PRO TO PRO CONTINUING EDUCATION

THE MYSTERY, THE MAGIC AND THE SCIENCE BEHIND THE OPHTHALMIC LENS BLANK

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[1 CE CREDIT]

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LEARNING OBJECTIVES:

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

1. Learn about the development of ophthalmic lens monomers.
2. Learn about lens casting.
3. See how a lens monomer becomes a finished or semi-finished lens blank.
4. Learn how to communicate the performance benefits of ophthalmic lens materials to the patient.

TO EARN CONTINUING EDUCATION CREDIT:

This course has been approved for one (1) hour of Technical Level II continuing education credit by the ABO. To earn ABO credit, please review the questions and take the test at 2020mag.com/ce. Note: As of January 2020, no tests will be graded manually. Please call (800) 825-4696 for more information.

This course is about understanding and communicating lens performance benefits to the patient.

ECPs generally know the benefits of various materials and how they apply to a particular patient's Rx. Yet, we know little about the material science or engineering of ophthalmic lens monomers or lens casting in the production of finished or semi-finished lens blanks used in the making of eyeglasses. Most of us possess a natural curiosity to learn about the making of things, such as ophthalmic lenses. I admit to knowing little about the development of what PPG chemists humorously refer to as the "magic goop." They use this term to describe the chemical solution that is the base of the lens monomer or coating formulary used in casting and coating of ophthalmic lenses. After a tour of the R&D facility of PPG, I was both overwhelmed and impressed by the amount of research and development required to produce the magic goop as was I impressed by the casting process for lenses.

In this course, you will gain a new appreciation for the ophthalmic lens, both semi-finished and finished, and the chemistry of ophthalmic lens monomers and coating formularies required for casting and coating. The next time you hold a PPG TRIVEX® material or PPG CR-39® material or the new PPG TRIBRID® material, lens blank, take a moment to be amazed at the planning, the R&D, the casting, the coating, and the marketing it takes to get that FDA Class 1 Medical Device into your hands and ultimately in a frame on the patient's face. As the patient's trusted ECP, your new appreciation and enthusiasm will transfer to the patient, raising their appreciation for the small but essential accessory that corrects their vision.

Chemistry is the study of matter, its properties, how and why substances combine or separate to form other substances, and how substances interact with energy. Everything in our physical world is made up of matter, including our bodies (biochemistry). Chemistry is one of the physical sciences that help us to describe and explain our world. Chemical elements influence lens properties, i.e., sulfur influences the index of refraction and hence thinness of a lens.

OPTICAL MATERIAL EXPERTS

We are all familiar with the revolutionary PPG CR-39 lens monomer developed by PPG Industries back in 1945. It was the first plastic resin to be used in the manufacture of ophthalmic lenses and continues to be a leading lens substrate worldwide. Before CR-39, lenses were made of glass, and while optically excellent, have many drawbacks, including weight and safety issues due to its tendency to shatter into pieces upon impact and lack of UV protection. With more than 70 years of experience engineering and producing optical monomers and coatings, PPG Industries is a leading producer of optical grade monomers used in the manufacture of ophthalmic lenses. PPG's line of optical monomers and coatings products includes CR-39 monomer and Trivex lens material, and the new Tribrid lens material. Trivex lens material provides the unique combination of optical quality (due to a high Abbe value) with lightweight comfort, strength, durability and high impact resistance for protection along with 100 percent UV protection. The newest member of the PPG lens monomer family is the Tribrid brand that combines the properties of Trivex with that of Hi-index. PPG's HI-GARD® lens coating solution provides a durable, scratch-resistant coating on ophthalmic lenses made from plastic materials. With Hi-Gard coating, plastic lenses are four to six times more abrasion resistant than uncoated lenses, while maintaining the optical quality.

THE MAGIC GOOP

Most ECPs have never been exposed to the material science, chemistry and multilayered processes that go into bringing a new monomer or coating (the magic goop) to market. The market for this ophthalmic lens "secret sauce"

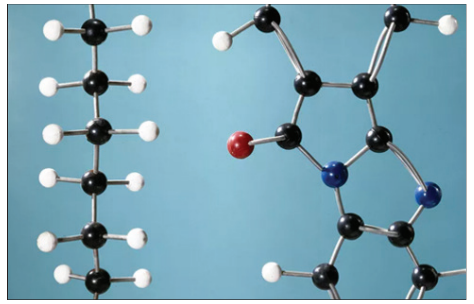


FIG. 1 Monomer definition: A monomer is a type of molecule that has the ability to chemically bond with other molecules in a long chain; a polymer is a chain of an unspecified number of monomers. Essentially, monomers are the building blocks of polymers, which are more complex type of molecules. Monomers—repeating molecular units—are connected into polymers by covalent bonds. (Anne Marie Helmenstine, Ph.D.)

is the lens casters. Can you think of a few? (ZEISS, Hoya, Essilor, Younger, Shamir, Signet Armorlite) The numerous stages, multilayered processes and exhaustive testing and time that goes into the research and development of monomers for lens materials and coatings will be discussed in this course. Note: Lens material formularies are proprietary and as such, are carefully guarded secrets.

There are many lens material formulas, but we will use Trivex to follow the journey of the ophthalmic lens blank from magic goop to the finished lens.

TRIVEX: THE SCIENCE, THE CHEMISTRY

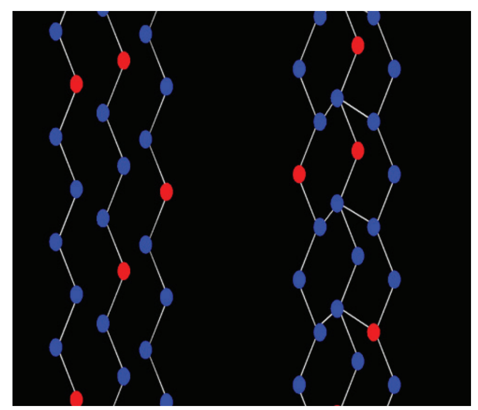
Originally developed as helicopter windshields and fighter jet canopies for the military, Trivex is an advanced polymer technology with extreme impact resistance, optical purity, and it's ultra-lightweight. In development for more than a decade by the U.S. military, the technology was subjected to rigorous ballistic and extreme performance testing. Trivex material is a unique category of lens material made possible only through complex chemistry and advanced production methods. Trivex material is a urethane-based pre-polymer that PPG developed and refined for use as an ophthalmic lens material.

Trivex is a unique lens material with an entirely new molecular structure built on polyurethane chemistry, similar to many optical lens materials. But PPG chemists found a way to enhance the base polyurethane molecule by enriching it with additional nitrogen. The result is a lens material that is not only optically superior but also exceptionally strong and ultra-lightweight.

- In **thermoplastics, the chains are independent** of each other and can flow freely to be reformed.
- **In thermosets, "cross-links"** are created during polymerization resulting in a complex, interconnected and permanent network.

Trivex lens material is the first optical lens material to combine the best of thermoplastics and thermosets into one unique material.

Lenses made from Trivex material are cast in molds using a special machine and thermally cured. The tri-performance properties of the material provide for crisp and clear, strong,

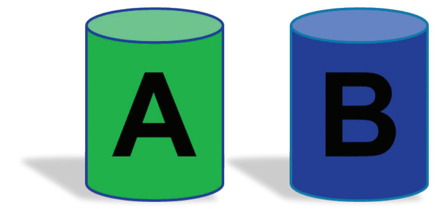


and safe, light and thin lenses when compared to other materials currently available. Trivex material's unique properties make it an ideal lens material perfect for over 80 percent of prescription eyeglasses sold in the U.S.

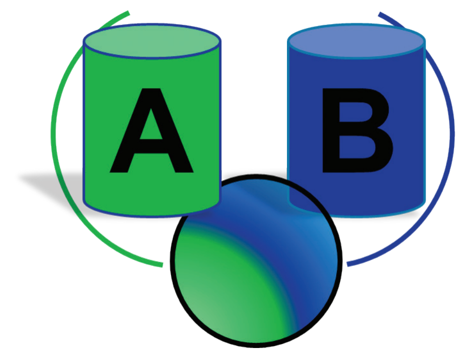
Before the lens material formula is brought to market, Research and Development go through a rigorous process consisting of: 1. Planning—determine requirements (quality and performance goals set). 2. Research and testing. 3. Protocols established. 4. Development stages, and 5. Implementation.

LENS CASTING

Once the formulary is ready for the casting of the lens blank, there are many steps involved, the first of which is to deliver the magic goop to the casters to form the lens blank. The lens manufacturers/casters receive the formulary and very specific processing instructions and protocols to follow. Let's see the steps involved in casting Trivex.



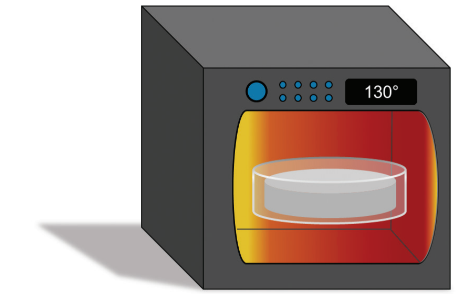
Trivex requires a unique casting technology: The casting of Trivex starts with two components, and each component must be handled carefully. They cannot be exposed to air from the moment they are created to the moment they are mixed together.



Mixing: A specially designed machine mixes the components at a precise ratio and temperature. Any variation in these parameters results in a poor quality lens. The chemical reaction of the two components is virtually instantaneous.

Mold filling: The material is then injected into a glass mold. The design of the mold determines the format of the lens—semi-finished or finished, single vision or progressive front, spherical or aspheric, etc.

Heat curing: The molds are thermally cured in an oven for approximately 7 to 10 hours using a specified heat cycle ranging from 85 degrees Celsius to 130 degrees Celsius. During



this step, the chemical reaction is driven to completion.

De-molding: The lenses are removed from the molds and pass through an inspection process. Afterward, the lenses are packaged and delivered to optical laboratories and eyecare professionals around the world.

In the case of Trivex material, the unique chemical formulary and casting process result in a unique lens material that has the best overall performance rating for key lens performance parameters. Here is a review of the technical features of Trivex material as measured by recognized industry standards for optical materials.

KEY LENS PERFORMANCE FACTORS

Optical Performance—Abbe Value (lens clarity): Trivex minimizes the dispersion of white light entering the lens into its rainbow of colors. The high Abbe value of Trivex material at 45 accounts for this reduction in chromatic (color) aberration in a lens.

FIG. 2 Trivex material has a very high Abbe value of 45. The higher the Abbe value, the less the chromatic aberration as illustrated here.

Visible Light Transmission (lens clarity): As light travels through a lens, a percentage is lost through absorption and reflection at each air-to-surface interface. The term used to describe this percentage of light that is not lost is visible light transmittance (VLT), and Trivex lens material has one of the highest VLT levels of all commonly used lens materials (without AR) at 91.4 percent. The higher the VLT, the sharper and clearer the optical experience for the patient. The percentage of light-transmitting through the lens to the eye is influenced by the quality of the lens material and lens type; more is better. After all, we need light to see, and we need clear lenses to see. And of course, if an anti-reflection coating is applied to the lens, surface reflections are further reduced to nominal amounts, and VLT is increased. VLT is an important factor that directly affects the actual brightness of an observed image.

WEIGHT AND THINNESS FACTORS

Specific Gravity (weight, comfort): The Specific Gravity number compares the relative density of an object to an equal volume of water. Anything with a specific gravity less than 1.0

will float. A lower Specific Gravity number equates to lighter weight and therefore, a more comfortable lens. The lower the value, the less dense (and subsequently lighter) the material is. The Specific Gravity of Trivex material is 1.11. This value makes it the lightest of all commonly utilized ophthalmic lens materials currently available. Compared to the density of CR-39 monomer (1.32), Trivex material is 16 percent lighter; compared to polycarbonate, it is 8 percent lighter and nearly 25 percent lighter than ultra-high index (1.66

and 1.74) materials. When aspheric curvatures are used on lenses, even more thickness and weight reduction can be achieved.

Refractive index (thinness and cosmetics): Trivex lens material has a 1.53 index of refraction. This mid-index value enables lenses made from Trivex material to be thinner, lighter and more comfortable. For example, when compared to lenses made with CR-39 monomer (with an index of 1.50) of the same power and diameter, lenses made from Trivex material are up to 50 percent thinner and 50 percent lighter, resulting in improved comfort for the wearer. Due to the strength of the Trivex material, it can also be surfaced to a 1.0 mm thickness, further reducing the weight and thickness. The higher the index of refraction of a lens material means that light will bend (refract) more upon entering and exiting the lens. Therefore, thinner lenses can produce the same refractive power as thicker lower index lenses.

PROTECTION FEATURES

Impact resistance: Lenses made from Trivex material are tough enough to pass the most rigorous optical industry standard for eyewear: The ANSI Z87.1 High-Velocity Impact Test is the test required for safety lenses that have center thicknesses as thin as 2.0 mm. In this test, the lens is mounted in a holder and is able to withstand an impact from a 1/4 inch steel pellet traveling at a velocity of 150 feet per second. In 1972, when the majority of spectacle lenses were made from glass, the U.S. Food and Drug Administration (FDA) required that all lenses must be impact resistant. Their regulation requires that all lenses must be capable of withstanding the impact of a 5/8 inch steel ball dropped from the height of 50 inches onto the horizontal upper surface of the lens. Lenses made from Trivex material can not only pass the FDA impact resistance test at the usual 2.0 mm center thickness, but they can also pass it at a 1.0 mm center thickness and are even stronger than the FDA requirement.

Ultra-violet absorption: The eyes and lids are susceptible to UV damage. Just as our skin needs sunscreen for UV protection, so do lenses need UV protection built into the monomer, to protect our eyes and lids. Ultraviolet radiation can have damaging short-term and long-term effects on both the anterior and posterior eye, including the retina. The wavelengths that pose these problems fall below 400 nanometers and the visible spectrum. Trivex lens material filters out the harmful UV-A and UV-B wavelengths naturally, thereby providing 100 percent UV blockage up to 394 nm, which exceeds the ANSI/ISO standard of 380 nm. For this reason, it is not necessary to add UV dye to the lens monomer when made from Trivex material to obtain this level of UV protection—the lenses inherently absorb harmful UV wavelengths.

CHEMICAL RESISTANCE

Lenses made from Trivex, polycarbonate and CR-39 materials were tested according to the ISO 1752 test method for chemical resistance. Each lens was immersed in separate containers of various chemicals commonly used in lens laboratories such as acetone (featured in this section) for 10 days. The test measures the changes in weight and diameter of the lenses after soaking and allows for visual inspection to assess any changes in clarity. The lenses made from Trivex and CR-39 did not register a difference in weight, diameter or clarity. The polycarbonate lenses turned white after soaked in acetone, as illustrated in Fig. 3.

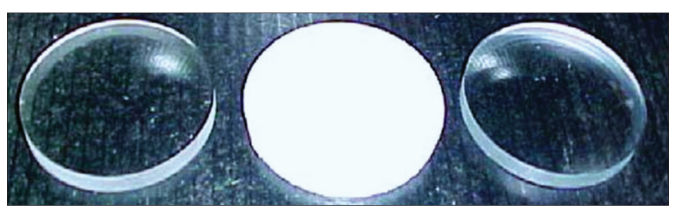


FIG. 3 Lenses immersed in acetone for 10 days (PPG in-house test followed ISO 175)

AFTER CASTING

After the lens blank is formed (cast) by the lens manufacturer, it is sent to the lab for surfacing of the Rx onto the back surface (exceptions are dual surface digital lens designs).

SURFACING

Once at the lab, the lens goes through a time-consuming series of steps:

- Lab order generated that indicates design selection for the Lens Design Software (LDS), which calculates the lens surface and creates a data points file to instruct the CNC machine cutting the lens surface.
- A tray assigned for the job with a trackable bar code.
- Lens blanks are picked and added to the tray.
- Protective tape or spray added to the lens.
- A secure holding block is attached to the lens (decentered for PD and on-axis).
- Surface design cut (prescription, lens design).
- Buff or polish
- Hard coat
- AR Coat
- Inspect

COATINGS

We have not discussed the complexity of developing and formulating coatings, both hard coat and anti-reflective coating layers, but like lens material formularies, coatings require extensive research and development time, and these formulas are closely guarded secrets.

To appreciate all that goes into the lens before it sits in a frame on the patient's face, here are some key things to know about the coating process.

Hard coats: All quality lenses should have a premium AR coat. AR coatings require a quality index-matched base or hard coat. A quality hard coat allows the lens and the AR to bond better, and hard coats increase lens durability and scratch resistance. Hard coats can be applied either as a dip coat or a spin coat, depending on the formula.

AR stack: Anti-reflective stacks consist of layers that interfere with reflections from the lens surface. The reflections of particular wavelengths are canceled. Their energy is added to the visible light (VLT) transmission of the lens. As discussed earlier, a high VLT is essential to lens clarity. AR coatings not only minimize lens surface and internal reflections, but premium coatings have oleophobic, hydrophobic and anti-static layers that make lenses easier to clean and keep clean. Dirty, smudged lenses are not clear and negatively affect the patient's visual experience. Easy cleanability is a benefit that patients love.

EDGING

Note: If the lab is finishing in addition to surfacing, then the frame has been traced, and with the new digital edgers, lenses are automatically blocked for axis and decentration required. The lens is marked R for right or L for left and then lined up and marked at the decentered PD measurement and on-axis in the lensmeter. Next, it's lined up in the edger, with all parameters entered, the lens blocked (decentered to PD and on-axis), next the frame is traced, and then the blocked lens is inserted into the chuck of the edger. The edger removes the excess material from the lens blank following the pattern of the frame eyewire shape traced. The finish edged lens is inserted into the frame, and the last step is to clean and do a final inspect.

Now that you appreciate the research, science, technology and time needed to bring the ophthalmic lens blank from magic goop to finished lens, let's talk about the patient: What do they care about?

BENEFITS, BENEFITS, BENEFITS = WIFY

Making the best recommendation begins with a conversation with your patients. Understanding their prescription and lifestyle needs allows you to build eyewear that improves their visual experience in all of their activities and tasks.

As their trusted ECP, can you fulfill the needs and wants of any patient with just one pair? The answer is a resounding NO! I understand that everyone is telling you to SELL multiple pairs. Pause; take a breath because I am NOT asking you to SELL more! I want you to present the patient with their best eyewear options that best meet all of their vision needs. When you do this, the patient will always require more than one pair. So present how each pair will help them see, look and feel better, then sit back and let them balance their finances. We buy based on emotion and justify our purchase decision with logic, and that is the crux of benefits versus features. There is no need to tell me how something functions until you tell me how it will make my life better.

> PRESENT THE PATIENT WITH THE BEST EYEWEAR OPTIONS THAT BEST MEET ALL OF THEIR VISION NEEDS.

Apply the benefits test to every visual task. What task-specific lens will provide comfort and the best vision for working at a computer for hours at a time? What lens will work best for their everyday lens, which for their sun protection lens, and well, you see where I am going with this?

Convey the benefits of unique materials, coatings, plus lens enhancing technologies, and explain how they contribute to better lens performance and better vision, comfort and protection for their eyes. Armed with this information, the patient makes an informed decision about their eyeglass lenses. Know the difference between benefits versus features. **Benefits** tell the patients "how" a product will improve their life: See better, feel better, look better, protects investment, protects eyes. On the other hand, **Features** describe "what" it is. For example, a Trivex lens feature is high impact resistance lens material but the benefit is keeping eyes safe from impact injury. High Abbe value: Feature = less chromatic dispersion, Benefit = see better with better peripheral vision and wider fields of view. High index: Feature = thinner, Benefit = better cosmetics and comfort. Specific Gravity: Feature = lighter weight, Benefit = comfort. High VLT: Feature = low reflectivity, Benefit = look better and see better especially when driving at night.

SUMMARY

I hope that this course has helped you appreciate the science and complexity that goes into developing lens monomers and the casting of lens blanks. With this newfound knowledge about the magic goop and lens casting and the coating process, don't overshare with the patient—remember they do not understand optical-speak, and they do not understand chemistry-speak. Please communicate with the patient using simple, non-technical terms that explain how lens and coating features will enhance their visual experience. Use words that convey how the lens will improve and "protect my vision and ultimately improve my life." Only informed patients make informed purchase decisions! Moreover, never underestimate word-of-mouth advertising. Informed patients are highly likely to tell friends and family members about a product when they understand the product performance benefits.

As you hold that finished pair of eyewear in your hand, pause for a moment of appreciation. Consider the years of research and development it took to get the magic goop formulary perfected to produce the monomer that is to be cast into a lens blank. Reflect on the chemistry involved to engineer the best lens performance optically, while instilling lightweight, strong, durable, impact-resistant and 100 UV protection material properties. Ponder how all of this is possible through chemistry and optical engineering. It isn't mysterious or magical; it's science! But isn't science as awe inspiring as magic? ■

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