Novel design for antireflection coatings

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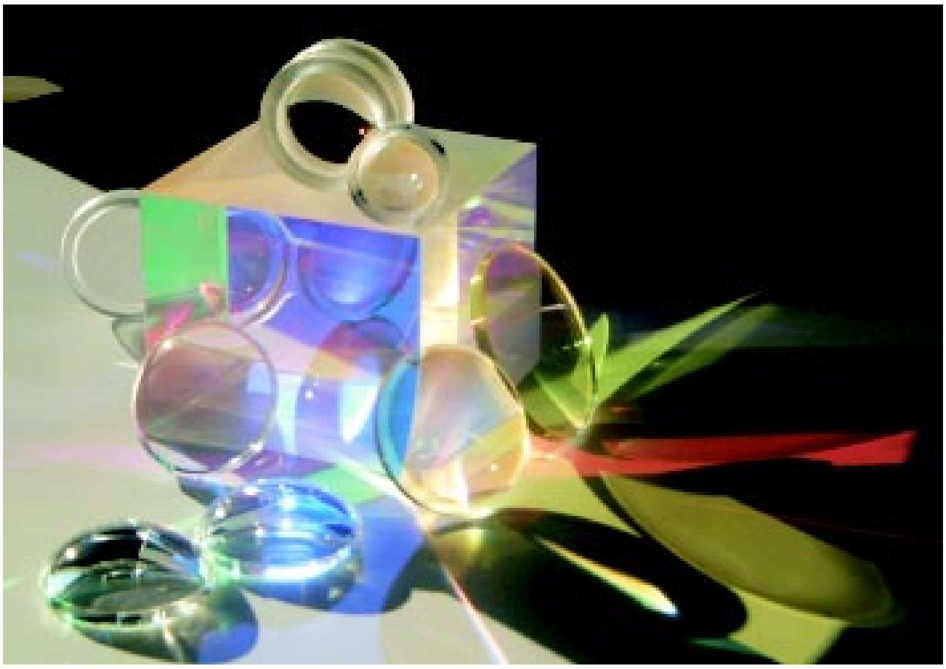


Fig. 1:
Scratch resistant and antireflection coated plastic lenses.

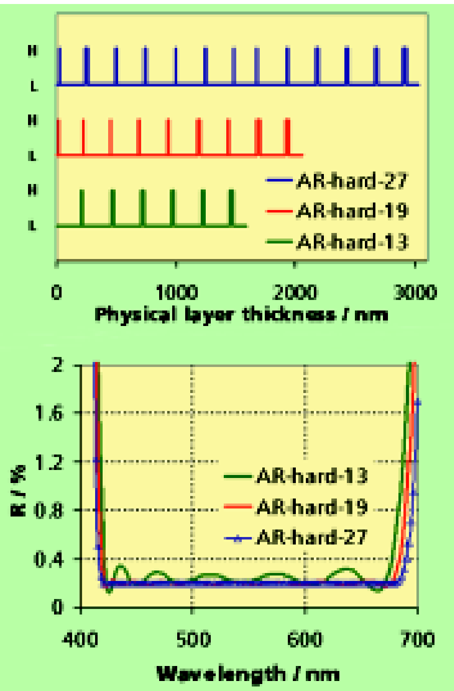


Fig. 2:
Index profiles and optical performances of designs AR-hard consisting of 13 (AR-hard-13), 19 (AR-hard-19) and 27 (AR-hard-27) layers. (substrate index n =1.49, back side disabled).

Coating of plastics for optical applications is intended to improve the mechanical durability of soft polymers and to provide an antireflection function. Hard scratch resistant coatings are not just interesting for spectacle lens manufacturers. They are also suitable for displays, such as used in automobiles, as well as for camera and endoscope lenses, which are need to be durable and achieve high light transmission (Fig. 1). Usually, a classical 4-layer antireflection system is added on top of a single layer hard coating therefore. On the other side there should be an increasing variety of different coating designs to realize a desired optical function if the total thickness of coating can be expanded. Aim of this work was to develop a broadband antireflection coating performing an average residual reflectance of about 0.4 % in the visible spectral range and an abrasion resistance as high as possible.

Physical thickness of coating had to be about 1 µm to 3.5 µm with minimized amount of the high index material. Considering this, needle optimization procedure has been used to design a novel type of thick antireflection coating by distributing the high index material in the whole stack instead of the usual combination of a very thick hard coating with a thin antireflection coating on top.

Needle optimization technique was applied starting with a total layer thickness of 1000 nm and a target value for residual reflection of 0.4 % in the spectral range 420 nm to 670 nm. The optimization procedure was interrupted after incorporation of 4 needle-layers. It was found, that the design can be modified to more or less layers. HL-layer pairs, where H is about 10 nm and L is about 245 nm, have to be added or removed border on the substrate side followed by design refinement. Uneven layer numbers between 7 and 35 at least are possible. Typically, the thicknesses of high index layers add up to less than 5 % of the total thickness and the high refractive material is almost evenly distributed over the multilayer system. We call the novel AR type "AR-hard". Figures 2 shows some possible index profiles and the resulting reflectance. An excellent uniform antireflection effect combined with high scratch resistance can be expected for the thicker coatings AR-hard.

It is obvious that the designs AR-hard may be regarded as periodic (or at least quasi-periodic) structures. Every period, consisting of approximately 5 nm to 15 nm Ta_2O_5 and about 240 nm SiO_2, has an optical thickness of three quarter-waves (QWOT) for a wavelength of nearly 516 nm, which is the reference wavelength of the designed coating. Reflection at this

wavelength is unchanged if L-layers will be reduced by optical thickness of one half-wave (excluding the last two layers). This type of AR-hard may be an alternative coating type for plastics if both antireflection at a single wavelength and high scratch resistance are required.
Coatings of new design type have been deposited on Topas®, Zeonex® and Polycarbonate using Plasma-ion assisted deposition. With coatings on both sides, transmission of thermoplastic materials was increased uniformly to more than 98 % in the visible spectral range (Fig. 3). Coated polymer parts withstand rubbing with steel wool (Fig. 4) and temperature changes between -35°C and +100°C. A low sensitivity of the AR-hard design type to systematic thickness errors of the high-index layers during the deposition process was observed. The low volume of high-index material inside of coatings of type AR-hard could be advantageously also for other spectral regions. Further modifications of the quasi-periodic design AR-hard can be expected for the future.

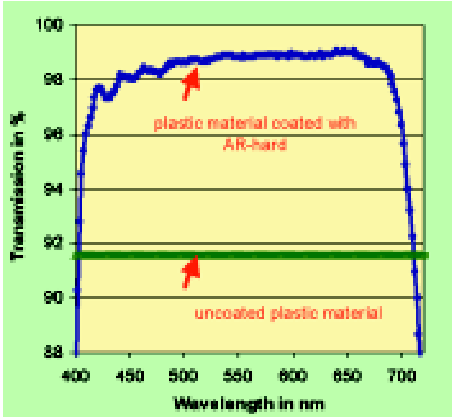
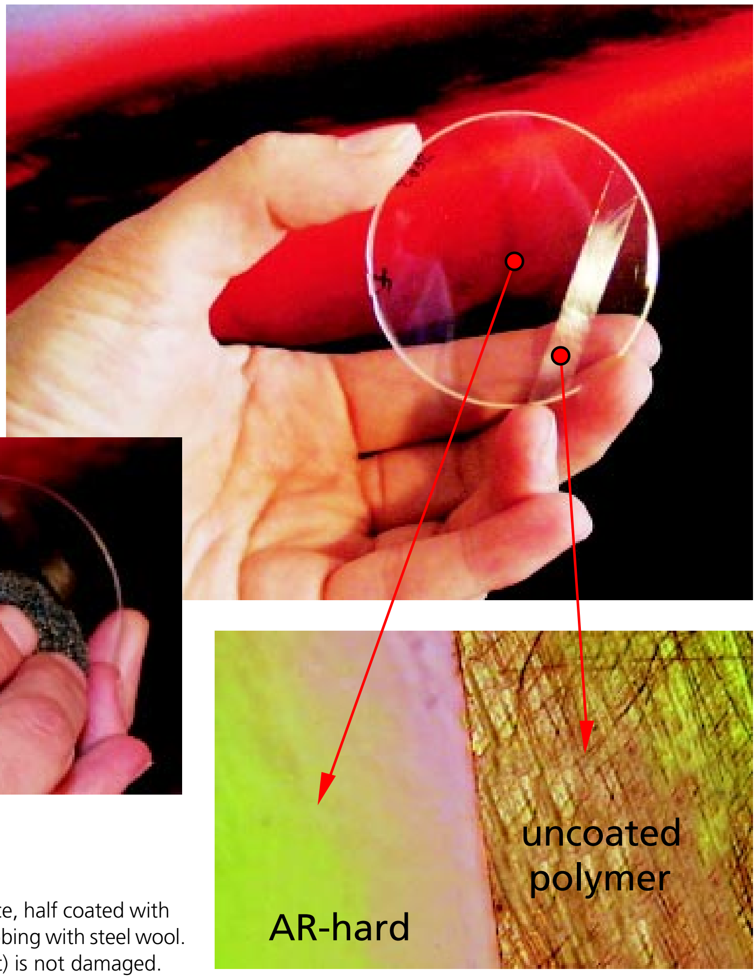


Fig. 3:
Transmission of Zeonex® before and after coating with AR-hard-27 on both sides.



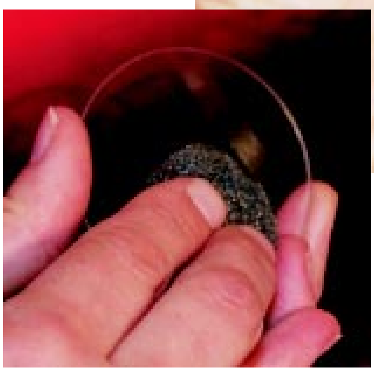


Fig. 4:
Polycarbonate surface, half coated with AR-hard-27 after rubbing with steel wool. The coated area (left) is not damaged.