performance is highly dependent on interfacial roughness / diffuseness
- Unprecedented level of interface control is required

XPS analysis: BN formation during nitridation



Optimized system



Goal: high performance (reflectivity) of optics

High optical contrast for high performance of x-ray multilayers requires:

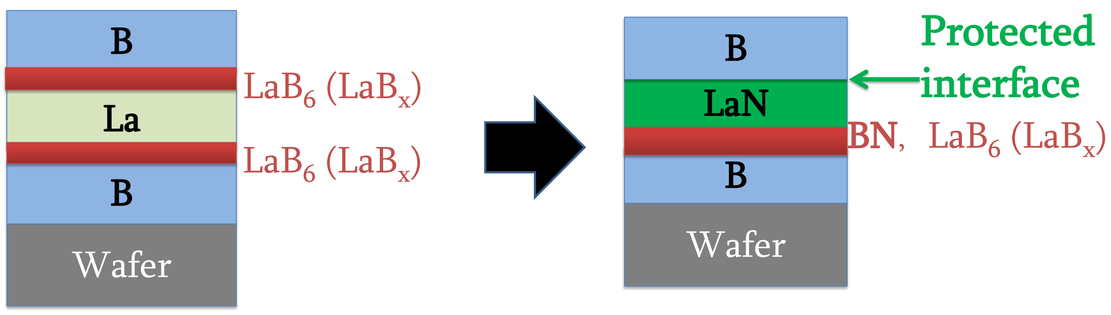
1) Controlling interface chemistry
   - Passivation of material(s)

2) Minimization of ballistic intermixing of atoms

3) Minimization of morphological roughness
   - Single-layer roughness
   - Roughness development (build-up) in multilayer

Passivation of lanthanum: nitridation

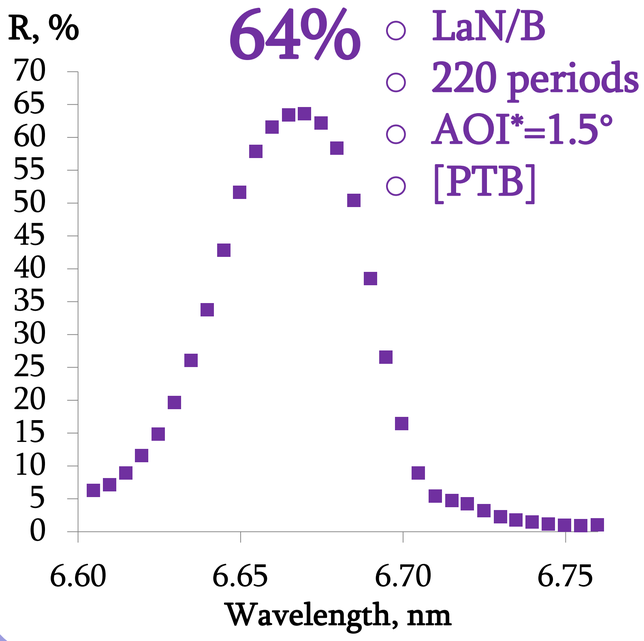
Magnetron sputtering deposition in nitrogen gas atmosphere [1]



Enthalpy, kJ/mol: $\Delta H(BN) = -255$ [2] >> $\Delta H(LaB_6) = -130$ [3]

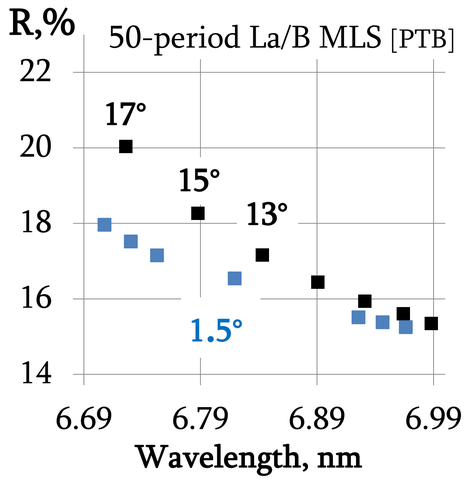
⇒ Protection of top interface,
but risk of BN formation at the bottom interface

New 6.x nm reflectivity record



Previous record [4]:
R=58.6%, AOI*=20.9°

Influence of AOI



*(AOI: off-normal incidence)

Literature

1. Igor A. Makhotkin, "Short period La/B and LaN/B multilayer mirrors for ~6.8 nm wavelength", Optics Express, Vol. 21, No. 24 (2013)
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3. A. I. Efimov "Properties of inorganic compounds", Handbook, Khimiya, Leningrad, 1983
4. N. I. Chkalo et al., "High performance La/B_4C multilayer mirrors with barrier layers for the next generation lithography", Applied Physics Letters 102, 011602 (2013)

Acknowledgements

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Conclusions and results

- Fully-passivated LaN layers synthesized
- Adverse effect of BN formation minimized
- New 6.x nm reflectivity record: 64%, AOI=1.5° [PTB]
- Program on further performance improvement identified