PRODUCT SPOTLIGHT: MR™ HIGH REFRACTIVE INDEX LENS MATERIAL

What You Should Know about MR™ High Refractive-Index Lens Materials

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[1 CE CREDIT]

THIS COURSE IS SUPPORTED BY AN EDUCATIONAL GRANT FROM MITSUI CHEMICALS

LEARNING OBJECTIVES:

Upon completion of this program, the participant should be able to:

1. Describe the optical performance features and benefits of various lens monomers.
2. Relate the history behind the development of MR-8™, 1.60 index lens material.
3. Explain the MR™ lens material benefits for the patient.

TO EARN CONTINUING EDUCATION CREDIT:

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Regarding lenses, material matters; lens performance is a direct product of the combination of lens material optical properties. This course teaches us about material properties and their effect on lens performance. We will learn how MR™ Series from Mitsui Chemicals combines the best lens properties in a high refractive index material.

Although we will individually address each lens material property, a lens material must be evaluated for its combined effects on vision, comfort (weight) and cosmetics (thinness and magnification). We are familiar with the many lens manufacturers in the optical industry, such as ZEISS, Younger, Essilor, Signet, Shamir and HOYA, to name a few. But we are less aware of the chemical companies that produce the raw materials for coatings, lens monomers, photochromic dyes or specific wavelength control for lenses. The research and development of unsung optical heroes such as Mitsui Chemicals advance lens, dye, and coating molecular science so that lens manufacturers can produce and ECPs can offer their patients excellent vision with thinner, lighter, stronger lenses and coatings. This course reviews the MR™ High Refractive-Index Lens Materials and how these benefits have elevated the MR lens material as the material of choice for labs and ECPs. All lenses of the same refractive index are not created equal. After reviewing the benefits of MR material in this course, you will want to specify MR material when ordering 1.67 or 1.74 refractive index lenses in the future.

MATERIAL MATTERS

Lens material properties impact: peripheral vision due to the distortion caused by chromatic dispersion, thickness, weight, impact resistance, visible light transmission, reflectivity, UVR absorption and toughness.

Did you know that almost 6 of 10 glasses sold in the U.S. have lenses that boast the benefits of thinner, lighter, more impact resistant lenses with 100 percent UV absorptive qualities? When asked why they chose "premium high-index material," surveyed opticians indicated that a higher refractive index lens material makes for thinner, better-looking lenses, a higher Abbe number or "ve" value and surface finish ensure clarity, and the high impact, high tensile strength and reduced notch sensitivity make them also perfect for rimless. But high refractive index material lenses have evolved, making them a lens material of choice for premium eyewear.

In addition to knowing the premium high refractive index lens materials available, it's important to know about those companies behind the scenes who vigorously research and develop lens material monomers, improving our ability to deliver better vision correction to the

eyeglass-wearing public. This course will cover each material property and how MR™ materials have advanced high refractive index material performance and quality.

MATERIAL BASICS: INDEX OF REFRACTION

All lens materials have unique features and benefits based on their material properties. We must understand these properties to give the patient good vision in a lightweight, cosmetically appealing lens.

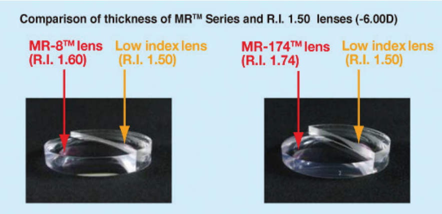

FIG.1 High refractive Index materials = flatter and better looking

The Refractive Index (RI) of a lens material is the ratio of the speed of light in a vacuum divided by the speed of light in the lens material (Fig. 1). Light refracts or bends more in a high-index material resulting in the power of the lens being achieved with a thinner lens.

Final lens thickness is a function of the following (Fig 2.):

1. Prescription power.
2. Lens size/diameter (the result of the frame's boxed dimensions and the patient's PD and fitting height required.
3. Base curve (steeper curves result in thicker lens edges).
4. Refractive index (higher indices make thinner lens edges).

-4.00 sphere, 70mm /

Index	Base	Center	% Thinner	% Lighter
Plastic (1.5)	3.00	2.0	-	-
Poly (1.59)	2.00	1.4	22%	29%
Hi Index (1.6)	2.00	1.4	22%	26%
Hi Index (1.67)	2.00	1.4	28%	29%
Hi Index (1.74)	2.00	1.4	35%	26%

+4.00 sphere, 70mm /

Index	Base	Edge	% Thinner	% Lighter
Plastic (1.5)	8.00	2.0	-	-
Poly (1.59)	6.00	1.5	22%	30%
Hi Index (1.6)	5.00	1.5	22%	25%
Hi Index (1.67)	5.00	1.5	27%	25%
Hi Index (1.74)	5.00	1.5	34%	25%

FIG. 2

5. Allowable minimum center or edge thickness.
6. Impact resistance.

High-index material = lower visible light transmission (VLT): Anti-reflective coatings improve the visible light transmission through all materials and cosmetics.

We need light to see; therefore, the higher the visible light transmission (VLT), the

Lens Material	Refractive Index	Reflectance (ρ) 1 Side	Reflectance (ρ) 2 Sides
CR-39 Plastic	1.499	4.0%	7.7%
Crown Glass	1.523	4.3%	8.3%
Spectralite	1.537	4.5%	8.6%
Polycarbonate	1.586	5.1%	9.8%
1.60 Plastic	1.600	5.3%	10.1%
1.66 Plastic	1.660	6.2%	11.7%

FIG. 3 Image courtesy of "Introduction to Ophthalmic Optics," Meister

better clarity experienced looking through a lens material (Fig. 3). Hi-index materials have high reflectivity and benefit from a premium AR coating to minimize reflections and increase visible light transmission. The cosmetic benefit of reducing reflections is that we can see the wearer's eye. We also improve night vision. Without AR coating, internal lens reflections produce ghost images, halos and glare from headlights and streetlamps when driving at night. And remember, we need light to see, so reduced reflections mean better VLT.

Premium AR is an essential addition to hi-index material lenses. Hi-index materials have a lower visible light transmission or VLT. AR selectively cancels reflections which increase VLT. So, we look better and see better when wearing lenses with an AR coating.

Benefits of AR coating:

1. See your eyes (minimizes surface reflections).
2. See the world clearer (minimizes internal reflections and halos during night driving).
3. Complementary to premium freeform digital lenses.
4. Complements premium brand eyewear.
5. Easy to clean, stays cleaner longer.

MATERIAL BASICS: ABBE

Relationship between eyeglass lens refractive index and Abbe: The Abbe number indicates the degree of light dispersion (Fig. 4). A higher Abbe number means lower dispersion, reduced chromatic aberration and peripheral distortion for higher visual quality. The Abbe number tends to be lower for plastic lens materials with a higher refractive index (RI.) This means opticians face a dilemma: choosing lenses with a higher refractive index to reduce thickness will result in more chromatic aberration (light dispersion into its component colors). But this dilemma can be avoided altogether by choosing both high RI and high Abbe

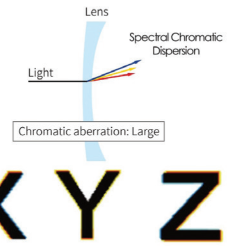

FIG. 4

value materials like MR-8™, 1.60 index lens material. This makes it possible to build thin lenses without the risk of chromatic aberration.

The lens material Abbe value is a number that determines the viewing comfort of glasses. When light passes through a lens (prism), it's dispersed into constituent spectral colors due to the effect of the refractive index on wavelength. We sometimes notice this phenomenon as color fringing (chromatic aberration) in blue or red in the field of view as seen

	MR-8™	Poly	Acrylic	ADC*	Crown Glass
Refractive index (ne)	1.60	1.59	1.60	1.50	1.52
Abbe number (ve)	41	28-30	32	58	59

FIG. 5 ADC and CR39 resin have the same refractive index *ADC: Allyl diglycol carbonate

through a lens. The aberration is especially noticeable in higher powers and in the peripheral regions of the lens, where the larger angle of incidence results in greater dispersion (Fig. 5).

MATERIAL BASICS: IMPACT RESISTANCE, STRENGTH AND TOUGHNESS

Strength: To keep eyeglass lenses in perfect condition for as long as possible, you need to focus on lens strength. The word strength, as used here, refers to overall resistance against deformation and breakage and encompasses a wide range of distinct properties, such as stress resistance to cracking or abrasion resistance. This means understanding the differences between the various lens material properties.

Impact resistance: In the case of plastic lenses, toughness differs among various plastic materials. Medium RI lenses and acrylic lenses have relatively low toughness and break (Fig. 6).

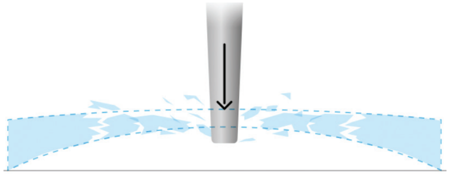

FIG. 6

In contrast, thiourethane MR™ materials not only offer high impact resistance but high toughness as well. The material is more likely to deform (bend) without breaking when force is applied rather than cracking or chipping (Fig. 7).

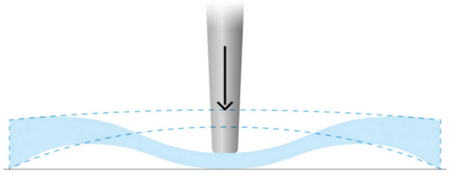

FIG. 7

Stress resistance: To measure stress resistance to cracking, you need to understand the property called toughness in addition to the simple strength of an object. Toughness refers to resistance against breaking when exposed to shock or pressure. We can also refer to the tenacity of a material. For example, while porcelain and glass have a specific strength and resist deformation, neither is especially tough and both tend to crack or chip.

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Go to Mitsui Chemicals' YouTube channel at https://youtu.be/SyuNG2qfj2c?t=1 to see a video of a pinpoint load applied to an acrylic lens versus MR™ lens. The acrylic lens shatters, sending tiny fragments flying around but MR™ lens bends and presses against the floor, but it doesn't break. The MR™ lens offers excellent toughness and impact resistance, making it less likely to shatter. As a result, it's a safer and more durable lens.

Tensile strength—pulling force: Rimless eyewear needs and especially heat resistance for tinting presented a challenge met with MR-10™ in 1998 (Index 1.67, Density 1.37gm/cc3, Abbe 31). MR-10™ improved the properties of MR-7™ by delivering a higher transition point for heat distortion (less heat-sensitive tinting). In addition, MR™ materials had improved density for drilled rimless (Fig. 8). As a result, MR-10™ materials, when drilled, produce a clean drill hole that will not distort when worn and resists breakage. Anecdotally, MR-10™ is known for surfacing efficiency, tinting, increased hard coat options and is easier to cast with a polarizing film.

FIG. 8

Scratch resistance: Scratches reduce toughness, but better coating adhesion equals more resistance to scratches and cracking. Even if a lens resists cracking, it will not be ideal for long-term use if it is not scratch-resistant. The thiourethane material can achieve better hard coating adhesion results, enhancing resistance to cracking even when the lens is scraped against a surface.

SDC Technologies Inc. has been part of the lab and lens caster supply chain for over 30 years providing material and processing inventions and tips. Acquired by Mitsui Chemicals in 2008, SDC continues to provide premium, high-quality thermal and UV-cure hard coatings to improve lenses' scratch and abrasion resistance under the CrystalCoat™ brand. Remember, improving the durability of the hard coat has three main effects.

First, lens scratch and abrasion resistance are improved. Second, a harder substrate improves any subsequent AR coating. That means that the anti-reflective layer's ultimate scratch and abrasion resistance becomes as hard or harder than the underlayer. Last, all this produces a lens that better exceeds the expectations and value assessment of the wearers and the ECP. Hard coating is applied in two layers. The first layer is a primer that is very sticky to the high-index surface and very sticky to the next hard coating layer. Thus, the hard coating layer can be cured to a harder, more scratch and abrasion-resistant surface. In some manufacturers' lenses, this allows an AR lens that is as abrasion resistant as glass. Next, the primer layer is an impact-enhancing coating layer. That means that upon impact, the primer layer will help manage a crack that may be propagating through the lens by diverting through the coating horizontally rather than vertically and slowing it to a stop.

WHY INDEX MATCHING?

When talking about high-index, it's essential to describe the evolution of scratch and AR coatings. Most hard coats' index of refraction closely matches standard plastic (hard resin, 1.50). If there is a mismatch

between the hard coat's refractive index and lens refractive index, the result is interference fringe.

The interference fringe appears as a rainbow pattern on the lens surface (Fig. 9). If the coating and lens have the same refractive index, the light passing through "sees" the two as one continuous substrate, and the reflections at the interface are minimized. For this reason, premium high refractive index lenses are matched with higher index coatings. The result is lenses without a reflective color pattern.

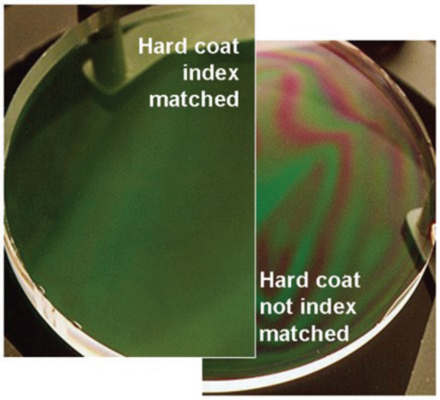

FIG. 9

Often optometry and optician online forums have posts speculating that this interference fringe is a problem with the Abbe of the material. Not so—it's a lens refractive index mismatch with the coating refractive index.

MATERIAL BASICS: SPECIFIC GRAVITY (DENSITY/WEIGHT)

Specific gravity describes the density of a lens material by comparing its density to the density of water. The higher the specific gravity of lens material, the higher the density and consequently, the higher the weight.

ABOUT MITSUI CHEMICALS

Mitsui Chemicals is the world's majority producer of high-index lens monomers for the lens casters that your lab uses regularly. Finished lenses and semi-finished lens blanks are made from the MR™ Series of

	MR™ series				Others				
	MR-8™	MR-7™	MR-10™	MR-174™	Poly-carbonate	Acrylic (R.I. 1.60)	Middle Index	ADC (CR-39© RAV7©)	Crown Glass
Refractive Index (ne)	1.60	1.67	1.67	1.74	1.59	1.60	1.55	1.50	1.52
Abbe Number (ve)	41	31	31	32	28 - 30	32	34 - 36	58	59
Heat Distortion Temp. (℃)	118	85	100	78	142 - 148	88 - 89	-	84	> 450
Tintability	Good	Excellent	Good	OK	None	Good	Good	Good	None
Impact Resistance	Good	Good	Good	OK	Good	OK	OK	OK	Poor
Static Load Resistance	Good	Good	Good	OK	Good	Poor	Poor	Good	Good

FIG. 10 Comparison of physical properties of lenses made with MR™ Series vs. other optical materials. CR-39 is a trademark of PPG Industries, Inc. RAV7 is a trademark of ACOMON AG. All properties are representative measurement figures obtained under specified test methods at Mitsui Chemicals, Inc. and are not guaranteed as specifications.

lens materials manufactured by Mitsui Chemicals in Japan. Each lens caster sources the monomer components to produce a portfolio of 1.60, 1.67 and 1.74 high-index lenses. Take a look at the contemporary material choices you make every day, listed in Fig. 10.

MR-8™ Plus is a new and more impact-resistant version of Mitsui Chemical MR-8™ 1.60 monomer that, when combined with SDC primer and hard coats, will pass ANSI Z87.1 safety impact testing. MR-8™ Plus has the same attributes as MR-8™, such as a high Abbe value and good tensile strength, but tints quicker than MR-8™.

The change from glass lenses to lighter and more impact resistant materials (Fig. 11): In the 1940s, we saw the evolution from glass to the plastic spectacle with the invention of the CR-39® monomer, a material initially invented as a liner for B-17 bomber fuel tanks. In 1972, an impact resistance standard became a federal requirement as FDA 21CFR801.410(c)(3). U.S. opticians were required (as you are today) to dispense only lenses that pass a drop ball test (or can be shown by sampling to pass). Plastic lenses were advantageous since they didn't require a surface chemical treatment or heat tempering like glass to improve impact strength. In addition, they were half the weight of glass lenses. Add the opportunity to make larger, lighter lenses, allowing frame manufacturers to create and offer larger frames. Plastic lens sales took off, replacing glass as the preferred and recommended lens material in eyeglasses. However, early ophthalmic lens plastic materials had challenges. While lighter, they were also thicker than their glass counterparts due to their lower refractive index. The good news is that the innovative optical

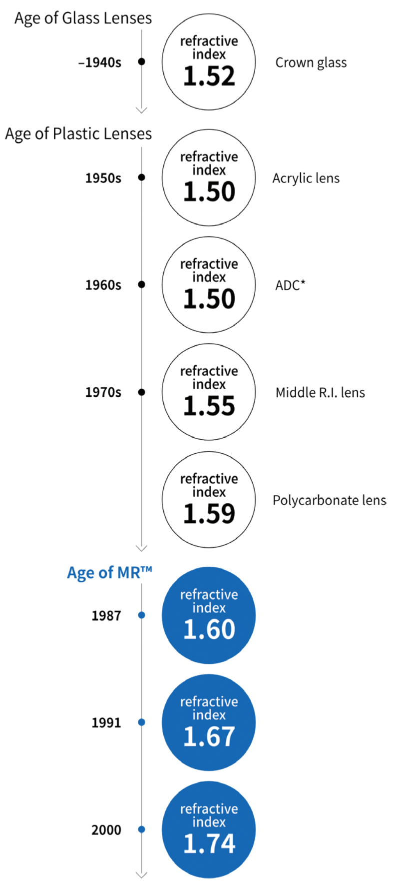

FIG. 11 Timeline of eyeglass lenses and refractive index

engineers, scientists and chemists from Mitsui Chemicals made plastic lenses better, improving thickness, optics and durability.

HIGH REFRACTIVE INDEX FOR THINNER AND LIGHTER LENSES

The MR™ Series optical lens material (Fig. 12) is suitable for use in the development of lightweight lenses. The MR™ Series offers three different refractive indices 1.60, 1.67, and 1.74. With the inclusion of this high refractive index material, it is possible to achieve thinner lenses with the same strength as thicker lenses.

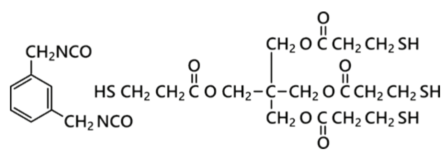

FIG. 12 Chemical structure of MR-6™: The innovative molecular structure of MR™ realized by thiourethane pioneered a new era in eyeglass lens

PROPERTIES OF MR™

Thin and light: Lenses generally become thicker and heavier as optical power increases. But with the development of high-index lens materials, it's now possible to make thinner, lighter lenses. So now, even high-power lenses can be made thin and comfortable to wear.

Safe and resistant to breakage: The toughness of thiourethane resin makes it possible to build thin eyeglass lenses with high impact resistance. In addition, thiourethane lenses resist breaking and chipping, even for drill mount or rimless glasses, making them safer to wear and use. Thiourethane lenses also exhibit superior workability, which means they can be formed into virtually any design.

Durability: Thiourethane lenses feature high wear resistance and resist discoloring over time. They also allow stronger adhesion of the coating material to the lens surface. As a result, the coatings are more resistant to peeling, even after extended use.

Clarity: Due to molecular design, MR™ achieves high Abbe with low chromatic aberration while being highly flexible.

The Abbe or ve number is a value associated with chromatic aberration (Fig. 13).

$$\nu = \frac{n_D - 1}{n_F - n_C}$$

FIG. 13

WITNESS THE STRENGTH OF MR™ LENSES

To witness the strength of MR™ lenses, go to Mitsui Chemicals' YouTube channel to see a video that compares an MR™ lens made of thiourethane with an acrylic lens. They look nearly identical; you wouldn't be able to tell them apart. But the two lenses are made of totally different materials and have significant differences in their physical properties. See the different effects when a metal ball is dropped on a lens made from MR™ material versus an acrylic lens: https://www.youtube.com/watch?v=SyuNG2qfj2c&t=1s

MECHANICAL STRENGTH

1. MR™ Series' good mechanical strength and stress-free properties make it suitable for unique lens designs such as "Rimless frame" or "High curve lens."
2. Good tensile strength.
3. Good processability for precisely designed progressive lenses (advantage of thiourethane materials).

Select the optimal MR™ material for your patient's individual needs.

MR-8™ Refractive Index 1.60: This is the standard lens high refractive index material. The exceptionally high Abbe number means minimal chromatic aberration for improved peripheral vision in the lens. The material is an ideal balance of properties such as impact resistance and thermal resistance. Abbe Number νe=41/ Heat Distortion Temp. 118 degrees C. The refractive index 1.60 MR™ works for a wide range of designs and purposes and optical powers.

MR-7™/MR-10™ Refractive Index 1.67: The 1.67 MR™ lens material features a balance of lens thinness, lightness and high impact resistance. MR-7™ offers good tintability. MR-10™ offers superb thermal resistance. MR-7™Abbe Number νe=31 / Heat Distortion Temp. 85 degrees C/. MR-10™Abbe Number ve=31/Heat distortion Temp 100 degrees C. The 1.67 MR™ lens material appeals to wearers uncomfortable with thick, heavy high-powered lenses. The MR-7™, with its good tintability, is ideal for sunglasses and fashion-oriented glasses. Furthermore, the best heat-resistant MR-10™ lens offers added safety for use under challenging temperature conditions.

MR-174™ Refractive Index 1.74: This lens material makes it possible to produce an ultra-thin lens with the highest refractive index. Additionally, this Do Green™ MR-174™ product is made using plant-derived materials. Abbe Number νe=32/ Heat Distortion Temp. 78 degrees C. The refractive index - 1.74 MR™ appeals to patients looking for the ultimate in thinness in a lens of the highest possible quality. The 1.74 MR™ material is ideal for the eco-conscious, who actively seek out eco-friendly products like 1.74 MR™ lenses (Fig. 14).

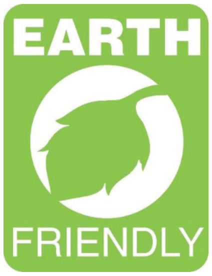

FIG. 14

All properties are representative measurement figures obtained under specified test methods at Mitsui Chemicals, Inc. and not guaranteed as specifications.

Available in specialty function lenses: MR™ is manufactured from a unique monomer polymerization process that makes it possible to add functions like control of specific wavelengths or photochro-

mic properties by blending special dyes. MR™ material is highly compatible with coating materials and film; it also makes it easier to manufacture highly functional polarized lenses.

MR™-based functional lens materials: For optical health, UV+420cut™ and Photochromic lenses, SunSensors™ and CrystalChrome™. For an enhanced view with vivid color and contrast, Neocontrast™.

Available in advanced photochromic solutions: SDC Technologies' (a wholly owned subsidiary of Mitsui Chemicals, Inc.) CrystalChrome™ products are best-in-class thermally cured dip coatings with photochromic technology designed for ophthalmic applications. CrystalChrome™ products (Fig. 15) are the newest high-tech photochromic coating solutions on the market. They feature fast activation and fade-back speeds combined with durability and an extended lifespan of photochromic performance without lens fatigue.

CrystalChrome™

FIG. 15

In addition, they come with abrasion resistance, chemical resistance and exceptional optical clarity. CrystalChrome™ technology is compatible with anti-reflective and metalizing coatings with availability in all substrates: Plastic, PC, MR-8™ (1.60 indexes), MR-7™/MR-10™ (1.67 indexes), MR-174™ and Trivex™. CrystalChrome™ products allow customers a high degree of control over production and photochromic performance; this, combined with the enhanced stability and durability, makes them ideal for customers seeking best-in-class photochromic performance.

SunSensors™ lens materials: Mitsui Chemicals acquired SunSensors™, photochromic lens materials with a refractive index of 1.55, an acrylic-based material from Corning Incorporated, USA, in May 2014. Later in 2017, Mitsui Chemicals expanded SunSensors™

SunSensors™ by Mitsui Chemicals

FIG. 16

(Fig. 16) product lineup based on MR™ series in the 1.51 index, a material modified from conventional 1.50 material such as ADC, and 1.55 SunSensors™ refractive index.

NeoContrast™: NeoContrast™ technology utilizes a specific wavelength filter to improve contrast sensitivity (Fig. 17). NeoContrast™ lenses provide better glare management, high color contrast and sharp vision by reducing

FIG. 17

the transmission of wavelengths centered at 585 nm. In addition, NeoContrast™ can be combined with UV+420cut™ or SunSensors™ for their combined benefits. NeoContrast™ specialty filters can improve contrast sensitivity, whether in the shade or for sports, leisure and entertainment, using a video display while reading or gaming. NeoContrast™ lenses improve contrast sensitivity, making reading and gaming while staring at a video display sharper and colors more vivid.

Every pair of clear lenses needs built-in 100 percent UV+420cut ™protection.

UV+420cut™: 80 to 90 percent of the UV rays get through on days with light clouds versus clear days. That number is around 60 percent on cloudy days and 30 percent on rainy days. And children's eyes have less built-in protection against UV transmitting through their cornea and lens back to their young retinas.

UV damage is cumulative and irreversible, so protection must start early in life (Fig. 18). UV+420cut™ technology with MR™ Series creates a lens to filter beyond UV radiation into high-energy visible (HEV) blue light radiation. The UV and HEV blue light filters are inherent in the lens material.

Eyeglass lenses need to provide the best clarity, safety, durability and aesthetics. The industry has long sought an innovative material that offers these properties in a balanced way. MR™ lens materials are made from thiourethane resin of which chemicals/materials were developed by Mitsui Chemicals to meet the requirements of modern ophthalmic lenses. Thiourethane comprises lens properties not available from other materials. That is why it has been eagerly adopted by lens casters around the world. When ordering lens materials, look for the MR™ trademark printed on the lens package or envelope, and when ordering, check with your supplier to confirm you're getting MR™ lenses. ■

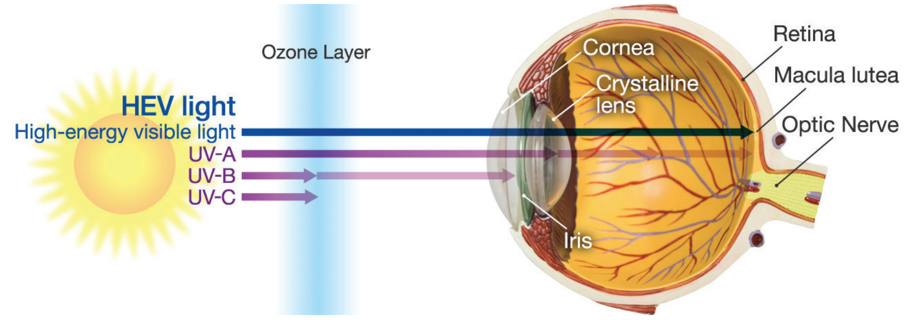

FIG. 18

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