Anti-reflection coating

OW Technical Editor ***Tony Jarratt***

The supply of coated lenses has now become an everyday occurrence, with the process now being applied to more and more spectacle lenses – particularly when produced from high index material. Before discussing coatings further, it should be noted that the word 'coatings' now covers a far wider range of applications that was previously the case.

In the ophthalmic context, 'coatings' originally meant only anti-reflection coatings. However, we now have to consider: Hard coatings, anti-reflection coatings, tinted coatings (mirror coatings) and hydrophobic coatings.

Sometimes these are supplied individually, but they can be applied to the lens surface in successive layers, or even in one continuous process.

This type of 'combined coating' is now most evident when we are talking about hard and AR coating. Many coatings now combine the properties of a hard and anti-reflection coating, sometimes with the added advantage of a hydrophobic or clean coat final layer – commonly known as a 'top coat'.

AR coating and reflections

AR-coating on lenses is used for two principal reasons – to improve the optical performance and/or to improve the cosmetic appearance. These are to some extent the same thing – if we improve the optical performance of the lens, we are quite likely to improve its appearance. The prescriber /dispenser will probably consider the optical aspects of applying such a coating whilst the end user – the wearer – will see the final effect from a cosmetic point of view – a reduction in surface reflections which will enhance the cosmetic acceptability of the lenses, thus making them more attractive when being worn.

The wearer will not necessarily realise that the improved appearance also means that there will be fewer ghost reflections and an increase in transmitted light, with the resultant improvement in contrast and visual acuity. Of course, if the dispenser has done a good job, then the user will have also been made aware of these added benefits.

Formation of reflections

If we consider the lens and eye in combination, we can see that they have three external surfaces between them – front and back surfaces of the lens and the surface of the cornea. Using this model, it can be shown that four different types of reflections are formed, depending on conditions. These reflections are:

1. **Frontal reflections –** some of the light incident on the front surface is reflected back towards an observer – therefore degrading the cosmetic appearance of the lens(es). An example of this type of reflection is that produced when a spectacle wearer is in front of a television camera – the very bright studio lights are reflected from the spectacle lenses, thus obscuring the wearer's eyes behind the lenses.

2. **Backward reflections –** some of the light from behind the wearer is reflected from the back lens surface onto the eye. This causes disturbing reflections, particularly in dusk conditions or when driving at night, e.g., where ambient light levels are low and there is a bright light source such as the headlights from a car behind the driver.

3. **Internal reflections –** light is reflected between the two lens surfaces, internally. This can be caused by light from any direction. It is the cause of the multiple 'rings' seen around the edge of some high minus lenses.

4. **Corneal reflections –** caused by light being reflected from the surface of the cornea and then interacting with the lens surfaces.

The last three reflections cause ghost images and can lead to lowering of visual acuity, due to blurring and reduced contrast. They therefore diminish the optical performance of the lens. Reflection number one would appear to be only a cosmetic problem, as it results in difficulty for an observer due to the frontal reflections. However, it does reduce the amount of transmitted light, which in turn reduces the efficiency of the lens.

Surface reflections

The ability to reduce the loss of light, caused by these reflections, has become more and more important as the dispensing of high index lenses has shown a continued growth. This is because the surface reflections increase along with an increase of the index of the material.

This increase in surface reflectivity is solely a function of the material index and cannot be affected by material design or composition, as can the *V* value (or Abbé number) and material density / weight. The amount of light reflected from a lens surface is given by the formula:

$$sr = \left[\frac{n' - n}{n' + n}\right]^2$$

where

sr = surface reflectance
n' = refractive index of lens material
n = refractive index of the substance in which the lens is immersed – for spectacles this is air and $n = 1$