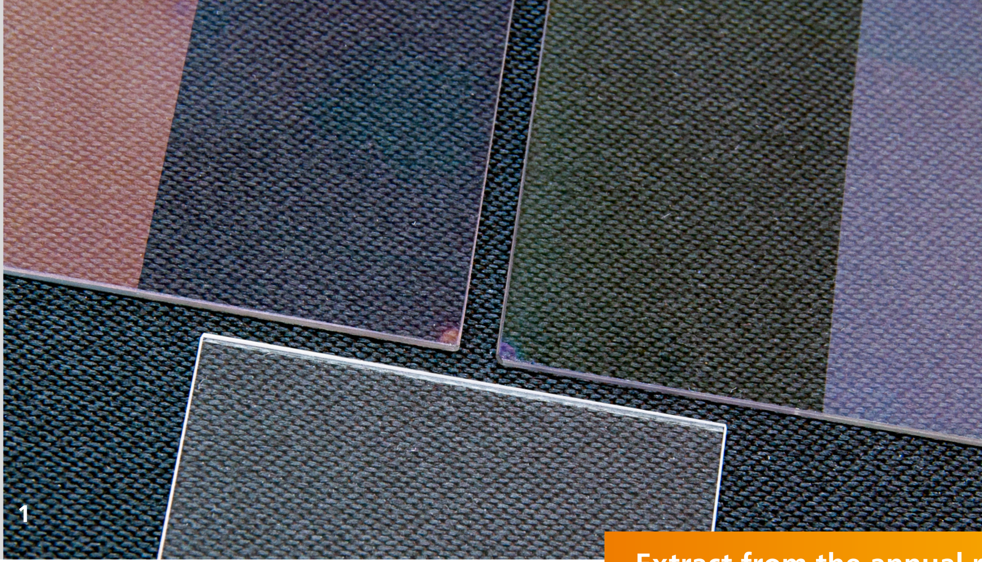


Extract from the annual report 2018
To the website: www.ist.fraunhofer.de/en.html

ANTI-REFLECTIVE COATING WITH DIAMONDS

Mostly undetected by the user, anti-reflective coatings (AR) are utilized in many products of daily life today. We encounter them on spectacle lenses, on the screens of smartphones or tablets, in the dashboards of our cars, and – in the age of the "smart home" – also on the control panels of the house management system, the refrigerator and the washing machine in the near future. New products and heightened requirements result in a growing demand for increasingly usable AR coatings with improved scratch and abrasion resistance. The major innovation in the work of the Fraunhofer IST was the enabling of the unsurpassed hardness of diamond to be utilized in optical coating systems for the very first time. The application of diamond promises the greatest possible mechanical strength which can be achieved for optical broadband anti-reflective coatings.

Diamond as an optical layer

For the development of optical diamond coatings, hot filament chemical vapor deposition (HFCVD) technology was applied. This technology was industrially introduced at the Fraunhofer IST on the largest coating surfaces in the world and is the only process with which diamond deposition is conceivable on a size scale relevant for optical components. Its utilization in optical applications, however, requires the production of extremely thin, defect-free coatings in a quality previously unattained for CVD diamond coatings as regards uniformity of coating thickness, transparency and refractive index. Consequently, the focus of the work at the Fraunhofer IST was directed at adapting the HFCVD process steps to the particularly challenging requirement profile of optical coating systems.

Optical simulation of diamond anti-reflective systems

With the help of optical simulation, differing anti-reflective systems were designed, realized and characterized. The simplest diamond AR layer system consists of a diamond layer and a surface layer of low-refractive silicon dioxide (SiO_2) with coordinated layer thicknesses (2-layer AR system). Furthermore, for an even greater broadband anti-reflective coating in the visible spectral range, four-layer stacks were developed in which, in addition to diamond and SiO_2, tantalum pentoxide (Ta_2O_5) was utilized as the second high-refractive material (4-layer AR system).

Figure 1 illustrates the anti-reflection effect achieved with both diamond AR coating systems. On the left is a 2-layer system, and on the right a 4-layer system, each with diamond as the penultimate sublayer. For comparison, an uncoated quartz glass is shown below. In order to accentuate the anti-reflection effect achieved in each case, the SiO_2 surface layer was omitted in both AR systems in the respective outward-facing third of the sample.

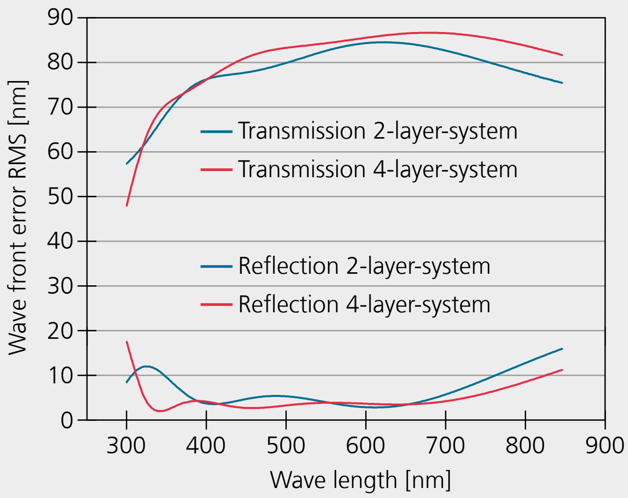
For a quantitative assessment of the achieved anti-reflection effect, transmission and reflection for both coating systems are plotted in Figure 2. As both coated quartz substrates only received the anti-reflective treatment on one side, the reflection can only be reduced to a residual value of 3.4 percent, even with perfect anti-reflective coating. This corresponds to half of the initial value. With the unilateral 2-layer system, a

1 *2-layer (top left), 4-layer (top right) anti-reflective systems compared to an uncoated quartz sample (below).*

reflection reduction to 4.9 percent was achieved; with the 4-layer system, actually a value of 3.9 percent was attainable. In each case, this was averaged over the spectral range of visible light.

Basis for further development

The diamond-based AR systems realized so far do not fulfill all the requirements yet. The fundamental feasibility and the huge potential of diamond AR systems have, however, been successfully demonstrated, thereby creating the basis for further development within subsequent projects.



Transmission (above) and reflection (below) for unilateral diamond-based anti-reflective coating systems with two or four sublayers (blue and red lines).

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