MAKING A MATERIAL DIFFERENCE

Optimizing deposition and annealing conditions for optical coatings in UV-applications

Matthias Falmbigl, Kyle Godin, Jason George, Binyamin Rubin, Christian Mühlig*

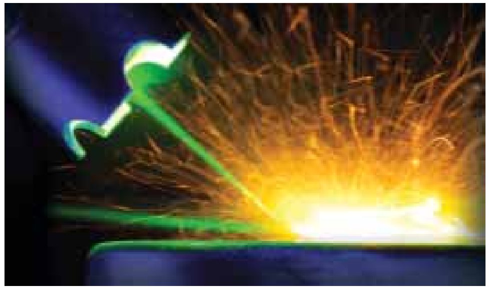
mfalmbigl@veeco.com

Veeco Instruments Inc., USA

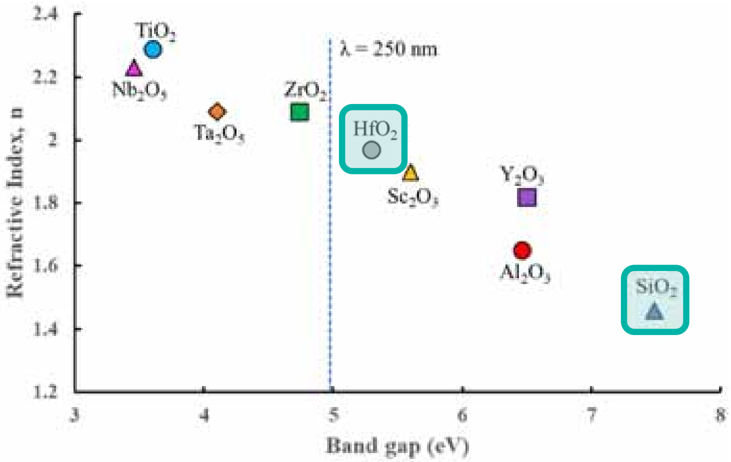
**Fraunhofer Institute for Applied Optics and Precision Engineering, Germany*

Introduction

- **Applications of UV-lasers:**
  - Micromachining
  - Semiconductor processing
  - Biomedical
  - Spectroscopy & Microscopy



- **Challenges for UV-optics:**
  - Increased absorption
  - Increased scattering
    - ➔Reduced laser damage resistance

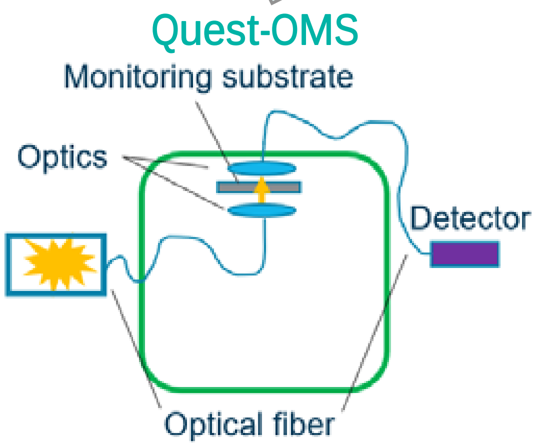


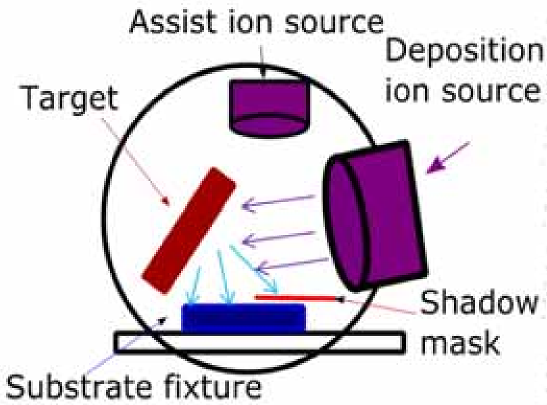
L. Gallais, Appl. Opt. 53 A186, 2014.

Coating is the weakest link in UV-optics

Spector® Ion Beam Sputtering System

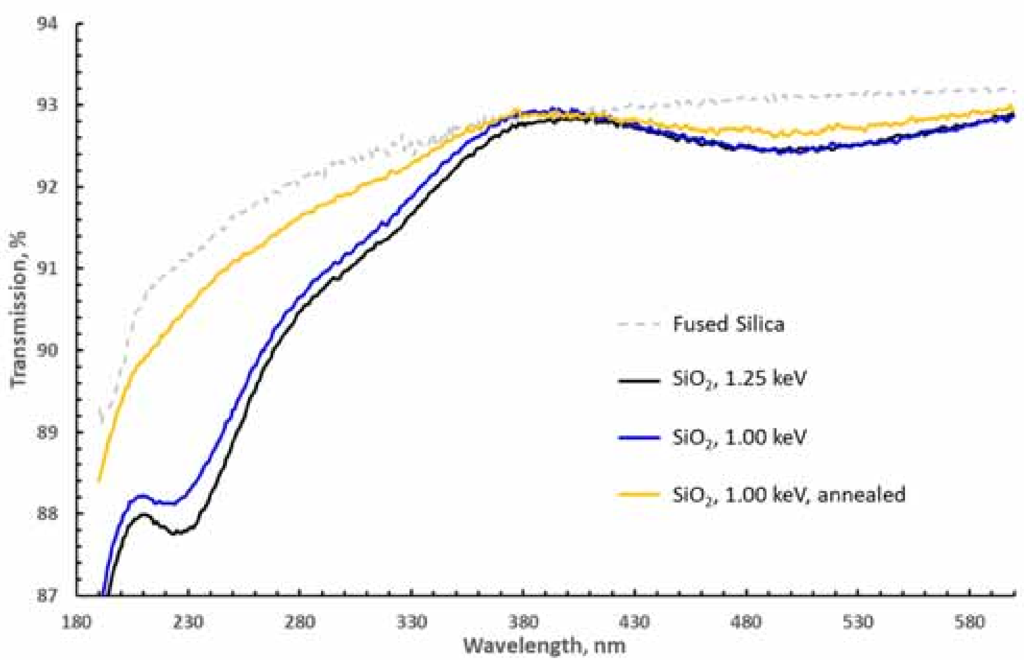
- Dual Ion Beam Sputtering System
- 16 cm RF Deposition Ion Source (Ar-gas)
- 12 cm RF Assist Ion Source
- Target materials:
  - SiO_2
  - Hf-metal (low Zr-content)
- Special UV grids for deposition source:
  - Reduced Mo content in coating
- Quest® Optical Monitoring System:
  - 400 – 1050 nm broadband monitoring

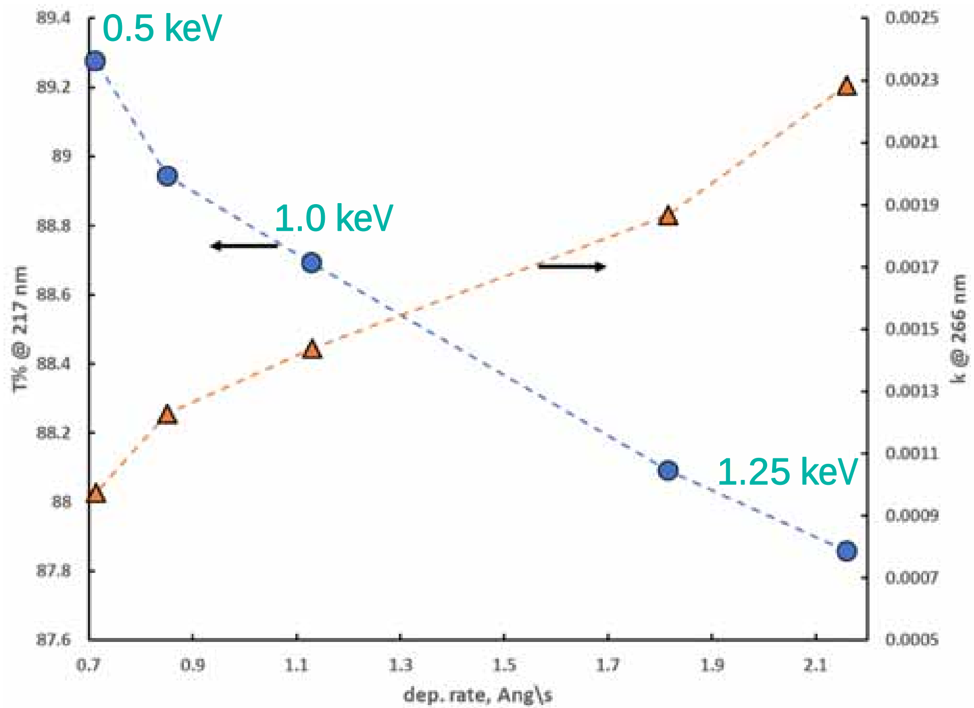




Single Layers – SiO_2

- SiO_2 from SiO_2 target is less sensitive to O_2 gas flow
- Ion beam energy influences absorption of as deposited layers
- Annealing at 475 °C significantly reduces absorption

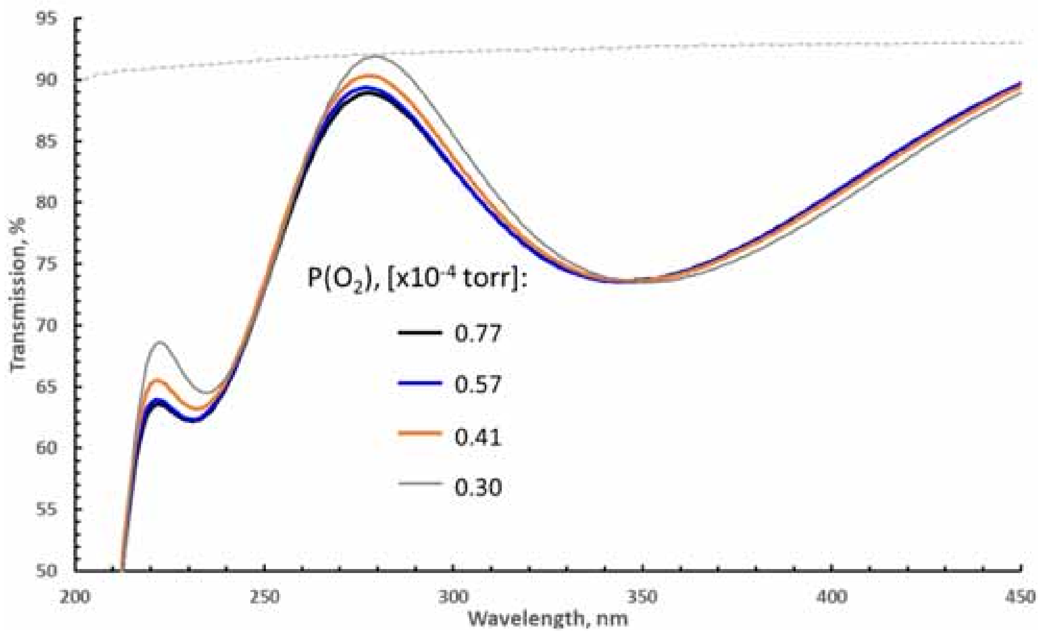


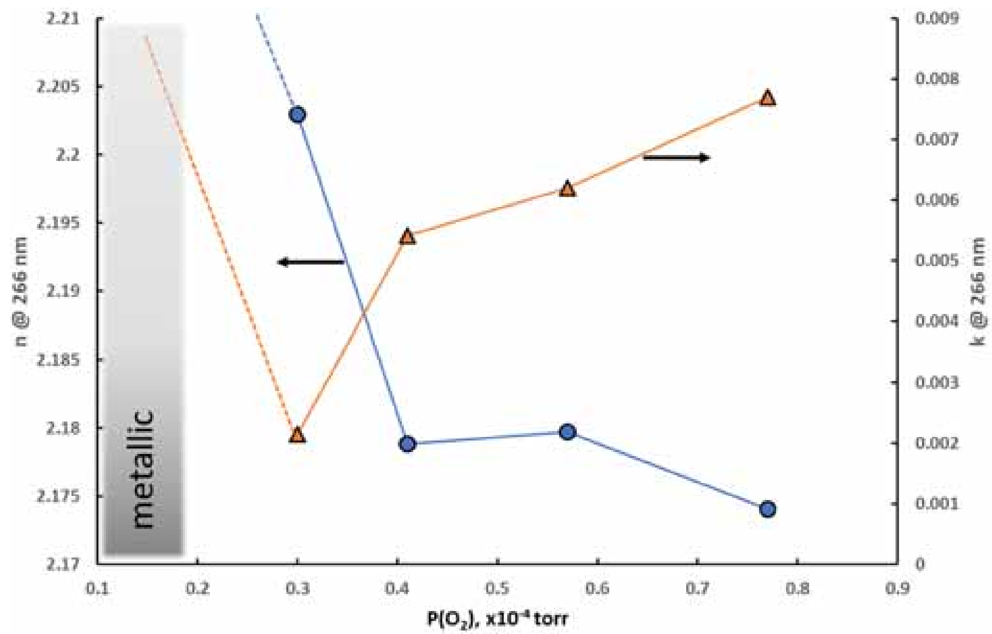


M. Falmbigl et al., Opt. Exp. 30/8 12326, 2022.

Single Layers – HfO_2

- O_2 flow is critical parameter for HfO_2 from a metallic Hf-target
- Lowest absorption close to undersaturation with O_2
- Annealing at 475 °C significantly reduces absorption



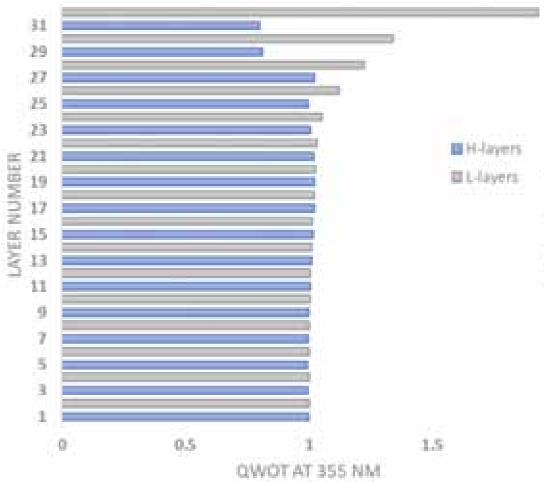


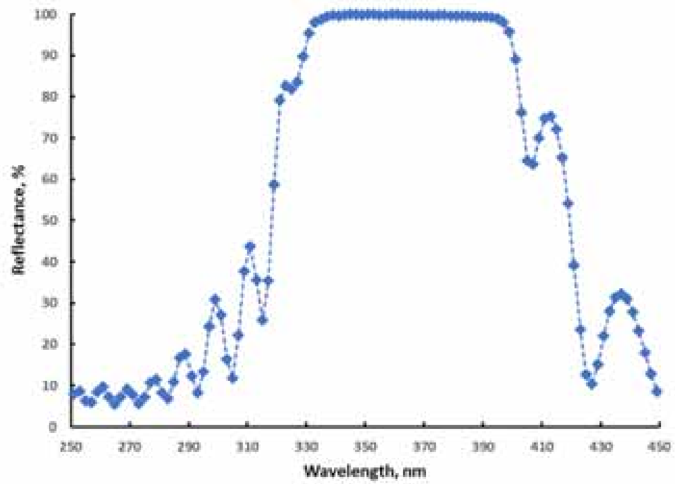
M. Falmbigl et al., Opt. Exp. 30/8 12326, 2022.

HR-mirrors & AR-coatings at 355 nm

HR-mirror:

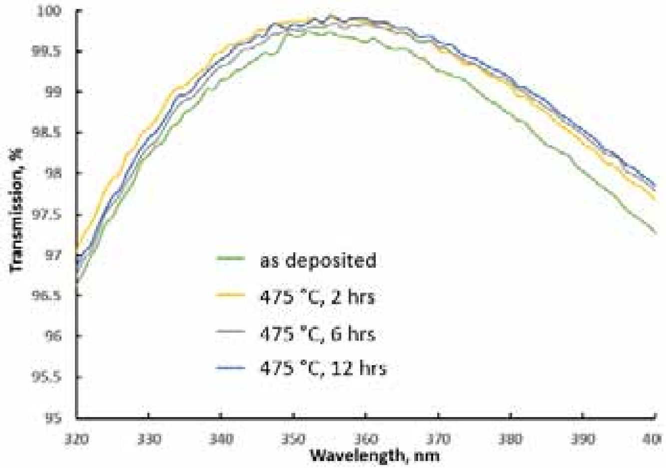
- Based on 32-layer design: $(HL)^{16}L$
- EFI-optimized
- Layer thicknesses OMS-controlled

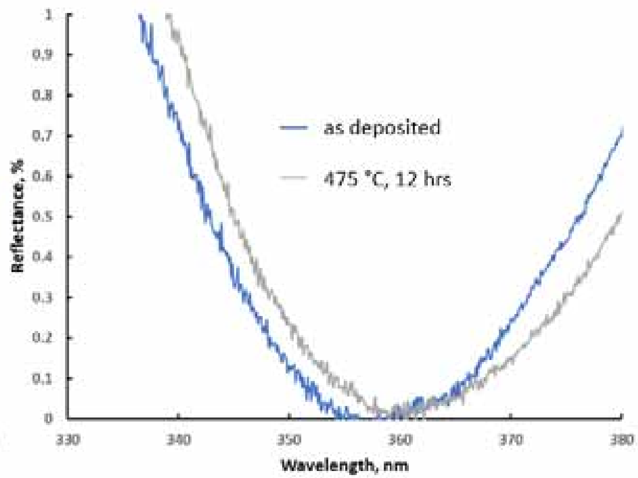




AR-coating:

- 2-layer V-coating
- HfO_2 layer kept thin
- Double-side coated
- Layer thicknesses OMS-controlled

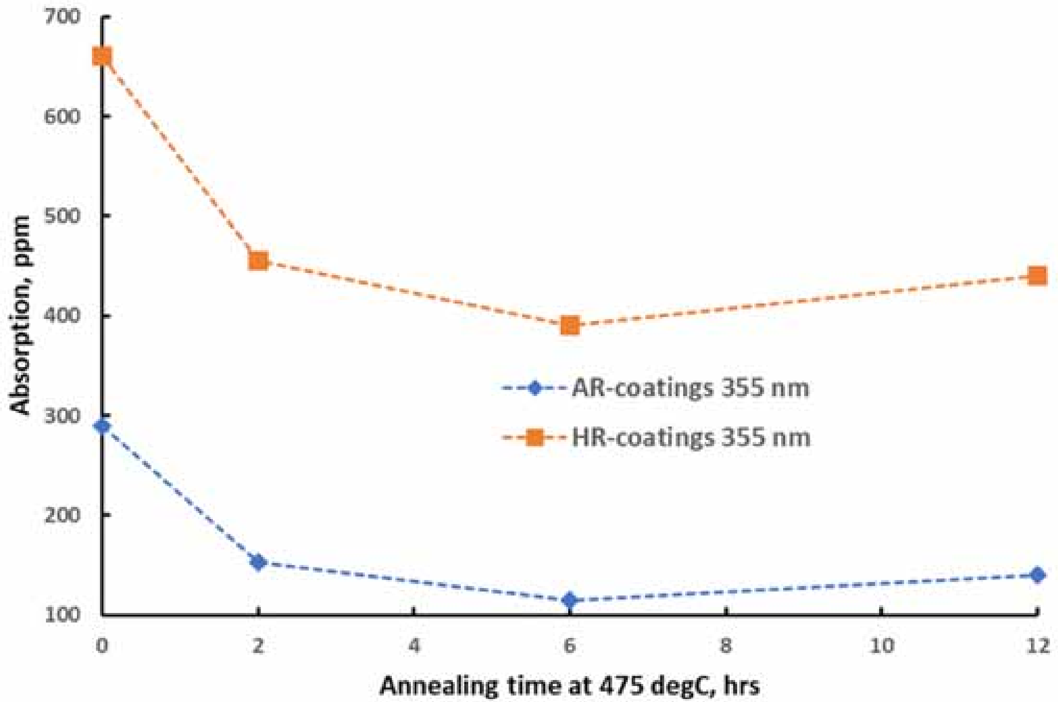




M. Falmbigl et al., Opt. Exp. 30/8 12326, 2022.

Absorption of AR- & HR-coatings at 355 nm

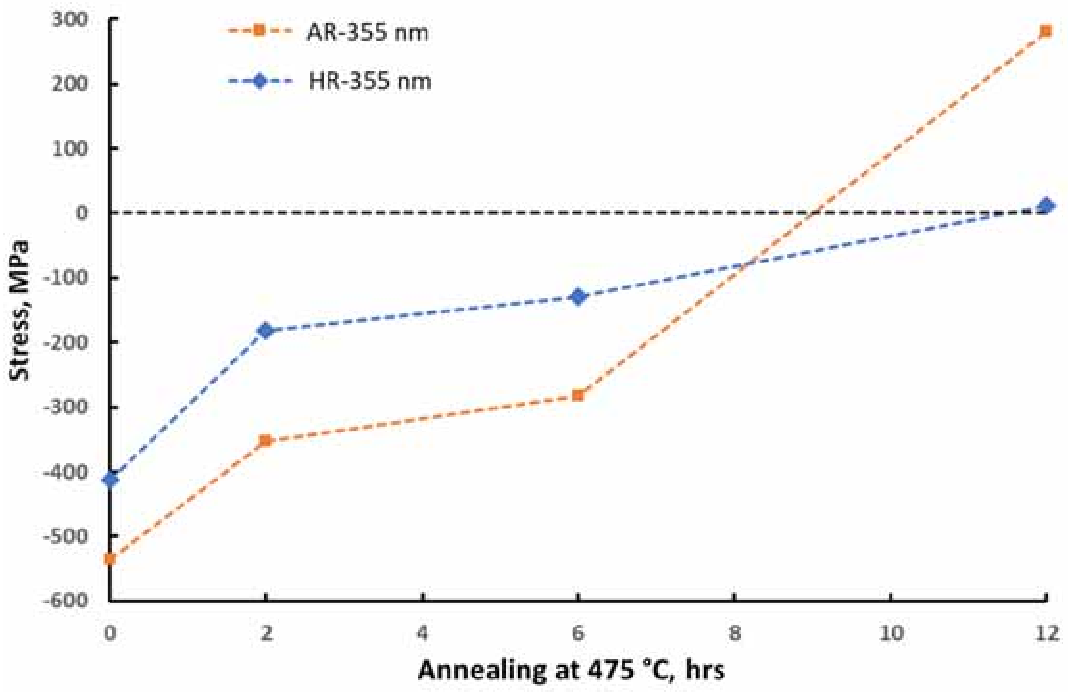
- Absorption at 355 nm measured by photothermal common-path interferometry
- Absorption reduced by a factor of ~2 for AR-coatings
- HR-mirrors exhibit higher absorption
- Both coating types exhibit similar trend



M. Falmbigl et al., Opt. Exp. 30/8 12326, 2022.

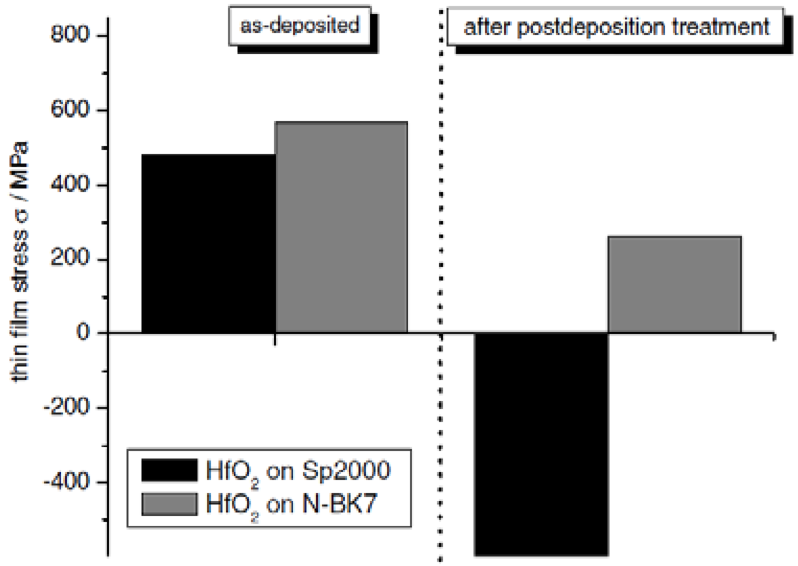
Stress of AR- & HR-coatings at 355 nm

- Stress was measured on 4” Si-wafers (different thermal expansion than glass substrates)
- As deposited: high compressive stress (SiO_2: -530 MPa; HfO_2: -365MPa)
- HR-mirror almost stress-free after annealing for 12 hours
- Similar trend for both coatings



M. Falmbigl et al., Opt. Exp. 30/8 12326, 2022.

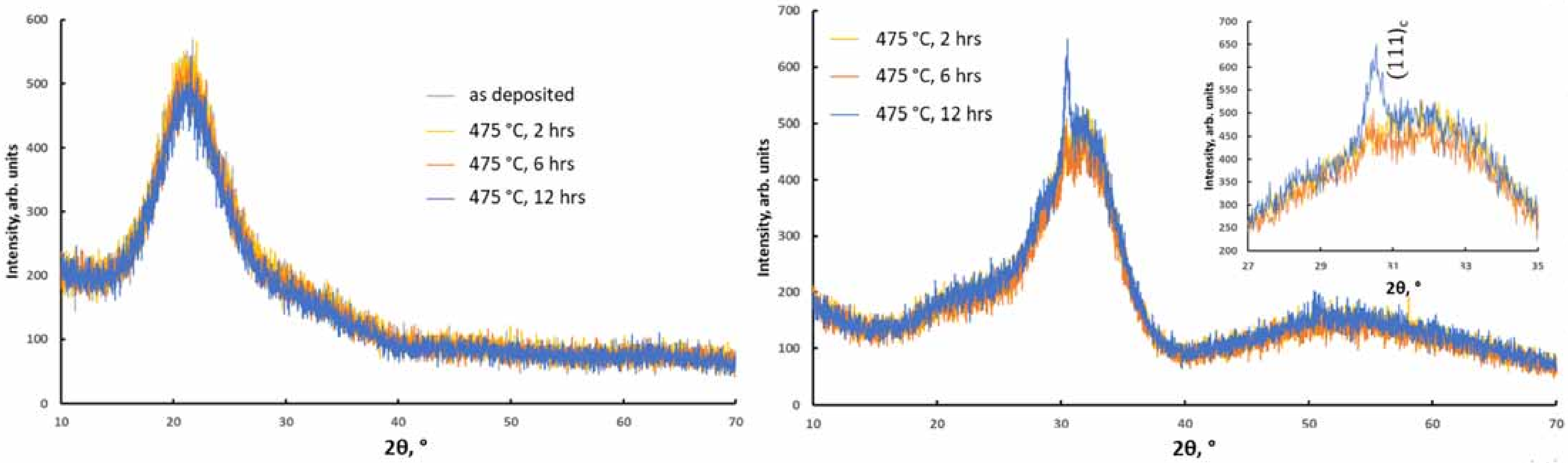
Influence of substrate:



M. Bischoff et al., Appl. Opt. 53/4 A212, 2014.

GI-X-ray diffraction of AR- & HR-coatings at 355 nm

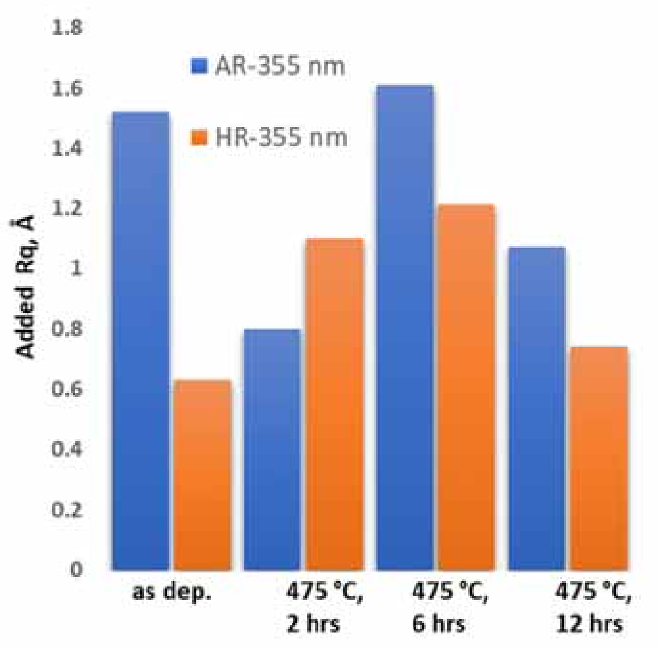
- Both coatings amorphous after deposition on fused silica substrates
- No crystallization for AR-coatings after annealing
- Crystallization of cubic HfO_2 for HR-mirrors after annealing for 6 hours



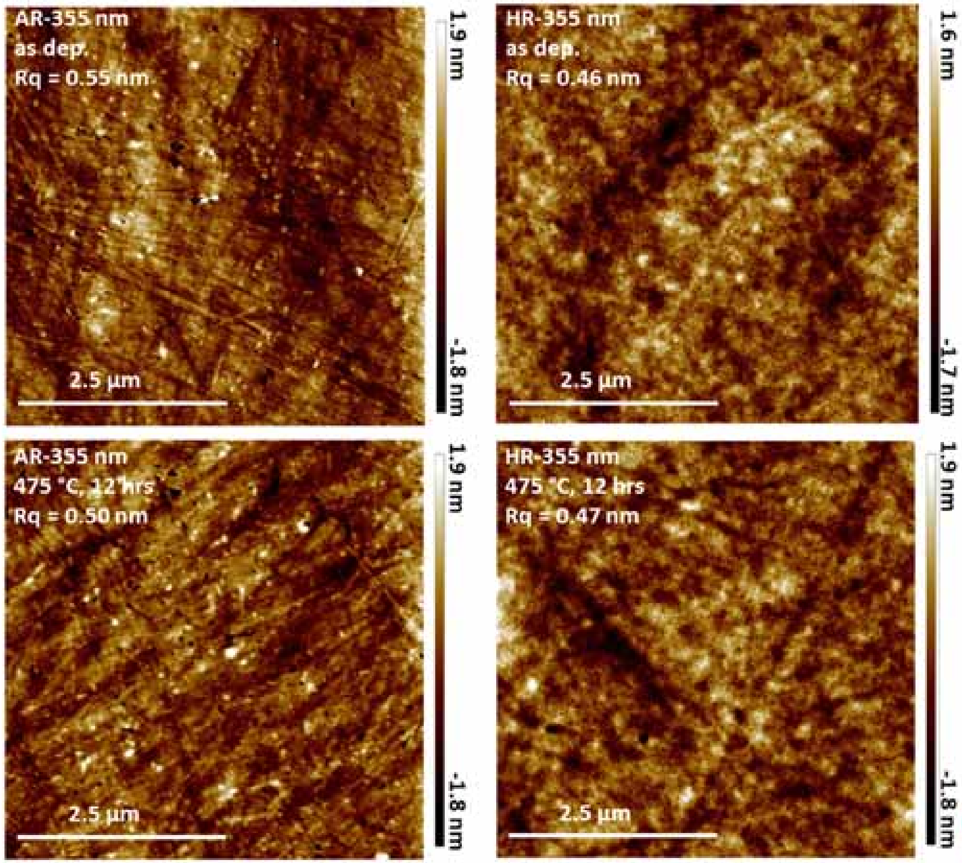
M. Falmbigl et al., Opt. Exp. 30/8 12326, 2022.

Surface roughness of AR- & HR-coatings at 355 nm

- Surface roughness was measured with AFM
- No clear correlation between annealing duration and surface roughness was found
- All AFM images show the traces from polishing indicating preservation of substrate surface



AR-coatings:

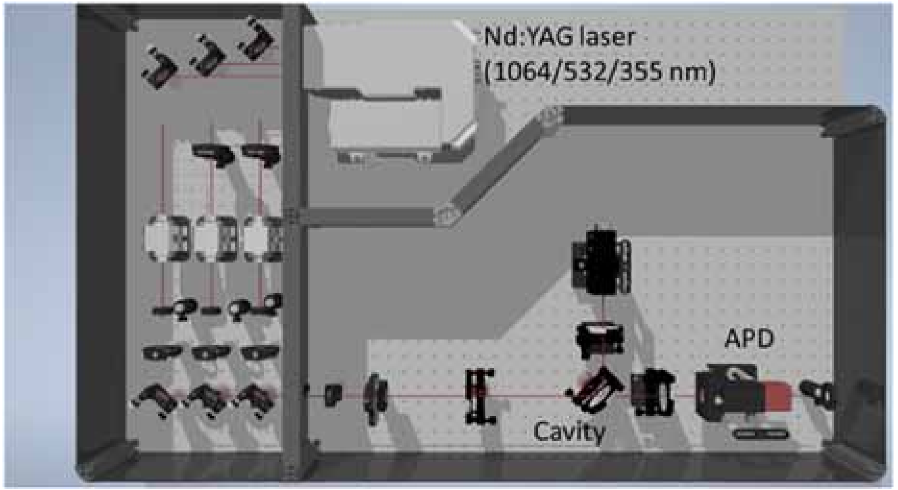


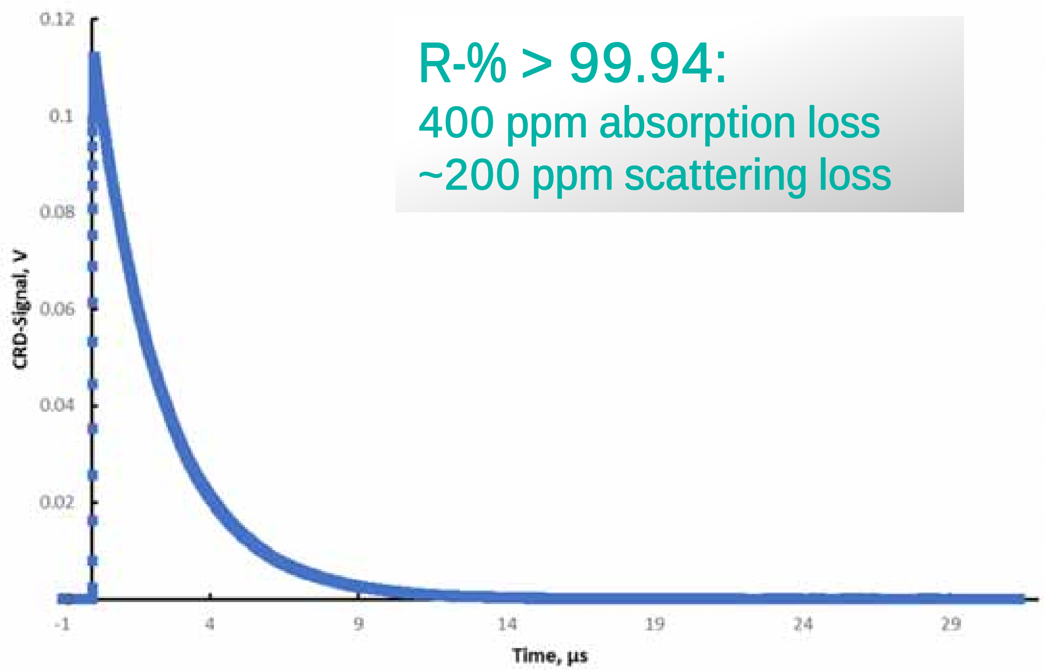
HR-mirrors:

M. Falmbigl et al., Opt. Exp. 30/8 12326, 2022.

Reflectance of the HR-mirror at 355 nm

- Cavity ringdown (CRD) at 355 nm with AOI = 0°
- Measured after 6 hours of annealing at Fraunhofer IOF



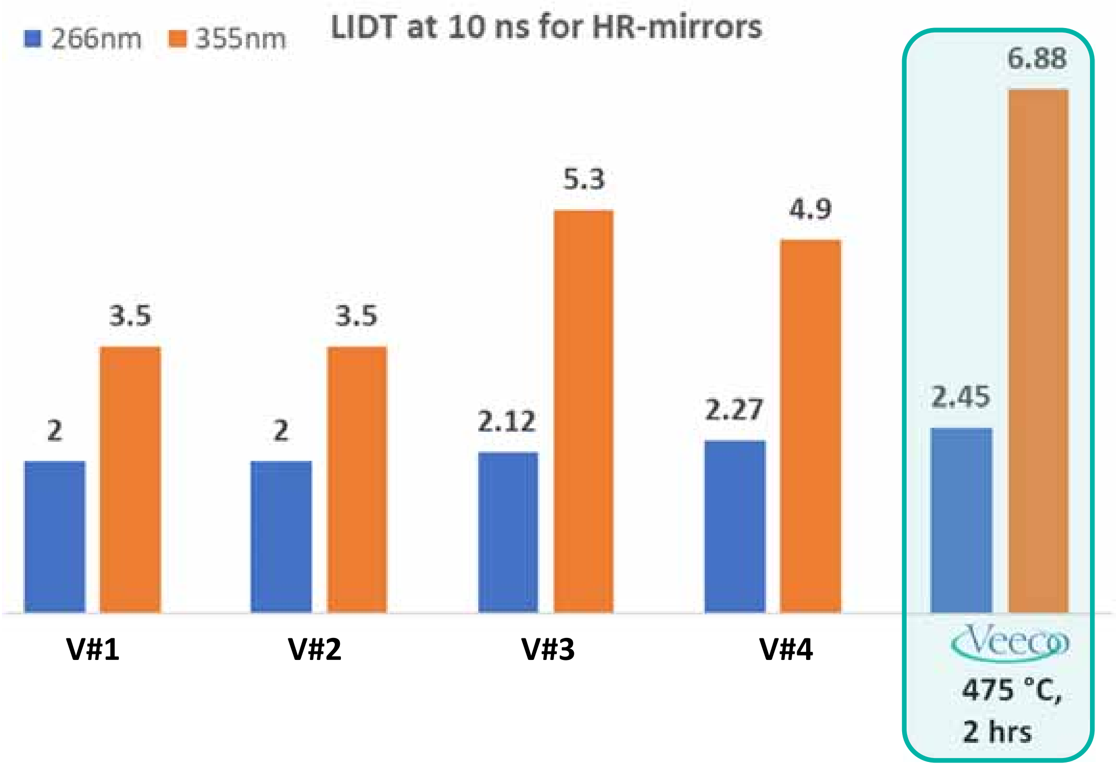


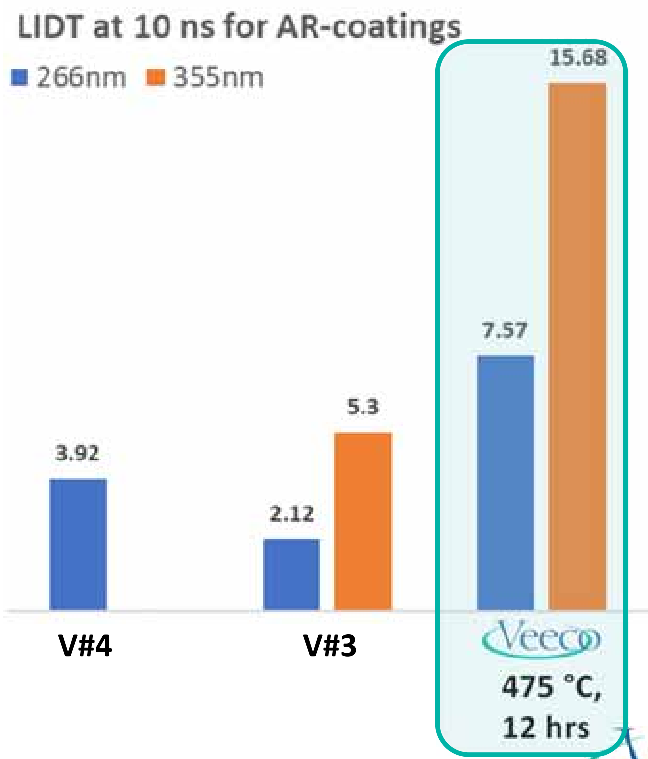
R-% > 99.94:
400 ppm absorption loss
~200 ppm scattering loss

M. Falmbigl et al., Opt. Exp. 30/8 12326, 2022.

Laser induced damage threshold (LIDT)

- Comparison between different vendor specifications and Veeco results
- LIDT values in J/cm^2 for 10 ns at 20 Hz
- Veeco coatings meet or exceed specifications for state of the art UV-coatings





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Conclusions

- Single layer absorption needs to be optimized for UV-applications
- Annealing significantly reduces absorption:
  - For AR- and HR-coatings at 355 nm lowest absorption was found after 6 hours at 475 °C
- Coating stress can be altered from compressive to tensile by annealing
  - HfO_2 crystallization might play a role in this change of stress
- Excellent reflectance and LIDT-values were demonstrated

Thank you for your attention

Any questions? Please feel free to contact me: mfalmbigl@veeco.com