LENS TREATMENTS

PART 3: ANTI-REFLECTION (PRACTICAL) INCLUDING HYDROPHOBICS

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This paper reviews various practical aspects relating to anti-reflection coating, including the materials used, the importance of a good vacuum, the use of ion-assisted methods, how a hydrophobic coating works, what factors affect durability and the standards that apply.

Why is it not possible to put a single layer AR onto low index lenses?

As explained in the previous article, an AR coating should have a refractive index which is the square root of the refractive index of the base lens. For low index materials like crown glass and CR39 this is not possible because a material having an index of about 1.22 (= √ 1.5) would be required. With the indices of gemstones like diamond at 2.17 and ruby at 1.76, glasses like Flint at 1.6 and Crown at 1.5, liquids like petrol at 1.46 and water at 1.33 it is clear that there is no practical coating material available with an index of about 1.22. The solution is to first lay down a high index layer (eg zirconium or titanium oxide) with an index of about 2.13. Then put on top a low index layer (eg silicon oxide - quartz) with an index of about 1.46 (= √ 2.13). Not only does this achieve the desired optical effect of destructive interference but it has the advantage of providing a layer of hard quartz as the top surface of the AR coating.

What is an adhesion layer and why is it needed when coating plastics?

When coating glass, relatively high temperatures can be used. Not only does this soften the surface of the glass, but also expands it so that when it cools (after removal from the coating chamber) the AR layer is put into compression. This cannot be done with plastics so an alternative technique for creating strong adhesion between the coating and the lens is required. Obviously a very (physically and chemically) clean lens surface is needed (so that the coating molecules come into close and intimate contact with the lens). However, there is a fundamental chemical problem because most optically clear coating materials are oxides and they do not normally adhere well to plastic. The solution is to use a very thin metallic layer (such as chromium) as an intermediate adhesion layer between the lens and the coating. Being a metal, this must be extremely thin to prevent a grey colour that would otherwise look like a pale tint. Typical adhesion layer thicknesses are only a few nanometres. To put this in context an AR coating is at least 100nm thick and a hardcoat at least 1000nm. (Remember that 1,000,000 nm = 1000 micron = 1mm).

Why is a vacuum necessary for AR coating?

Coating material is heated so that it evaporates and travels as single molecules from the crucible towards the lens that is to be coated. It needs enough energy to do this, and should not be prevented by too many air or gas molecues en-route. **Table 1** indicates what percentage of molecules will travel a distance of one metre at different vacuum pressures. The vacuum pressure is given in millibar. (Normal atmospheric pressure is 1000millibar.)

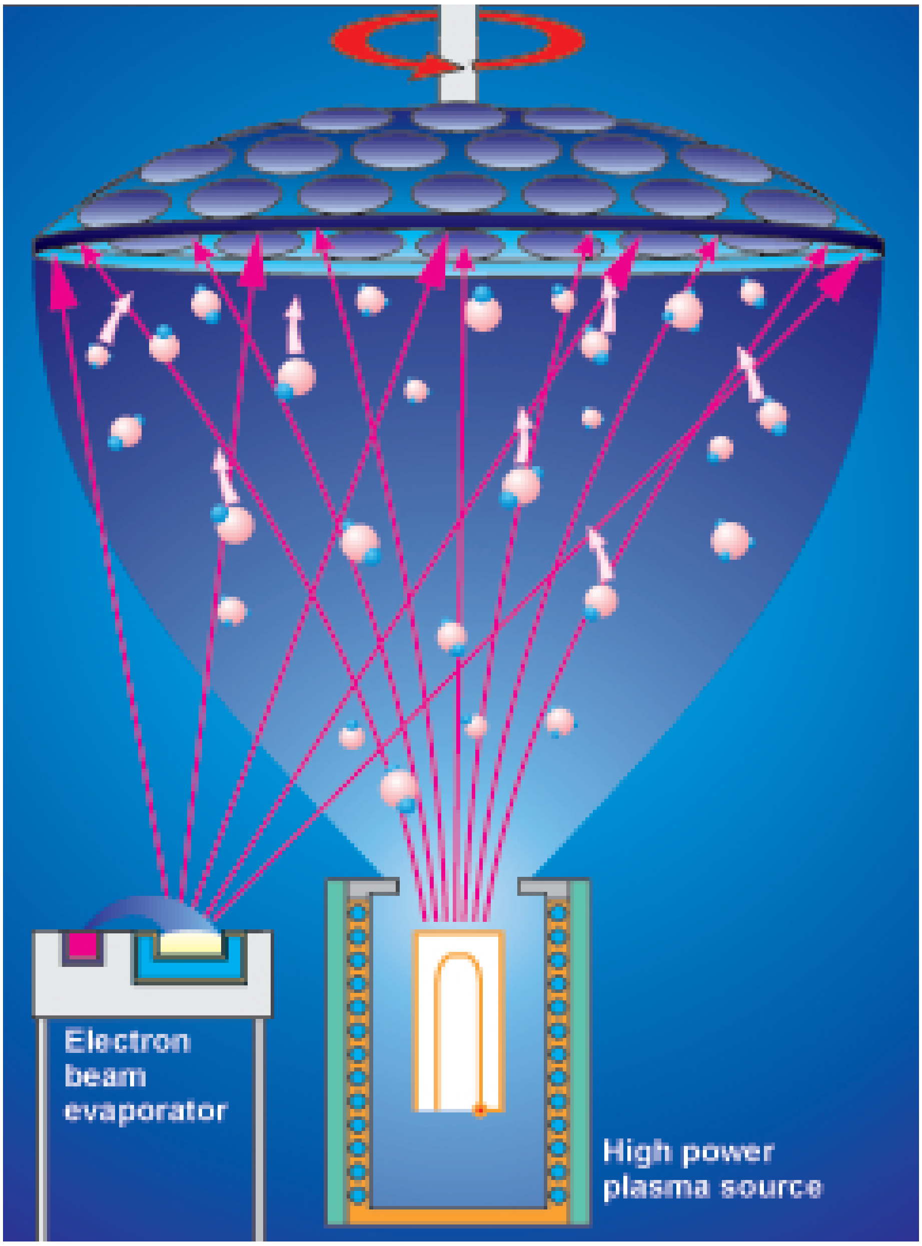
What is meant by evaporative coating, ion assist, plasma assist, plasma deposition, IAD, PIAD etc?

The detailed differences between evaporative, ion assist and plasma deposition etc are best left to the production experts. All are capable of producing anti-reflection coatings with very similar optical characteristics. However, there can be considerable mechanical differences that may affect other properties such as the durability of the coating. To the production person, the differences mainly concern the efficiency and consistency of manufacture as well as how a uniform coating can be achieved on a curved lens surface. To the spectacle wearer, what matters is how these different techniques might affect the durability of the coating. The key factor is not which coating technique has been used, but whether that technique was suitable and compatible with the base lens material to which the coating was applied. **Table 1** indicates how far molecules could travel in a vacuum when evaporated within a vacuum chamber. Adding what is called ion assist (IAD) or plasma ion assist (PIAD) to the evaporation-deposition process, is a way of adding energy (while it is travelling from crucible to lens) so that the coating molecule travels further and impacts the lens with higher energy to create a superior adhesion and a more uniform coating.

The advantages of increased energy will generally provide a harder, more durable AR coating, however there are also some disadvantages. The processes are more expensive and can only be justified in high volume production and require well qualified staff because of the increased complexity and equipment maintenance requirements. The increased energy can create some problems when coating lenses without hardcoats. In fact, a general rule is that lenses without hardcoats should generally be AR coated without ion assist, but lenses with hardcoats should generally be AR coated with ion or plasma assist. One of the biggest practical problems with ion and plasma assisted technology, is that a 'cloud' of 'ions' is produced that can get around to the back surface of the lens. This can produce adhesion problems on the side which will be coated second unless special precautions are taken.

One particular advantage of ion and plasma technology is that thicker layers may be created which allow vacuum deposited hardcoats to be created within a vacuum chamber. A second advantage is that hydrophobic coatings can be produced more easily. It is now quite common for a hydrophobic topcoat to be applied as standard by AR coating companies. Thirdly, AR coatings can sometimes have a variation in reflection colour across the lens surface, particularly on steep curves. This problem can be reduced using ion and plasma technology.

Plasma sputtering is a slightly different technology to plasma assisted deposition, although the final results are rather similar. Its main advantage is that cheaper, smaller machines can be produced making the AR coating process financially viable for a laboratory coating about 50 pairs per day. Large machines used by the major ophthalmic companies often coat well in excess of 50 pairs in



▲ **Plasma ion assisted coating** *(Photograph courtesy of Leybold)*

Vacuum pressure in millibar		Percentage of molecules that will travel a distance of 1 metre
1000	= 10^3	None
1.0	= 10^0	None
0.0001	= 10^{-4}	10%
0.00001	= 10^{-5}	78%
0.000001	= 10^{-6}	98%

▲ **Table 1:** How far will coating materials travel in a vacuum? (*Table information source: Balzers*)

What is a hydrophobic coating and how is it produced?

The word hydrophobic simply means that water molecules are repelled. This is achieved by using the electrical charges on certain types of molecules. A layer only one molecule thick is required. The electric charge decreases the wetting angle so that water droplets do not spread over a surface, but form spherical droplets. The droplets then run off the surface in much the same way as they do after waxing the body of a car. This is usually applied within a vacuum chamber immediately following AR depostion. Some methods allow a special material to enter the vacuum chamber and this coats both sides of the lenses simultaneously. An alternative technique is to dip the lenses into a special liquid (like tinting) and then to bake this in an oven. This latter method is very effective but may not have such a long lasting effect. The vacuum applied hydrophobics are sometimes not quite so effective at repelling water, but their effect is usually long lasting. The main advantage of a hydrophobic coating is that the lens remains cleaner longer and less cleaning by the wearer is required. This inevitibly results in less cleaning scratches (the most common cause of user complaints).

Why is lens cleanliness and critical surface inspection essential?

The normal 8% reflection from an uncoated lens can easily hide small defects that become much more obvious when the lens only has a 1% reflection. Simple logic suggests that a lens needs to be 8 times cleaner and have surface defects and scratches that are eight times less obvious, if they are not to be seen as defects after coating. This is a common cause of tension between lens suppliers and lens coaters. The coaters are frequently accused of having caused scratches, when in fact it is simply the lower surface reflection that is showing up defects too small to be easily seen before coating. This is why coating companies normally use specially bright lamps to inspect lenses before coating. The ultrasonic cleaning process can also open-up small defects and remove polishing rouge that was filling small scratches. Ultrasonic cleaning is however essential, not only to create an optically clean surface, but also to create a chemically clean surface to obtain good ahesion. Strong caustic and acid solutions are sometimes used for this process.

Another common accusation is that AR companies remove some of the tint in a lens. Part of this is just an optical effect because a lower surface reflection implies a higher transmission and although the tint absorption remains the same, the lens appears ‘paler’. When a particular lens transmission factor has been requested the 7% increase in transmission should be allowed for before coating by tinting the lens 7% darker. This problem does not occur if the Continental system of specifying tint absorption is used. There is also the practical problem of tints ‘washing-out’ during the lens cleaning process. This can be minimised by removing the tint from the lens surface after tinting (and is something that is recommended even if an AR coating is not applied to prevent the tint fading with time). The easiest way of removing surface tint is to overtint the lens and then to put it into the bleach for a few seconds. This removes the surface tint but the tint deeper into the lens remains.

Common questions about AR coatings?

A common question is why not put the hardcoat on top of the AR coating (to protect it) instead of underneath it? The simple answer is that light will be reflected by the hardcoat before it reaches the AR coating thus negating its effect.

Why might a glass lens have a circular shaped patch with a different colour AR? This may be due to the lens being a fused glass bifocal. The index of the bifocal segment is greater than the index of the lens and this will affect the colour of the reflection.

Why might two lenses in a pair have different AR reflection colours? This may be due to them being of different indices, or more likely they have the same index but the coating manufacturer did not achieve the same reflection colour on the two lenses. This could be because they were coated in different batches, or even because of variations across the coating chamber within the same batch.

Why might the AR reflection be different on the front and the back surface of a lens? This is a very common problem and is normally due to the refractive index of the front and back surface coatings being different. One surface may have a hardcoat and the other not, or they may have hardcoats with different refractive indices.

One of the best ways of avoiding some of these problems is to ensure that the refractive index of the hardcoat has a reasonably similar value to the index of the lens. Some of the quality lens coaters ensure this by having available a number of hardcoats, each with a different refractive index.

What is the normal lifetime of an AR

Manufactured correctly, and handled with reasonable care, there is no reason why an AR coating should not last as long as an uncoated lens. Investigating returns to coating laboratories shows that a small number are returned within a few weeks because of serious problems that are the responsibility of the coating laboratory. The greater number of returns occur between 9 and 15 months, and can be classified as durability problems associated with poor adhesion. Common causes for this are, incompatibility between hardcoat and the particular type of AR process used, use of an unsuitable hardcoat, or no hardcoat. For subcontract coaters there is the difficulty of ensuring that they are aware of full details of the type of lens and any hardcoat. In fact, it is usual for the company doing the AR to also apply the hardcoat. For companies coating lenses from a large number of different manufacturers there is the difficulty of ensuring that the appropriate processes are used on each lens type. These problems should not deter opticians from prescribing AR coatings, because they are becoming increasingly rare, but they should ensure that they use a well managed coating company that has in place a carefully regulated coating process that takes account of the wide range of lens types to be coated.

What are the factors that affect AR durability?

Quality of manufacture is obviously crucial, as is appropriate handling and cleaning by the wearer. For instance the wearer should be advised whenever possible never to clean the lens dry, but to wash off dirt initially, preferably with a very mild soapy washing-up liquid in water, and then to dry the lens carefully, preferably with a special microfibre cloth. Advice on cleaning is often provided by the coating manufacturer. Other factors are temperature (so avoid leaving lenses on a car dashboard), exposure to humidity and ultraviolet, and mechanical stress.

What standards exist for AR durability

Although not yet published, there is an International Standard in the course of preparation, which defines standard tests for the durability of coatings. Copies of a draft of this document are available to coating companies through their associations. Producing coatings that will conform to this standard when applied to a normal stock hardcoated lens is not difficult, but more care is required when coating a variety of hardcoats on a variety of lens indices and tints. Other additional features such as coating on polarised, photochromic or other special lens types need special care. While developing the new ISO standard, investigations have shown that many factors can affect the durability of a coating, and a wide range of tests may be needed to satisfy all possible factors. The most important factors that will be included into the proposed ISO standard for AR durability, are variations in humidity, variations in temperature, exposure to UV light, and physical stress due to excessively tight glazing. ■

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A list of other references and further reading will be published at the end of the final article in the series. ■