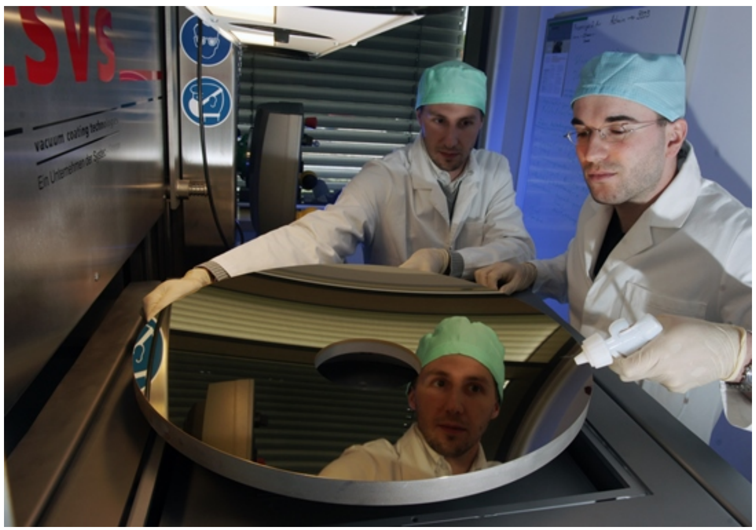
Progress on the Manufacture of Optical Coatings



Norbert Kaiser

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

Workshop Optical Coatings for Laser Applications
11th June 2015
NTB Buchs, Switzerland

Fraunhofer IOF

09. Juli 1946:

Gründung der Gerätebau-Anstalt in Balzers

durch Fürst Franz Josef II.,

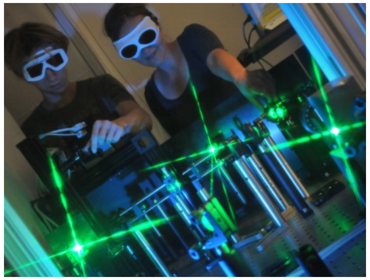
Dr. Max Auwärter und

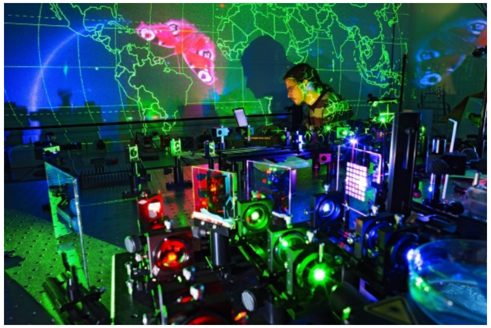
Emil Georg Bührle


Webster's
NewWorld
Jones

OUTLINE

- Markets
- Advanced AR systems
- Space and astro-optics from EUV to IR
- International trends
- Summary

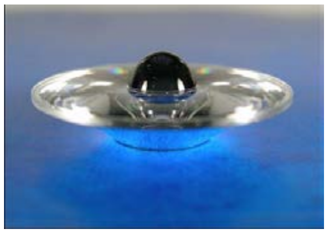


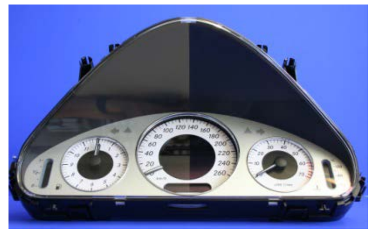


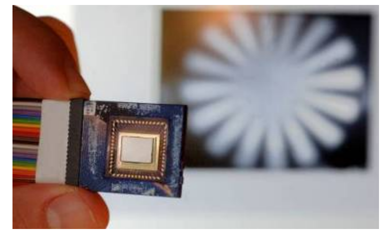
OUTLINE

- **Markets**
- Advanced AR systems
- Space and astro-optics from EUV to IR
- International trends
- Summary

Optical Technology – Key Enabling Technology



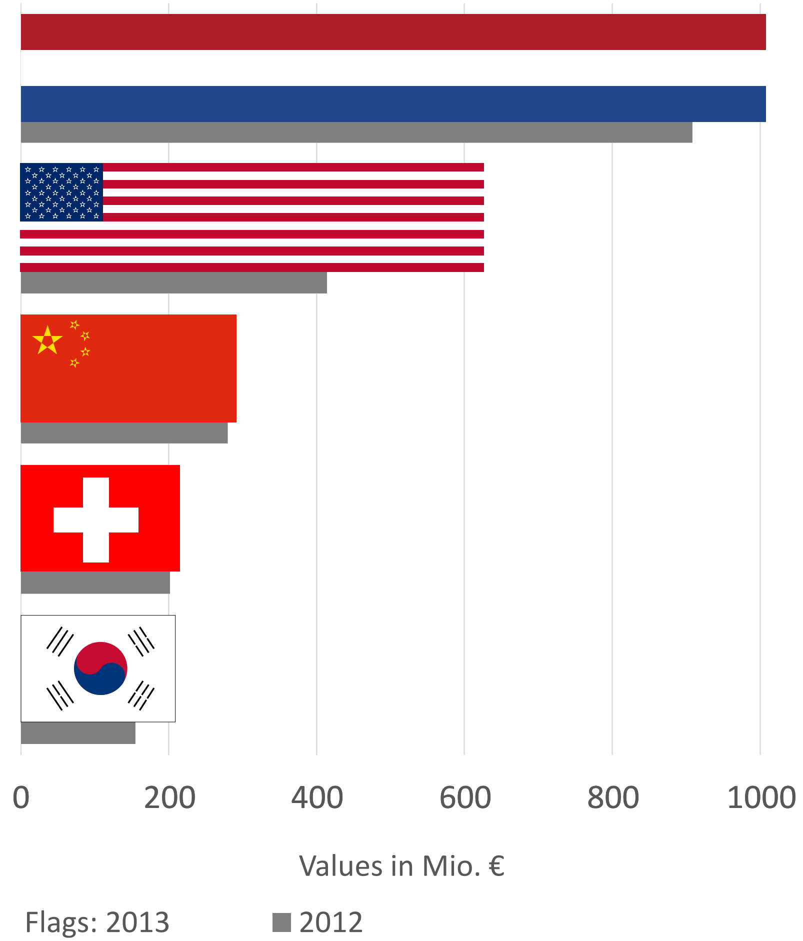




Markets

- Production
- Aerospace
- Information
- Medical technology
- Automotive
- Astronomy
- Communication
- Life science
- Illumination
- Security
- Electronics
- Research

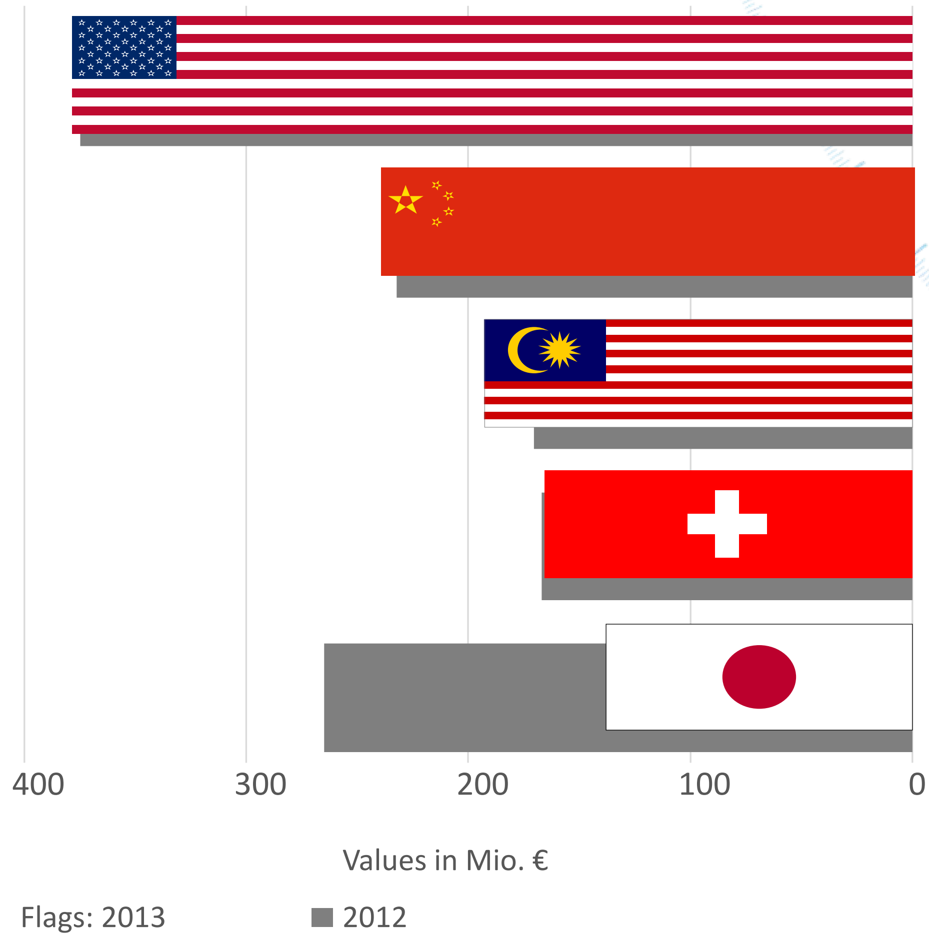
EXPORT



Quelle: Statistisches Bundesamt, SPECTARIS

SPECTARIS

IMPORT
Optical Components + Lightsources



Quelle: Statistisches Bundesamt, SPECTARIS

SPECTARIS

OUTLINE

- Markets
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Transparency is a Beautiful Thing - Greta oto

nature COMMUNICATIONS

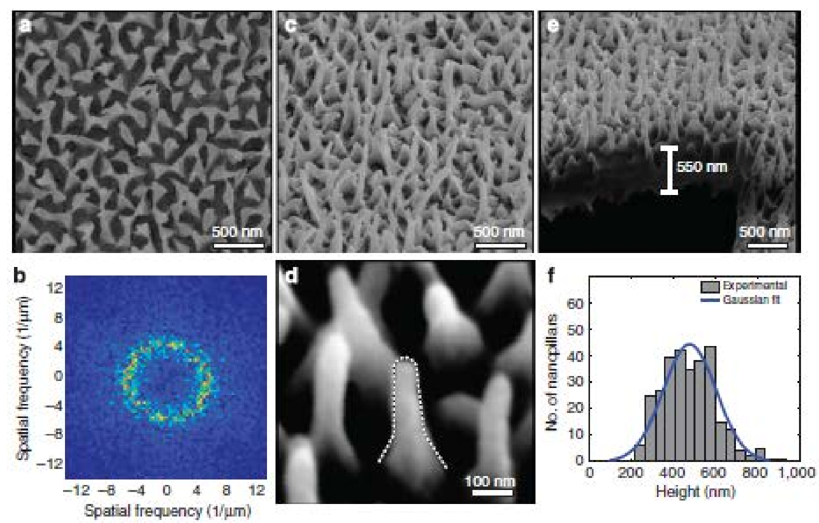
ARTICLE

Received 26 Jun 2014 | Accepted 13 Mar 2015 | Published 22 Apr 2015

DOI: 10.1038/ncomms7909

The role of random nanostructures for the omnidirectional anti-reflection properties of the glasswing butterfly

Radwanul Hasan Siddique[1], Guillaume Gomard[2] & Hendrik Hölscher[1]



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Glass Wing Butterfly (Greta Oto)

Broadband and wide-angle AR coatings containing organic nanostructured layers

Antireflection coatings with step-down index profile containing plasma-etched organic layers

Ulrike Schulz*, Friedrich Rickelt, Henning Ludwig, Peter Munzert and Norbert Kaiser

Fraunhofer Institute of Applied Optics and Precision Engineering, A.-Einstein-Str. 7, 07745 Jena, Germany
*ulrike.schulz@iof.fraunhofer.de

Received 20 Mar 2015; revised 21 Apr 2015; accepted 21 Apr 2015; published 4 May 2015
(C) 2015 OSA 1 Jun 2015 | Vol. 5, No. 6 | DOI:10.1364/OME.5.001259 | OPTICAL MATERIALS EXPRESS 1259

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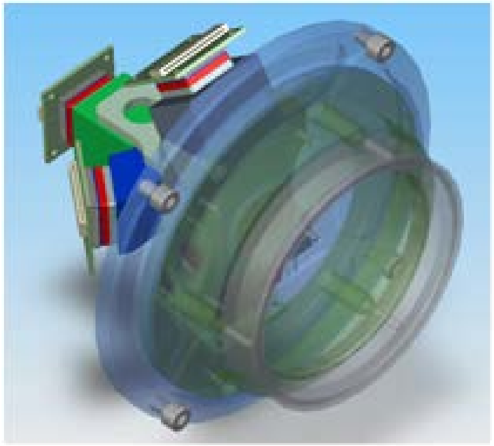
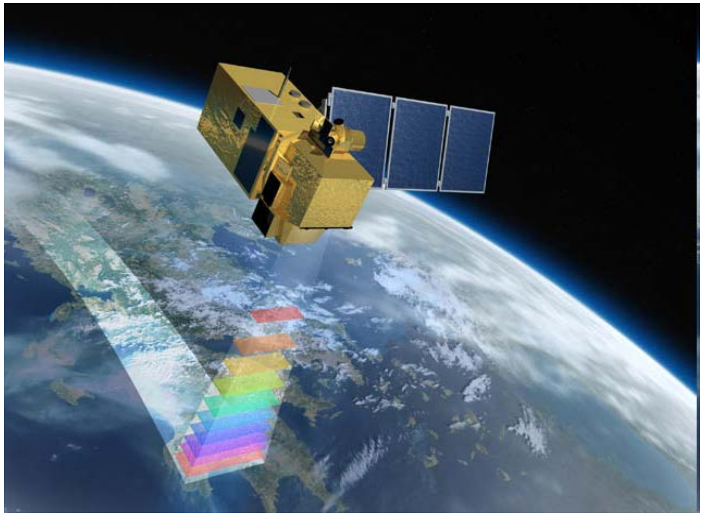
Requirements for broadband antireflection

- Enhanced spectral ranges UV- VIS -NIR
- Broad range of light incidence angles
- Camera systems containing curved lenses



Multispectral- camera



Picture: © Astrium

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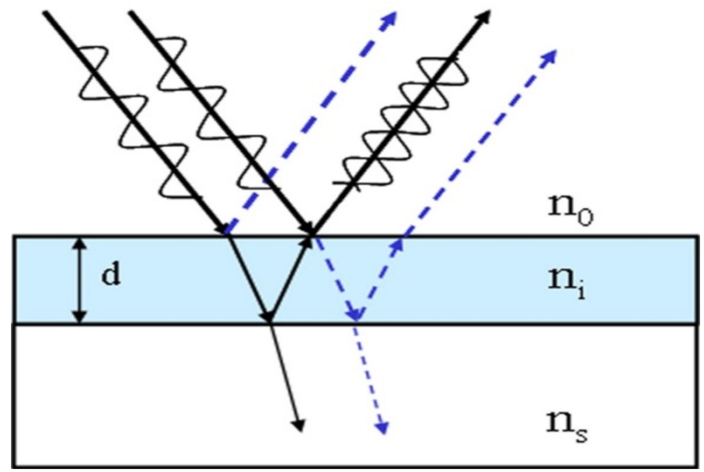
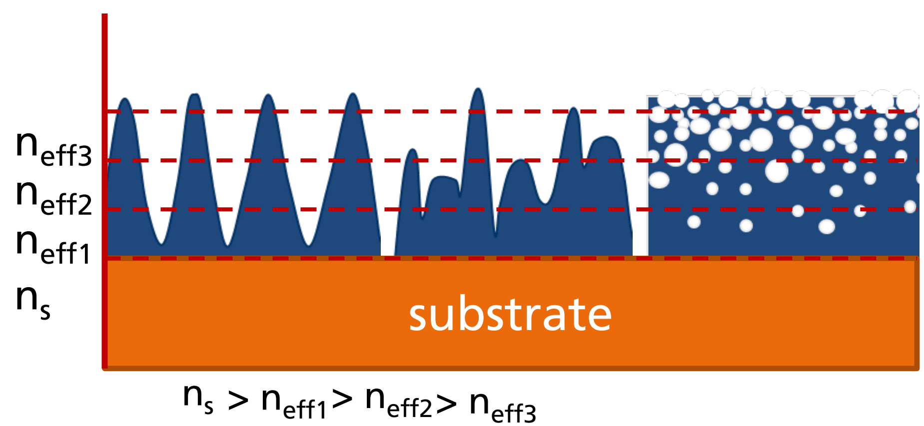
Principles to achieve AR properties

- interference coatings
  → destructive interference



- nanostructures
  → effective medium
  → low „effective“
  refractive index n



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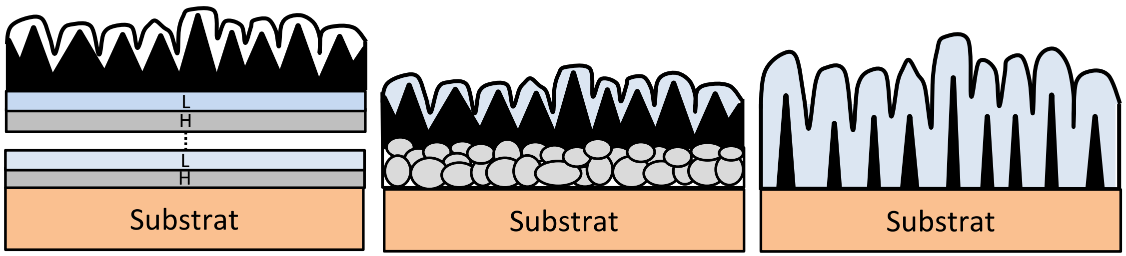
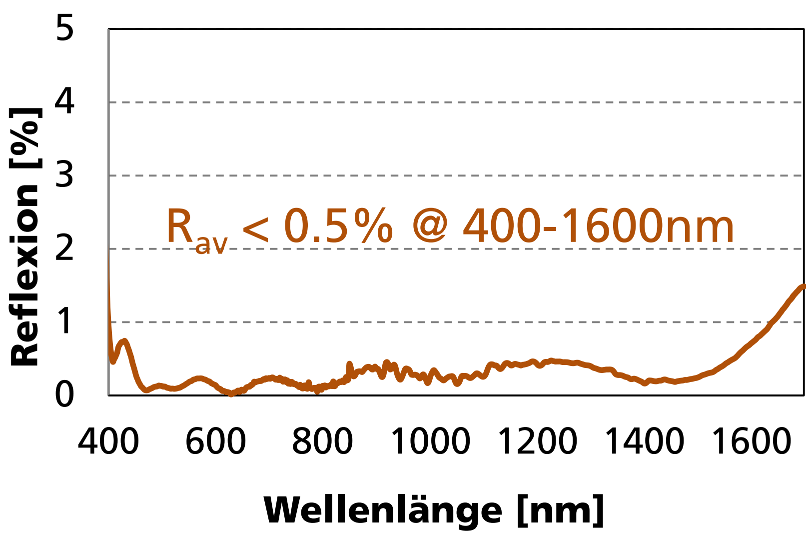
BMBF-Verbundprojekt FIONA (2012-2015)

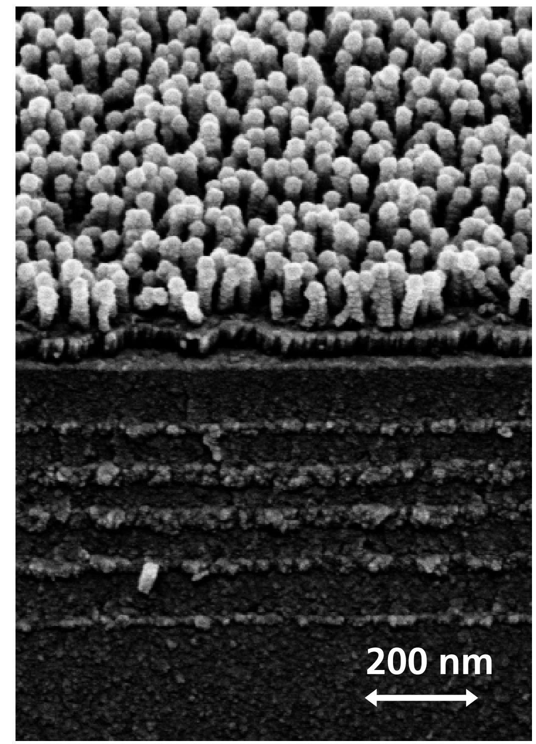
- Ziel: Farbneutrale Interferenzschichten zur Entspiegelung unter Berücksichtigung organischer Nanostrukturen
- Ergebnis: Verschiedene Systeme mit ausgezeichneter Entspiegelungswirkung



Patent IOF WO09127581 Patent IOF US20140374377 Patent IOF DE102013103075

- Beispiel:





OUTLINE

- Markets
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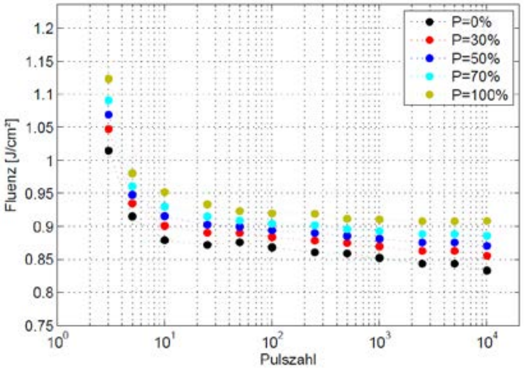
- **Space and astro-optics from EUV to IR**
- International trends
- Summary

Metall-dielektrische Schichten für Scanspiegel für Ultrakurzpulslaser

- **Metallspiegel:**
  technisch und wirtschaftlich attraktive Lösung für Scanspiegel
- **Hohe Oberflächenqualität NiP-Schicht, Diamantbearbeitung und Politur:**
  Hochfrequenzrauheit < 0,2 nm rms
- **Metall-dielektrische Schicht:**
  qualifiziert für Anwendung in Laserscannern
- **Laserzerstörschwelle (LIDT):**
  > 0.8 J/cm² @ 1030 nm, 425 fs, AOI 45°



Institute of Applied Physics
Friedrich-Schiller-Universität Jena
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4966 Vol. 54, No. 16 / June 1 2015 / *Applied Optics* **Research Article**

applied optics

Description of particle induced damage on protected silver coatings

Stefan Schwinde,[1,2,*] Mark Schürmann,[1] Paul Johannes Jobst,[1,2] Norbert Kaiser,[1] and Andreas Tünnermann[1,2]

[1]Fraunhofer-Institute for Applied Optics and Precision Engineering IOF, Albert-Einstein-Straße 7, 07745 Jena, Germany
[2]Friedrich-Schiller-University Jena, Institute of Applied Physics, Abbe Center of Photonics, Albert-Einstein-Straße 15, D-07745 Jena, Germany
*Corresponding author: stefan.schwinde@iof.fraunhofer.de

Received 24 March 2015; revised 28 April 2015; accepted 28 April 2015; posted 28 April 2015 (Doc. ID 236643); published 21 May 2015

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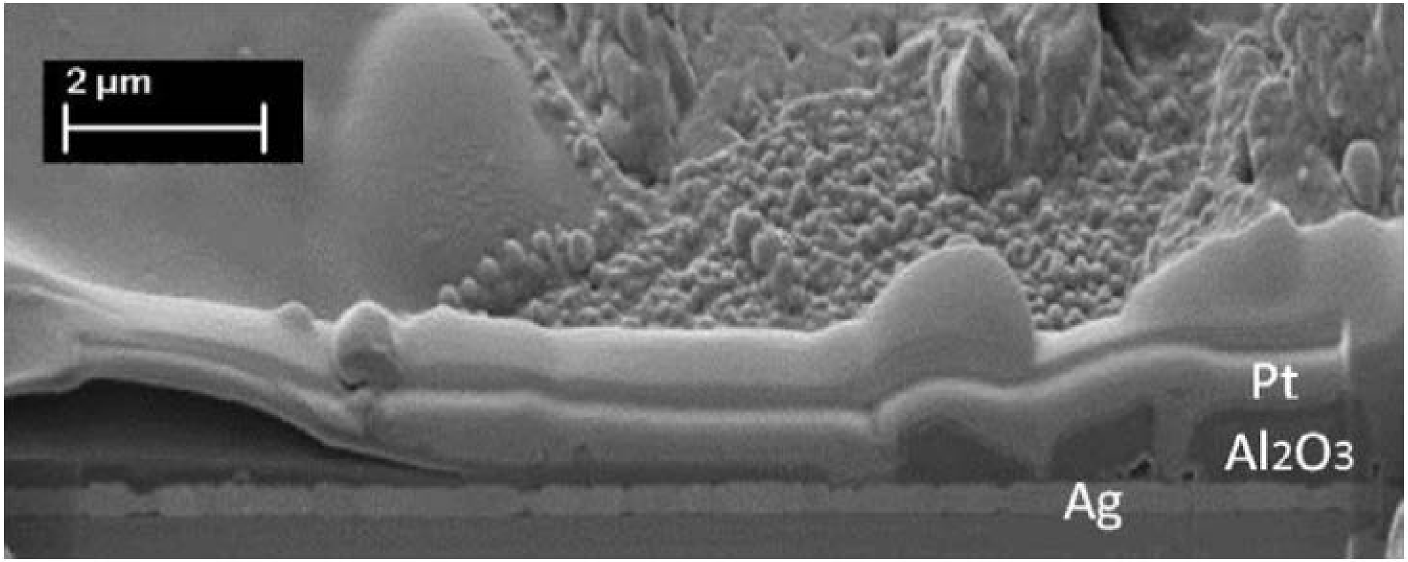
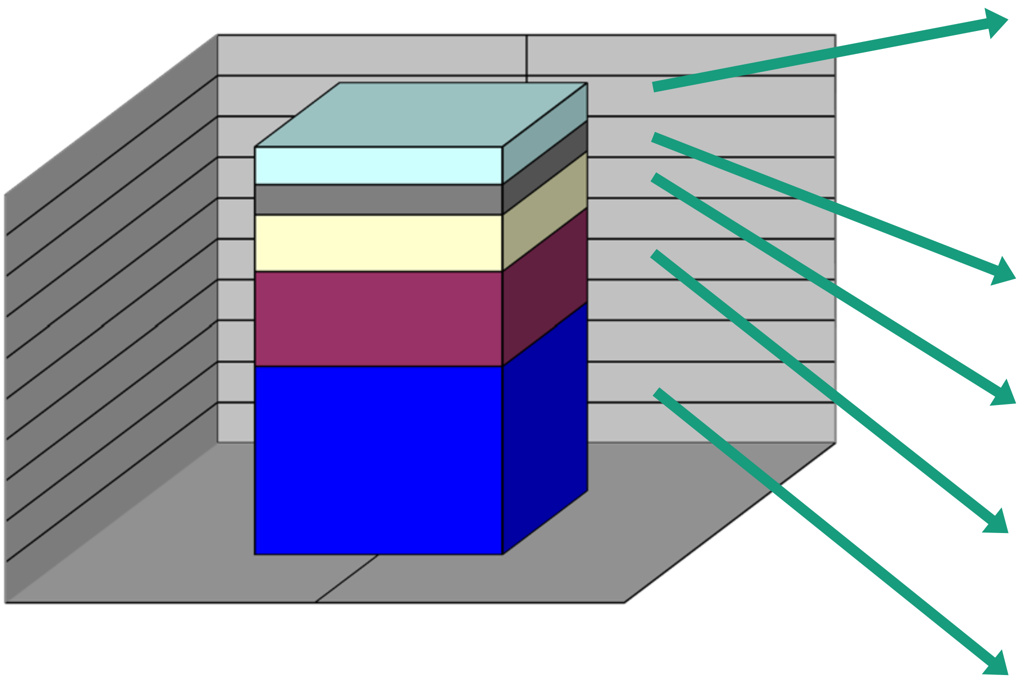


Fig. 2. Cross section of the surrounding area of a particle in the center of a defect in a protected Ag coating. Preparation by FIB and imaging by SEM.

Composition of protected silver coating



Protective layer:

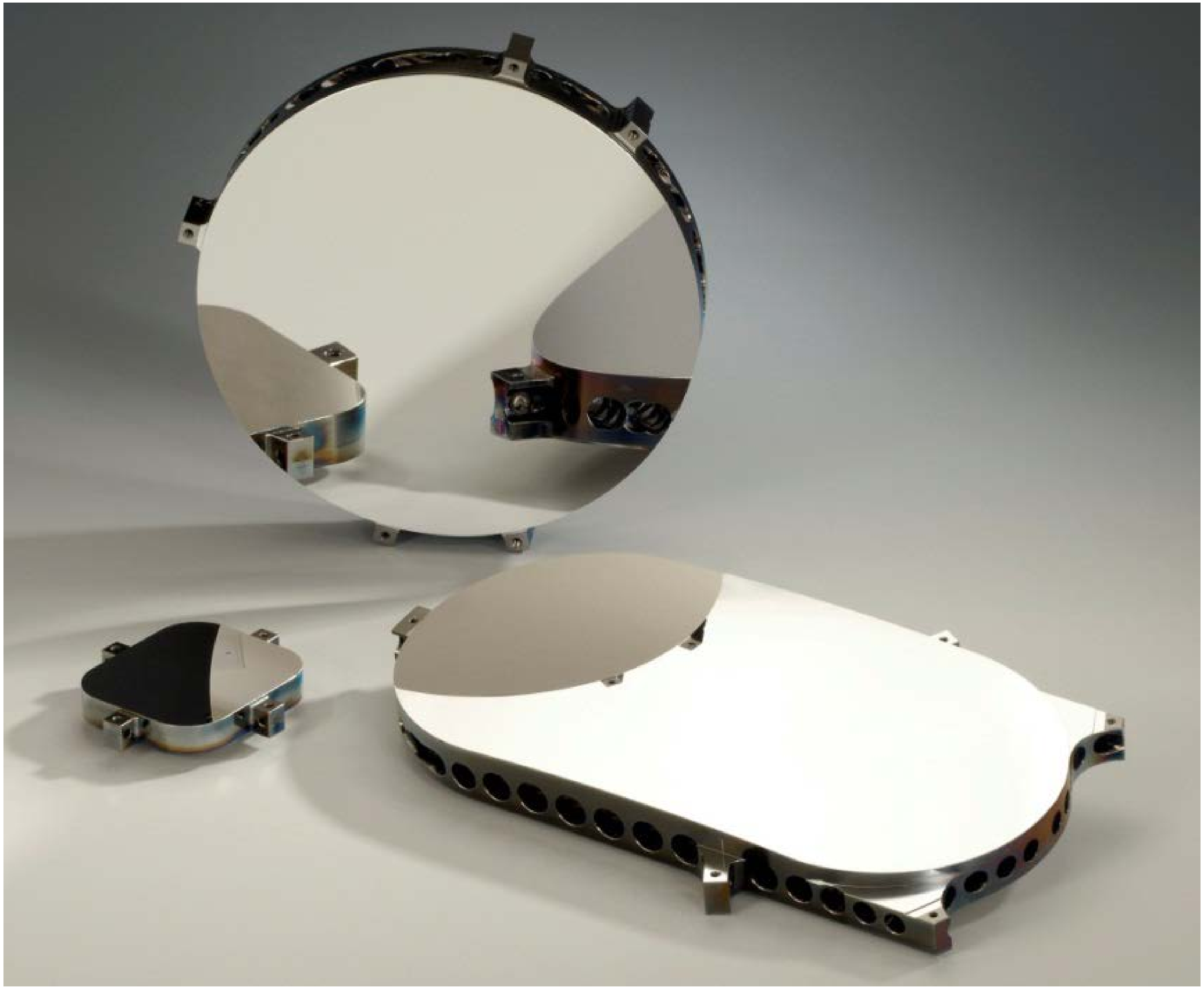
- environmental stability
- optical performance
- dielectric material
  (metal oxides, metal nitrides)

High-reflective silver layer

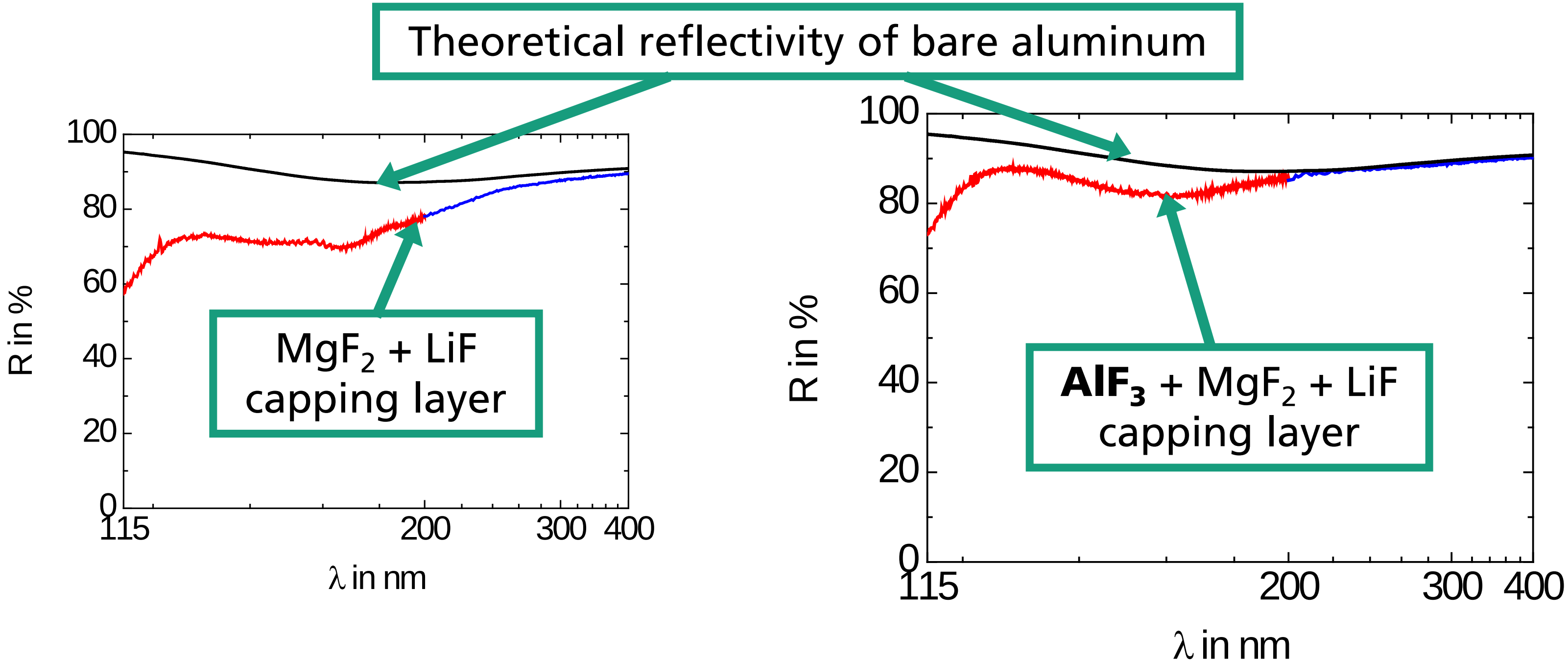
Adhesion layer / diffusion barrier

(Polishing layer, e.g. NiP)

Substrate (for example metals)



DUV and VUV – 120 nm -> 400 nm
Aluminum reflectors



Increased reflectivity due to addition of AlF_3 to capping layer system

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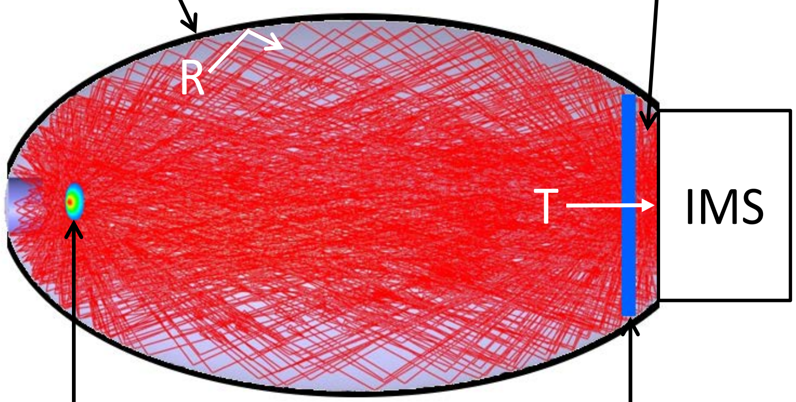
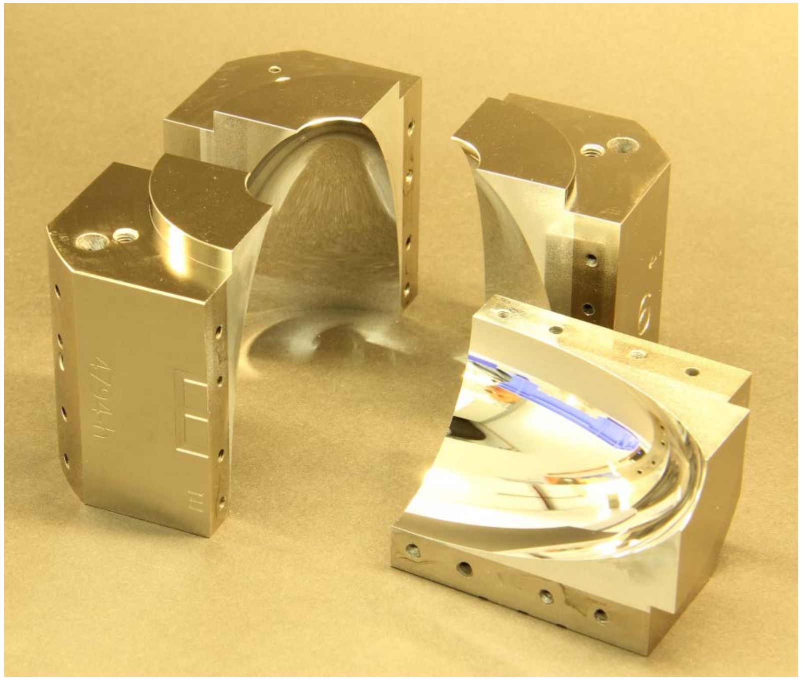
Kompetenz VUV-Reflektorbeschichtung: Multipass-Reflexionszelle für DIVE

Prinzip



praktische Umsetzung



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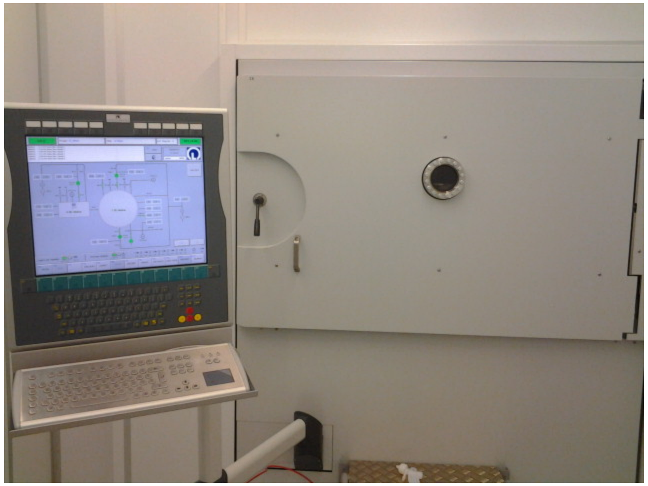
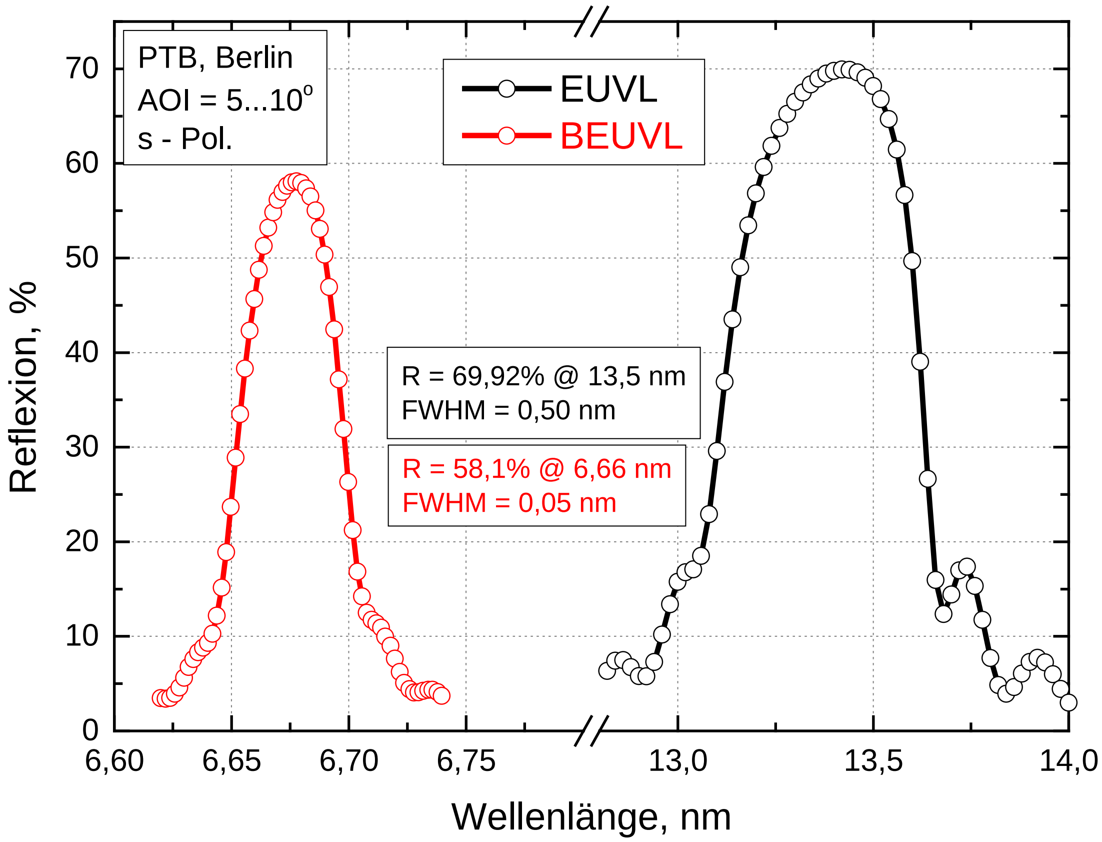
Beschichtung hochreflektierender Spiegel für EUV/BEUV Lithographie

Beschichtungsanlage Nessy-3:

- in Betrieb seit Ende 2013
- Substrate bis ∅ 200 mm
- Metallschichten & dielektrische Schichten





Beschichtung hochreflektierender Spiegel für EUV/BEUV Lithographie

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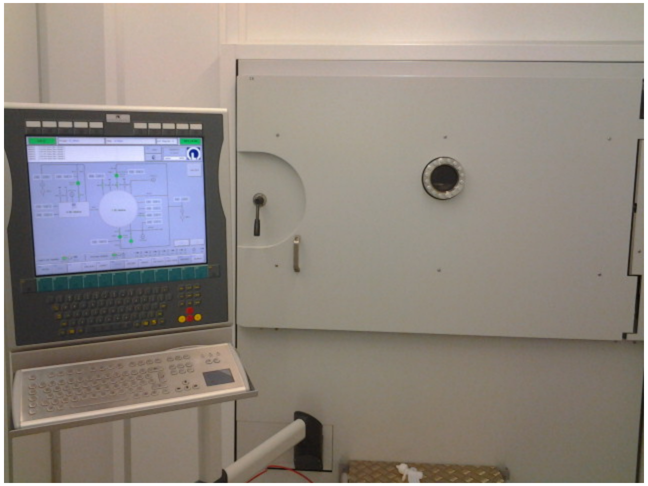
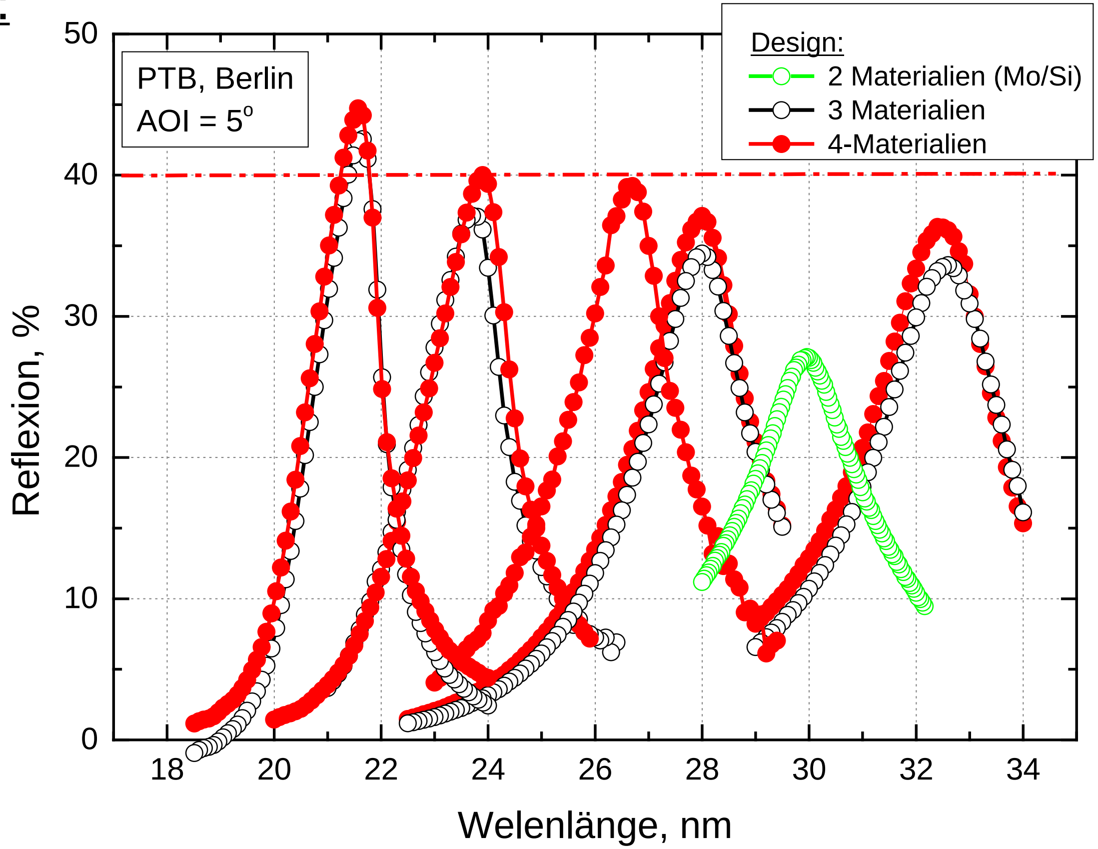
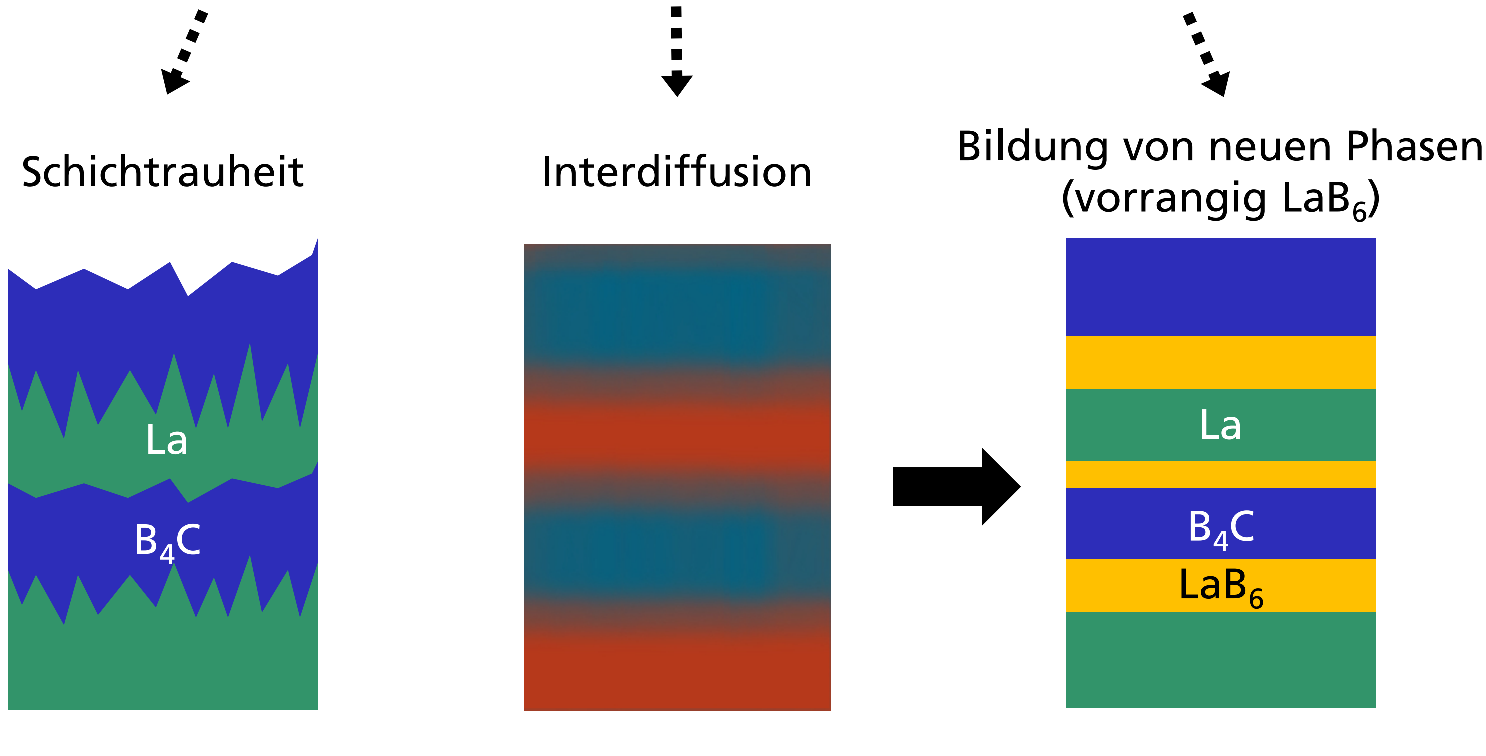




Ergebnisse

Grenzflächenbeschaffenheit in La/B_4C Multilayern

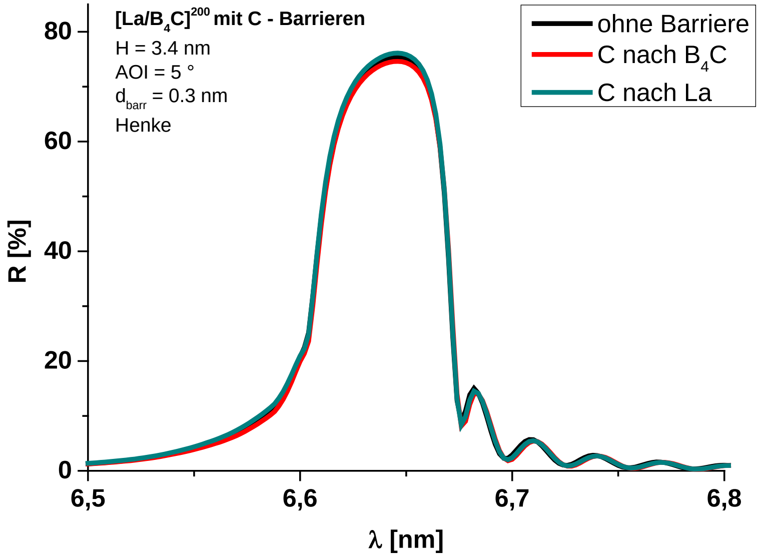
- Grenzflächen in La/B_4C Multilayern sehr breit (σ ≈ 0,6 - 0,8 nm)

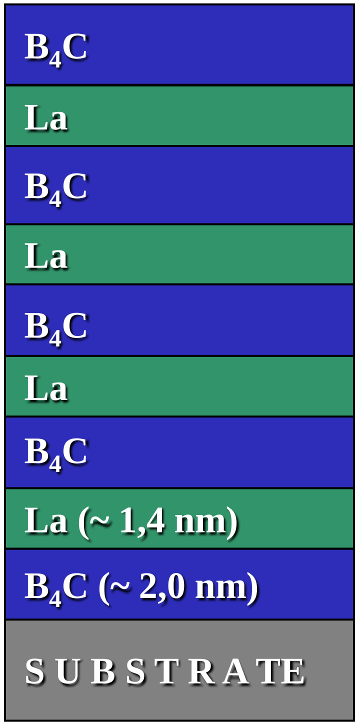


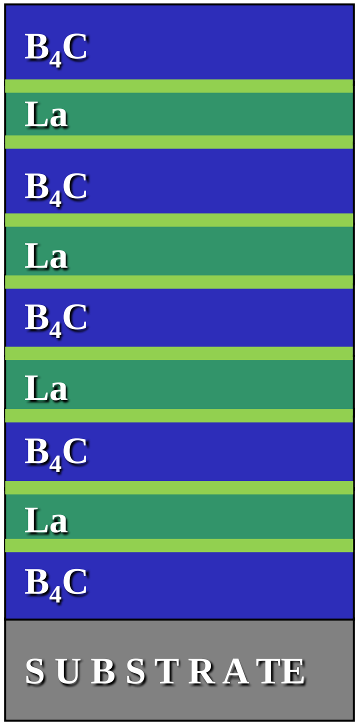
Ergebnisse

Anwendung ultradünner Diffusionsbarrieren

- ultradünne C-Barrieren an Grenzflächen
- Dicke: d_{barr} = 0,3 nm







OUTLINE

- Markets
- Advanced AR systems
- Space and astro-optics from EUV to IR
- **International trends**
- Summary

Physical insight toward electric field enhancement at nodular defects in optical coatings

Xinbin Cheng,[1,2,3] Abudusalamu Tuniyazi,[1,2] Zeyong Wei,[1] Jinlong Zhang,[1,2] Tao Ding,[1,2] Hongfei Jiao,[1,2] Bin Ma,[1,2] Hongqiang Li,[1] Tongbao Li,[1,2] and Zhanshan Wang[1,2,3,*]

[1]*MOE Key Laboratory of Advanced Micro-Structured Materials, Shanghai, 200092, China*
[2]*Institute of Precision Optical Engineering, School of Physics Science and Engineering, Tongji University, Shanghai, 200092, China*
[3]*IFSA Collaborative Innovation Center, Shanghai Jiao Tong University, Shanghai 200240, China*
[*]wangzs@tongji.edu.cn

#231132 - $15.00 USD Received 17 Feb 2015; revised 18 Mar 2015; accepted 19 Mar 2015; published 27 Mar 2015

6 Apr 2015 | Vol. 23, No. 7 | DOI:10.1364/OE.23.008609 | OPTICS EXPRESS 8609

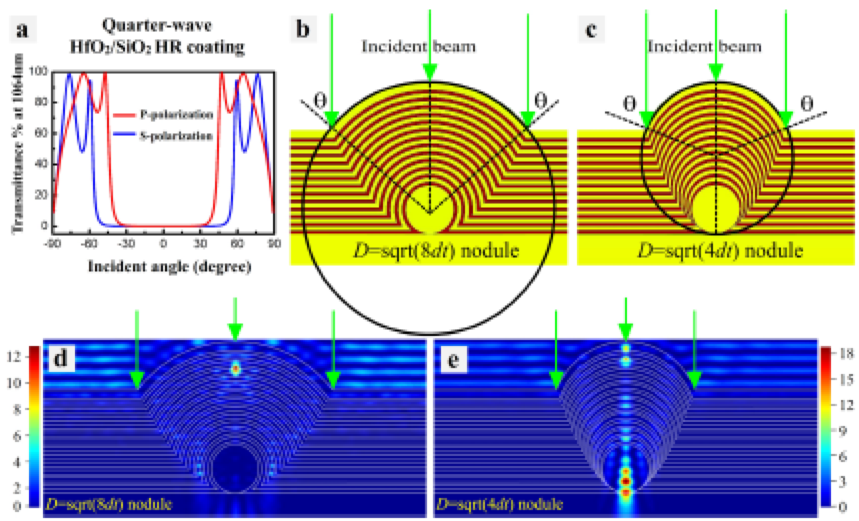


Fig. 1. The D = sqrt($8dt$) and D = sqrt($4dt$) nodules in the quarter-wave HfO_2/SiO_2 HR coating. (a) P-polarized and S-polarized angular dependent transmission curves of the quarter-wave HfO_2/SiO_2 HR coating. (b and c) Geometrical modeling of the D = sqrt($8dt$) nodule (b) and the D = sqrt($4dt$) nodule (c). (d and e) FDTD-simulated P-polarized EFI distributions in vicinity of the D = sqrt($8dt$) nodule (d) and the D = sqrt($4dt$) nodule (e). Two nodular geometries show quite different EFI distributions.

Nanosecond laser-induced damage of nodular defects in dielectric multilayer mirrors [Invited]

Xinbin Cheng,[1,2] Abudusalamu Tuniyazi,[1,2] Jinlong Zhang,[1,2] Tao Ding,[1,2] Hongfei Jiao,[1,2] Bin Ma,[1,2] Zeyong Wei,[1] Hongqiang Li,[1] and Zhanshan Wang[1,2,*]

[1]Key Laboratory of Advanced Micro-Structured Materials, Ministry of Education, Shanghai 200092, China

[2]Institute of Precision Optical Engineering, School of Physics Science and Engineering, Tongji University, Shanghai 200092, China

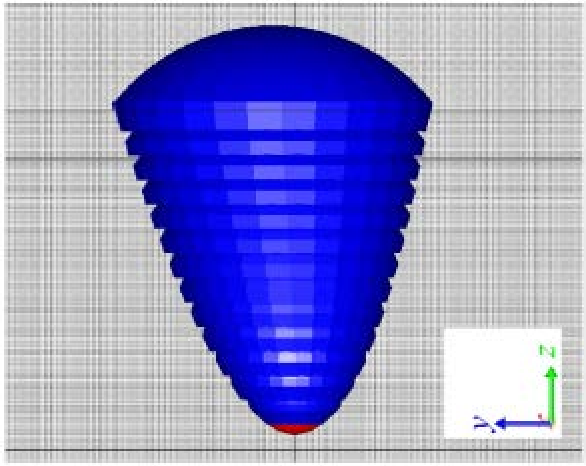


Fig. 6. 3D geometry of an asymmetrical nodule initiating from a 0.9 μm silica microsphere.

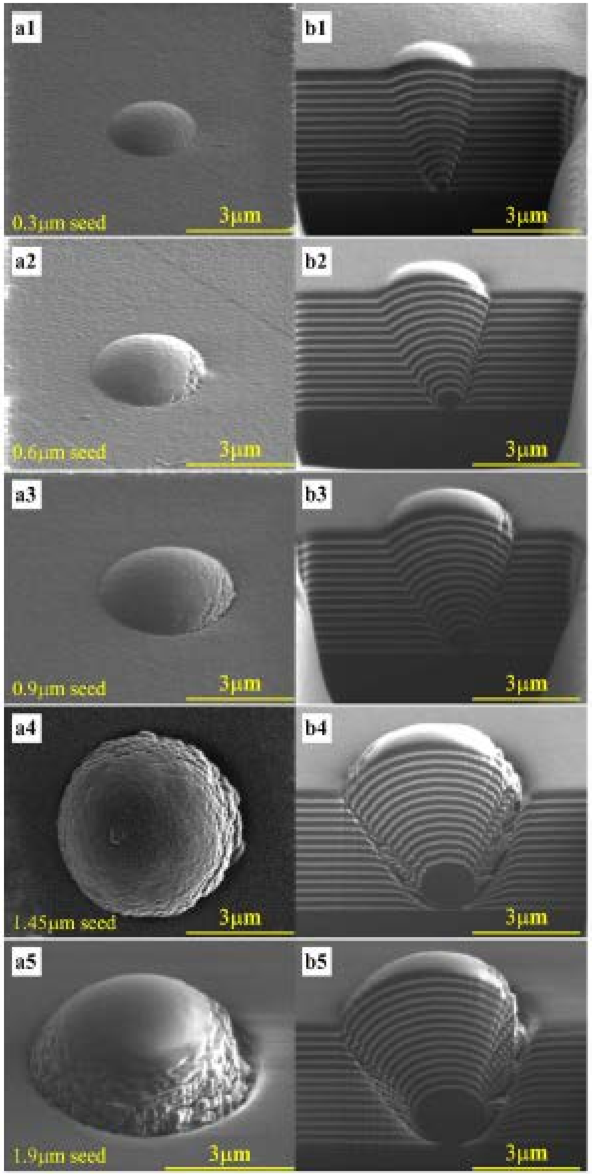
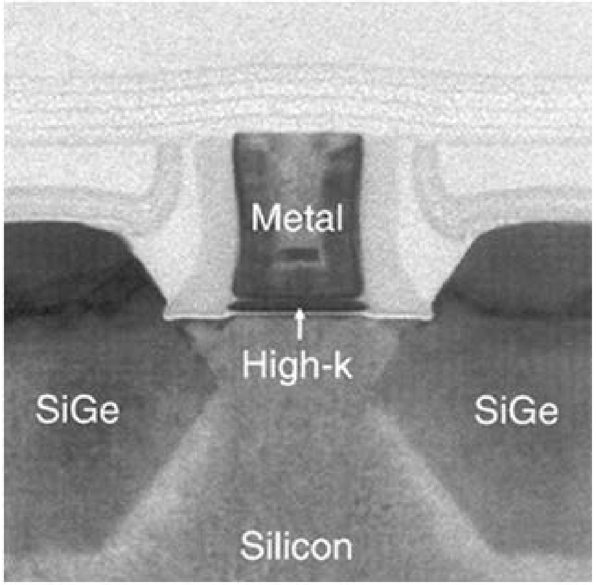
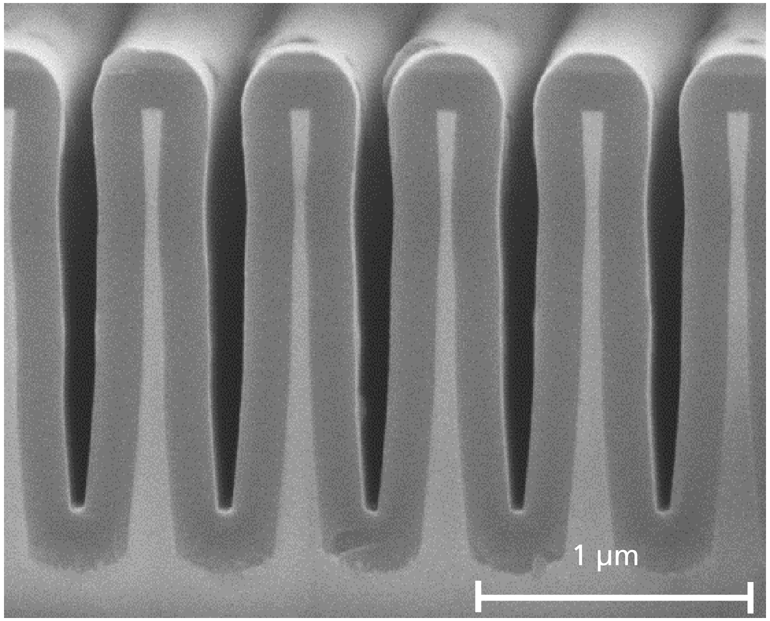


Fig. 5. (a1)–(a5) Top-view micrographs of asymmetrical nodules. (b1)–(b5) Cross-sectional micrographs of the corresponding asymmetrical nodules.

Atomic Layer deposition (ALD)



Intel, 2007



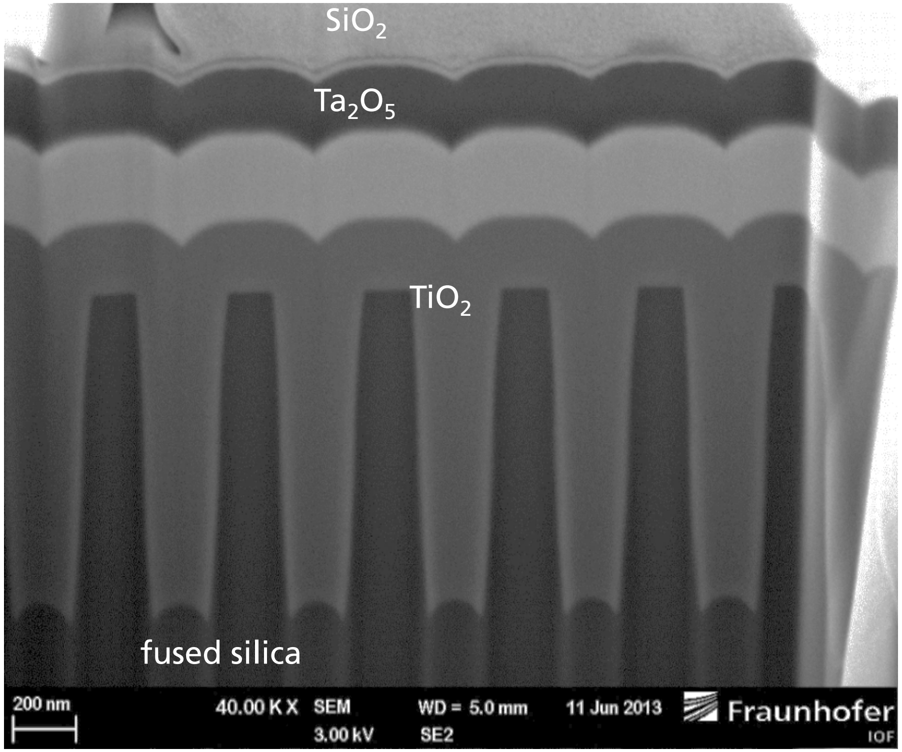
ALD Semiconductor-Industry

⇨ Optical Coatings

Tuesday, June 24, 11:40 – 12:00 S3-03

Plasma-ALD of SiO_2 layers for optical applications

A. Bingel[1 2], L. Ghazaryan[1], S. Ratzsch[1], A. Szeghalmi[1], P. Munzert[2], U. Schulz[2], N. Kaiser[2], A. Tünnermann[1 2]
[1] Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University [Germany]
[2] Fraunhofer Institute for Applied Optics and Precision Engineering [Germany]



New Materials

Today, the thin film technology is employed in a wide range of applications. Among the various deposition methods, physical vapor deposition (PVD) and chemical vapor deposition (CVD) processes are widely used in industry. However new processes and/or new materials have to be developed to improve the film properties and to enable synthesis of new materials.

OUTLINE

- Markets
- Advanced AR systems
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- International trends
- **Summary**

Recent developments in the field of optical coatings from XUV to IR wavelength

So what does all this add up to?

Leadership in optical thin film plasma–technology is not only a direct key for the development of competitive future concepts and products in optical technology, it also promises a high economical prosperity of the affected industrial companies because of the high net product achievable with optical thin films.

Acknowledgments

Fraunhofer FEP

ZEISS

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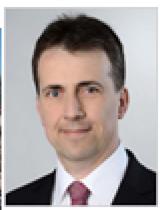
SPECTARIS



GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

LASER ZENTRUM HANNOVER e.V.

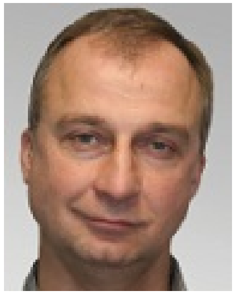
LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

MAX-PLANCK-INSTITUT FÜR QUANTENOPTIK GARCHING

MPQ

Acknowledgments

Ulrike Schulz



Sergiy Yulin

Olaf Stenzel

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Fraunhofer IOF - Research for the future

Thank you for your attention!