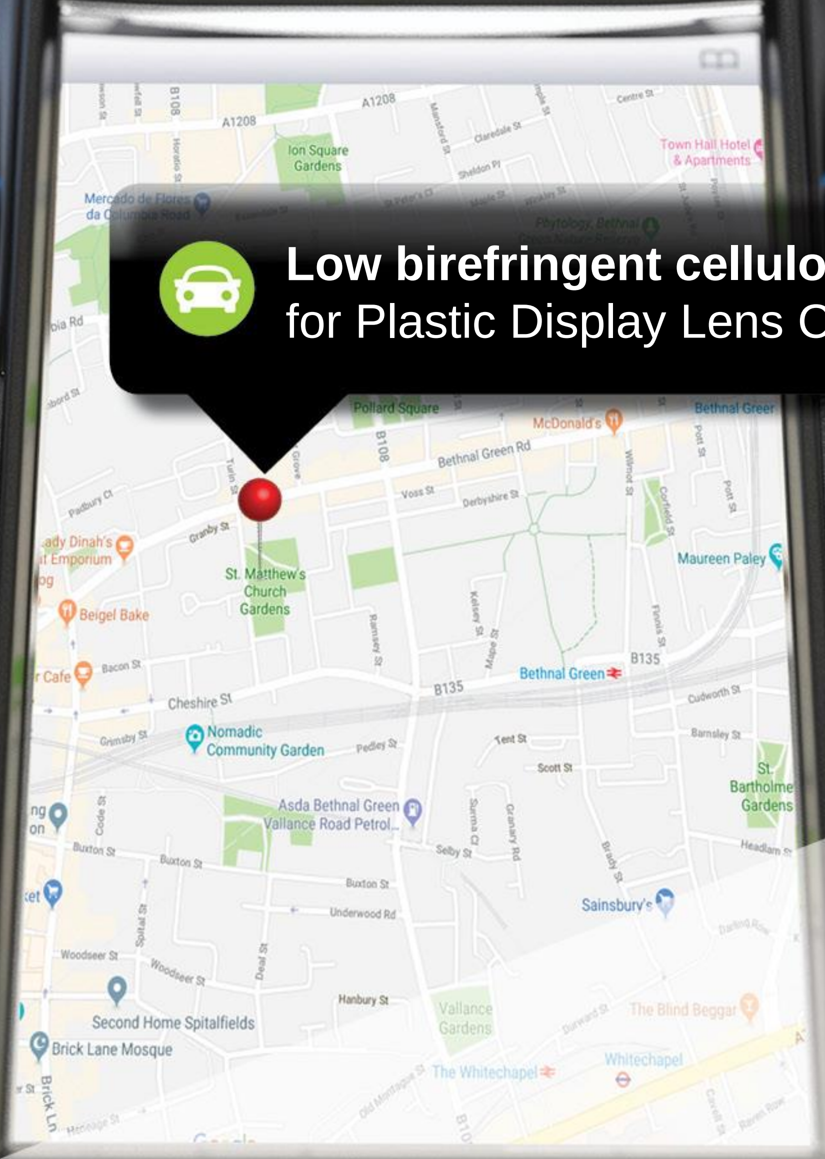

Low birefringent cellulose acetate propionates
for Plastic Display Lens Covers

Presenters:
Chris Scarazzo
Laura Weaver
Eastman Chemical Company

EASTMAN
The results of insight™

Excerpts from
SPE-ANTEC 2018

Objectives

- Introduction to Eastman
  - Specialty Plastics
- Biocertified cellulose ester chemistries
  - Use in low-birefringent display films
  - New cellulose esters for injection molded automotive display lens covers
  - Development of functional coatings
- Conclusions and paths forward

Additives & Functional Products

- 2017 sales revenue: $3.3 B
- 35% of total Eastman sales

Advanced Materials

- 2017 sales revenue: $2.6 B
- 27% of total Eastman sales

Chemical Intermediates

- 2017 sales revenue: $2.7 B
- 29% of total Eastman sales

Fibers

- 2017 sales revenue: $852 M
- 9% of total Eastman sales

A diverse and attractive **portfolio** of businesses

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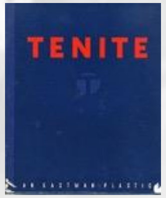
Cellulose esters: a rich history at Eastman

A century of innovation

1924 — Kodak introduced first non-flammable X-ray film based on cellulose acetate

1929 — First acetate yarn extruded

1932 — Tenite™ cellulose acetate plastic introduced



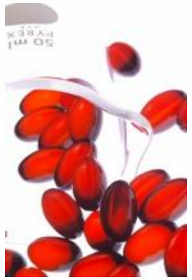
1938 — Tenite™ cellulose butyrate production begins

1947 — Tenite™ cellulose propionate motion picture film introduced

1950 — Lower viscosity mixed cellulose esters introduced for coatings applications

1953 — Acetate filter tow

1955 — Cellulose triacetate for photographic and motion picture film introduced



1960 — Controlled release C-A-Ph developed for enteric coatings

1970 — Introduction of CAB's for high quality automotive coatings market

1990 — Cellulose esters for marker reservoirs

2000 — Ultra-high quality cellulose esters developed for optical film applications

2010 — Ensure™ cellulose esters developed for release applications

2017 January — Eastman Naia™ cellulosic yarn, the ultimate product for fashion apparel

2017 April — Eastman Treva™ engineering bioplastic

Historical presence in display films

Eastman Visualize™ materials

- ***Polarizer film materials*** that enable and protect LCD displays
- ***Transparent conductive films***, including optically clear films used in optoelectronic devices such as flat-panel displays, e-readers, and resistive and capacitive touch screen applications
- ***Light-diffusing film*** materials that make electronic displays brighter
- ***Compensation film*** materials that improve contrast, view angles, clarity, and overall optic quality

Saflex® VIEW ST head-up display interlayer technology

Head-up displays (HUD) allows projection of needed information onto windshield. Eastman interlayers improve HUD experience to deliver:

- ***Safety & security***
- ***Crash avoidance***
- ***Navigation***
- ***Comfort***
- ***Connectivity***

"We think the interior is going to change more in the next 10 to 20 years than it did in the last 100"

- Han Hendriks, VP Product Development, Yanfeng Automotive Interiors

Automotive touchscreen megatrend

Consumers want:

- Less distractions
- Luxurious look and feel inside the cockpit (harmonious integration of HMI with the rest of the interior components)
- Infotainment without glare, easy legibility
- Antifingerprint

Automotive touchscreen megatrend

The problems are:

- Glass surfaces are hard to add 3D dimensionality and are brittle.
- Traditional injection moldable grades of PC shows birefringence (rainbows).
- PMMA exhibits low birefringence but is brittle and exhibits poor heat resistance.

Automotive touchscreen megatrend

But there is opportunity with a new material that shows:

- Low birefringence
- Good flow in injection molding
- Low VOC
- Biobased manufacture

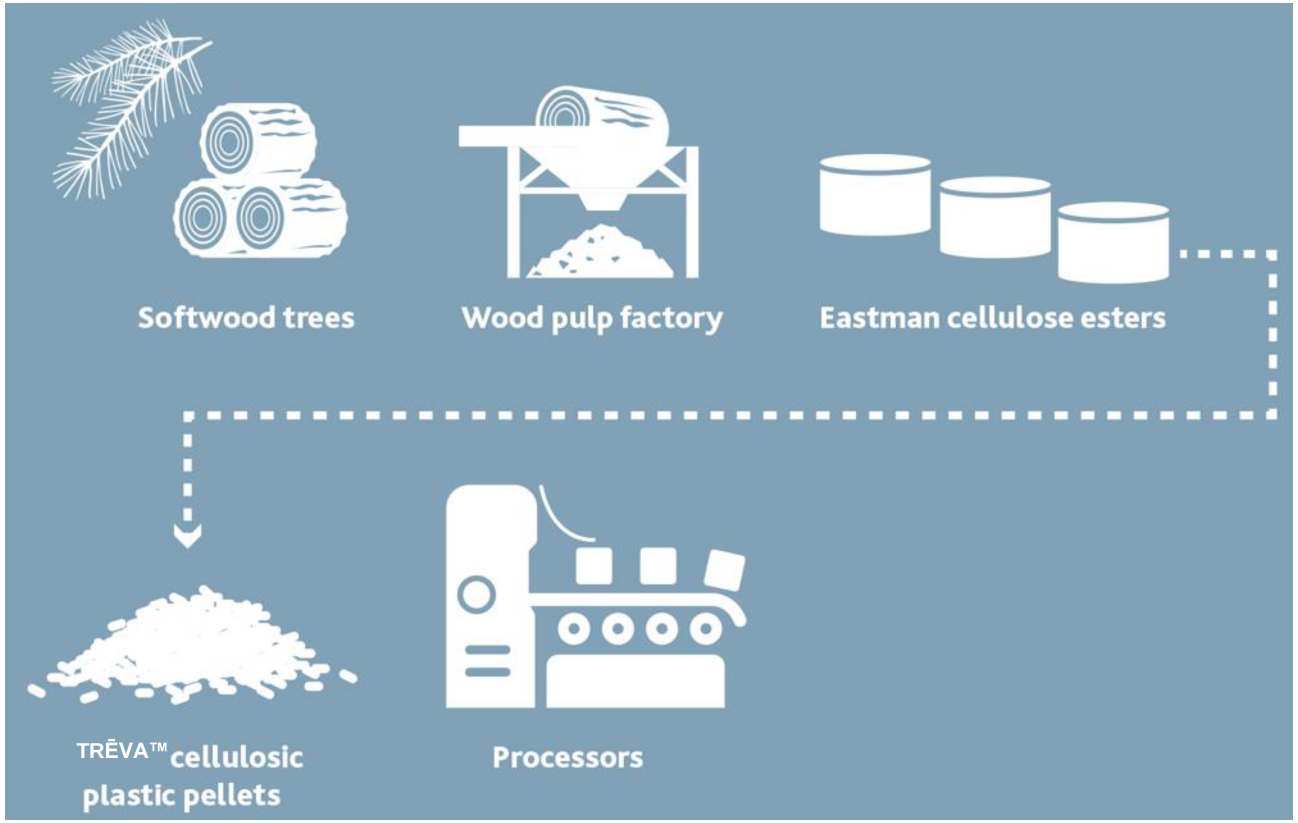
Eastman TRĒVA™

engineering bioplastic

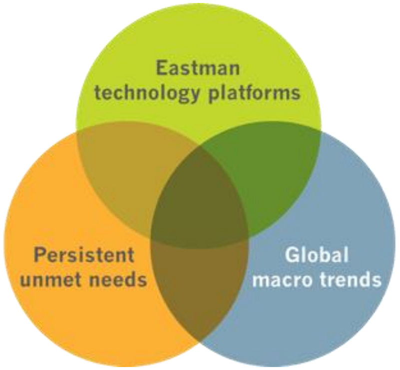
Eastman TRĒVA™

engineering bioplastic

Naturally Better



Extensive technical expertise providing engineering resin performance with a biobased polymer to meet the demands of our changing world.



Life Cycle Analysis Data

Global Warming Potential*	2.8 kg CO_2 eq./kg
Energy	46 MJ/kg

* Includes biogenic carbon

FSC
www.fsc.org
FSC® C140711
The mark of responsible forestry

BIO-BASED/ RESPONSIBLY MANAGED

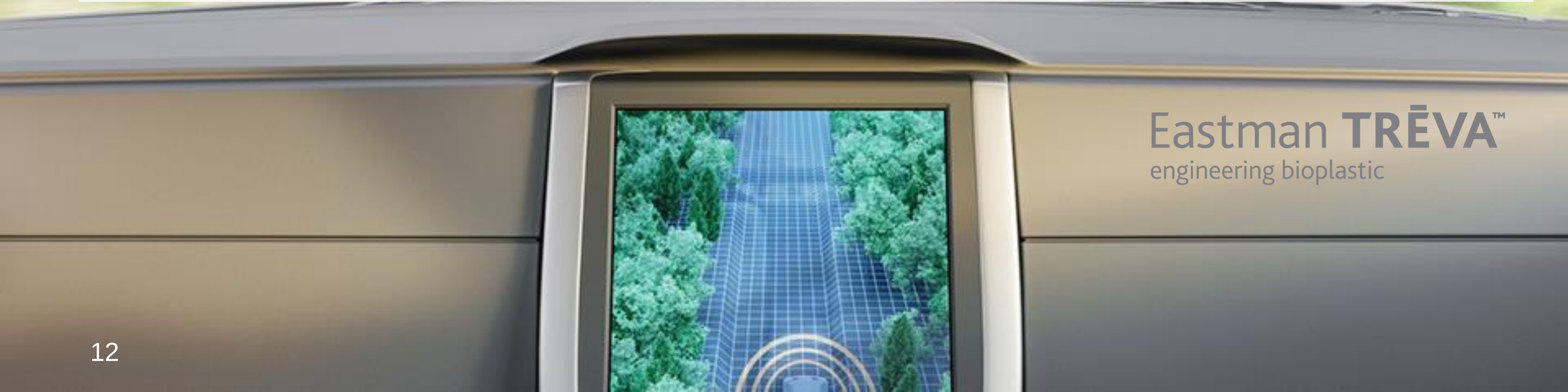
Eastman carries FSC® chain of custody certification.

USDA CERTIFIED BIOBASED PRODUCT
PRODUCT 42%

GC 6021

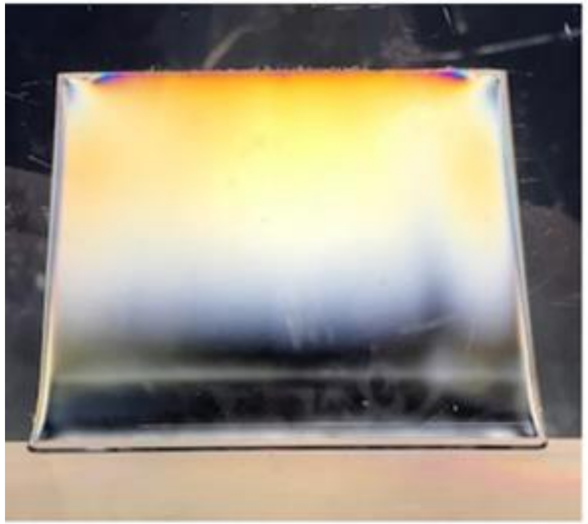
Properties for automotive applications

- Birefringence, haze, light transmittance
- Viscosity—flow for injection molding
- Low volatile organic components
- Biobased with performance
- Heat resistance, heat aging—95°C/7 day
- Impact resistance at 23°C and -30°C
- Humid aging, UV testing
- Coatings for added functionality

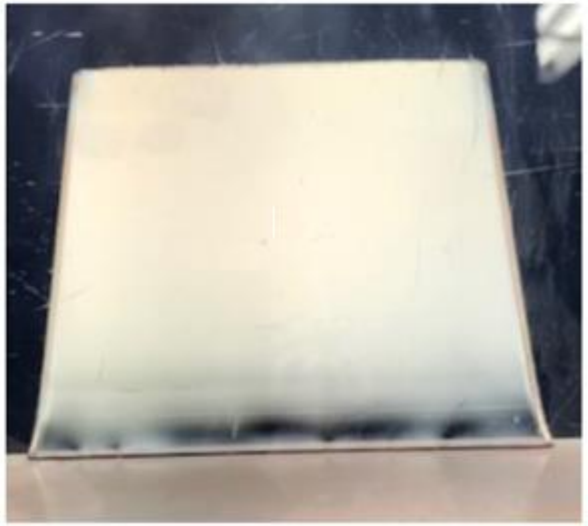


Birefringence

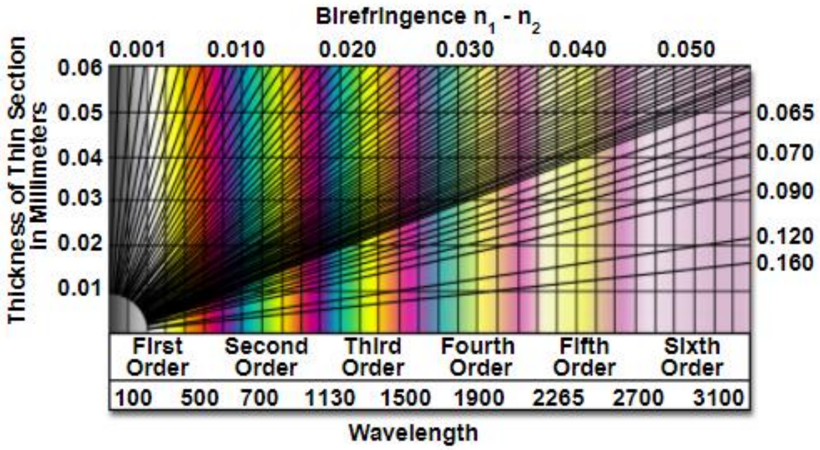
PC



TRĒVA™



PMMA



Effects of gate design on Birefringence in HMI Mold

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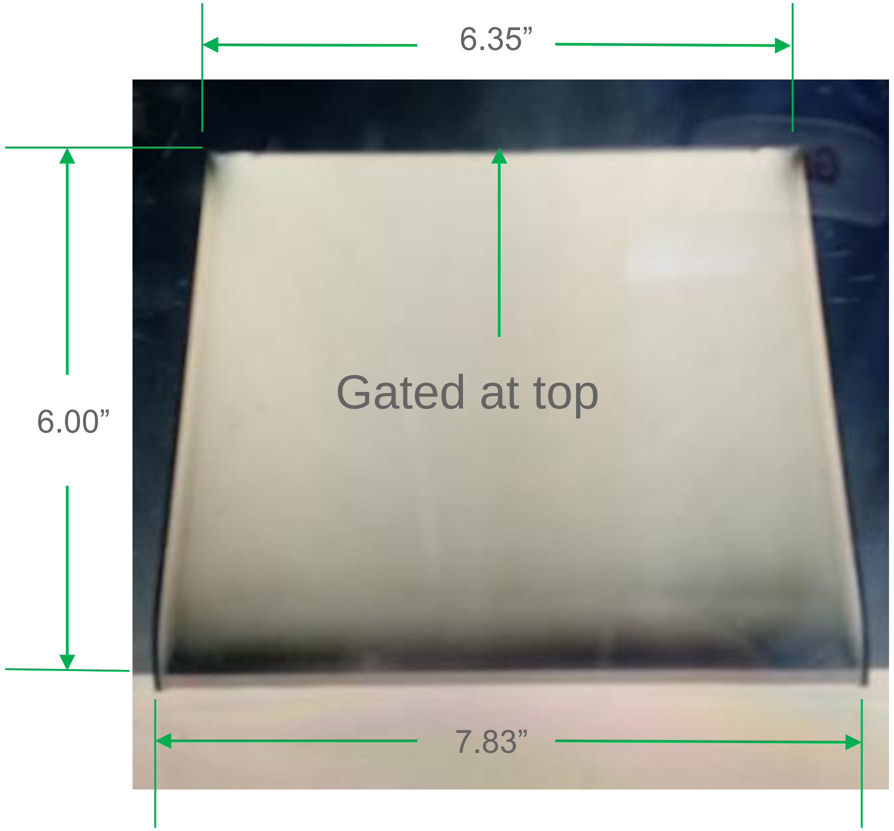
Birefringence in HMI molds—experimental description

- Mold Treva in HMI mold on 200 Ton TOYO press
- Use molding parameter changes and gate designs to produce parts with low birefringence
- Use cross polar light box to determine level of birefringence in the molded parts
- Molding Variables
  - Mold Temperature
  - Melt Temperature
  - Fill Speed
- Determine effects of gate design on birefringence
  - Film Gate
  - Tab Gate
  - Fan Gate
- Record molding parameters and use the learnings to produce low birefringence parts in future applications for Treva

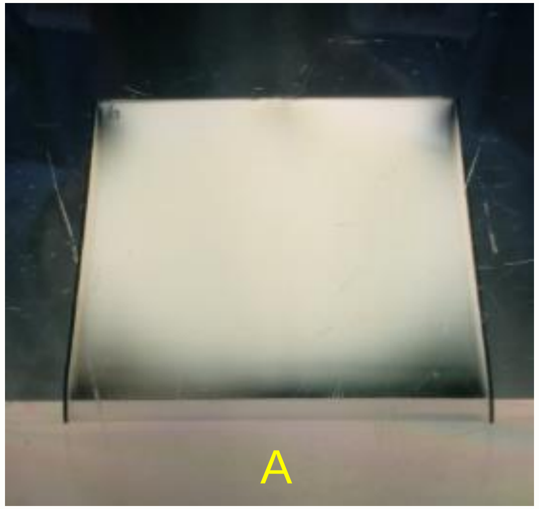
HMI part dimensions

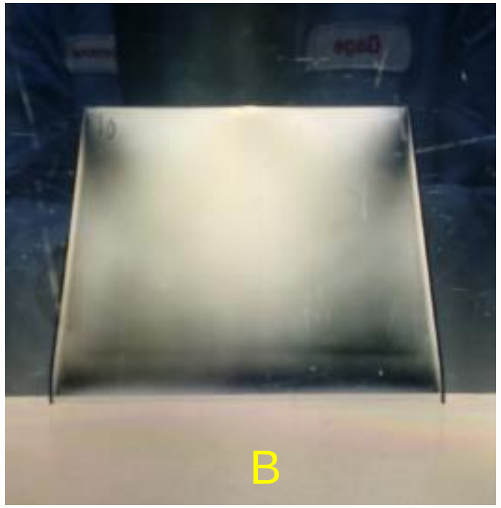


Part shown with gate detached

Part thickness = 0.08 inches

Tab gate results



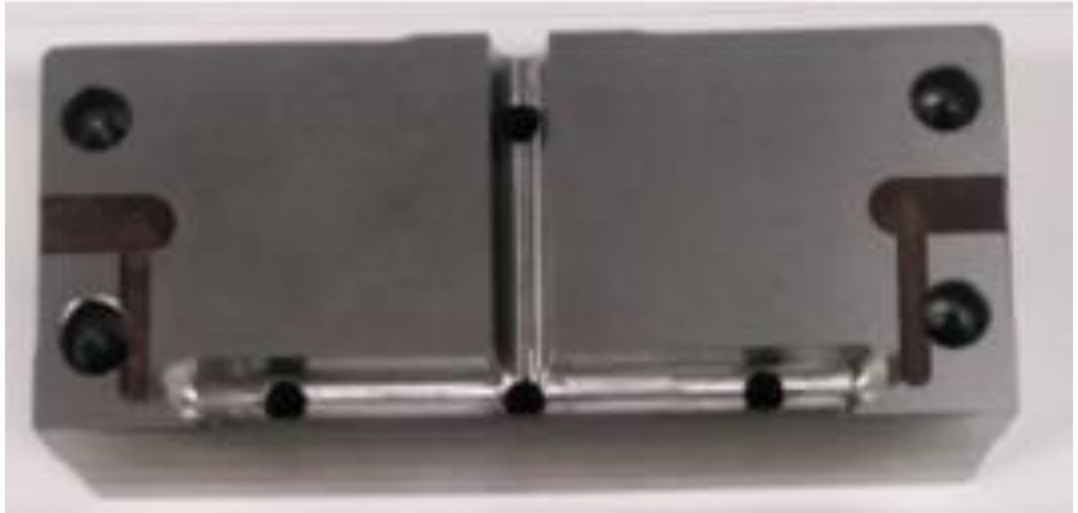


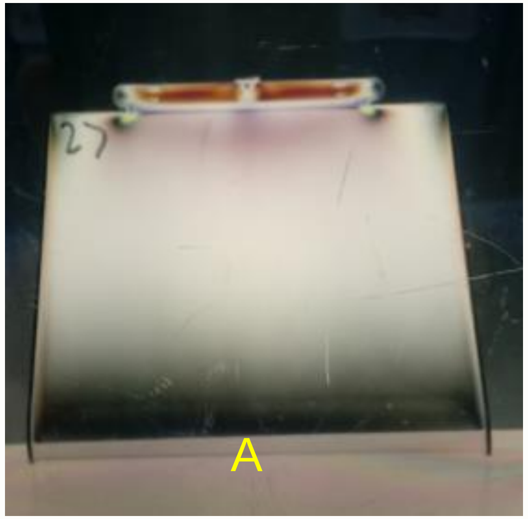
Part photos taken with cross polar lighted background to show birefringence

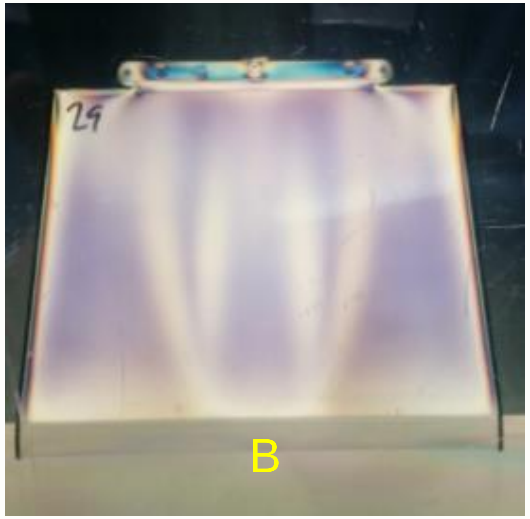
Part	Barrel Temperature Setpoint (°F)	Mold Temperature (°F)	Fill Speed (in/sec)	Screw Speed (RPM)	Back Pressure (psi)	Cycle Time (seconds)
A	485	185	0.7	100	100	30.2
B	485	185	4.0	100	100	29.1

High mold temperature in combination with slow fill speed produced the lowest birefringence parts but was never able to eliminate the shadowed corners through process variations

Film gate results





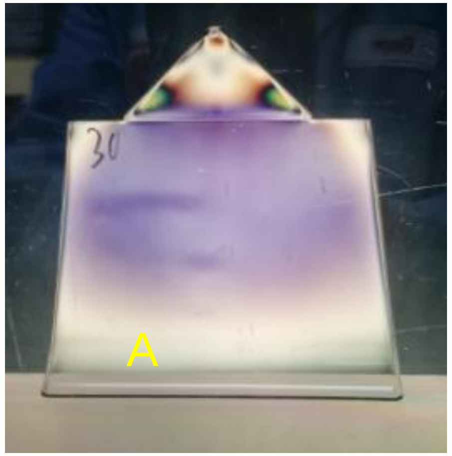


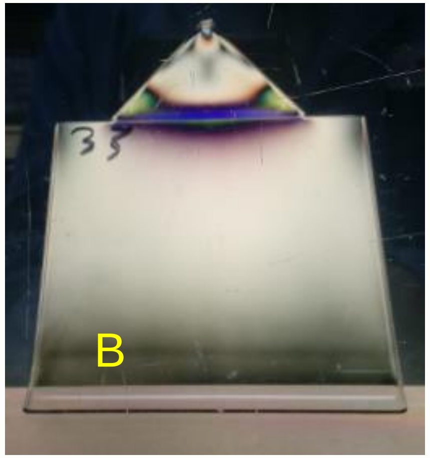
Part photos taken with cross polar lighted background to show birefringence

Part	Barrel Temperature Setpoint (°F)	Mold Temperature (°F)	Fill Speed (in/sec)	Screw Speed (RPM)	Back Pressure (psi)	Cycle Time (seconds)
A	485	185	2.6	100	100	28.7
B	485	185	0.35	100	100	34.1

High mold temperature in combination with fast fill speed produced the lowest birefringence parts but was unable to eliminate the shadow and streaking protruding into the part from the gate area via processing changes.

Fan gate results



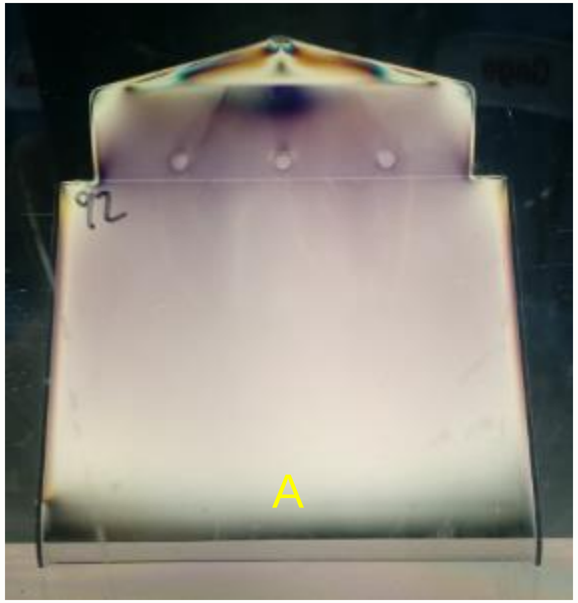


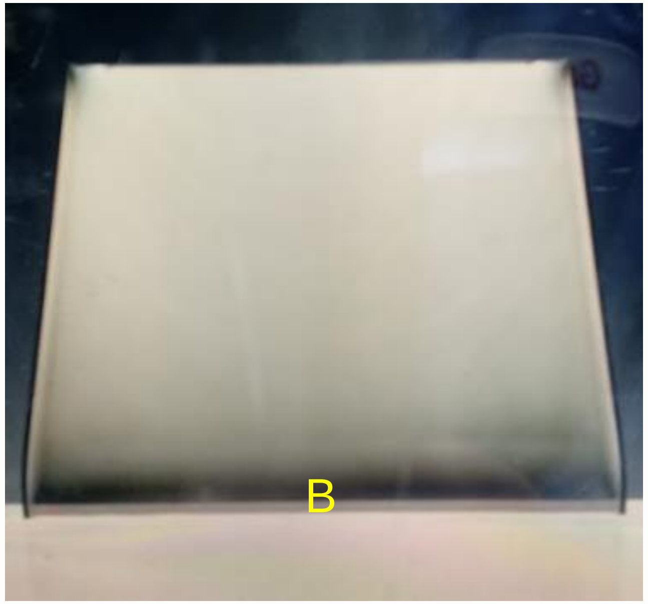
Part photos taken with cross polar lighted background to show birefringence

Part	Barrel Temperature Setpoint (°F)	Mold Temperature (°F)	Fill Speed (in/sec)	Screw Speed (RPM)	Back Pressure (psi)	Cycle Time (seconds)
A	485	185	0.83	100	100	30.5
B	485	185	3.3	100	100	28.4

The fan gate with high mold temperature in combination with fast fill speed produced the lowest birefringence parts out of the three gate designs tested. The results from these experiments led to further modification of the fan gate to move the shadow completely out of the part and back onto the gate area.

Widened fan gate results





Part photos taken with cross polar lighted background to show birefringence

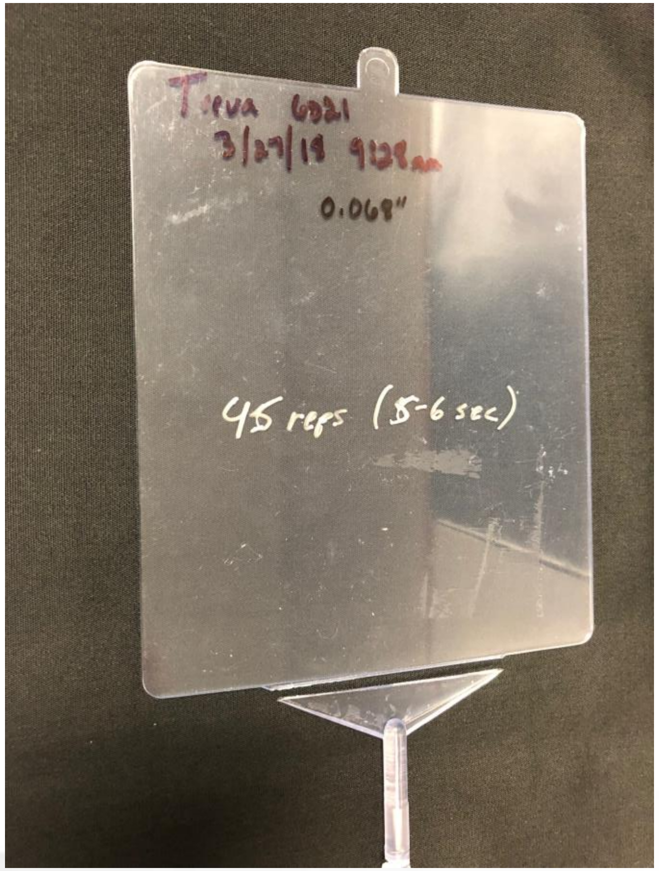
Part	Barrel Temperature Setpoint (°F)	Mold Temperature (°F)	Fill Speed (in/sec)	Screw Speed (RPM)	Back Pressure (psi)	Cycle Time (seconds)	Press Tonnage
A	485	185	* 0.83	100	100	30.5	200
B	505	185	2.5	140	100	28.4	310

** Couldn’t inject faster due to flash*

- Fan gate was modified by widening the gate entry area and moving the transition angle back towards the sprue.
- Added surface area required moving the mold to a 310 Ton press to prevent part flashing
- The modified fan gate design gave the most uniform and lowest birefringence when viewed through cross polar lighting.
- The widened fan gate resulted in successfully moving the previously experienced shadow from the part to the gate area via faster injection speed, high mold temp and high melt temp

Laser cutting

- CO2 laser used (Keyence)
- Clean and perfect cut edges
- No charring, popping, cracking
- No post processing necessary
- No tool cleaning or sticking of parts after cutting
- No tool wear



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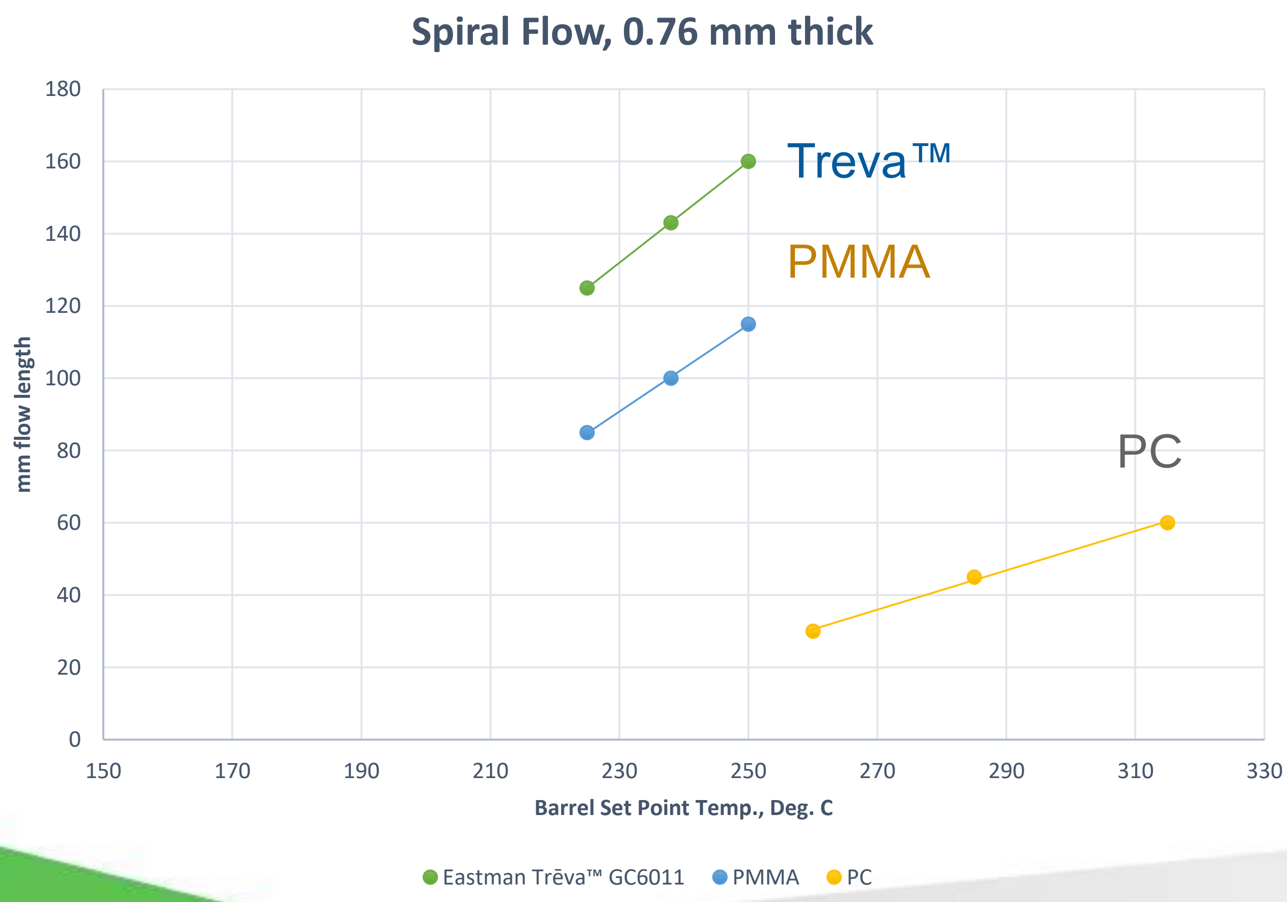
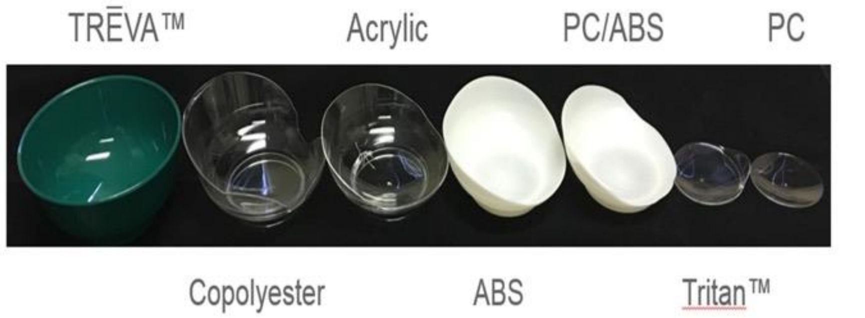
Viscosity enables thin part molding





Hot runner with valve gate
Small pin gate

Eastman Trēva™ engineering bioplastic fills the part while others cannot.

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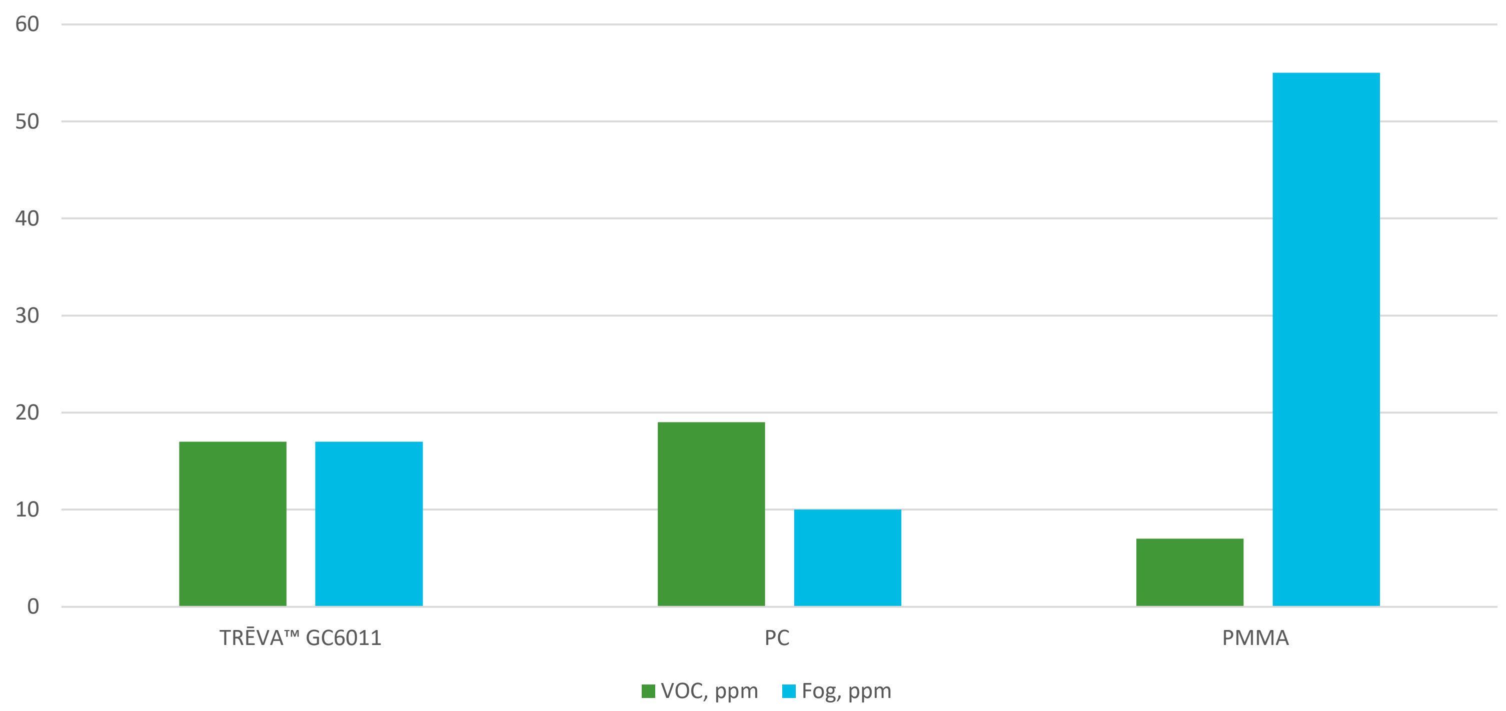
Volatile Organic Components*

VDA 278 test method   (measured in-house)



* Intertek – 3rd party results for Trēva = 2.25 ppm VOC, 0.5 ppm Fog

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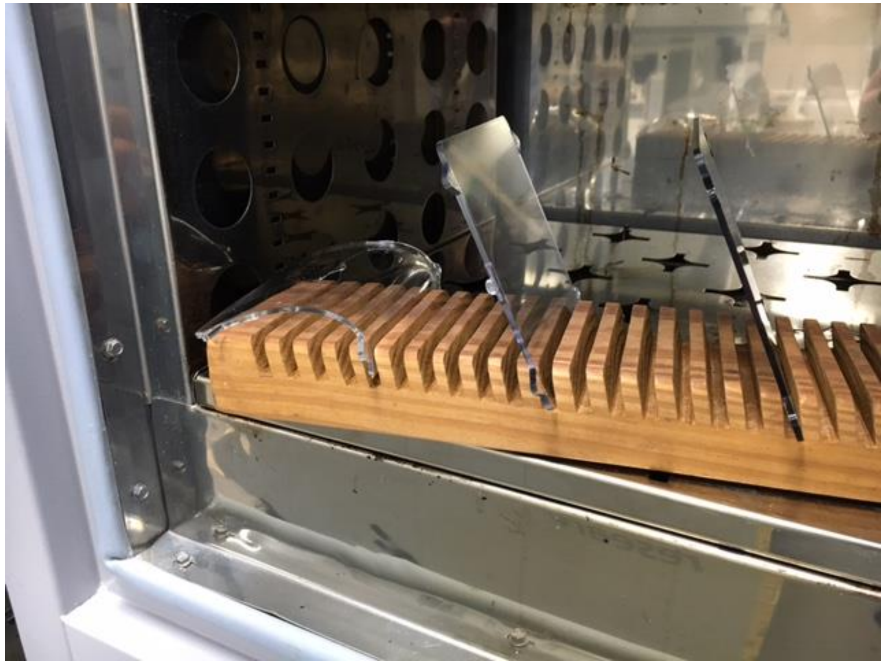
Heat resistance

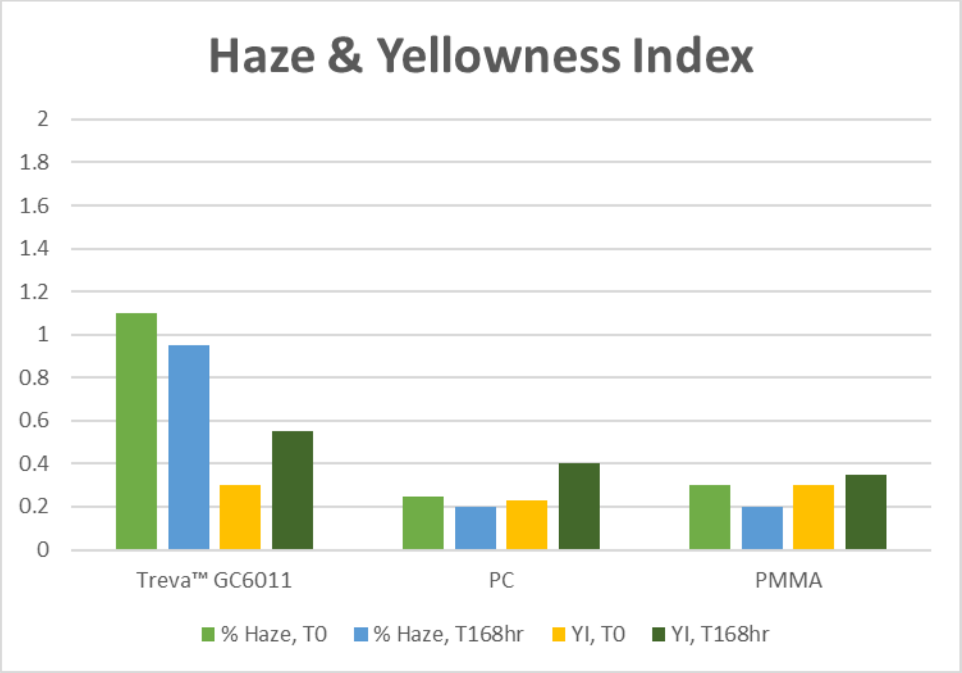
Oven sag test (95°C, 7 days)



PMMA PC Trēva

Heat aging (95°C, 7 days)

Target <2% haze



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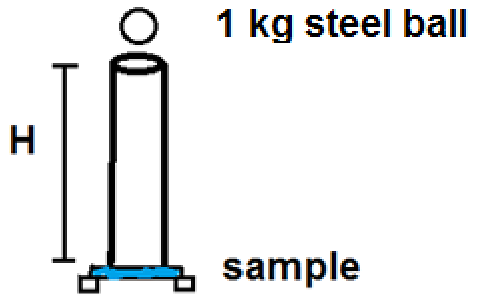
Impact properties

Uncoated plaques



	1 kg Steel Ball Drop Impact			
2 mm thickness	23 Deg. C		(-)30 Deg. C	
	1 Joule	5 Joule	1 Joule	5 Joule
PMMA	**Fail**	**Fail**	**Fail**	**Fail**
PC	**Pass**	**Pass**	**Pass**	**Pass**
Eastman TRĒVA™ GC6011	**Pass**	**Pass**	**Pass**	**Pass**

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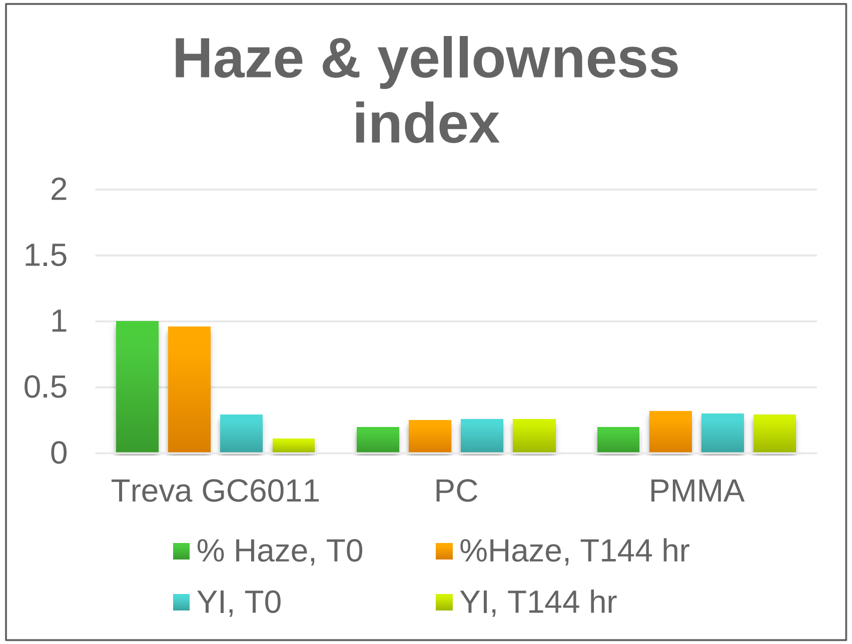
Humidity and UV

Uncoated plaques

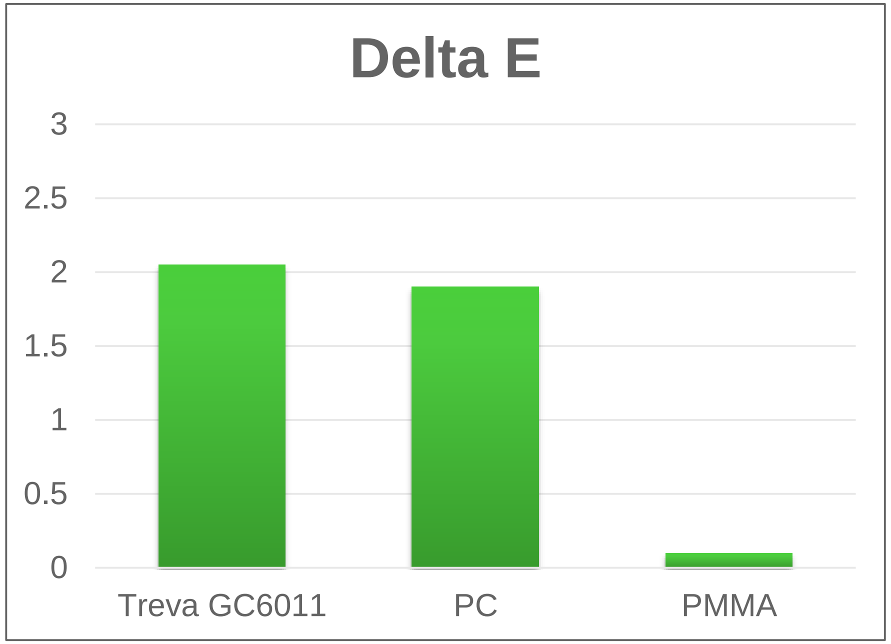
95% RH, 40ºC, 144 hr

Target <2% haze



UV cyclic testing – SAE J2412

300 hr., 601.6 kJ/m^2, target <3 Delta E



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Conclusions and path forward

- Cellulose acetate propionate(s) benefits for display lens covers:
  - Biocertified engineering thermoplastic with petroleum based engineering thermoplastic performance
  - Low birefringence with proper gate design and processing
  - Low VOCs and fogging
  - Flow in thin walled injection molding
  - Impact toughness (5 Joule) at both 23º and -30ºC
  - < 2% Haze after 7 days of heat and humid aging
  - Dimensional stability after 7 days @ 95ºC
  - <3 Delta E after 601 KJ/m^2 of cyclic UV testing (1240 -2500 KJ/m2 data by Aug.)
- Process development expertise available to support customer programs
- Multi-generation product development for improved optics
- Partner with surface enhancing technology partners to address OEM and Tier display targets

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Thank you!

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