Eastman Tritan™ Renew VX351HF-50 copolyester

Technical guidance for injection molding eyewear lenses

Sustainable eyewear materials

Sustainability trends in the eyewear industry have been on the rise in recent years. Eastman has developed Tritan™ Renew VX351HF-50 to support sustainable material needs in eyewear market. It is made with 50% certified recycled content,[1] produced with technology that uses waste plastic as a feedstock and breaks it down at the molecular level. There is no compromise on quality and performance. Tritan Renew VX351HF-50 offers identical performance to heritage grade Tritan. Any processes that apply to heritage Tritan, including all processing conditions, mold designs, design options and secondary operations, can be adopted for Tritan Renew.

Scope

Tritan Renew can be used for injection-molded eyeglass lenses, including sun lenses (both polarized and non-polarized) and reader lenses.

Material

Tritan Renew VX351HF-50 exhibits excellent flowability and low internal stress and is the recommended Eastman material for lens applications. If a lens-making process (such as hard coating) requires a material with high temperature performance, Tritan Renew VX401-50 is recommended in the place of Tritan Renew VX351HF-50.

Most of the resins currently used in lens applications can be replaced by Tritan Renew, including polycarbonate (PC), transparent polyamide (tPA) and CR-39. If there are any special material needs, contact an Eastman engineering specialist.

[1]*Via mass balance allocation*

Lens injection process

Proper shot-to-cylinder size

An injection machine with suitable shot-to-cylinder size (30%–70%) is necessary. Improper shot-to-cylinder size can cause undesired molding issues. For example, polymer in the barrel can be easily degraded if small parts (shots) are molded on a very large injection machine (barrel).

Melt residence time

Maximum residence time would be halved with T 10° higher or doubled with T 10° lower (example: TR < 5 min @ 280°C, TR < 10 min @ 270°C). The time in the hot runner should also be included in residence time.

- The calculation of residence time in barrel is: TR (minutes) = (injection stroke/ (injection start – cushion) x (cycle time/60) x 2

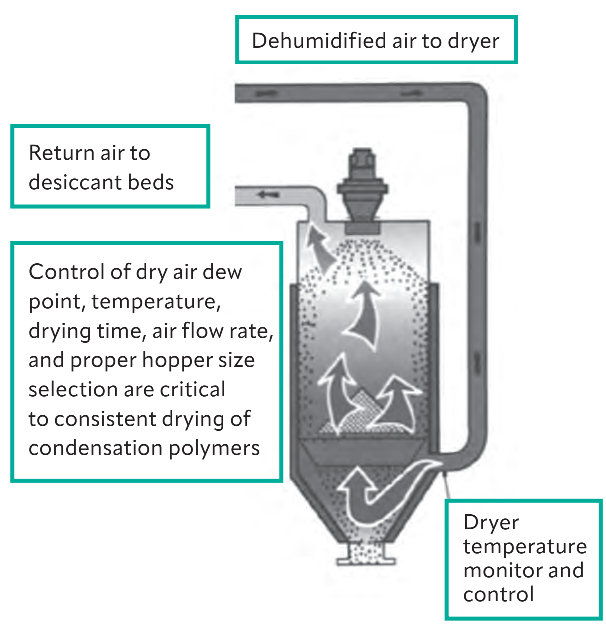
Screw

Recommended screw compression ratio is 2.8~3.2:1 and a length-to-diameter ratio of 18~22:1.

Dryer

A desiccant dryer is recommended to provide a hermetic connection between the dryer and injection machine feeding port by vacuum hose. A desiccant dryer with a hermetically sealed vacuum hose connection between the dryer and injection machine feed port is recommended. Dew point of the dryer should be less than —30°C.

Figure 1. Dryer



Please limit dried resin's exposure to the outside environment. This can reduce the possibility of moisture reabsorption and also avoid the risk of contamination.

See Table 1 for recommended drying conditions for Tritan Renew.

Table 1. Drying conditions for Tritan Renew copolyesters

Drying temp	88°C
Drying time	4–6 hours
Dryer dew point	< –30°C

A pellet moisture content below 0.03% (300 ppm) or 0.015% (150 ppm) is required.

Mold temperature

Mold temperature could be adjusted in the range of 38°–66°C. A high mold temperature (60°C or higher) is preferred for eyeglass lens processing; however, be aware that higher mold temperatures may cause additional surface shrinkage or distortion.

Pellet moisture

Tritan Renew resin should be dried to 0.03% (300 ppm) or lower as measured by Karl Fischer titration or an equivalent calibrated weight-loss method.

Barrel purging

- It is recommended to purge the barrel with Tritan (Renew or heritage) pellets.
- PC also can be used as purging material before Tritan Renew processing. However, take note of possible BPA contamination.
- PE, PP, PS and PMMA should be avoided as they can mix with Tritan and result in extended purging times.
- If a processing interruption or disturbance of more than five minutes occurs, purging approximately five shots is recommended.

Melt temperature

- For Tritan Renew, normal processing temperatures are in the range of 260°–280°C. Higher injection temperatures can be used to produce lenses with low internal stress. In this case, the melt temperature should be slightly higher than 280°C, but residence time should be kept as short as possible.
- Melt temperature can be measured by air shots or in the nozzle. Ensure proper back pressure settings are used and care is taken when using an air-shot technique.
- Calculate residence time, and adjust the temperature settings to avoid material degradation.

Regrind

Regrind is not recommended for lens applications. Using reground material in the molding process will introduce contamination and negatively impact optical quality in the lenses.

IV retention

- Molecular weight (IV) affects many polymer properties, including tensile properties, impact properties, creep and chemical resistance.
- When properly processed, Tritan Renew will show minimal IV loss.
- Eastman can support customers in IV loss analysis.

Table 2. Typical processing conditions for Tritan Renew

General guidelines	Difference in final and initial IV	VX351HF-50
Nominal pellet IV*	0.00	Typically 0.63
Proper processing	< 0.05	> 0.58
Poor drying/processing	0.05–0.08	0.55–0.58
Unacceptable	> 0.08	< 0.55

** A slight decrease in IV generally indicates good processing. High IV loss indicates improper drying, high melt temperature and/or excessive residence time. High IV loss can lead to part failure.*

Shutdown procedure

In general, material feed can be stopped and injection molding can continue until screw and barrel are empty. When switching to another material, purge with material of interest or commercial purge compound and run the screw empty before powering down the equipment.

When stopping production with Tritan Renew for some time (provided that production will resume with Tritan Renew):

- Run the barrel empty.
- Move the screw forward.
- Shut down the barrel heater.
- Reset barrel temperature to nominal.
- Purge with dried Tritan Renew or Tritan resin until clean material exits from the nozzle.

- To avoid chemical or aesthetic contamination, do not use other polymers.

When purging Tritan Renew in preparation for production with other polymers:

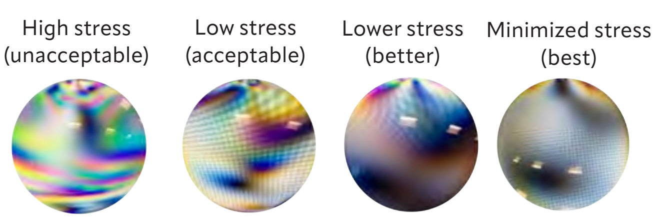
- Run barrel empty.
- Purge machine with appropriate purge compound using ~260°C barrel setting temperature.
- Move screw forward.
- Change to the targeted polymer.
- Purge as usual using the new polymer temperature settings (low range).
- Run production.

Lens internal stress

It's critical to minimize residual stress in Tritan Renew lenses. Techniques that can be used to achieve low internal stress include:

- Melt temperature higher than normal; to improve flowability, > 280°C is suggested for lens molding.
- Use a profile injection setting, reducing the last two injection speeds. Lower speeds are better, but be aware of record grooves in the surface of the molded lenses. As injection speeds get too high, the rainbow effect (internal stress) becomes very obvious under polarized light.
- Holding pressure and holding time are critical to controlling residual stress and the rainbow effect; lower/shorter is recommended.
- A small V/P switchover is better, and a short cushion (4–6 mm) is better. It is suggested to use position for the V/P switchover instead of time. If time must be used, ensure the injection pressure is lower (> 600 bar is suggested).
- It is recommended to have separate cooling for each cavity to have a balanced mold temperature. A higher mold temperature (> 60°C) is preferred for quality lenses, but be aware of surface shrinkage caused by higher temperatures.
- Lens thickness can play a role in residual stress as well.

Figure 2. Residual stress comparison



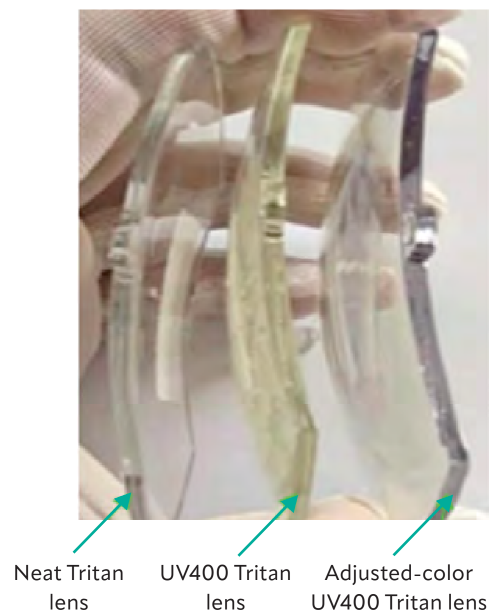
Functional additives

For small-scale lens production, pigments, UV blockers and other additives are hand mixed (bag blended) into dry Tritan Renew pellets prior to injection molding.

- UV 400 additives are generally added at a loading of 0.5–1.0 wt%. Most commercial UV-block additives work in Tritan Renew lenses.
- Depending on desired aesthetics and tint needs, color pigments are generally added at a loading of 1.0–3.0 wt%.
- If the application requires blue-light blocking functionality, those additives are introduced during the bag-blending step.
- For large-scale lens production, mixing machines are used between drying steps and injection molding.

The addition of UV additives in lens resins causes a yellowing effect. It is recommended to add appropriate toners and/or colorants to offset yellowness. Figure 3 shows neat Tritan Renew lens (left), the effect of UV 400 additives (middle), and the toner-adjusted lens (right).

Figure 3. Neat Tritan lens vs. UV400 Tritan lens vs. adjusted-color UV400 lens



Product designs

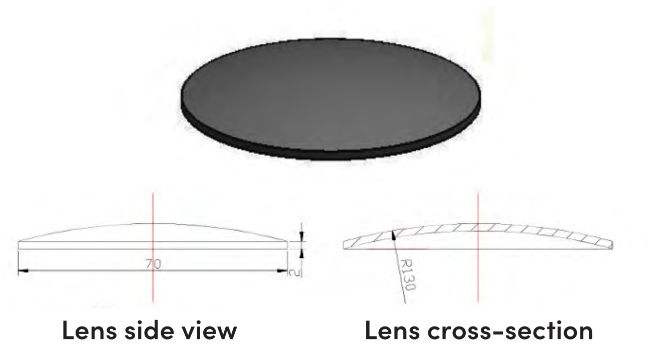
- Tritan Renew can be used to inject an array of lens types, including sun lenses (non-polarized and polarized) and reader lenses.
- From a rheological standpoint, Tritan Renew can easily fill molds cut for PC.

Lens permutations

Base

Base curve refers to the amount of "wrap" a lens has, which affects the curvature of the frame, allowing the frame to fit different face shapes. Lens bases can range from 0 to 12, depending on amount of curvature needed.

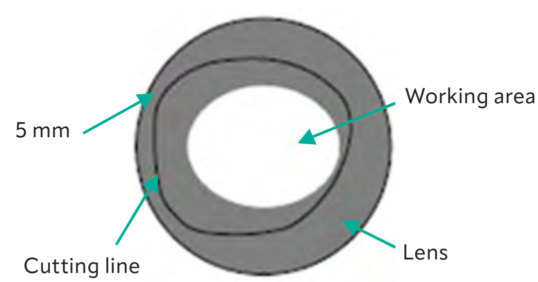
Figure 4. Cross-section diagram to show lens curvature



Diameter

Lens diameters can range from 50–80 mm, depending on final frame design. It is generally recommended to leave a 5-mm area between the edge of the starting lens and frame cutting line. The lens maker will select starting lens diameter based on these recommendations.

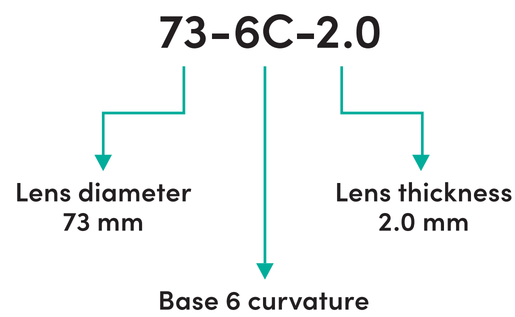
Figure 5. Frame cutting recommendation



Thickness

Lens thicknesses are generally between 1.5 and 3.0 mm. Oftentimes, lenses are cataloged by thickness, diameter and base curvature. Figure 6 shows a typical lens numbering system.

Figure 6. Typical lens numbering system



Transportation and packaging

Figure 7 shows a standard, untreated lens. The lens will be cut to shape during secondary processing. Lenses are placed on jigs or hung on fixtures to minimize touching and/or scratching during most coating and treatment steps.

Figure 7. Frame cutting recommendation

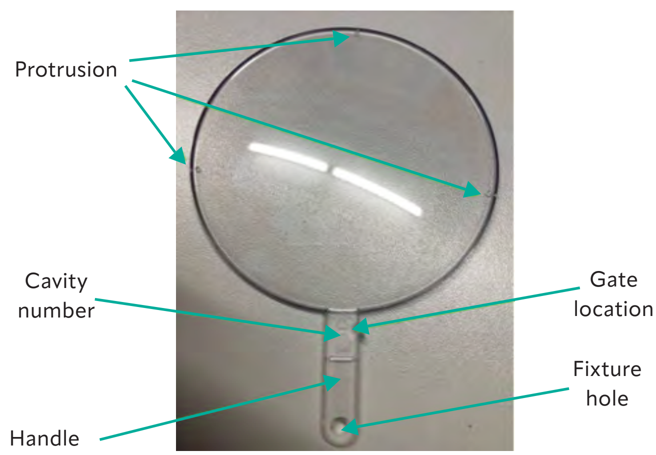


Figure 8. Lens transport in manufacturing plant

Protrusion points on the lens surface allow for a small gap of air to be present, preventing lenses from vacuum sticking together during packaging (see Figure 9).

Figure 9. Alternative packaging techniques

Alternative packaging techniques for Tritan Renew lenses include individually wrapping each lens, an effective but costly option.

Polarized lens

Polarized lenses are a great option for anyone doing high-glare activities, such as boating, driving or snowboarding. Polarized lenses reduce glare and improve color perception while protecting eyes from harmful rays.

Figure 10. Polarized lenses made with Tritan Renew

Polarized sunglasses

Polarized sport glasses

The manufacturing process for Tritan Renew polarized lenses is very similar to traditional methods using PC or tPA lens substrates. Polarizing wafer films (consisting of layers of TAC/PVA/TAC/PC or TAC/PVA/TAC/tPA) are generally applied to the surface of the lens to add polarized functionality. In certain cases, the adhesion layer between the film and the lens is PSA, a type of pressure-sensitive adhesive. Options are outlined in Figure 11. Polarized film can be over-molded to lens surface during injection process, or (less common) laminated to the lens as a secondary process.

Figure 11. Polarized film manufacture process in supplier

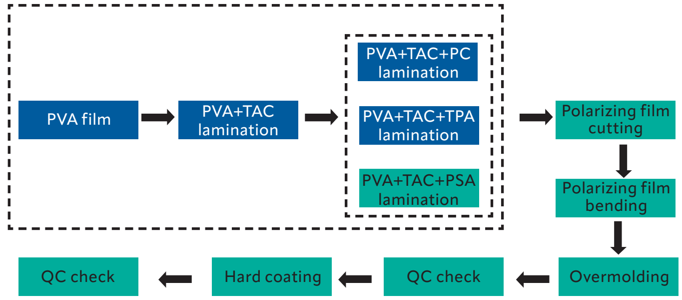


Figure 12. Starting polarized lens

Figure 12 shows a starting polarized lens before any additional processing and/or cutting. Most processes implemented for non-polarized sun lenses are performed on polarized lenses.

As the polarized film is a component of the overall lens thickness, considerations must be made for the injection process. Fill speeds and pack pressures may need adjusted, and overall mold design may need to be improved over non-polarized mold designs.

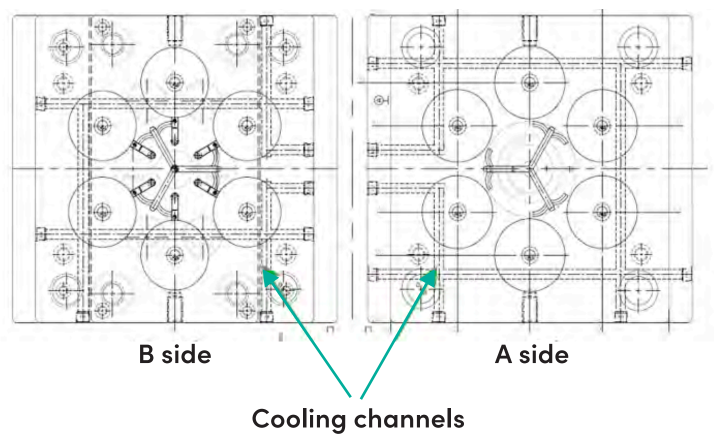
Mold design

- Proper cooling of mold tooling can significantly reduce cycle times during molding. However, increased mold temperatures can reduce internal stresses in the lens. Therefore, it is critical to optimize cooling and mold design for final application's needs.
- A properly sized gate opening can dramatically improve the moldability of a design. Thinner gates will experience excessive filling pressure and result in lenses with high internal stress.
- A larger and wider gate opening will lower internal stress, especially in polarized lenses.

Cooling system

Proper cooling system designs can reduce injection cycle times and yield high-quality lens products. Ideally, the cooling inlets and outlets of the cooling circuit should be independently connected to a water chiller. Figure 14 shows the recommended cooling design for eyeglass lenses. Temperature control units can provide low- and high-temperature water for lens molds. Generally, mold temperatures are uneven for each lens cavity, leading to inconsistencies in internal stress across the lenses. It is critical to optimize cooling in the lens mold to get quality lens outputs.

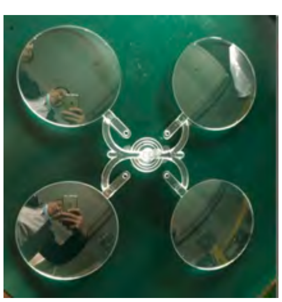
Figure 13. Recommended cooling design for eyeglass lenses



Cavity design

For non-polarized lens applications, molders generally use mold designs with two, three, four or six lens cavities.

Figure 14. Four-cavity mold and six-cavity mold design



Four-cavity lens mold

Six-cavity lens mold

Alternatively, for polarized applications, it is recommended to utilize molds with either two or four lens cavities.

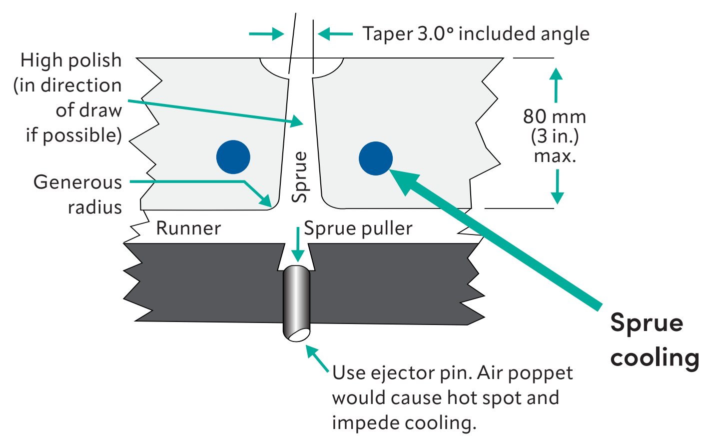
Figure 15. Two-cavity lens mold

Runner and gate design

Sprue design

- A maximum sprue length of 80 mm with draft angle of 3.0°~5.0° is suggested. To aid in ejection, polish the sprue in the draw direction. Put a generous radius or supporting ribs at the junction of the sprue and runner system to avoid breakage during ejection.
- Set separate cooling circuits to cool the root of sprue if possible. Efficient cooling in this area can provide cycle time advantages by reducing the cooling time.
- Place an ejector pin under the sprue puller rather than an air poppet valve. An air poppet here would cause a hot spot and impede cooling.

Figure 16. Sprue design

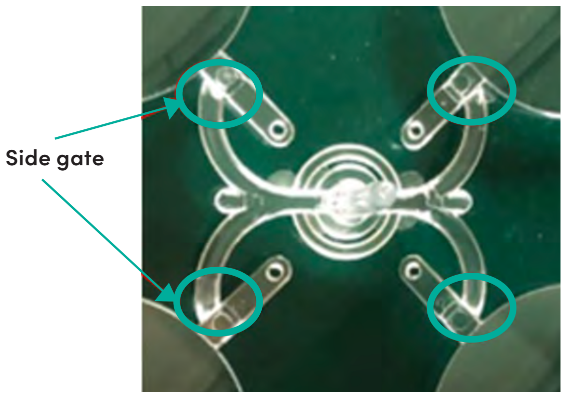


Runner and gate type

Non-polarized lenses

- A cold runner and side gate are recommended for non-polarized lenses.
- The gate location should be on the side of the lens handle (see Figure 17).
- The side gate thickness is should to be > 60% of handle thickness.
- Manually cut or remove the gate with nippers.

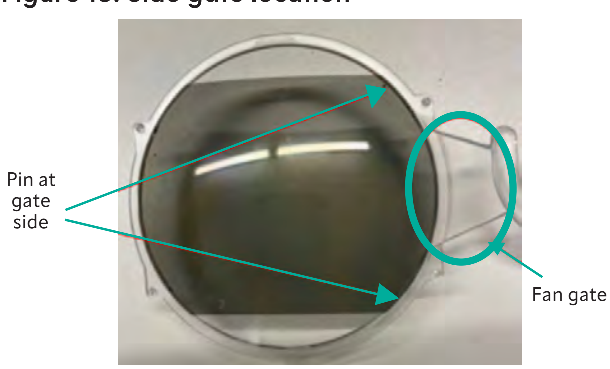
Figure 17. Side gate location



Polarized lenses

- A cold runner and fan gate are recommended for polarized lens applications.
- The gate should be directly on the side of lens, as shown in Figure 18.
- The fan gate design helps to improve overall internal stress of the lens.
- Additionally, the recommended gate location is transverse to the direction of polarizing film (usually vertical polarizing slits in wafer film).
- Two pins, located near side of fan gate, are used to keep polarized film in place during the injection process.

Figure 18. Side gate location



Mold venting

Venting

- Air displaced during filling process must be vented.
- Poor venting can result in:
  - Incomplete fill (short shot)
  - Burn marks (heat of compression)
- Suggested vent depths typically recommended are 0.0005 to 0.0015 inches.
- This can be affected by:
  - Size of part
  - Location in the cavity
  - Part fill pressure requirements
  - Viscosity of resin

Figure 19. Mold venting

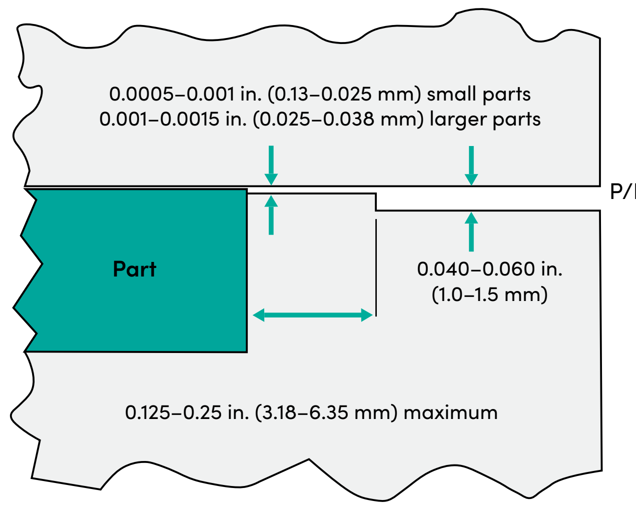
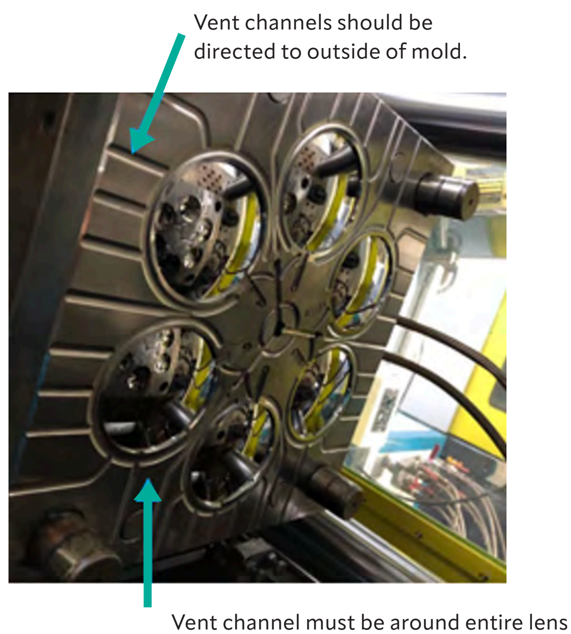


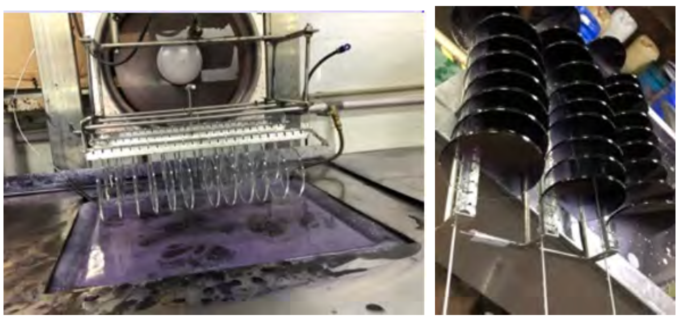
Figure 20. Venting around lenses



Secondary operations

- Table 4 summarizes secondary operations for Tritan Renew lenses. Tritan Renew is fully compatible with polarized and non-polarized sun lenses, as well as with reader lenses.
- Gradient-tint aesthetics are not generally found in polarized lenses, as the polarized film is a solid color. Additionally, no tints/pigments need to be added to polarized lens resin during injection molding.
- Tritan Renew is not recommended for three-piece mount designs in which the lenses must be drilled.

Figure 21. Dip process/final gradient tint on lenses



Dip process lenses　　Gradient tint

Table 3. Secondary operations for Tritan Renew lenses

Lens type	Non-polarized	Polarized
Surface treatment		
Gate removal	✓	✓
Gradient tint	✓	No
Hard coating	✓	✓
Antifog coating	✓	✓
PVD		
Mirror coating	✓	✓
Anti-glare	✓	✓
Lens cutting		
Grinding/surfacing	✓	✓
CNC	✓	✓
Drilling (3-piece mounts)	In development	In development
Assembly		
Full rim	✓	✓
Semi-rimless	✓	✓
Rimless	In development	In development

Gate removal

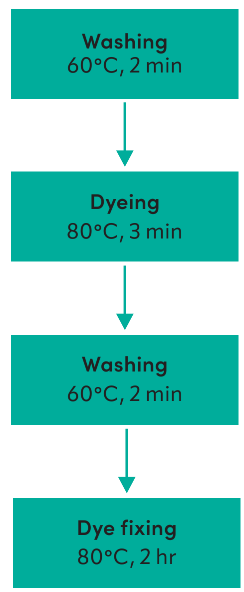
Gate removal methods for non-polarized lenses are different than polarized lenses due to different overall designs.

- As the HDT of Tritan Renew (85°C at 1.80 MPa) is lower than that of PC (125°C at 1.80 MPa), certain precautions should be taken regarding:
  - Processing/cooling temperatures
  - Contact time
  - Clamping force

Gradient tint

- Gradient tint is achieved by controlled dipping/extraction of lenses into a colored solution. Recommended temperature of the solution should be below 80°C for Tritan Renew.

Figure 22. Lens dyeing process



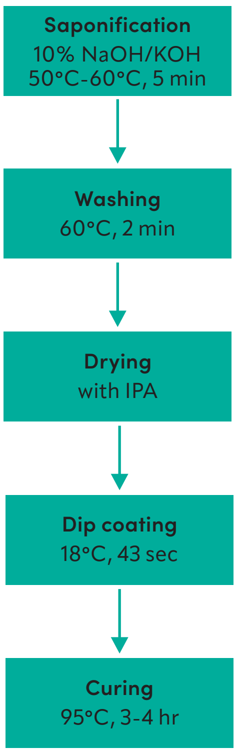
Hard coatings

- As the overall chemical resistance of Tritan Renew is very good, the surface of Tritan Renew lenses must be activated/treated prior to hard-coating procedures. General saponification techniques prove effective for most hard-coating processes.
- There are two options for applying hard coatings to lenses, both of which work on Tritan Renew:
  - UV spin coating
  - Thermal dip coating (most common)
- For thermal dip coat processes, the hard-coat solution must be optimized for Tritan Renew lenses.

Hard coatings for PC and tPA do not work due to lower HDT of Tritan Renew.

- Lenses are fixed to a mobile hanger system in the downward direction. This allows for the lenses to be dipped into tint and/or hard-coat solutions.
- Drying/curing conditions must be adjusted for hard-coated Tritan Renew lenses. Generally, lower temperatures (below 95°C) for extended time (3–4 hours) are recommended.

Figure 23. Lens dyeing process



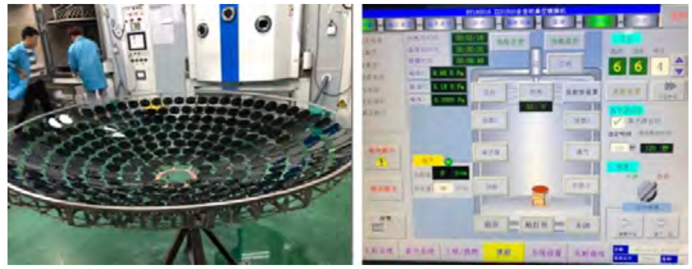
Antifog coatings

- As with anti-scratch hard coatings, Tritan Renew requires special antifog coatings that perform at lower temperatures than solutions for PC or tPA. Consult with Eastman's technical team for recommendations on coating solutions.

Mirror, multilayer and antireflective coatings

Mirror coatings and other antireflective (AR) coatings are applied via physical vapor deposition (PVD) methods. This method deposits a thin layer of functional coating on the surface of the lens. General guidance for Tritan Renew and PVD coatings is to keep processing temperatures lower than 50°C.

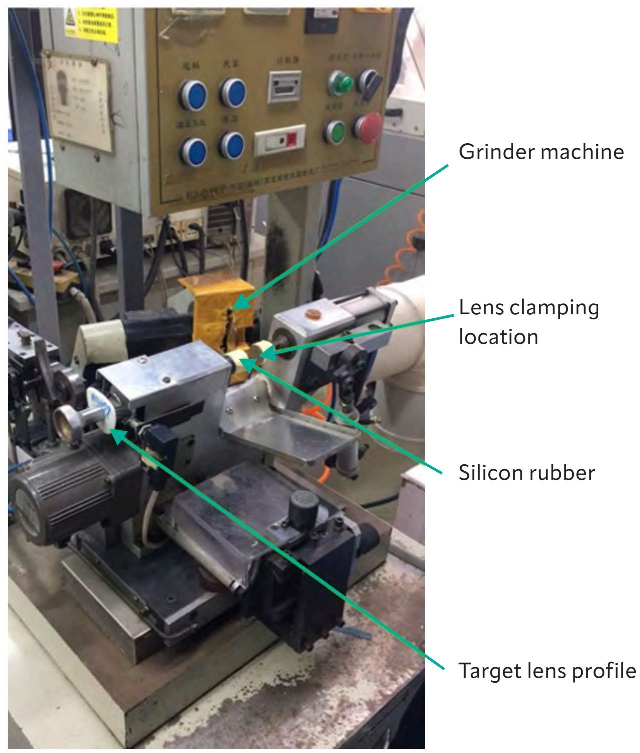
Figure 24. Mirror coatings and antireflective coating applied via physical vapor deposition (PVD) method



Packaging

It is recommended to package Tritan Renew lenses separately to avoid scratching caused by contact with neighboring lenses.

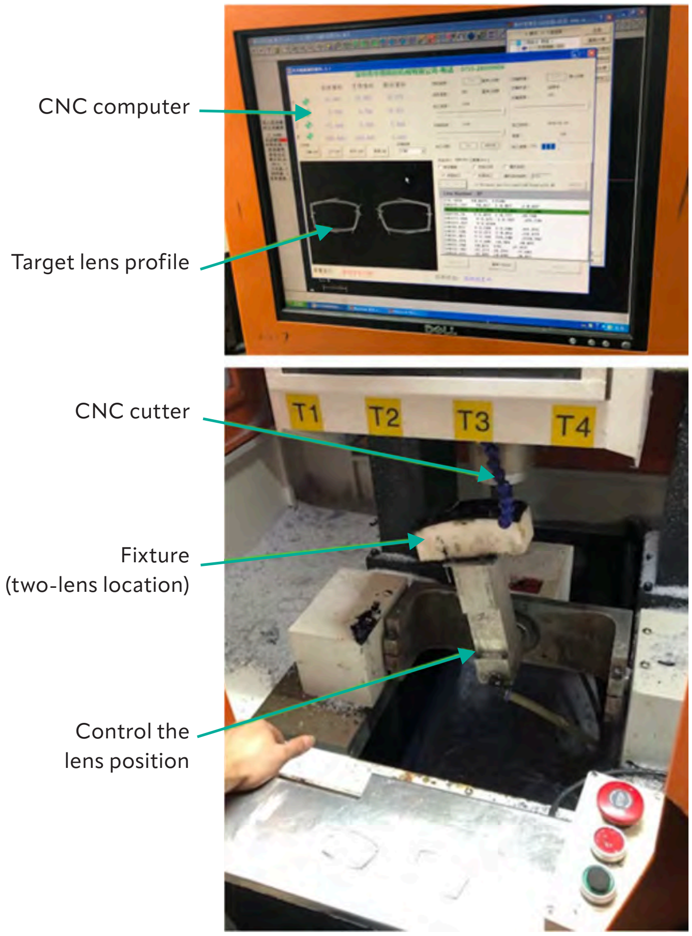
Figure 25. Edge grinding machine



CNC cutting

Before lens cutting, the operator should input the program in the computer. Then we can put the lens on the fixture, which is soft surface and negative pressure adsorption on the right location. It can cut a pair of lenses in same time as is shown in Figure 23.

Figure 26. CNC cutting machine



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