ZEISS UVProtect.

Full Protection From Hazardous UVR In All Popular Lens Materials.

Ultraviolet radiation (UVR) can cause many harmful effects in the eye, conjunctiva and eyelids, as shown by scientific and medical evidence. Daylight exposes us to a lot of UVR throughout the year, from mid morning to late afternoon, whether facing toward or away from the sun. Spectacles can provide significant eye and eyelid protection from UVR. Yet the most popular clear spectacle lens materials do not completely block the most plentiful source of UVR, the solar spectrum between 350 and 400 nm. Some ophthalmic lens standards ignore the hazard of UVR wavelengths longer than 380 nm, creating a UVR protection gap. ZEISS scientists have found new ways to change its most popular lens materials to block harmful solar UVR up to 400 nm, with no visibly significant effect on light transmission. ZEISS UVProtect ensures that clear ZEISS plastic lens materials provide protection from hazardous UVR.

Daylight Ultraviolet Radiation (UVR)

Ultraviolet light is high-energy radiation between the x-ray and visible light part of the electromagnetic spectrum. In biomedical research, it is called UVR. In spite of much negative news about UVR, it actually produces several beneficial effects for humans, including vitamin D production via skin exposure. But UVR exposure does not benefit the eyes or their surrounding structures. Ultraviolet radiation (UVR) damages the eye and can causes photoaging and cancer of the eyelids. (Figure 1).

Eyeglass wearers typically are aware of some of the damaging effects of UVR, but many think that their eyeglasses already provide complete UVR protection. In many cases, their eyecare professionals have been led to think the same thing. Very often they are wrong.

Ophthalmic prescription lens standards for UVR are derived from studies of damage caused by short, high-intensity exposure to UVR to structures only in the eye itself. Yet the eyelids are perhaps even more susceptible to UVR damage. The cumulative damage to skin from low-level exposure to UVR over many years is well documented but many people will not put sunscreen on their eyelids.

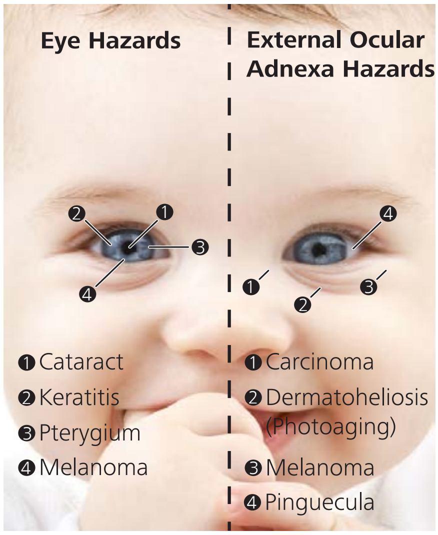

Figure 1. In her lifetime, this child will face many UVR hazards.

Recent research suggests that the action spectrum used in some ophthalmic lens standards does not solely represent the risk to the eye itself and that further spectra should be considered in addition. As we understand more about photo ageing and pre-cataract changes to the lens of the eye, it is becoming apparent that that long-wavelength UVR is more important than previously thought.

Exposure to UVR

Sometimes people are exposed to UVR hazards from artificial light sources including welding arcs, tanning lamps, UV sterilizers and UV curing lamps. Although these can cause immediate damage, the acute effects are usually short-lived and will heal. For most people, daily exposure to natural UVR outdoors is a much greater problem. The sun is a prodigious source of UVR as well as visible light while the exact composition of UVR and visible light in daylight depends on specific local circumstances.

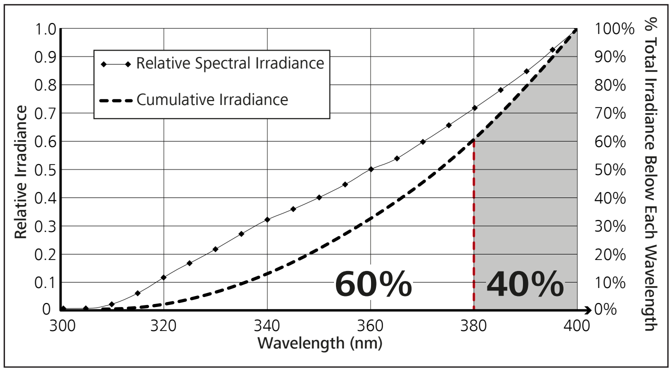

Figure 2. ISO 8980-3 solar UVR spectrum normalized to its maximum value at wavelength of 400 nm.

Almost all medical and scientific organizations that define UVR state that its spectrum extends to 400 nm and standards organizations must decide on a particular UVR distribution to use. For example, the ISO ophthalmic lens standard (ISO 13666:2012 – Ophthalmic optics – Spectacle lenses – Vocabulary) refers to an average solar daylight spectrum[2, 3] (Figure 2), but defines the upper limit of UV radiation to be at 380nm. Using that definition, 40% of solar UVR exposure on Earth's surface is within a spectral band that is ignored by this standard. In contrast the Australia/New Zealand sunglass standard[4] (AS/NZS 1067:2003. Australian/New Zealand Standard™. Sunglasses and fashion spectacles) considers UVR up to 400nm.

The way that UVR reaches the eye and its surrounding structures depends on several atmospheric and geometric factors. Intense exposure may happen even on hazy or partially cloudy days. In fact the greatest UVR exposures often occur in mid morning and mid afternoon, not at noon as many are inclined to believe. Around noontime, the eye itself is typically not exposed to the direct rays of the sun. Much more ocular UVR exposure can come from reflection from surfaces below the eye, and by atmospheric scatter (Figure 3). The total extent of the sky is nearly 100,000 times larger than the sun so its contribution to UVR exposure can be very large.

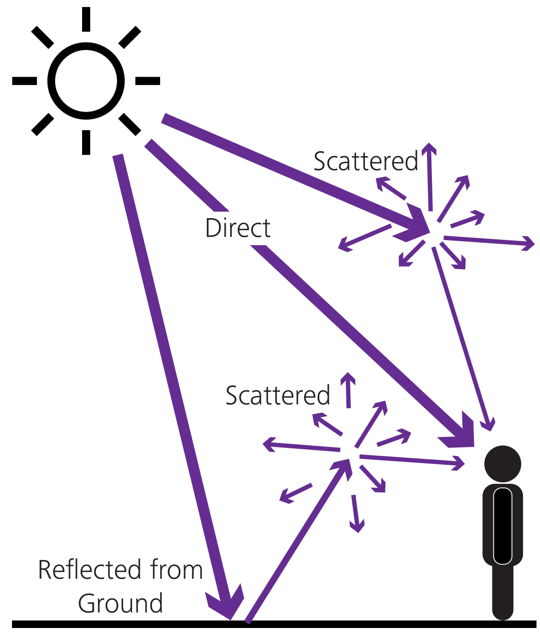

Figure 3. People are exposed to UVR directly from the sun and reflected and scattered from the ground and atmosphere (adapted from CIE 151:20032).

UVR Protection from Spectacles

Eyeglasses can block a substantial amount of UVR depending on factors including lens size, their distance to the face, and the UVR absorption of the lens material.

The largest part of potential UVR exposure to spectacle wearers is from light passing through the lenses. In a study using mannequins, the residual amount of UVR that passed around spectacle lenses averaged about 6% of total UVR irradiance and was greatest when the mannequin faced toward the sun, probably due to the greater intensity of direct sunlight reflecting off of spectacle frames and facial features of the mannequin[4].

Figure 4 shows that UVR exposure of the eye is defined by two factors: the angular expanse of the UVR source and the area of the aperture through which the UVR must pass.

For the extended UVR source presented by the sky and ground, the angular extent of the source that can send UVR from a rearward exposure of the eye is much narrower than the angular extent of a forward exposure. Likewise, the area of the gap presented by spectacles to rearward exposure, here labeled "V," is much smaller than the area of a spectacle lens (labeled "A").

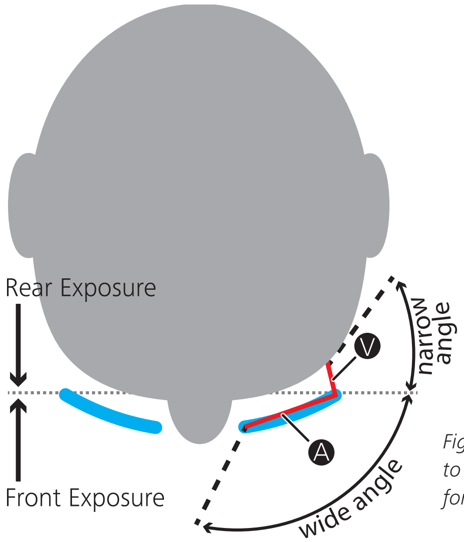

Figure 4. Potential exposure to UVR is greatest from the forward direction.

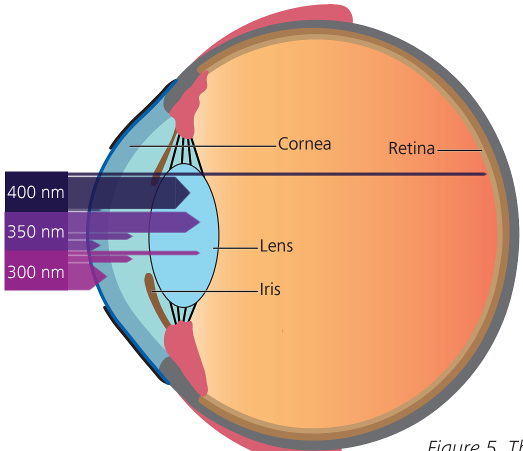

Figure 5. The location of absorption of UVR in the eye depends on wavelength.

Taken together, the total UVR irradiation of a lens from the front is up to twenty times larger than the UVR irradiation passing from behind the wearer and through the gap between lens and head. Furthermore, some of the rearward UVR will miss the face and pass into the lens; only a perfect UVR mirror could return all of those rays to the face.

One paper has claimed that a significant portion of hazardous UVR exposure of the eye is reflected from the back surface of spectacle lenses[5]. That conclusion only makes sense if most spectacle lenses already completely absorb hazardous UVR, but they do not.

The implications of UVR exposure for eyecare professionals and eyeglass wearers should be clear. For many wearers the greatest potential exposure may occur when wearing sunglasses is not practical or desirable. Most of the UVR that can reach the eye and eyelids strikes the spectacle lens first. It is important that spectacle lenses render it harmless.

Damage and Disease Caused by UVR

The location of absorption of UVR in the eye depends on wavelength (Figure 5). The many kinds of damage caused by UVR are typically divided into acute and chronic. Acute damage happens with short but intense exposure. Most acute damage is painful or irritating and results from temporary damage to the skin or surface of the eye that will heal completely. Chronic damage and the diseases that follow are caused by much lower levels of exposure over a long period of time, often many years. Some of the kinds of damage are described as phototoxic, others as photoaging. All are irreversible and most require medical treatment. Chronic conditions are insidious because they happen very slowly, and wearers are unlikely to notice the changes as they happen.

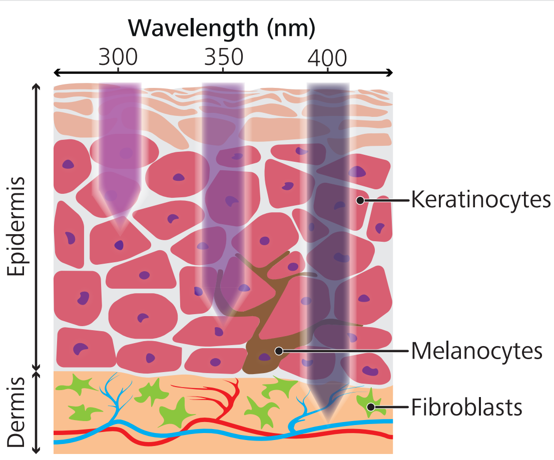

Figure 6. Long wavelength UVR penetrates deep into the skin, damaging skin cells and causing photoaging.

Sites and Types of UVR Damage

Eyelids and periorbital skin: UVR damage to the eyelids is common. Experts recommend sunscreen on the eyelids to prevent damage but people often refuse to do it because of eye irritation[6]. Chronic skin conditions caused by UVR include:

- Photoaging of the eyelids. This makes skin thicker and leads to prominent wrinkles. Long wavelengths of UVR penetrate into the deepest part of the skin, damaging collagen and comprising the structural integrity of the eyelids.
- UVR damage to sebaceous glands. Such damage can lead to xerosis (dry skin)
- Actinic keratosis. An advanced type of damage to the skin characterized by dry red patches; it is considered pre-cancerous.
- Skin cancers of the eyelid. These account for 5 to 10 % of all skin cancers and because of the local anatomy may easily spread.

Conjunctiva: A pinguecula is a thickened deposit of fat, protein and calcium that is visible over the white of the eye. Unless it grows into a pterygium, it usually is only an unsightly cosmetic problem.

Figure 7. A pinguecula of the conjunctiva can develop into a pterygium that grows onto the cornea.

Iris: Melanoma tumors are the most common cancer of the eye, and evidence suggests that UVR is one of its leading causes. When located on the iris, the most common location is at the bottom, where daylight UVR exposure is strongest.

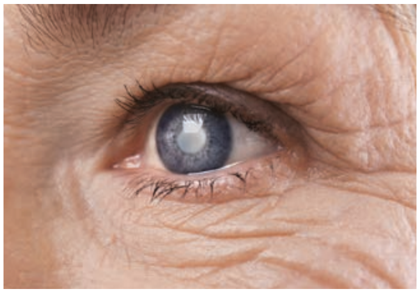

Figure 8. UVR photo aging causes deep wrinkling of the skin of the eyelids and causes changes in the lens leading to cataract.

Lens: UVR causes pre-cataractous changes by causing proteins to clump together. The early signs are loss of contrast and muted colors. As the eye ages, protective pigments in the lens are converted into pigments that react to UVR, further damaging the outer layer of the lens and lens proteins. When enough damage has accumulated, the lens develops cataracts that severely compromise vision.

Retina: In young eyes a portion of the longest wavelengths of the UVR spectrum reaches the retina and may cause photochemical damage. This damage may be augmented by medications or herbal supplements that increase damage.

Evaluating and Protecting Against UVR Hazards

A UVR hazard analysis proceeds after making some decisions about the kind of UVR light source and the kind of hazard that is being evaluated. These decisions are guided by many years of research and several global standards. The most important source of UVR is solar daylight so that is the relevant spectrum. One must also define an action spectrum for UVR that weights each wavelength of UVR according to its ability to cause a specific type of damage. Since there are different sites and mechanisms for UVR damage, different action spectra may be used. But the action spectra for some kinds of UVR damage have not been defined.

One of the most widely used action spectra for hazard analysis is published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP)[7]; the same action spectrum is used by the American Council of Government and Industrial Hygienists (ACGIH)[8]. Even the ophthalmic lens standard ISO 8980-3 "Ophthalmic optics - Uncut finished spectacle lenses - Part 3: Transmittance specifications and test methods"[9] cites the ACGIH as the authority for its use of this action spectrum in UVR calculations.

There are at least two points of dispute regarding this adoption.

- The original hazard evaluation methods define UVR hazard extending up to 400 nm. In spite of this, both ISO and ANSI have chosen to ignore wavelengths between 380 and 400 nm[10 11].
- The ICNIRP Guideline cautions that the possible low-level chronic effects of UVA on the eye calls for "a more cautious approach for chronic ocular exposure," suggesting that its Guidelines might not even properly be applied to the most common eye hazards.

The current action spectrum chosen gets smaller as wavelengths get longer throughout the range from 350 to 400 nm. Not all action spectra behave that way. For example, the CIE Photocarcinogenesis action spectrum[12] treats wavelengths between 380 and 400 nm the same as wavelengths between 350 and 380 nm. It is apparent that the choice of action spectrum and wavelength range is very important.

Ophthalmic Standards: 380 vs 400 nm

A close reading of ISO 8980-3 and its supporting documents reveal that the 380 nm cutoff was a semantic choice based on a need for a simple definition. That definition started with a decision to choose 380 nm as the starting point for visible light, but only for ophthalmic lenses. It proceeded to define UVR as consisting of wavelengths

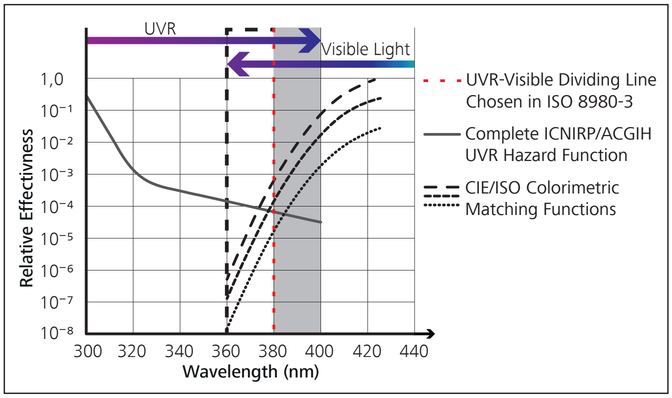

Figure 9. Overlapping spectral region of UVR hazard up to 400nm, and visual repsonse of human visual system as of 360nm.

shorter than visible light. Even though its source document for hazard evaluation says that the UVR hazard extends to 400 nm, ISO 8980-3 ignored wavelengths between 380 and 400 nm because it had defined UVR only extending to 380 nm (Figure 9).

In spite of its decision, the definition support document cited by ISO 8980-3 does admit that UVR is typically defined up to 400 nm. Yet another ISO standard concerning visible light colorimetry defines visible light starting at 360 nm[13]. As ISO understands, there actually is a substantial degree of overlap between a visual response to wavelengths of electromagnetic radiation and the harmful biological actinic effects of that radiation.

Irrespective of whether current industry standards truncate UVR wavelengths at 380nm, the threat from those UVR wavelengths between 380m and 400nm still exists, and those wavelengths are the most plentiful in the solar UVR spectrum.

Findings in some recent studies of the damaging effects of UVR wavelengths from 315 nm to 400 nm may also challenge the choice of a 380 nm cutoff. One of those studies is especially interesting because it published two new UVR action spectra[14]. When applied to the solar UVR spectrum, the results suggest a much larger threat from wavelengths longer than 380 nm (Figure 10).

Does the Full UVR Spectrum Really Matter?

Acceptance of traditional ophthalmic industry standards for UVR transmission depends on whether one accepts the use of the specific weighting functions and wavelength ranges they chose.

If the ACGIH/ICNIRP action spectrum is acceptable, then perhaps the traditional standards might be acceptable. If UVR wavelengths longer than 380 nm are truly irrelevant, then the 380 standard is "probably" OK[15]. But if one recognizes that recent research suggests that damage from UVR wavelenths up to 400 nm is widespread, then it is not acceptable.

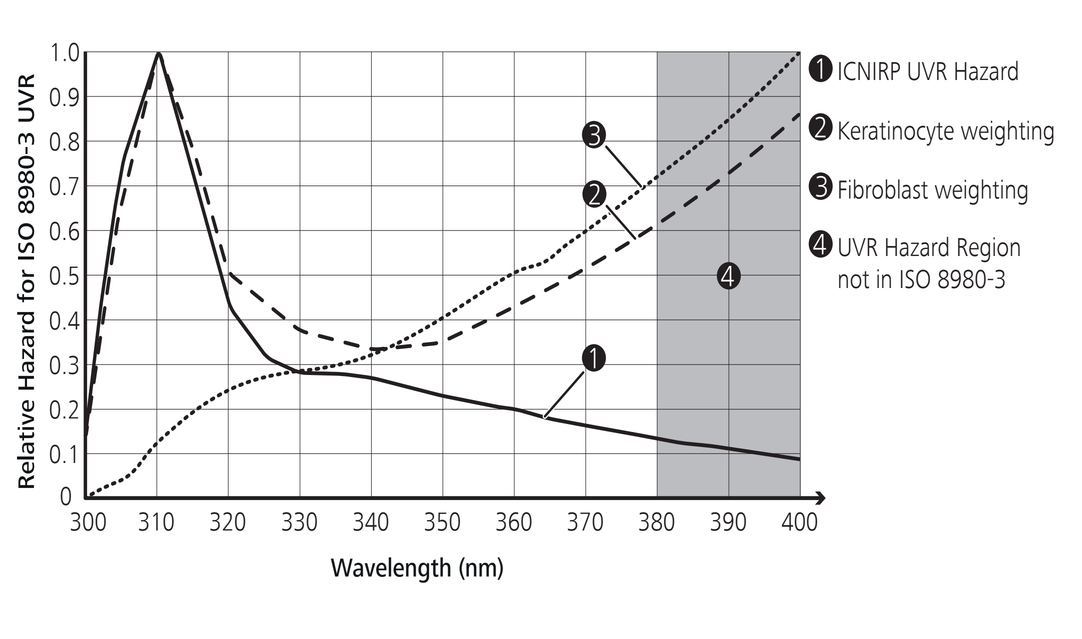

Figure 10. Application of the results of Latimer et al suggests that long wavelength UVR may be much more important (Keratinocyte and Fibroblast weighting) than current ophthalmic standards considered action spectrum (ICNIRP UVR hazard weighting respecting acute erythemal damage to eye and skin).

In fact, current ophthalmic UVR standards are being challenged, and some authors have called for standards to be revised upward to 400 nm. For example, the Australia/New Zealand sunglass standard uses the ICNIRP action spectrum over the full UVR wavelength range to calculate UVR transmittance[16]. And even that standard may not be good enough, because other action spectra for UVR damage show a greater contribution to damage by wavelengths close to 400 nm.

Whichever action spectrum you choose, the way to get maximum protection is to block as much UVR as possible, all the way to 400 nm. As a recap and looking at current UVR protection performance of market offerings in clear lenses, almost two-thirds of daylight UVR lies in wavelengths not fully blocked by the most common clear spectacle lens material (e.g. 1.50 index plastic passes a large amount of UVR over the region between about 350 and 400 nm), while approximately 40% of daylight UVR lies in wavelengths not fully blocked by materials that claim "100% UV protection" by blocking only to 380nm. (e.g. polycarbonate and 1.60 index plastic also pass a significant amount of UVR at wavelengths shorter than 400 nm). (Figure 11a).

ZEISS has decided to change its clear plastic lens materials to provide full blocking of harmful UVR according to the strict Australia/New Zealand sunglass standard. By that standard each of these materials transmit less than 0.4% solar UVR (Figure 11b) The new materials are identified by the UVProtect brand name; for example the new 1.50 index is called ZEISS 1.50 UVProtect. Now all eyeglass wearers can get sunglass-level UVR protection in a clear lens.

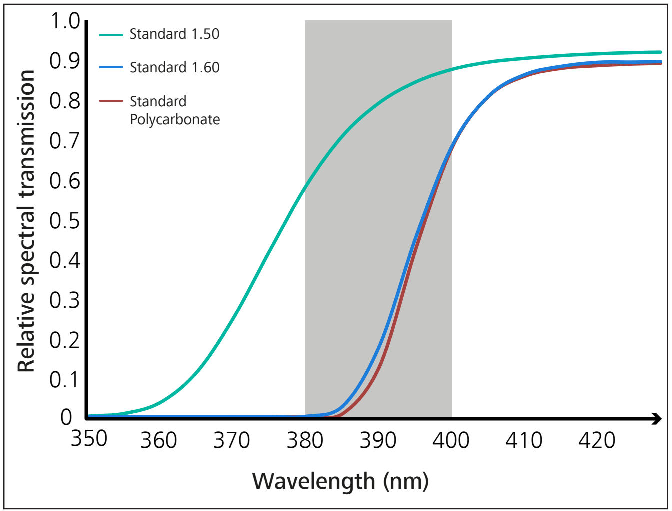

Figure 11a. Standard lens materials pass significant amounts of UVR.

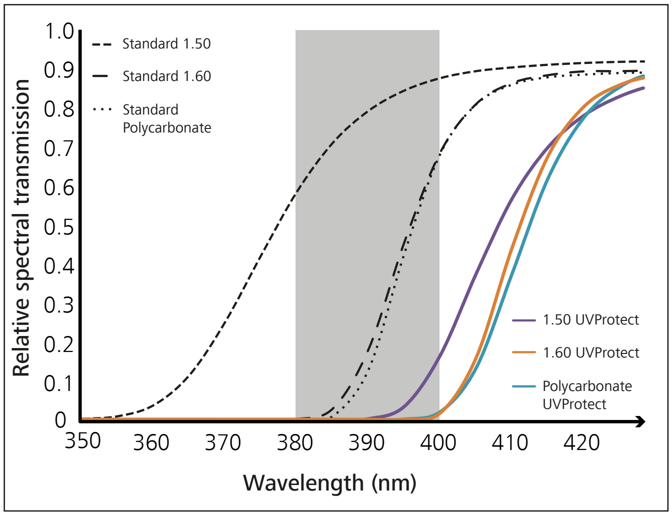

Figure 11b. ZEISS UV Protect materials pass only visible light.

Sunglass-Level UVR Protection in a Clear Lens

The ophthalmic industry has long accepted the 380nm standard and resisted a move to a 400nm requirement because it comes with a potentially significant manufacturing complexity in terms of cost and aethetics. Polymers such as allyl diglycol carbonate (1.50 index) and polycarbonate do not inherently block all UVR. Additives must be incorporated in the polymers and there are consequences for quality control: too little and UVR will not be blocked fully, too much and the lenses may be discolored. ZEISS scientists have found ways to modify its clear lens polymers for full UVR protection without noticeably changing visible light transmission.

Many eyecare professionals are aware that lenses tinted with UVR absorbing dye may look different after treatment. As shown in Figure 9, UVR wavelengths as short as 360 nm affect the perceived color of light. Typical UVR absorbing dyes introduce significant changes to visible light transmission and cause noticeable changes of hue. ZEISS UVProtect lenses have been designed to have visible light transmission virtually identical to unmodified standard lens materials. When examined in the way that spectacles are worn, the very slight change of hue is unnoticeable by consumers.

In a recent ZEISS market study consumers were asked to look through standard lenses and ZEISS UVProtect lenses; a majority stated that they actually preferred vision through ZEISS UVProtect, both indoors and outdoors[17]. This means that from a consumer point of view there is no visual compromise to be expected when using ZEISS UVProtect.

Summary

Lens manufacturers continue to sell lens materials that transmit significant amounts of potentially hazardous ultraviolet radiation. A growing body of research suggests that current ophthalmic lens standards defining UVR transmission may need revision. ZEISS has decided to anticipate the future by changing its manufacturing process to provide full protection from hazardous UVR in its clear plastic lenses. The new lenses carry the ZEISS UVProtect brand name.

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17. Randomized, masked presentation of lenses, held in the as-worn position, viewing outdoor and indoor scenes; n=51.

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