PHOTOCHROMIC LENSES: A BRIEF LOOK AT THEIR HISTORY, HOW THEY WORK, AND THE VARIOUS MANUFACTURING TECHNOLOGIES

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LIGHT TO DARK: THE TECHNOLOGY OF THE PHOTOCHROMIC LENS

Photochromic lens technology adds value and versatility to prescription eyewear. When worn indoors, photochromics are nearly as clear as a standard pair of prescription lenses and in some cases, just as clear. But when they are exposed to the ultraviolet (UV) rays of sunlight, the photochromic lenses automatically darken. Fitted with photochromic lenses, a single pair of eye glasses can provide a patient with excellent comfort in a wide range of light situations.

PHOTOCHROMIC LENS HISTORY

The first photochromic technology was offered for glass lenses in 1966 by Corning. Silver halide crystals added to the molten glass would cause the finished lenses to darken in reaction to UV in just a few minutes, and would achieve maximum darkness after about 15 minutes. The more intense the UV exposure, the deeper the darkness, so the lenses could provide constantly adjusting comfort in a variety of light conditions. Though not recognized as a key benefit at the time, the photochromic lenses also protected the eyes from UV exposure. Early lenses would return to 65 percent transmittance in about 10 minutes after the UV exposure was terminated, and reach 85 percent transmittance after an hour.

These early photochromic lenses did not always perform ideally. If the prescription called for one lens to be thicker than the other, the thicker lens would darken more quickly and become darker than the thinner lens. The photochromic performance could be short-lived, and the lenses often appeared slightly dark indoors. However, in the 45 years since the first photochromic lens was introduced, advances in lens material and manufacturing have significantly improved the performance of this light-responsive technology. Photochromics are now available in prescription and non-prescription eyewear, goggles, and even face shields for motorcycle helmets.

HOW PHOTOCHROMICS WORKS

The glass version of these lenses achieve their photochromic properties through the embedding of microcrystalline silver halides (usually silver chloride), or molecules in a glass substrate. Plastic and polycarbonate (PC) photochromic lenses rely on organic photochromic molecules (for example, naphthopyrans and spirooxazines) to achieve the reversible darkening effect. The reason these lenses darken in sunlight but not indoors under artificial light, is that room light does not contain the UV (short wavelength light) found in sunlight. The absorption of UV light causes the molecules of photochromic material to change shape and absorb more visible light, and thus makes the lenses appear darker. Shape changing of the photochromic molecules is a reversible process. In the absence of UV light, photochromic molecules return to their original shape and lose their visible light absorbing property. Automobile windows also block UV so these lenses would darken less or not at all in a car. With the photochromic material dispersed in the glass substrate, the degree of darkening depends on the thickness of glass, which poses problems with variable-thickness lenses in prescription glasses. In current plastic and polycarbonate lenses, the photochromic molecules are typically embedded into the layer near the surface in a uniform thickness of up to 150 μm and do not have the darkness differential problem.

The performance of a light-responsive lens is temperature dependent. Heat causes the photochromic molecules to favor a transparent state. In very hot weather, it's difficult for a photochromic lens to achieve the darkness of regular sunglasses. However, a photochromic lens may get extremely dark in cold weather, as a lower temperature causes the number of activated molecules to increase. All ophthalmic lenses are required to have an eight percent luminous transmission in order to meet ANSI/ISO light transmission standards for general use eyewear. Cold lenses are also slower to go back to a near-clear state after they are indoors.

The speed with which the light-responsive lens darkens, or activates, and then fades back to its clearest state, is obviously a key measure of photochromic performance. Ideally, to offer the most comfort, the lens would darken very quickly when the patient steps from indoors into sunlight, and then revert to its clearest state just as quickly when the patient goes back indoors. Different photochromic technologies react more quickly than others, and achieve a deeper level of darkness in bright light. Generally, light-responsive lenses fade to clear more slowly than they darken, but recent improvements have reduced fade time by one-half to one-third compared to earlier lenses. Today's best photochromic lenses can change from clear to dark in less than 15 seconds, and then fade back to the clearest state in 2-to-20 minutes, depending on manufacturer and temperature.

The range from deep darkness in sunlight to a residual effect indoors is another measure of the performance of a photochromic lens. Standard lenses offer 86 to 98 percent light transmission, depending on the lens material and coatings. The best photochromic lenses can achieve about 90 percent transmission, virtually indistinguishable from a regular lens. The industry standard for regular sunglasses is at least 8-18 percent light transmission, and some photochromic lenses are able to match that performance. However, there is a range of performance among different types of photochromic lenses.

Photochromic lenses are not always a good replacement for prescription sunglasses, or for regular glasses. Because they need to be in direct contact with UV light for the process to activate, photochromics do not darken behind the windshield of an automobile, leaving a driver or passenger squinting in bright light. Furthermore, darkened photochromic lenses behave more like tinted lenses, capable of increasing contrast by reducing the transmission light. However, they are not able to eliminate the glares from reflections like polarized sunglasses. Finally, the photochromic lenses may not fade quickly enough to provide safe vision in some situations, such as a patient stepping from outdoors directly into a dimly-lit worksite.

WHO'S A GOOD FIT FOR PHOTOCHROMIC LENSES?

Almost any patient who wears prescription eyewear could benefit by switching to light-responsive lenses. Photochromic lenses enhance comfort because they adjust to different levels of sunlight because of its UV content. They reduce strain on the eyes and increase the contrast of vision outdoor under direct sunlight. They offer the patient the convenience of being able to navigate the world with one pair of glasses they can wear comfortably indoors and out. This is especially handy for people who are frequently moving from indoor to outdoor environments during the workday. Finally, photochromic lenses offer protection from harmful UVA and UVB radiation.

Patients who are a particularly good fit for photochromic lenses include:

- Children because they often spend a lot of time outdoors.
- Patients with active lifestyles that don't want to be bothered with changing glasses, and will appreciate lenses that self-adjust to a wide range of light conditions.
- Contact lens users who need glasses but don't want to buy multiple pairs.
- Presbyopes, who often lose the ability to quickly adjust to changing light conditions.
- Post-surgical patients who are rendered more light-sensitive.

COMPARING FOUR PHOTOCHROMIC MANUFACTURING TECHNOLOGIES

There are presently four methods for achieving photochromic behavior in corrective lenses.

- **In Mass:** The photochromic molecules are mixed into and become a homogeneous component of the glass or plastic lens material. The original Corning glass photochromic lens used the in mass process, as the dye was added to the glass while the material was in a molten state. In mass lenses were introduced by Corning in 1966 in glass, and by Corning in 1999 as SunSensors in plastic. SunSensors are available in the U.S. market from Signet Armorlite, Inc.; Polycore Optical USA; and Thai Optical Group.

- **Imbibed:** Multiple layers of a special coating are applied to the front of the lens. The photochromic dyes are deposited over these coatings and then subjected to high heat, which causes the dyes to penetrate into the surface material of the lens. A final hard coat is then applied over the photochromic layer. The Transitions brand is a joint venture of Essilor and PPG, and has been through eight generations in plastic and polycarbonate since its introduction in 1991. The latest version is Transitions VI.

- **Wafer:** Photochromic dyes are added "in mass" to a resin wafer, which is poured into a mold and then bonded with a thicker, clear cast lens. A scratch-resistant coating is then applied to the front surface to protect the photochromic wafer material. Introduced in 2004 by Signet Armorlite under the Kodak InstaShades brand.

- **Film:** A film containing photochromic dye is laminated between strong layers of polycarbonate. This laminate is then molded to the front of a polycarbonate lens. This Vision-Ease Lens technology was introduced as LifeRx in 2005, and has since become known for its exceptional clarity indoors and its ultra-quick fadeback performance.

VISION-EASE LENS CHANGERX: THE NEW PLASTIC PHOTOCHROMIC ALTERNATIVE

ChangeRx is a hard resin (1.50 Refractive Index) photochromic lens manufactured with homogeneous in mass technology. It delivers outstanding light-sensitive performance, exceptional stability in higher temperatures, and better efficiency in hot and cooler weather. Photochromic molecules are embedded throughout the lens material, just like the old glass photochromic lenses described earlier. However, unlike the glass lenses, the photochromic materials are special organic molecules tailored for the substrate. Therefore, the photochromic reactivity tends to be faster and activation color more uniform. Most importantly, the resin has a much lower density and offers much lighter weight comfort for the patients.

ChangeRx Advantages

- The optical performance of 1.50 hard resin in a material that is lighter in weight (specific gravity of 1.18) and thus more comfortable than standard hard resin (specific gravity of 1.32) or Crown glass (specific gravity of 2.59).
- Available in multiple styles.
- Achieves darkness (ISO sunglasses category 3) at 50°F in less than 60 seconds.
- Displays a uniform tone throughout the activation process.
- Provides 100 percent UVA and UVB protection.
- Enables both front and back direct surfacing capability without losing its photochromic property.