DuraVision® Platinum AR Coating by ZEISS:

For the Hardest ZEISS AR-Coated Lenses Yet

By Darryl Meister, ABOM

The ZEISS brand has become synonymous with premium anti-reflective (AR) coatings. After inventing the very first AR coating for optical lenses nearly 75 years ago, thin film scientists at Carl Zeiss Vision have continued to push the performance envelope. Premium ZEISS AR coatings are more robust, dirt resistant,easy-to-clean and offer first-rate antireflective properties. Now, with the development of the new DuraVision Platinum AR coating, scientists have responded to the demand of eyeglass wearers for lenses that are more robust, dirt-resistant and easy to clean.

Continued Innovation Driven by Consumer Demand

In 1935, the first anti-reflective (AR) coating was invented at Carl Zeiss. These coatings significantly reduced annoying lens reflections while increasing light transmittance and visual clarity. The commercial availability of prescription spectacle lenses with anti-reflective coatings arguably represented one of the greatest technological advancements in ophthalmic optics in the twentieth century. Unfortunately, while these coatings represented a significant technical achievement, early anti-reflective coatings suffered from several limitations that hindered wearer acceptance:

- Although noticeably clearer than uncoated lenses, early AR coatings exhibited relatively bright residual reflections, making it more difficult to justify the added expense and care.
- The porous nature of early AR coatings attracted water, oil, and particulates that were difficult to remove, resulting in coatings that were difficult to clean and to keep clean.
- Early hard coatings were not specifically engineered for good adhesion and mechanical compatibility with AR coatings, resulting in coatings that frequently crazed or peeled.
- The state of the art in polymer science and thin film engineering at the time did not allow for the development of extremely durable coatings that provided glass-like scratch resistance.

Fortunately, ongoing advancements in vacuum deposition technology, thin film engineering, and polymer science by engineers at Carl Zeiss Vision have continued to yield incremental improvements in coating performance. Previous AR coatings by ZEISS have been engineered to deliver unsurpassed transparency and ease of cleaning with sufficient durability. However, an international market research study conducted among 6,000 consumers indicated that the robustness or durability of their lenses was the most important feature. Transparency, on the other hand, was ranked much lower in importance.[1] Eyecare professionals also agree that hardness is the most important lens feature.[2]

This research indicates that, while anti-reflective performance is important to eyecare professionals, the resistance of the lens to abrasion or scratching is paramount. Eyeglass wearers demand lenses that will stand up to wear and tear. With this in mind, engineers at Carl Zeiss Vision have placed an even greater emphasis on improving the durability of the coating. The DuraVision Platinum AR coating by ZEISS represents the latest coating innovation from the renowned pioneers of AR technology. The DuraVision Platinum AR coating comprises an integrated system of coating layers that have again been carefully engineered to deliver high transparency and ease of cleaning. There has been an even greater emphasis, however, on the *durability* of the coating system, resulting in ZEISS lenses that provide nearly glass-like scratch resistance (Figure 1).

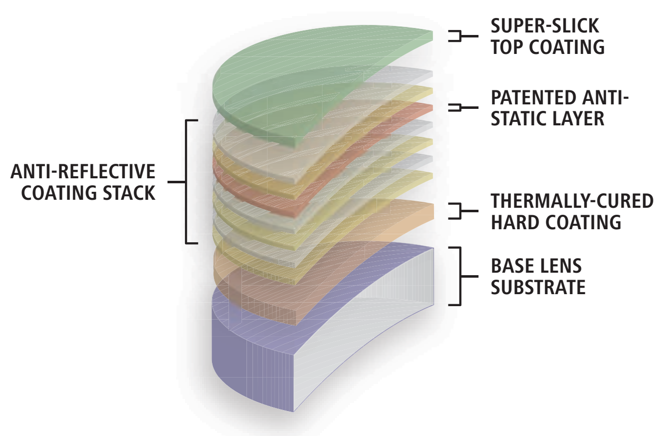


Figure 1. DuraVision Platinum by ZEISS is an integrated system of nine precisely applied coating layers that have been carefully engineered to deliver unsurpassed transparency and convenience with an even greater emphasis on durability.

Ongoing Improvements in Science and Technology

» DuraVision Platinum AR coating relies on the latest developments in thin film engineering

Although all premium anti-reflective coatings by Carl Zeiss Vision exhibit exceptional resistance to wear, consumers studies have emphasized the importance of durability to eyeglasses wearers. Consequently, thin film scientists at Carl Zeiss Vision have continued to explore new developments in vacuum deposition and materials science. Additionally, there has been a greater emphasis than ever before on product evaluation and testing, utilizing the latest tools and technologies. The result has been significant improvements in AR coating performance.

AR coatings are produced from extremely thin, brittle layers of ceramic metal and semi-metal oxides. Significant differences exist between the physical properties of these brittle coatings and the relatively soft, plastic lens substrate, including differences in elasticity, hardness, and the rates of expansion under pressure or during temperature changes. These mechanical differences often led to delaminating, crazing, scratching, and other forms of "AR Failure" with early AR coatings. Modern ZEISS AR coating deliver exceptional, long-lasting durability by utilizing a system of integrated coating layers that have been engineered for maximum compatibility and robustness. A state-of-the-art vacuum deposition process further improves coating adhesion and durability.

The foundation layer of the DuraVision Platinum AR coating is a thermally-cured hard coating that has been engineered from an organosiloxane resin with microscopic particles of colloidal *silica*—the chief ingredient in glass—dispersed throughout its matrix. The addition of mineral-like silica to the synthetic coating resin increases abrasion resistance while promoting adhesion and mechanical compatibility between the relatively brittle anti-reflective layers and the more pliable plastic lens substrate. The DuraVision Platinum AR coating therefore offers extremely high abrasion resistance without cracking, peeling, or flaking when the lens is exposed to temperature extremes and other stresses.

The durability of the DuraVision Platinum AR coating has been maximized through the use of *ion-assisted deposition*. During the application of the AR layers, the lens is bombarded with high-energy ions from an inert gas as the AR materials condense on the surface, transferring the momentum of the ions to the coating molecules. This results in more densely packed coating layers with stronger adhesion. Unlike previous ZEISS AR coatings, five layers of the AR stack are now applied using this technology, instead of three (Figure 2). Further, the various AR layers have also been optimized to reduce the sensitivity of the coating to scratching.

New methods of evaluating the abrasion resistance and hardness of lens coatings were also utilized by engineers at Carl Zeiss Vision during the development of the DuraVision Platinum AR coating. More realistic methods of evaluating coating durability were developed to ensure an accurate assessment of long-term wear. A new precision instrument for evaluating coating hardness of thin films was utilized to facilitate the development of exceptionally robust, durable AR coatings (Figure 3).

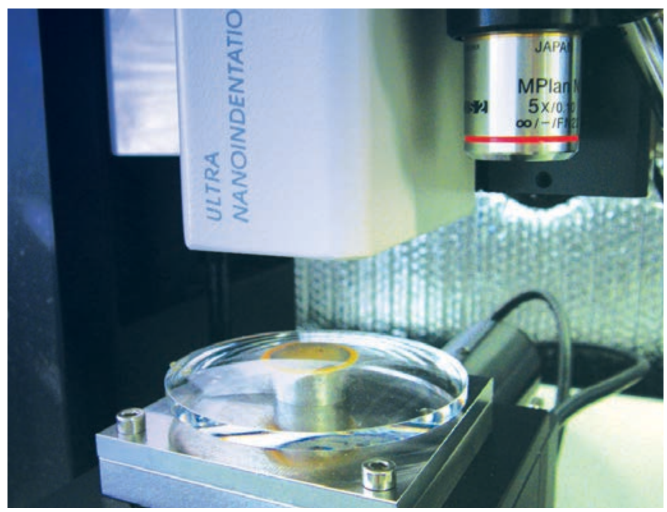
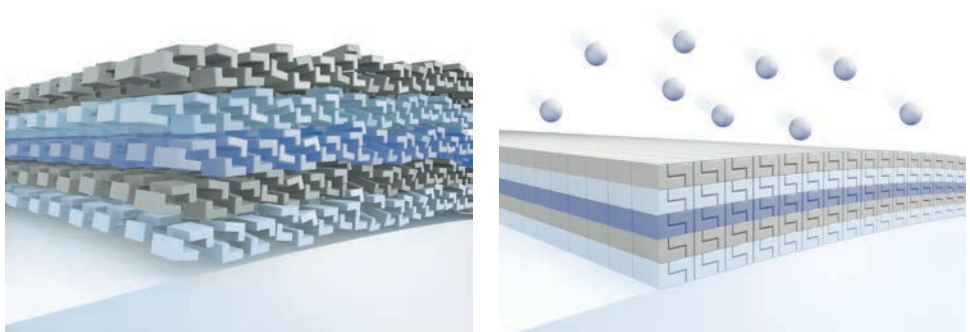


Figure 3. Thin film hardness was evaluated using a CSM Ultra Nanoindentation instrument, which evaluates coating hardness at a sub-micron level.

Figure 2. Unlike the application of many conventional AR coatings, each of the layers of the DuraVision Platinum AR coating is applied using ion-assisted deposition, which bombards the surface with ions in order to increase the momentum of the coating molecules, resulting a more densely packed, durable AR coating as shown in this conceptual drawing.

CONVENTIONAL AR APPLICATION **DuraVision Platinum AR APPLICATION**



Proven Durability

The DIN/ISO 14577 "Instrumented Indentation" test is commonly employed to evaluate the mechanical properties of materials. *Nanoindentation* is particularly useful for evaluating the hardness of thin films and coatings. A pointed tool is pressed into the coating. The pressure due to the load placed on the tool and the cross-section of the tool as it indents the coating is then calculated, resulting in a *hardness* value. The hardness of the DuraVision Platinum AR coating has been increased significantly compared to previous ZEISS AR coatings. Moreover, the hardness at a depth of around 0.2 microns, the most critical range for visible scratches, is up to 50% higher with the DuraVision Platinum AR coating compared to previous ZEISS AR coatings (Figure 6).[3]

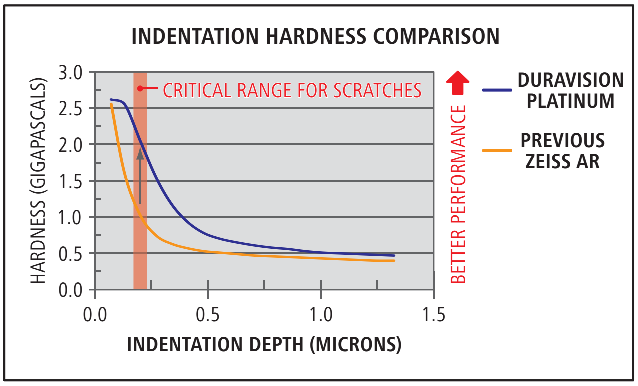


Figure 6. As demonstrated by indentation testing, DuraVision Platinum AR coating is significantly harder than previous ZEISS AR coatings.

» DuraVision Platinum AR coating is significantly more robust than previous ZEISS AR coatings

Additionally, the applied force necessary to break the coating was also evaluated using nanoindentation testing. The force required to break the coating was significantly higher compared to previous ZEISS AR coatings (Figure 7). This extensive testing confirms that ZEISS lenses with the DuraVision Platinum AR coating are harder and more scratch-resistant than ZEISS lenses with previous ZEISS AR coatings.

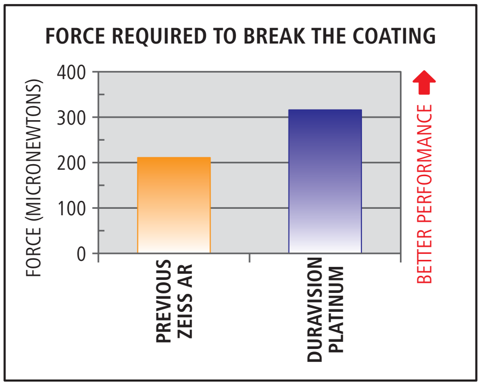


Figure 7. It takes significantly more force to break DuraVision Platinum AR coating compared to previous ZEISS AR coatings.

The ASTM F735 "Bayer" or "Oscillating Sand" test is commonly employed to evaluate the abrasion resistance of spectacle lenses and coatings. In this test, the lenses being tested along with an uncoated hard resin control lens are shaken 600 times in a pan filled with a sand-like abrasive. The gain in the scattered light haze of the control lens due to scratching is then compared to the test lenses, resulting in a *Bayer ratio*. The Bayer ratio represents the relative abrasion resistance of the test lens. The DuraVision Platinum AR coating achieves an exceptionally high Bayer ratio, between 10 to 19, depending upon the lens material. This represents over ten times the abrasion resistance of uncoated hard resin and three times the abrasion resistance of the previous ZEISS AR coating (Figure 4).[4]

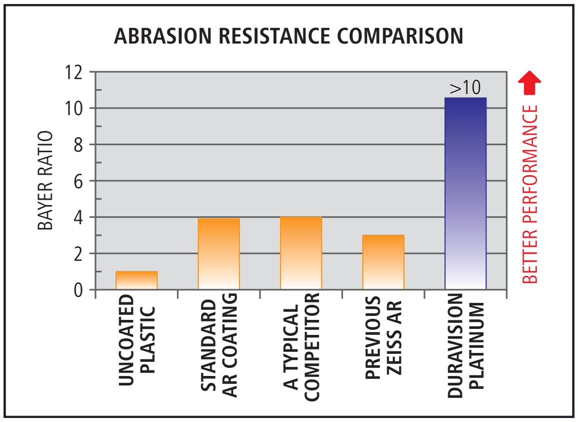


Figure 4. DuraVision Platinum offers exceptional abrasion resistance.

The "Standardized Dirt Wiping" test, developed by engineers at Carl Zeiss Vision, simulates wear as a result of cleaning the lenses with a dry cloth. The test lens is wiped 600 times with a dry cloth containing abrasive particles under a significant amount of applied pressure (4 kilograms). The lens is then evaluated subjectively for damage. Although previous ZEISS AR coatings show significant damage after this test, the DuraVision Platinum AR coating remains virtually clear (Figure 5).

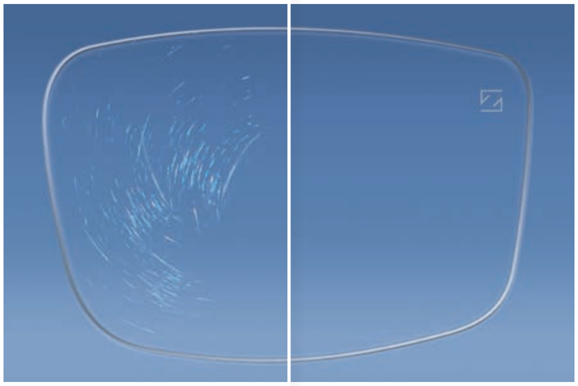


Figure 5. Whereas previous ZEISS AR coatings show significant damage after simulated cleaning, DuraVision Platinum remains virtually clear.

Dirt-Resistant and Very Easy to Clean

> » DuraVision Platinum AR coating is easy to clean and easy to keep clean, to prolong the life of the lens

Eyeglass wearers have long expressed concern over the difficulty in cleaning—and keeping clean—lenses with an anti-reflective coating. Water and oil readily cling to the relatively porous AR coating materials. Additionally, AR coatings can generate static electricity when being wiped while cleaning due to the *Triboelectric effect*. This static electricity can actually *attract* dust and dirt particles to the lens that both soil the surface and increase the likelihood of abrasion. Further, without the benefit of reflections to obscure particulates on the surface, the visibility of smudges and debris is dramatically enhanced.

The integrated layers of the DuraVision Platinum AR coating are sealed with a final top coating layer that provides a protective barrier against the environment, while also producing a super-slick surface that is easy to clean—and keep clean. This top coating has been engineered with high fluorine content, which imparts the lens with extremely good *oleophobic* (oil resisting) and *hydrophobic* (water resisting) properties by decreasing the energy at the lens surface that causes attraction between fluids and the lens. Fluids therefore bead up on the surface, instead of clinging to it. This beading action is described by the *contact angle* of the lens or coating surface, which is the angle that the edge of a droplet of water makes with the surface. Because the DuraVision Platinum AR coating has a higher contact angle, the coating repels smudges, water, and oil better than standard AR coatings (Figure 8).[5]

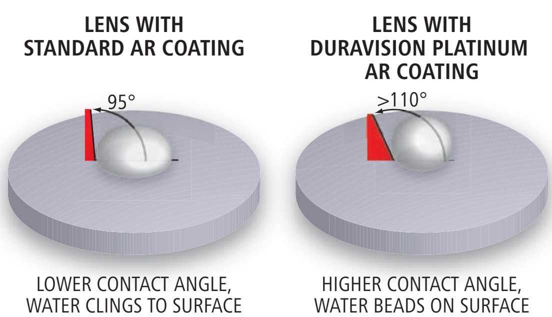


Figure 8. DuraVision Platinum AR coating has a higher contact angle than standard AR coatings, which results in better beading action and an easier to clean lens.

Moreover, although most AR coatings are easy to clean and care for when new, the top coating applied to many AR coatings tends to wear quickly, leaving the AR stack exposed. The DuraVision Platinum AR coating, however, utilizes a long-lasting top coating that is applied inside the vacuum chamber. Applying this quality top coating inside the actual vacuum chamber ensures that the DuraVision AR coating will maintain its hydrophobic properties over the lifetime of the prescription. Many leading AR coatings, on the other hand, lose significant hydrophobic performance over time.

Additionally, the plastic and ceramic materials often used to make spectacle lenses and coatings act as electrical *insulators* that store electrical charge at the surface when the lens is rubbed while cleaning, rather than dissipating the charge like *conductors*. This build up of static electricity attracts dust and particulates to the lens. The DuraVision Platinum AR coating incorporates patented "anti-static" technology.[6] Permanently encapsulated within the coating system is a thin layer of an electrically conductive metal oxide material with high transparency. This unique anti-static layer dissipates static electricity, preventing the build up of electrostatic charge and the attraction of particulates (Figure 9).

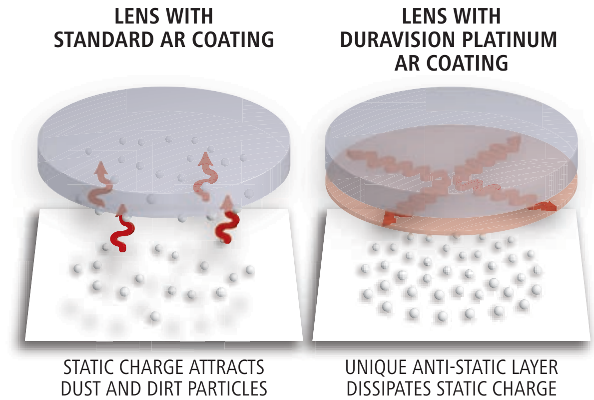


Figure 9. DuraVision Platinum incorporates a patented anti-static layer that dissipates the static charge that would otherwise attract dust and dirt particles.

Uncoated hard resin and standard anti-reflective coatings can store a significant amount of static electricity. Because of this patented anti-static technology, however, the DuraVision Platinum AR coating produces up to 90% less build-up of static electricity. Consequently, compared to standard AR coatings, the DuraVision Platinum AR coating will keep the lens considerably more free from dust and dirt, which can soil and damage the coating (Figure 10).

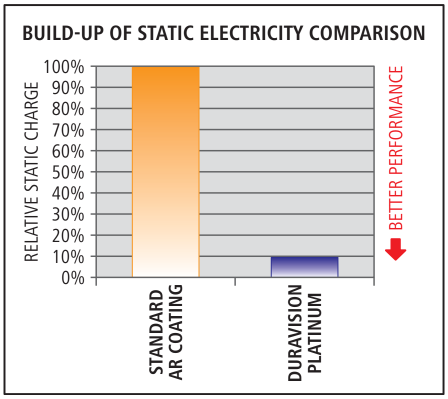


Figure 10. Standard AR coatings can store up to ten times as much static electricity as DuraVision Platinum.

Unsurpassed Transparency

» DuraVision Platinum AR coating has up to 20% less reflections than other leading AR coatings

Anti-reflective coatings are produced by applying one or more thin layers of ceramic or metal oxides to the lens surface. By varying the refractive index of each layer, reflections from one layer can be made to interact with reflections from the next layer. Through the process of *destructive interference*, the magnitude of these reflections is significantly decreased, while the amount of light transmitted by the lens is likewise increased. Early anti-reflective coatings utilized only a single layer in the coating stack. Unfortunately, a single layer can only fully eliminate surface reflections for one color (or *wavelength*) of the visible spectrum. Other wavelengths are partially reflected, resulting in residual reflections from the other colors of the spectrum that remain visible. Maximum lens transmittance is therefore not achieved.

Eventually, modern *multi-layer* or *broadband* anti-reflective coatings were introduced. The use of multiple layers in the anti-reflective coating stack allowed these coatings to increase the transmittance of the lens by decreasing the total reflectance of the lens to less than 1 or 2%. This resulted in clearer, less conspicuous lenses. Nevertheless, residual reflections still remained that often exhibited a distracting hue or *reflex color*.

The choice of reflex of color is important. The sensitivity of the human eye to the colors of the visible spectrum varies with each wavelength. The peak sensitivity of the eye lies within the green region of the spectrum at 555 nanometers, whereas the eye is considerably less sensitive to wavelengths at the blue and red ends. Therefore, green colors appear brighter than colors at the other ends of the spectrum. The *luminous* reflectance of a lens represents the reflectance of the lens weighted by the sensitivity of the eye to each color. The maximum reflectance of standard AR coatings often lies within the green region of the spectrum (Figure 11).

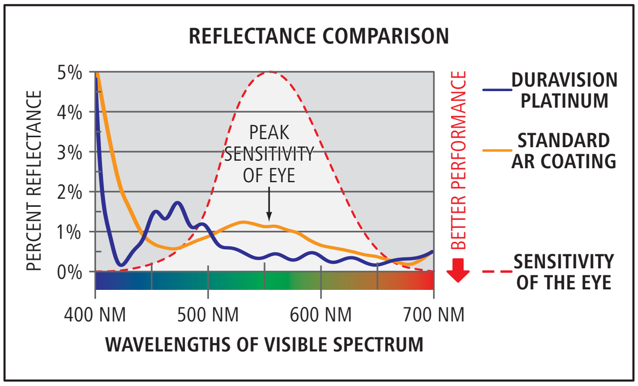


Figure 11. Although conventional AR coatings produce maximum reflectance near the peak sensitivity of the eye, the maximum reflectance of DuraVision Platinum AR coating has been shifted to the blue end of the spectrum for reduced visibility.

The choice of a greenish reflex color limits the visual performance of many standard AR coatings. The DuraVision Platinum AR coating, however, utilizes a coating with maximum reflectance displaced away from the peak sensitivity of the eye toward the blue end of the visible spectrum. By judiciously controlling the luminous reflex color of the coating in this way, the luminous reflectance of each lens surface is decreased to approximately roughly 0.5%, resulting in less noticeable residual reflections, while the luminous transmittance of the lens is increased to over 98%. In fact, the DuraVision Platinum AR coating has up to 20% less luminous reflectance than many other leading AR coatings with greenish reflex colors (Figure 12).[7]

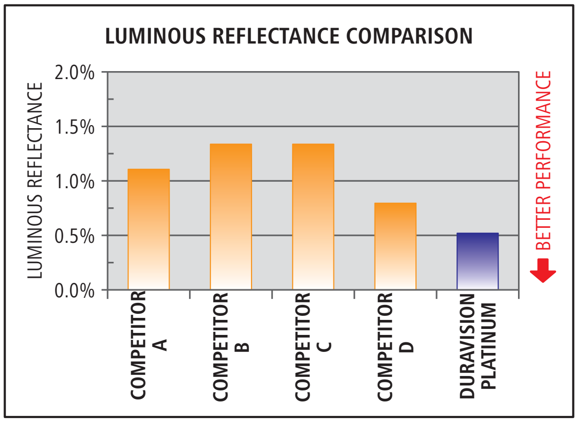


Figure 12. DuraVision Platinum AR coating produces significantly less luminous reflectance and greater luminous transmittance than many other leading AR coatings.

Further, by shifting the maximum reflectance to the blue end of the visible spectrum, the DuraVision Platinum AR coating produces a more cosmetically pleasing, "arctic blue" reflex color. Due to the reduced color sensitivity of the eye for blue hues, this subtle blue hue is less conspicuous than the greenish reflex color of many conventional AR coatings (Figure 13). Wearers will therefore enjoy unsurpassed cosmetics in addition to maximum visual clarity.

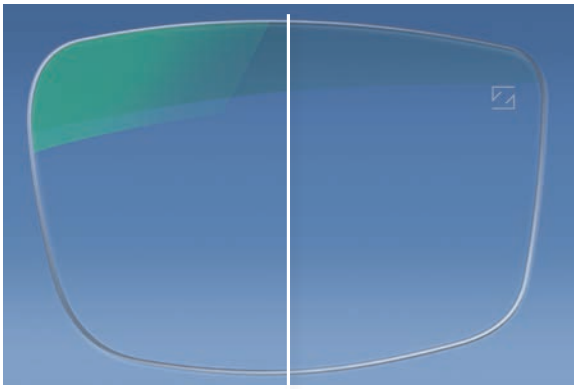


Figure 13. Actual photographs of DuraVision Platinum AR coating and a conventional AR coating, taken side by side, demonstrate the dramatic difference in visibility of the residual reflections off each coated lens surface.

Importance of High-Performance AR

Each surface of a spectacle lens reflects a significant amount of incident light, resulting in both cosmetic and visual consequences. Cosmetically, external surface reflections originating from sources of light in the environment and internal surface reflections originating from the edge of the lens exacerbate how thick and conspicuous the lens appears. In minus lenses, for instance, unsightly internal reflections of the edge of the lens exaggerate the "coke bottle" effect. Moreover, because lens reflections often obscure the wearer's eyes and nearby facial features, personal interaction may be hindered by reflections that make it more difficult for observers to make eye contact or to recognize important facial expressions.

Visually, lens reflections also result in a loss of image brightness and contrast. Lens reflections not only reduce light transmittance, but also serve both as a source of distracting "ghost images" of bright objects in the field of view and as a source of veiling glare. Ghost images and veiling glare result in "visual noise" that degrades retinal image quality while reducing visual comfort and performance. Clinical studies have shown that AR coatings provide crisper and more comfortable vision than uncoated lenses. These studies have also demonstrated significant improvements in contrast sensitivity under low-light conditions, such as night driving, with AR coatings.[8]

Furthermore, the reflectance of a lens surface increases as the refractive index of the lens material increases, so the cosmetic and visual ramifications of surface reflections are especially problematic with today's popular "high-index" lens materials. A total reflectance as high as 14% can occur with some of the "ultra-high-index" lenses that are now available (Table 1). Given the premium positioning of these lens materials, which often command a higher price, these eyeglass wearers deserve the best optical performance and greatest protection against wear possible from these lenses.

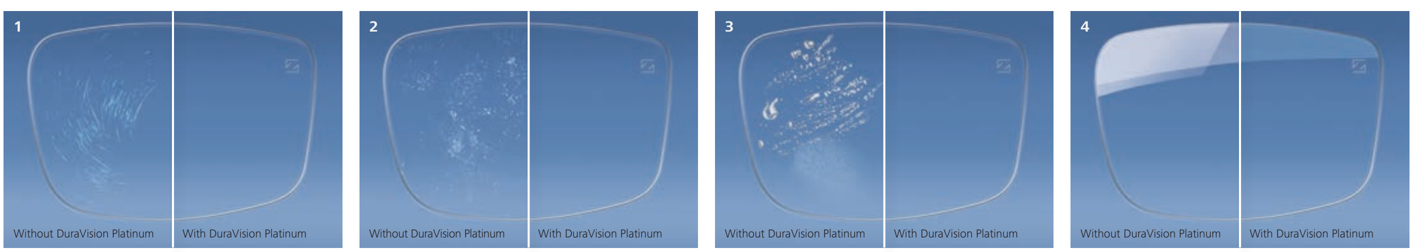
» DuraVision Platinum by ZEISS offers a true high-performance AR coating

Table 1. Total reflectance increases with the refractive index of the lens material.

Refractive Index	**1.50**	**1.55**	**1.60**	**1.67**
Reflectance	7.7%	8.9%	10.1%	11.8%

Consumers demand high-performance products that enhance their visual experience. By virtually eliminating annoying lens reflections, AR coatings provide eyeglass wearers with clearer and more cosmetically appealing lenses. With the introduction of the DuraVision Platinum AR coating by ZEISS, eyeglass wearers can enjoy the clearest vision possible with the convenience of trouble-free cleaning and the confidence of rugged durability (Figure 14).

In a nutshell: ZEISS lenses with DuraVision Platinum AR coating …



… are harder than ever.

… are dirt-resistant.

… are very easy to clean.

… offer first-rate anti-reflective properties.

Figure 14. The benefits of DuraVision Platinum in a nutshell.

1. Image and awareness tracking conducted among consumers in 8 countries by an external market research institute in 8 countries (n = 6,000).
2. Quantitative research conducted in Japan and China by an external market research institute (n = 120) and qualitative research conducted internally in the US and Europe (n = 38).
3. Based on DIN/ISO 14577 instrumented indentation test conducted using a CSM Ultra Nanoindentation instrument on coated 1.6 high-index lenses.
4. Based on Bayer test conducted in accordance with the COLTS standard operating procedure and COLTS-certified abrasive on coated hard resin lenses.
5. Based on water contact angle measurements conducted on coated hard resin lenses.
6. Marechal N. and Blacker R. "Anti-Static, Anti-Reflection Coating." US Patent 6,852,406; 2005.
7. Based on luminous reflectance measurements conducted on coated 1.6 high-index lenses.
8. Ross J. and Bradley A. (1997) "Visual performance and patient preference: a comparison of anti-reflection coated and uncoated spectacle lenses." *J. Am. Optom. Assoc.* 68(6), 361-365.

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