Fraunhofer
FEP

Fraunhofer Institute for Electron
Beam and Plasma Technology FEP

Large area anti-reflective coatings

Large area anti-reflective coating on glass substrate

Vertical in-line sputtering plant for coating of large area surfaces

Large area anti-reflective coatings

Various anti-reflective (AR) coating systems on glass or polymer surfaces are required in many fields of application. The aim is the adaptation between the different refractive indices of glass and ambient media (e. g. air). This can be easily be realized for one wavelength λ by the deposition of one low-index layer in the optical thickness of a quarter-wave of this special wavelength. In air, the optimal refractive index of such a layer results in $n_{layer}=\sqrt{(n_{glass})}$.

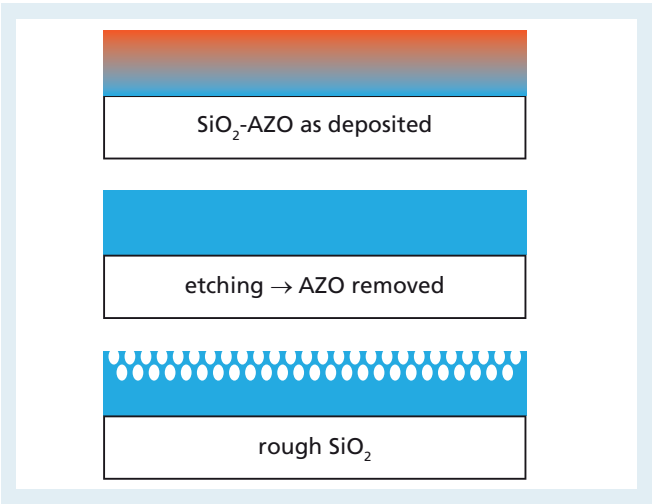
However, such a perfectly suitable AR material cannot be found for most of the potential glass materials. Therefore, it is necessary to replace it by multilayer systems with alternating low and high index layers of naturally occurring transparent metal oxides or e. g. nitrides, etc.

In practical applications, broader bandwidths of reduced reflectance are usually required, for example wavelength ranges of several hundreds of nanometers in the visible spectral range (VIS). Consequently more sophisticated multilayer designs are needed for this purpose.

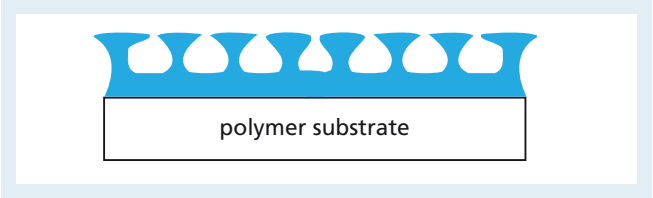
Anti-reflective surface functionality can be realized by different optical principles: Nanostructured surfaces, gradient coatings and interference multilayer coating systems.

Structured surfaces have a graded refractive index between glass (or polymer) substrate and air by an adjusted porosity of coating material or substrate surface. In this way, the approximation of the effective medium between coating or substrate material and air-filled cavities is valid.

Nanostructured surfaces



Nanostructures for anti-reflective surfaces (Example I)



Nanostructures for anti-reflective surfaces (Example II)

Example I:

- Co-sputtering of a SiO_2:AZO-mixing layer of gradual concentration profile
- Wet-etching by hydrochloric acid (HCl) selectively removes the AZO fraction from the SiO_2:AZO-mixing layer
- Result is an SiO_2-coating of graded porosity → thus of graded refractive index

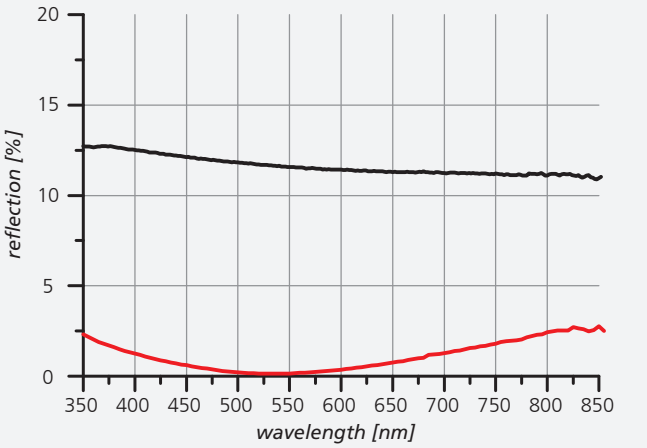
Example II:

- Plasma etching process PolAR of Fraunhofer FEP directly at polymer surface (e. g. of flexible foil or lacquer)
- Result is a significantly reduced reflectance of polymer surfaces by nanostructure

Properties of nanostructured AR-coatings:

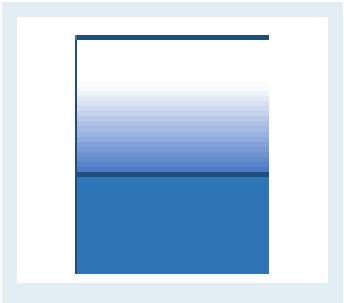
- Color-neutral
- Reflection reduction over a wide range of wavelength
- Mechanically sensitive surface → lowered mechanical durability in real applications (covered installation preferred)

Roll-to-roll pilot sputter coater



Reflection spectra of PET films

Gradient coatings

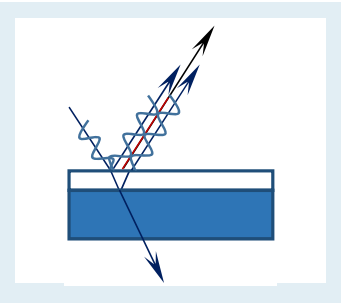


Gradient coatings

Anti-reflective **gradient coatings** need a decreasing refractive index of the gradient layer(s) from glass to ambient media (air). This can be realized by two principles:

- Mixture of 2 coating materials of different refractive index (Co-sputtering)
  → effective-medium-approximation of effective refractive index
  → materials concentration gradually changes in film-growth direction of the coating
- Mixture of one coating material and air-filled voids
  → leads to a structured surface

Interference coatings



Destructive interference at optical multilayer thin film stack

Interference multilayer coating systems are based on quarter-wave optical thin film thicknesses or on effective refractive indices of sublayer-sequences.

- Quarter wave-principle or e. g. needle designs
- Experienced use of several thin film design software solutions at Fraunhofer FEP

These multilayer designs can be additionally optimized:

- Color targets (chromaticity coordinates)
- Mechanical stress management
- Anti-dust properties
- Water and dirt repellency
- Anti-fingerprint properties

Our offer

All these AR systems are offered by Fraunhofer FEP at an area of up to 0.6 × 1.2 m² or roll-to-roll with roll width up to 650 mm. The coating systems can be adapted to real application conditions:

- Temperature and environmental stability
- Corrosion resistance
- Mechanical durability
- Mechanical stress optimization

Several substrates could be used:

- Thick glass and ultra-thin glass
- Polymers and lacquered surfaces
- Customer-specific substrates

We are able to adjust various process parameters of the coating and/or etching processes:

- Sputtering of planar or rotatable targets
- Large variety of coating materials: Si, Ta, Nb, Ti, Zr, … and their oxides and nitrides; ITO, AZO, …
- Metallic or ceramic targets; reactively controlled sputter processes
- Plasma etching station

We offer feasibility studies, samples for testing and pilot production as well as technology and license transfer.
We look forward to developing your specific solution for a precisely custom-fit anti-reflective multilayer, gradient or structured design for your application requirements.

Contact

Fraunhofer Institute for Electron Beam and Plasma Technology FEP
Winterbergstr. 28
01277 Dresden, Germany

Contact
Dr. Kerstin Täschner
Phone +49 351 2586-376
kerstin.taeschner@fep.fraunhofer.de

Dr. Cindy Steiner
Phone +49 351 2586-143
cindy.steiner@fep.fraunhofer.de

Dr. Jörg Neidhardt
Phone +49 351 2586-280
joerg.neidhardt@fep.fraunhofer.de

www.fep.fraunhofer.de

Follow us!

We focus on quality and the ISO 9001.

Management System
ISO 9001:2015
ISO 50001:2018
www.tuv.com
ID 9105050079

Picture credits

Title: Jürgen Lösel
Finn Hoyer: 3R
Fraunhofer FEP: 4L
Ronald Bonss: 3L