TECHSHIELD ANTI-REFLECTIVE COATINGS:

PRINCIPLES AND PROGRESS

TECHNICAL WHITE PAPER

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TechShield Anti-Reflective Coatings: Principles and Progress

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INTRODUCTION

Unwanted reflections are an inherent problem with eyeglass lenses. The only way to address this problem and provide patients with maximum visual clarity is by means of an anti-reflective (AR) coating. AR coatings have been available for eyeglass lenses for more than 60 years, but early coatings were marred by relatively poor anti-reflective performance and durability issues. Today's superior AR coatings, as exemplified by TechShield® Anti-Reflective Coatings, represent a total clarity system for eyeglasses that combine highly efficient reflection reduction with easy cleaning and protection against lens material surface damage. The result is a generation of TechShield AR Coatings with the potential to improve patient satisfaction with their overall visual experience.

LENS REFLECTIONS

When light travels from one medium to another, as from air to an eyeglass lens, not all of it passes through. Some light incident on the lens surface is reflected back into the air. Light reflected from a smooth surface like an eyeglass lens is known as specular reflectance.

The amount of light that is reflected off the lens surface depends on the index of refraction of the lens. The index of refraction is a measure of how fast light travels through the lens compared to how fast it travels through the air—the higher the index, the greater the difference in light speed. As the index of refraction increases, so does the reflectance of the lens.

The same amount of reflectance occurs when the transmitted light passes through the back surface of the lens into the air again. Therefore, the total reflectance of the lens is the sum of the reflectance of the front and back surfaces (minus the percentage of light that has already been reflected off the front surface). The total (two-sided) reflectance of the most common lens materials used today is shown in Table 1.

Material	Two-Sided Reflectance
CR-39	7.7%
Trivex	8.3%
Polycarbonate	9.8%
1.60	10.1%
1.67	11.8%
1.74	13.6%

Table 1: Two-sided reflectance of common lens materials.

EFFECTS OF LENS REFLECTIONS

Reflections from an eyeglass lens have two basic effects. Reflections off the front surface have a cosmetic effect, as they can obscure the eyeglass wearer's eyes as they interact with other people. They can also interfere with the wearer's ability to communicate with others as a significant amount of nonverbal communication occurs through eye contact.

More significant for most eyeglass wearers is the effect of lens reflections on vision.

The primary effect of lens reflections that is often unmentioned is a reduction in light reaching the eye. Light transmittance is the inverse of light reflectance—a 1.74 lens with almost 14% two-sided reflectance is transmitting only 86% of incident light to the eye. The world seems less bright; a problem that becomes more acute in low-light conditions.

This is of particular concern as we age. A typical 60-year-old receives only about one-third as much retinal luminance as a typical 20-year-old[1], because of the increased absorbance of the crystalline lens and the natural shrinking of the pupil. Older people can ill afford to lose even more retinal illuminance through lens reflections.

1. Norman, J & Norman, Hideko & Pattison, Kristina & Taylor, M & Goforth, Katherine. (2007). Aging and the Depth of Binocular Rivalry Suppression. Psychology and Aging. 22. 625-31. 10.1037/0882-7974.22.3.625.

Another detrimental reflectance effect is the formation of ghost images: fainter secondary images of objects in the field of view. Ghost images can be formed in multiple ways. For example, light entering the lens from in front of the wearer can be reflected off the back surface of the lens, and some of this reflected light will again be reflected off the front surface of the lens and back into the wearer's eyes (Figure 1).

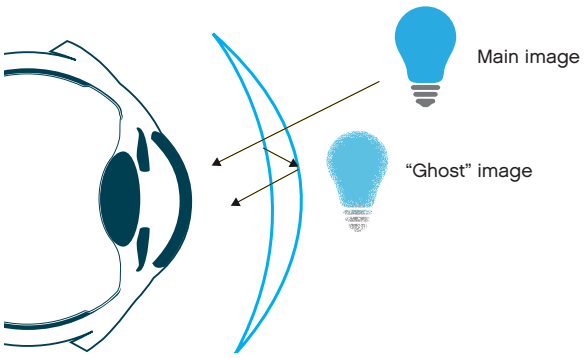


Figure 1: Ghost image formation.

PRINCIPLES OF ANTI-REFLECTIVE COATINGS

AR coatings for eyeglasses employ the principle of destructive interference—the cancelling of a light wave through the creation of another wave that is out of phase with it. A layer of material with a thickness of one-quarter the width of a given wavelength of light is applied to the lens (Figure 2). As light strikes the front surface of the layer (n1), some of it is reflected away (R1). The light wave then strikes the back boundary of the layer, producing a second reflection (R2). At this point, the wave has travelled one-quarter of a wavelength farther, and the reflection travels another one-quarter wavelength on its way back to the air. The wave is therefore out of phase with the front surface reflection. The two reflections cancel each other out, allowing the light to travel through the lens as intended.

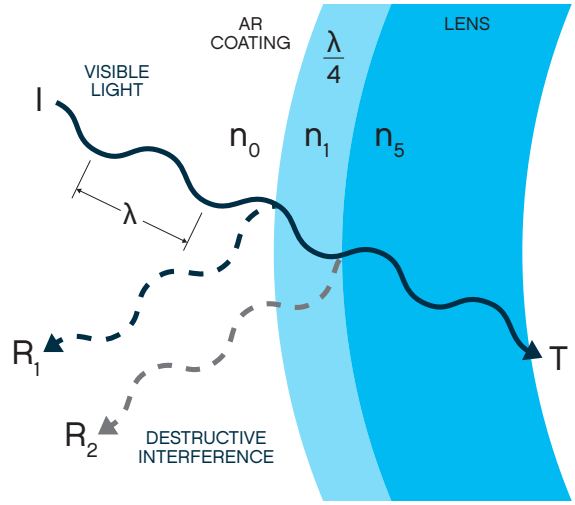
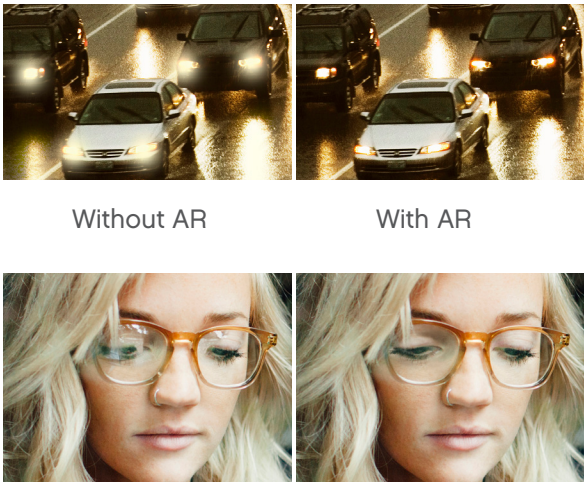


Figure 2. How an AR coating creates destructive interference Illustration: https://commons.wikimedia.org/wiki/File:Optical-coating-2.png

Destructive interference greatly reduces distracting reflections and visual noise, allowing better contrast, improved visual acuity, and better cosmetics (Figure 3). When reflected light is eliminated, light transmission is accordingly increased allowing more light to reach the retina, providing the wearer with a brighter view of the world.



Without AR With AR

Figure 3. Visual and cosmetic benefits of AR coating.

SHORTCOMINGS OF EARLY ANTI-REFLECTIVE COATINGS

Anti-reflective coatings first became available for glass eyeglass lenses in 1959, and for plastic lenses in 1974. These early coatings employed one layer of anti-reflective material designed to cancel a wavelength of light in the middle of the visible spectrum. These single-layer coatings were not very efficient in cancelling reflections across the whole spectrum, resulting in limited reduction in lens reflectance.

Early AR coatings were also difficult to clean. The surface of an early AR coating, when viewed under a powerful microscope, is very uneven—not unlike an English muffin. Because of this, tiny droplets of grease (the composition of a smudge) could lodge in the nooks and crannies of the lens, requiring a very careful cleaning regimen that wearers were not always willing to follow.

Additionally, these coatings tended to scratch easily. An AR coating is extremely thin—about 1,000 times thinner than a piece of plastic wrap. Plastic lenses are relatively soft, and their surfaces have a certain amount of "flex." A tiny particle on the coating's surface, when rubbed with a cleaning cloth, could actually crack the thin coating, resulting in a scratch (Figure 4). When cleaned improperly, the lens could develop a network of extremely small scratches that could look like a haze on the lens. Early AR coatings were also often poorly bonded to the lens surface, resulting in delamination of the coating.

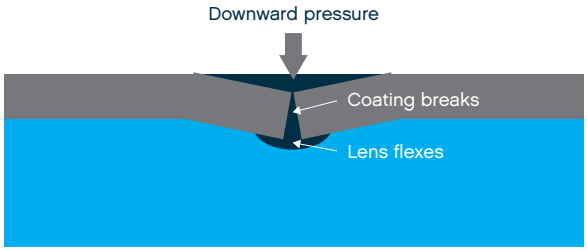


Figure 4. Scratch formation on an early AR-coated lens.

The cleaning and scratching issues associated with early AR coatings countered, to some extent, the main benefits of the product, which were improved visual clarity and better appearance—scratches and smudges diminish both. Early AR coatings required a very committed wearer willing to take extra care with their lenses to realize the benefit. It is little wonder that the market share of AR lenses in the U.S. was quite low. While the market share has steadily increased, it is still less than half of all lenses sold (about 45%[2]).

TECHSHIELD AR COATINGS—THE NEWEST GENERATION OF PREMIUM AR COATINGS

Today's premium AR coatings address all of the problems discussed in the previous section. TechShield Anti-Reflective Coatings represent the latest evolution of the anti-reflective technology, resulting in a total clarity system that increases lens performance in three ways: lower reflectance, improved scratch resistance, and easier removal of smudges.

Lower Reflectance. TechShield AR Coatings use multiple layers of anti-reflective material, with each layer cancelling reflections for a different wavelength of light. This broadband reflection control results in a residual reflectance of 2%; in other words, 98% of incident light reaches the eye.[3]

Improved Scratch Resistance. Scratching and delamination issues have been addressed by means of a primer on the lens surface to ensure adhesion, on top of which is a coating that creates a very hard surface. The hardness of this coating prevents the flexing that could cause the lens to scratch, and provides a solid bond between the lens and the coating to prevent delamination. The excellent scratch resistance of TechShield AR Coatings has been confirmed by the Bayer abrasion test. The "Bayer ratio" compares the number of fine scratches on the surface of an AR lens to an uncoated lens, with a higher ratio indicating

2. The Vision Council, "U.S. Optical Industry Report Card," June 2020

3. Because there are practical limitations to the number of AR layers that can be produced, it is impossible for an AR coating to completely eliminate reflections in all wavelengths. An AR-coated lens will always have some residual reflectance, which will appear in a certain "reflex hue" (green in the case of TechShield AR.)

greater scratch resistance. Any coating with a Bayer ratio above 4.0 is considered premium. The Bayer ratio for TechShield AR Coatings is over 7.0, meaning that it has seven times the abrasion resistance of the uncoated lens. This Bayer score indicates that lens will stand up well against daily wear and tear as well as real-world (non-ideal) cleaning methods.

Easier Cleaning. Cleaning has become dramatically easier through the application of an advanced super-hydrophobic coating. This coating improves cleanability in two ways: by filling in the nooks and crannies of the AR layers for a smoother cleaning surface, and by repelling water and oil—essentially making water and oil droplets stand up on the lens so they are more easily wiped off. Droplets on TechShield AR Coatings have a contact angle of greater than 115°, meaning that the area in contact with the lens surface is considerably less than 50% of the droplet's diameter (Figure 5).

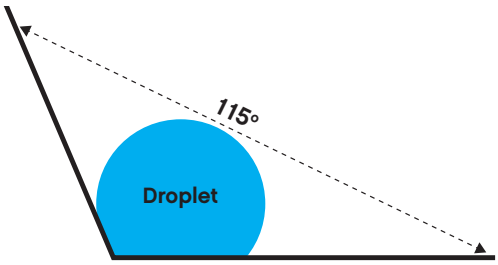


Figure 5. TechShield Elite's super-hydrophobic contact angle.

BLUE LIGHT ATTENUATION

In addition to its visual and cosmetic benefits, TechShield AR Coatings are available in a formulation that reduces the wearer's exposure to blue light, branded TechShield Blue. Digital screens like laptop monitors and smart phones emit significant quantities of blue light. This blue light contributes significantly to digital eye strain because it is intrinsically myopic—that is, it comes to a focus in front of the retina, rather than on it, creating a visual perception of discomforting glare for many patients. The presence of this glare increases the effort required to focus on objects on a screen, contributing to digital eye strain.

TechShield Blue's unique properties provide excellent anti-reflective performance throughout the visible spectrum, while targeting blue light waves associated with digital eye strain (400–430 nm), reducing exposure by as much as 85% at its peak (Figure 6).

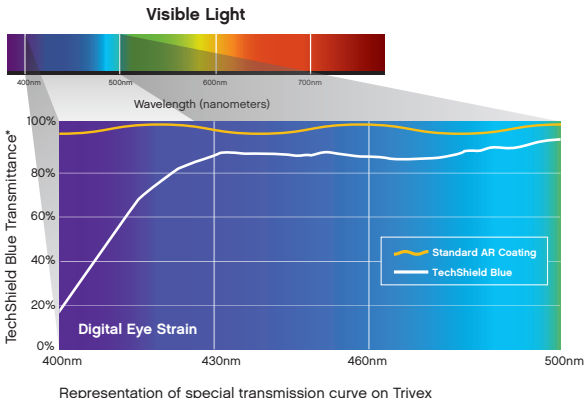


Figure 6. Spectral transmission of TechShield Blue.

COMMUNICATING THE AR MESSAGE TO PATIENTS

As we have seen, AR coatings are an enhancement that will benefit every eyeglass lens wearer, and today's most advanced AR coatings are highly scratch-resistant and easy to care for. Yet, less than half of patients actually purchase an AR treatment for their glasses. The key to increasing AR coating sales is communication. Following are some tips to help communicate the benefits of AR coatings to patients:

Talk to Every Patient about AR Coatings. Never assume that patients who don't currently have an AR coating on their lenses aren't interested in purchasing it. It could be that they have never heard the benefits explained clearly (or at all), or that they had a bad experience with an older or inferior AR coating.

Patients should always be presented with the opportunity to get the best lens performance with an advanced AR coating. Consider starting the conversation with inclusion of an AR coating as standard, and communicate the benefits that would be eliminated if the patient chooses to remove the AR coating from the lens system.

Showing Is Better than Telling. People have trouble visualizing "better." Patients who haven't had an AR coating before probably won't buy based on a verbal description of how they will see and look with an AR coating on their glasses. Show with and without photos like the ones shown above (Figure 3), and use a demonstrator tool (Figure 7). This could be as simple as a frame with one lens with an AR coating and one uncoated lens. And of course, you should always wear glasses with a premium AR coating when interacting with patients.

Figure 7. TechShield demonstrator tool. The inner circle of the lens is AR-coated; the rest of the lens is not.

Make It Personal. Showing the difference is powerful, but putting it in the context of the patient's life is even more so. If a patient is concerned about seeing well when driving at night, a TechShield AR Coating will reduce visual noise and allow more light to reach the patient's eyes. If the patient is a heavy user of digital screens, TechShield Blue will reduce digital eye strain while reducing reflections from overhead lights and bright windows. If a patient is choosing a designer frame to enhance their look, they should know that lens reflections can detract from the effect. And for all patients, eyeglasses are an investment in vision; they need to know that the only way to get the most from that investment is with AR coating.

Kids Too. According to **Visionandlearning.org**, 80% of what we perceive, comprehend, and remember depends on the efficiency of the visual system, so clear vision is crucial for school-age children. Bright overhead lighting or sunlight through windows can interfere with a child's ability to see what's going on at the front of the classroom. Children will get the best results with an AR coating, and today's most durable coatings will stand up to the wear and tear that stems from a child's active life.

Create a Package. Since great AR coating performance is integral to great lens performance, should it really be considered an "extra"? Patients are more likely to purchase an AR coating if it is included the basic price of the lens, rather than as an "add-on" (which can easily become a "subtract off").

CONCLUSION

Today's TechShield AR Coatings are the culmination of decades of technological evolution. They are vastly more efficient at reducing reflections than early generations, and they eliminate the problems that used to turn people away from AR coatings. However, the fact that a great product exists doesn't mean people will automatically buy it, no matter how great the benefits are. Making those benefits easy to understand and relevant to the patient's life will help them see AR coatings as an opportunity to get the most from their eyewear rather than an added expense. Once they experience those benefits in daily life, they will likely become AR coating wearers forever.