EPX 150

EPX 150 exhibits excellent chemical resistance, mechanical performance, is autoclavable and suitable for extended use at high temperatures.

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EPX 150 Mechanical Properties – Inert Baked

Tensile Properties	Test Standard	Metric	US
Tensile Modulus	ISO 527-2 Type IA 5 mm/min	2700 MPa	390 ksi
Yield Strength		76 MPa	11 ksi
Ultimate Tensile Strength		76 MPa	11 ksi
Elongation at Break		5%	5%
Tensile Modulus	ASTM D638 Type V 1 mm/min	2810 MPa	408 ksi
Yield Strength		77 MPa	11 ksi
Ultimate Tensile Strength		77 MPa	11 ksi
Elongation at Yield		6%	6%
Elongation at Break		9%	9%

Flexural Properties	Test Standard	Metric	US
Flexural Stress at 5% strain	ASTM D790-B	123 MPa	18 ksi
Flexural Modulus (Chord, 0.5-1%)		2980 MPa	432 ksi

Impact Properties	Test Standard	Metric	US
Gardner Impact	ASTM D5420	0.9 J	0.7 ft-lb
Unnotched Charpy	ISO 179-1/1eU	37 kJ/m^2	18 $ft\text{-}lb/in^2$
Notched Charpy (Machine Notched)	ISO 179-1/1eA	3 kJ/m^2	1.4 $ft\text{-}lb/in^2$
Unnotched Izod	ASTM D4812	567 J/m	10.6 ft-lb/in
Notched Izod (Machine Notched)	ASTM D256	36 J/m	0.7 ft-lb/in
Unnotched Izod, -30 °C	ASTM D4812	576 J/m	10.8 ft-lb/in
Notched Izod (Machine Notched) , -30 °C	ASTM D256	36 J/m	0.7 ft-lb/in

Heat Deflection Temperature	Test Standard	Metric	US
HDT at 0.455 MPa/66 psi	ASTM D648	148 °C	298 °F
HDT at 1.82 MPa/264 psi		132 °C	270 °F

Heat Deflection Temperature, Dry*	Test Standard	Metric	US
HDT at 0.455 MPa/66 psi	ASTM D648	155 °C	311 °F
HDT at 1.82 MPa/264 psi		140 °C	284 °F

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity unless otherwise noted.

*Samples were kept in dry conditions and tested within 24 hours.

EPX 150 Mechanical Properties – Air Baked

Tensile Properties	Test Standard	Metric	US
Tensile Modulus	ISO 527-2 Type IA 5 mm/min	2900 MPa	420 ksi
Yield Strength		79 MPa	11 ksi
Ultimate Tensile Strength		79 MPa	11 ksi
Elongation at Break		4%	4%
Tensile Modulus	ASTM D638 Type V 1 mm/min	2750 MPa	399 ksi
Yield Strength		79 MPa	11 ksi
Ultimate Tensile Strength		79 MPa	11 ksi
Elongation at Yield		6%	6%
Elongation at Break		7%	7%

Flexural Properties	Test Standard	Metric	US
Flexural Stress at 5% strain	ASTM D790-B	124 MPa	18 ksi
Flexural Modulus (Chord, 0.5-1%)		3080 MPa	447 ksi

Impact Properties	Test Standard	Metric	US
Gardner Impact	ASTM D5420	0.7 J	0.5 ft-lb
Unnotched Charpy	ISO 179-1/1eU	29 kJ/m^2	14 ft-lb/in^2
Notched Charpy (Machine Notched)	ISO 179-1/1eA	3 kJ/m^2	1.4 ft-lb/in^2
Unnotched Izod	ASTM D4812	250 J/m	4.7 ft-lb/in
Notched Izod (Machine Notched)	ASTM D256	26 J/m	0.5 ft-lb/in

Heat Deflection Temperature	Test Standard	Metric	US
HDT at 0.455 MPa/66 psi	ASTM D648	142 °C	288 °F
HDT at 1.82 MPa/264 psi		126 °C	259 °F

Heat Deflection Temperature, Dry*	Test Standard	Metric	US
HDT at 0.455 MPa/66 psi	ASTM D648	153 °C	307 °F
HDT at 1.82 MPa/264 psi		142 °C	288 °F

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in an air oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity unless otherwise noted.

*Samples were kept in dry conditions and tested within 24 hours.

EPX 150 General Properties

Thermal Properties	Test Standard	Metric	US
Coefficient of Thermal Expansion (-30, 50 °C)	ASTM E831	$76*10^{-6}$ ppm/°C	$42*10^{-6}$ ppm/°F
Heat Capacity, 23 °C	ASTM E1269	1.4 J/g-°C	0.34 BTU/lb-°F
Thermal Conductivity	ASTM C518	0.176 W/m-k	0.1 BTU/hr-ft-°F
Flammability	UL 94	HB (1.5 mm) HB (3.0 mm)	

Dielectric/Electric Properties	Test Standard	
Dielectric Constant	ASTM D150	2.810
Dissipation Factor	ASTM D150	0.00456 (1 KHz)
	CTG-TM-0100-2018	0.0106 (10 GHz), 0.0114 (24 GHz)
Dielectric Strength	ASTM D149	14.2 kV/mm
Volume Resistivity	ASTM D257	$1.84*10^{17}$ ohm-cm

General Properties	Test Standard	
Poisson's Ratio	ASTM D638, 5 mm/min	0.36
Shore D Hardness	ASTM D2240	87 (instant), 86 (5 sec)
Bulk Density	ASTM D792	1.09 g/mL
Taber Abrasion	ASTM D4060 CS-17, 1 kg, 100% vacuum	19 mg/ 1000 cycles

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity unless otherwise noted.

EPX 150 Liquid Properties

Liquid Properties	
Liquid Density (Part A)	1.07 g/mL
Liquid Density (Part B)	1.12 g/mL
Liquid Density (Part A+B)	1.08 g/mL
Part A:B Volume Ratio (Mass Ratio)	4 (3.82)
25 °C Viscosity (Part A)	3500 cP
25 °C Viscosity (Part B)	90 cP
25 °C Viscosity (Part A+B)	1300 cP

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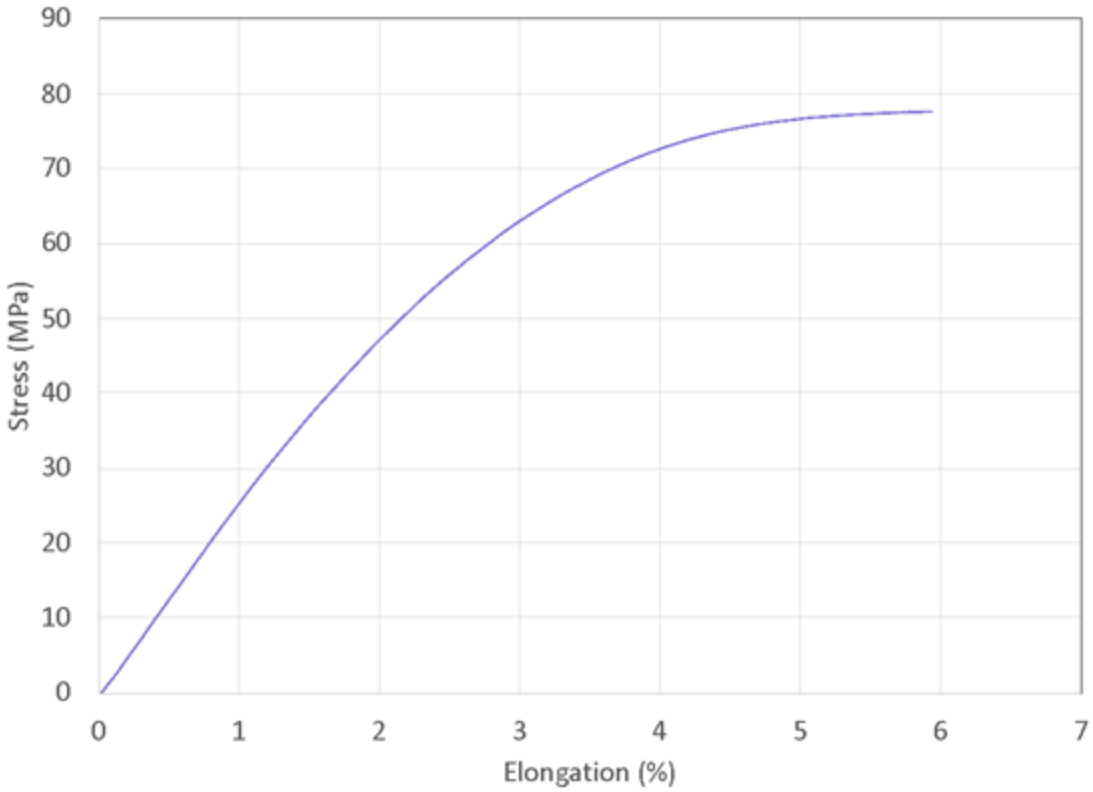
EPX 150

Extended TDS

EPX 150 Mechanical Properties

Representative Tensile Curve

ISO 527-2, Type 1A, 5 mm/min

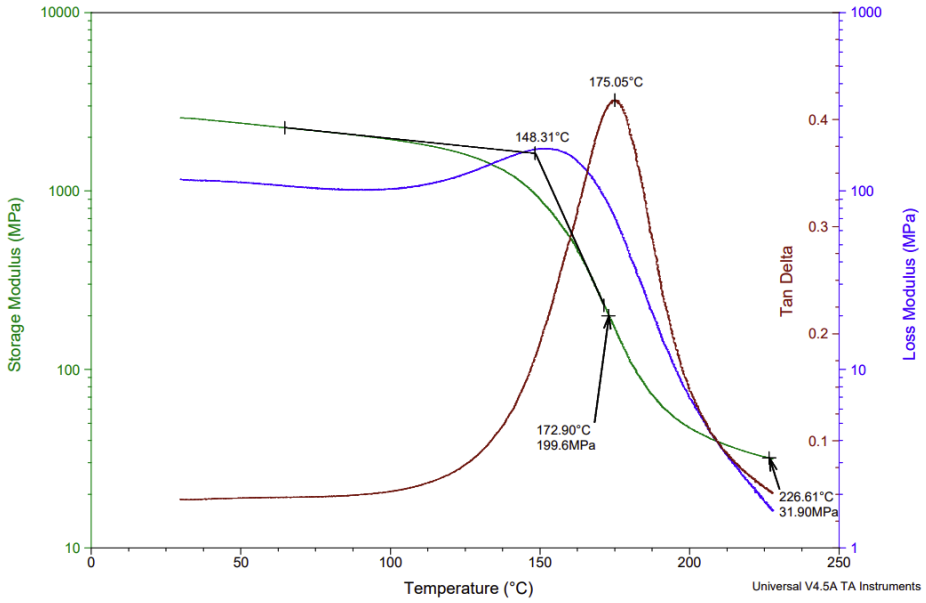


Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity.

EPX 150 Thermal Properties

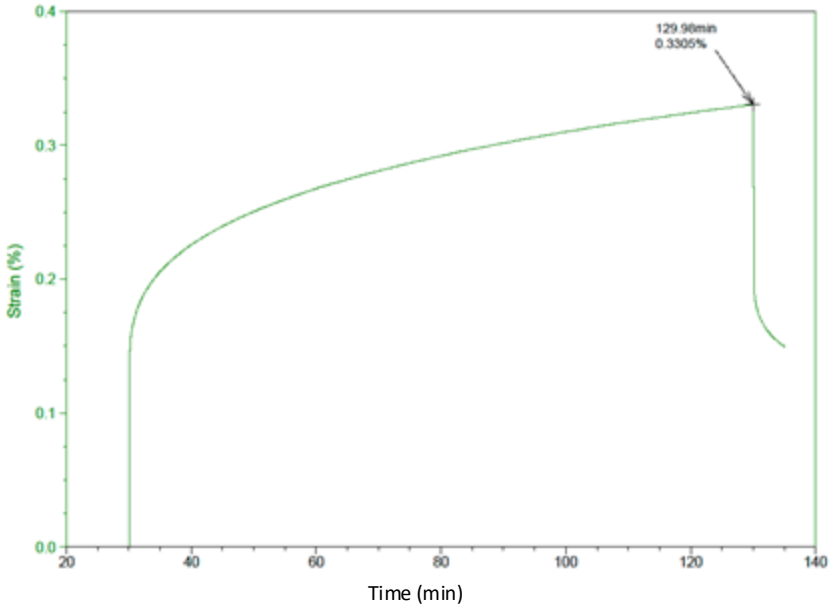
DMA Temperature Sweep

EPX 150 has excellent heat resistance, with a heat deflection temperature (0.455 MPa) greater than 150 °C (exact value depends on sample conditioning). Dynamic mechanical analysis was conducted using a TA Instrument DMA Q800 which indicated a glass transition temperature (Tg) of 175 °C. Representative curves for storage modulus, loss modulus and tan Delta are shown below.



Creep

EPX 150 has excellent heat resistance, with a heat deflection temperature (0.455 MPa) greater than 150 °C (exact value depends on sample conditioning). Creep performance (Strain%) under constant stress of 2.0 MPa at 125 °C was tested by using single cantilever mode on TA Instrument DMA Q800 at 125 °C. A representative creep curve is shown below.

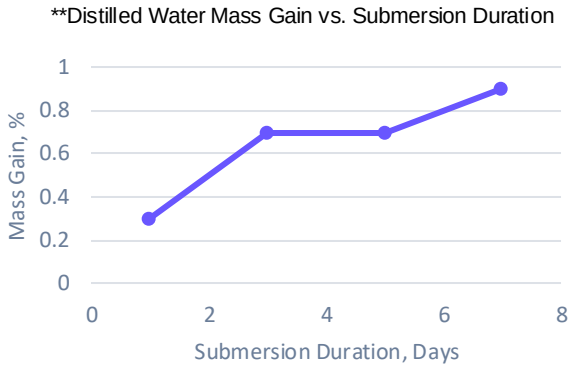


Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity unless otherwise noted.

EPX 150 Chemical Compatibility

ASTM D543

	Mass Gain* (%)
Household Chemicals	
Bleach (NaClO, 5%)	< 5%
Sanitizer (NH_4Cl, 10%)	< 5%
Distilled Water**	< 5%
Sunscreen (Banana Boat, SPF 50)	< 5%
Detergent (Tide, Original)	< 5%
Windex Powerized Formula	< 5%
Hydrogen Peroxide (30%)	< 5%
Ethanol (95%)	< 5%
Industrial Fluids	
Engine Oil (Havoline SAE 5W-30)	< 5%
Brake Fluid (Castrol DOT-4)	< 5%
Airplane Deicing Fluid (Type I Ethylene Glycol)	-
Airplane Deicing Fluid (Type I Propylene Glycol)	-
Airplane Deicing Fluid (Type IV Ethylene Glycol)	-
Airplane Deicing Fluid (Type IV Propylene Glycol)	-
Transmission Fluid (Havoline Synthetic ATF)	< 5%
Engine Coolant (Havoline XLC, 50%/50% premixed)	< 5%
Diesel (Chevron #2)	< 5%
Gasoline (Chevron #91)	-
Skydrol 500B-4	< 5%
Strong Acid/Alcohol/Base	
Sulfuric Acid (30%)	< 5%
Sodium Hydroxide (10%)	< 5%



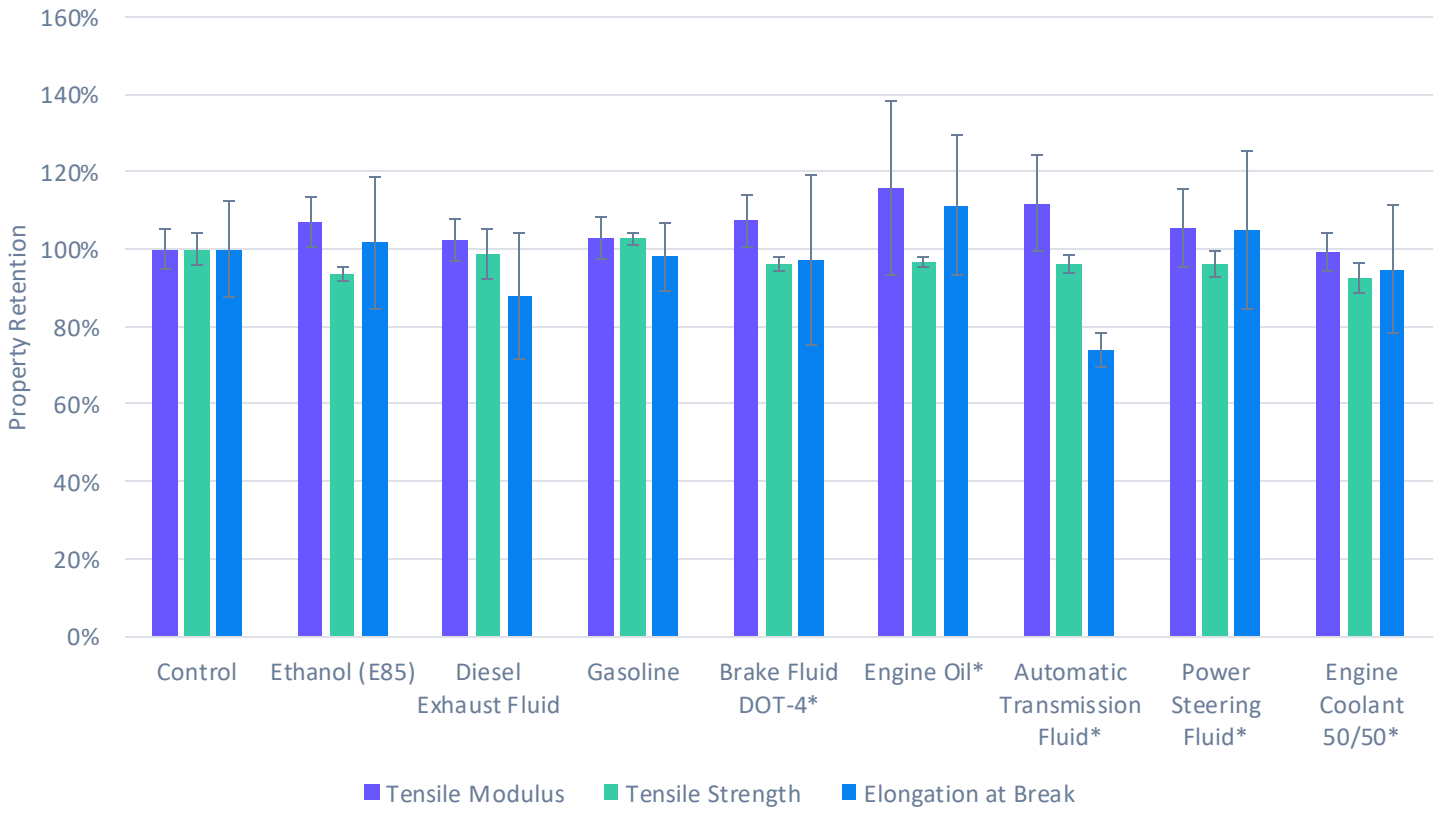
*Percent weight gained after 1 week submersion following ASTM D543. Values do not represent changes in dimension or mechanical properties.

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven.

EPX 150 Chemical Compatibility

USCAR2

Epoxies as a chemical family exhibit excellent chemical resistance. EPX 150 shows similar performance, showing no surface blemishes and minimal change in tensile properties after chemical exposure simulating splash contact per USCAR2 conditions. The tensile property retention after exposure to automotive fluids is shown in the graph below.



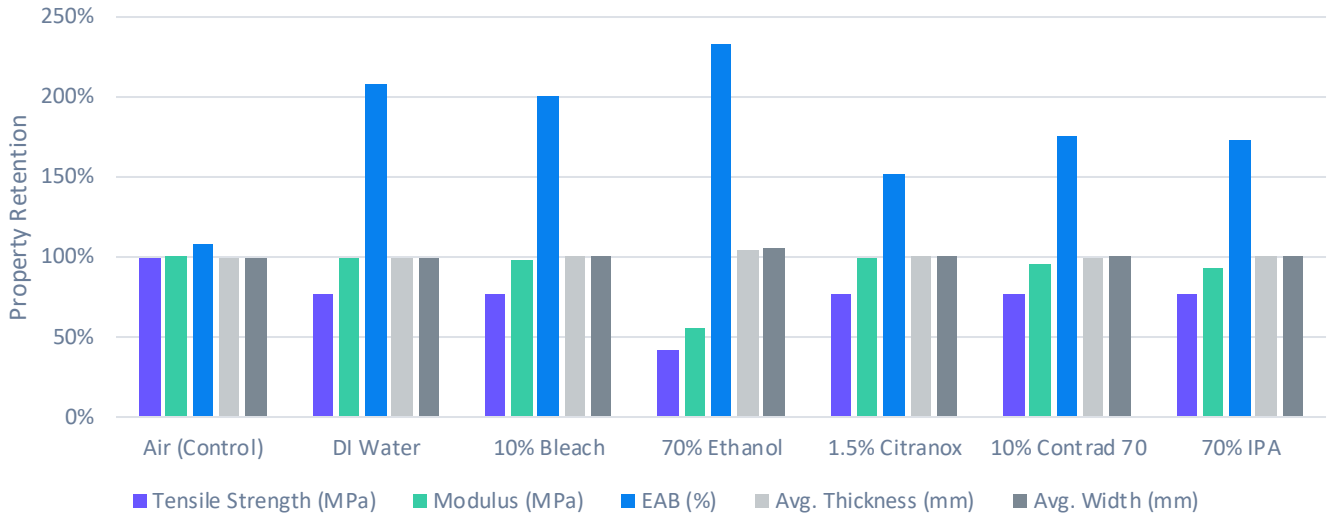
Treatment Method: Samples submerged in test liquid for 30 minutes at 23 °C or 50 °C (starred) then removed from test liquid and allowed to sit at ambient room temperature conditions for 1 week (samples were not wiped).
Test Method: ISO 527-2, Type IA, 5 mm/min

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven.

EPX 150 Chemical Compatibility

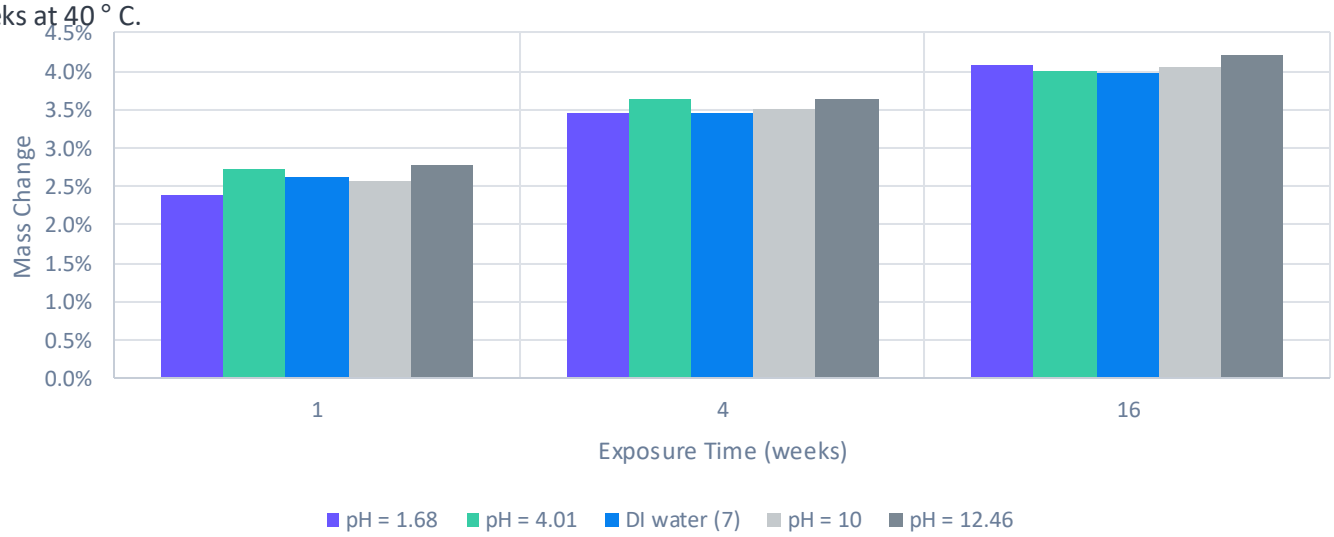
Disinfecting Solvents

For industrial and medical applications, EPX 150 is *compatible* with commonly used disinfecting chemicals and reagents showing no surface yellowing, no blemishes and with minimal change in tensile properties after chemical exposure to most of the solvents (except 70% ethanol/water when subjected to longer durations).



Treatment Method: Samples submerged in test liquid for 28 days at 23 °C then removed from test liquid and washed with DI water.
Test Method: ASTM D638, Type V, 1 mm/min

EPX 150 is compatible for long term use with chemical exposure to aqueous buffer solutions across wide range of pH (2-12) showing no chemical degradation, cracking or surface yellowing with all samples having a mass increase of < 5% after 16 weeks at 40 ° C.



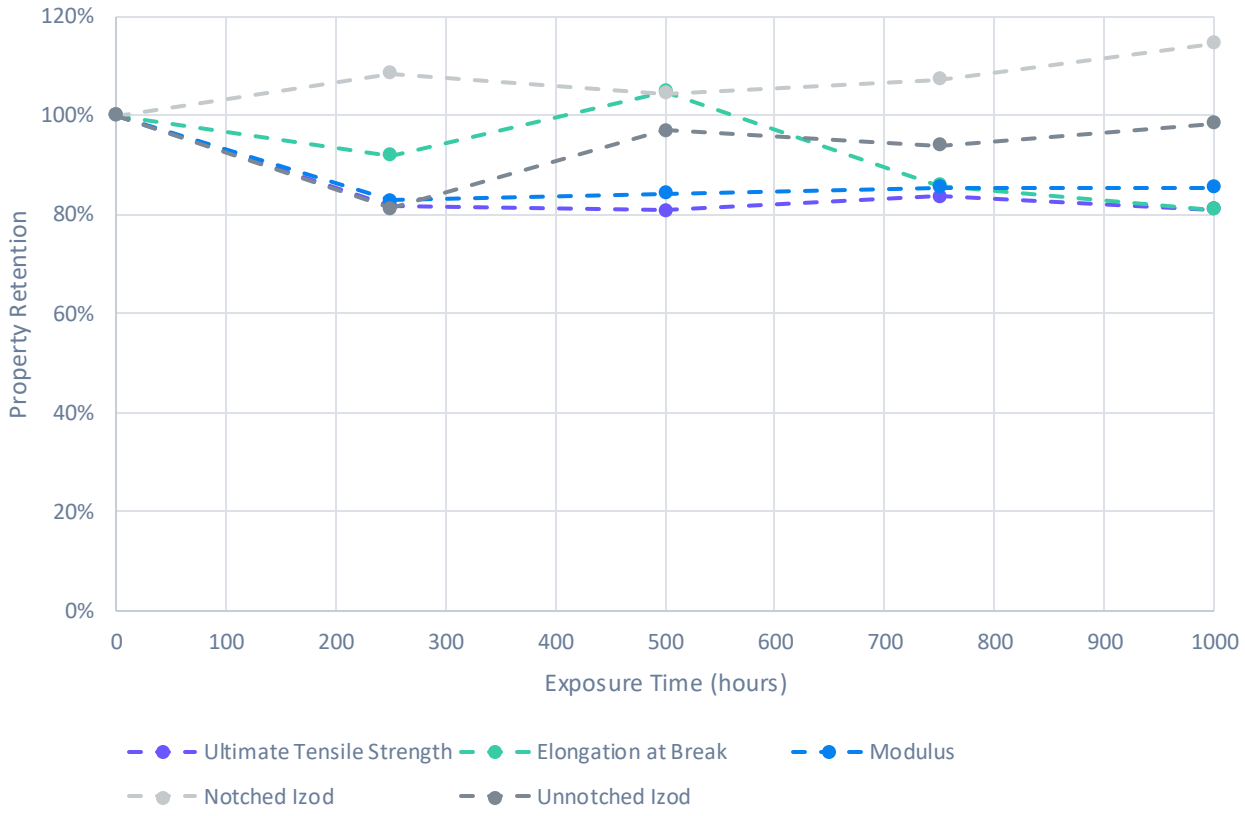
Treatment Method: 5 mm by 5 mm by 5 mm cube submerged in solutions at 40 ° C

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven.

EPX 150 Chemical Compatibility

Submersion in Water at 85 °C

EPX 150 demonstrates exceptional hygrothermal stability with no surface degradation, retains mechanical properties under extended exposure to water at 85 °C, with no significant drop in impact strength and >80% retention for elongation at break, modulus and ultimate tensile strength.



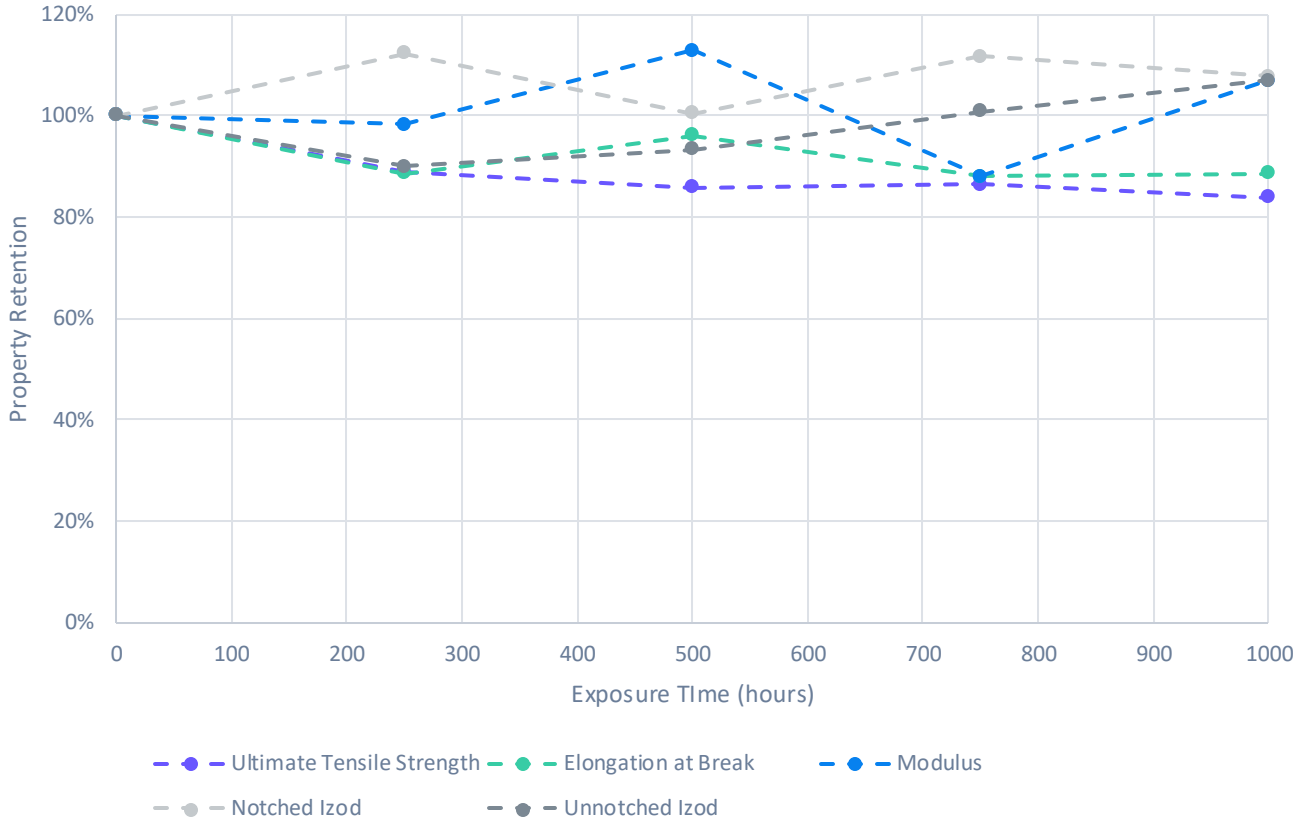
Test Method:
ASTM D648, Type V, 1 mm/min
ASTM D4812, unnotched Izod
ASTM D256, notched Izod (machine notched)

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity.

EPX 150 Chemical Compatibility

Submersion in Coolants / Antifreeze at 85 °C

EPX 150 demonstrates exceptional chemical resistance under extended exposure to coolants (water & glycol 50%/50% mixture) at 85 °C, with no significant drop in notched and unnotched Izod impact strength and >80% retention for elongation at break, modulus and ultimate tensile strength. EPX 150 is ideal for automotive/industrial production parts like nozzles, sensors, and actuators.



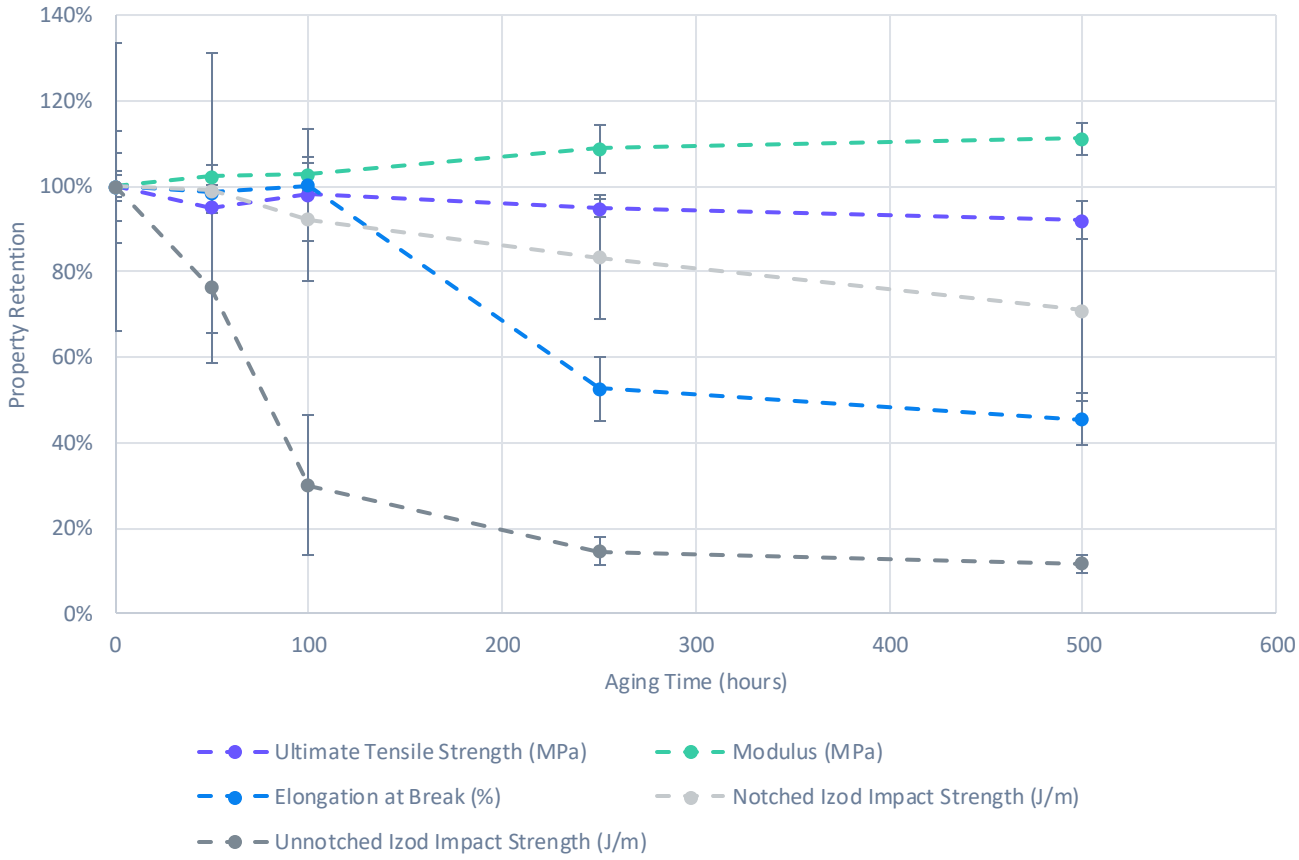
Test Method:
ASTM D638, Type V, 1 mm/min
ASTM D4812, unnotched Izod
ASTM D256, notched Izod (machine notched)

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity.

EPX 150 UV Aging Stability

ASTM D4459

Natural polymer aging can occur in the presence of light, sun, and heat. Carbon evaluated the UV aging performance of EPX 150 using ASTM D4459, which is intended to simulate indoor exposure of solar radiation through glass.



ASTM 4459: Q-Sun XE-1, 0.8 W/m^2/nm at 420 nm, 55°C

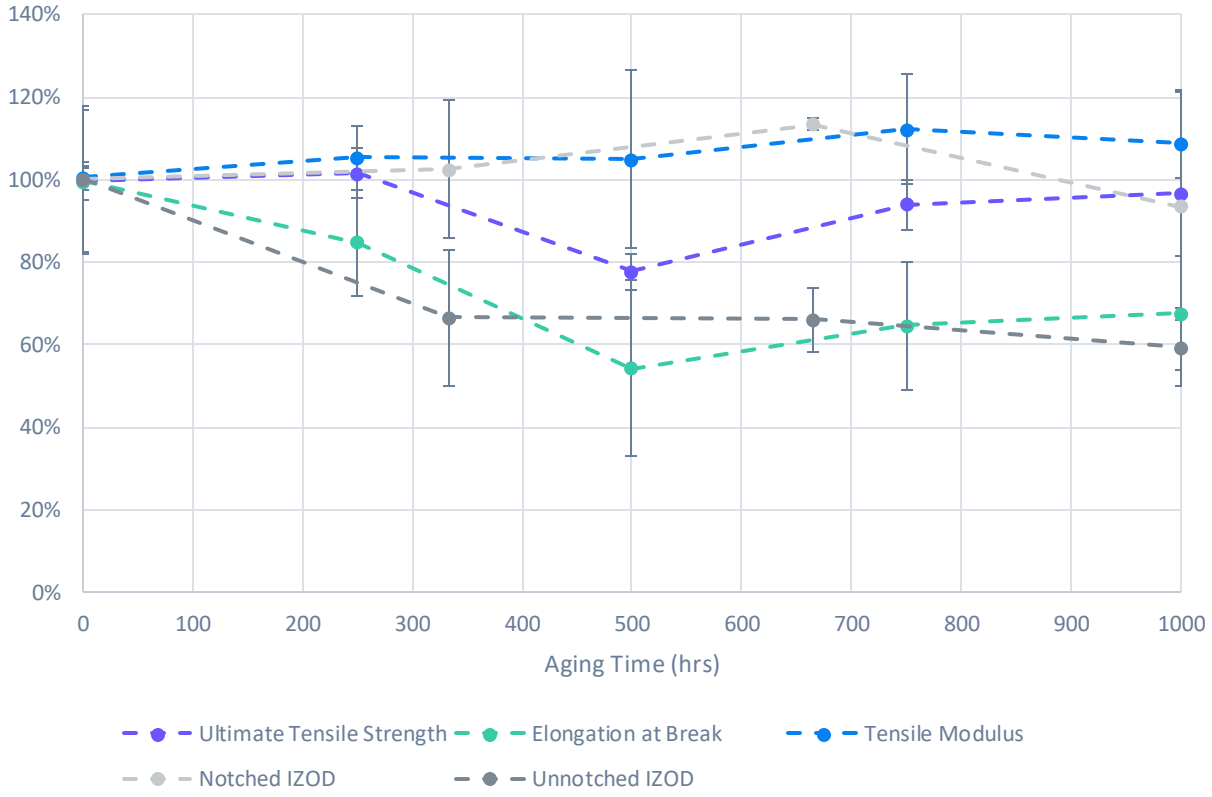
Test Method:
ASTM D638, Type V, 1 mm/min
ASTM D4812, unnotched Izod
ASTM D256, notched Izod (machine notched)

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity.

EPX 150 Thermal Stability

Thermal Aging to 1000 hours at 125 °C

Accelerated thermal aging of samples is used to evaluate materials performance for automotive applications in real world applications. EPX 150 inert bake tensile and impact samples were subjected to 125 °C heat aging for 1000 hours. The results indicate that samples retained mechanical performance with minimal change in tensile modulus, ultimate tensile strength (UTS), and notched impact after 1000 hours of heat aging at 125 °C. Due to some surface degradation , elongation at break and unnotched Izod impact values show a decrease in performance during heat aging while maintaining >60% retention after 1000 hours ensuring functional end use.



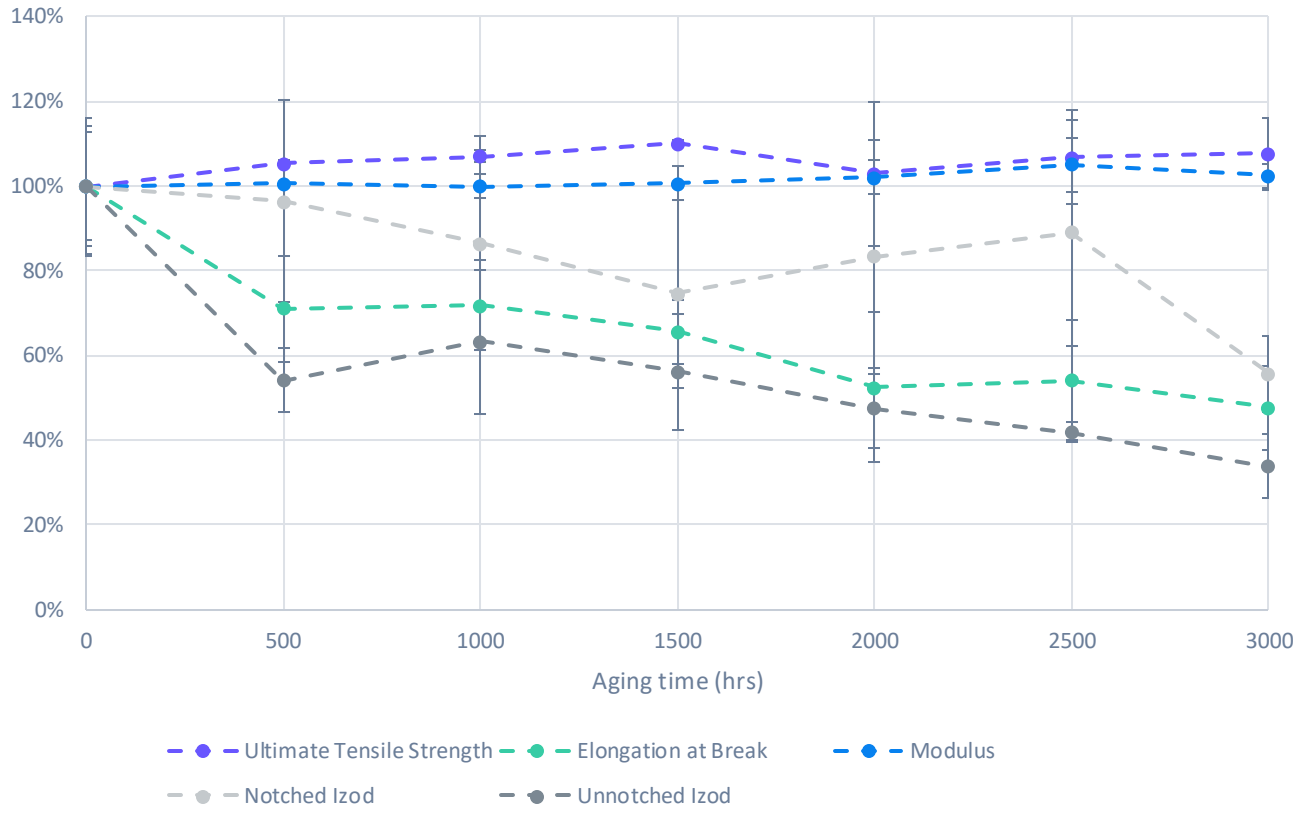
Test Method:
ISO 527-2, Type IA, 5 mm/min
ASTM D4812, unnotched Izod
ASTM D256, notched Izod (machine notched)

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity.

EPX 150 Extended Endurance

Thermal Aging to 3000 hours at 125 °C

EPX 150 was thermal aged at 125 °C for extended aging time up to 3000 hours. The retention of the properties is shown in the graph below. Ultimate tensile strength and modulus stayed unchanged after 3000 hours. Notched Izod retained above 50% while both unnotched Izod and elongation at break dropped to below 50% after 3000 hours.



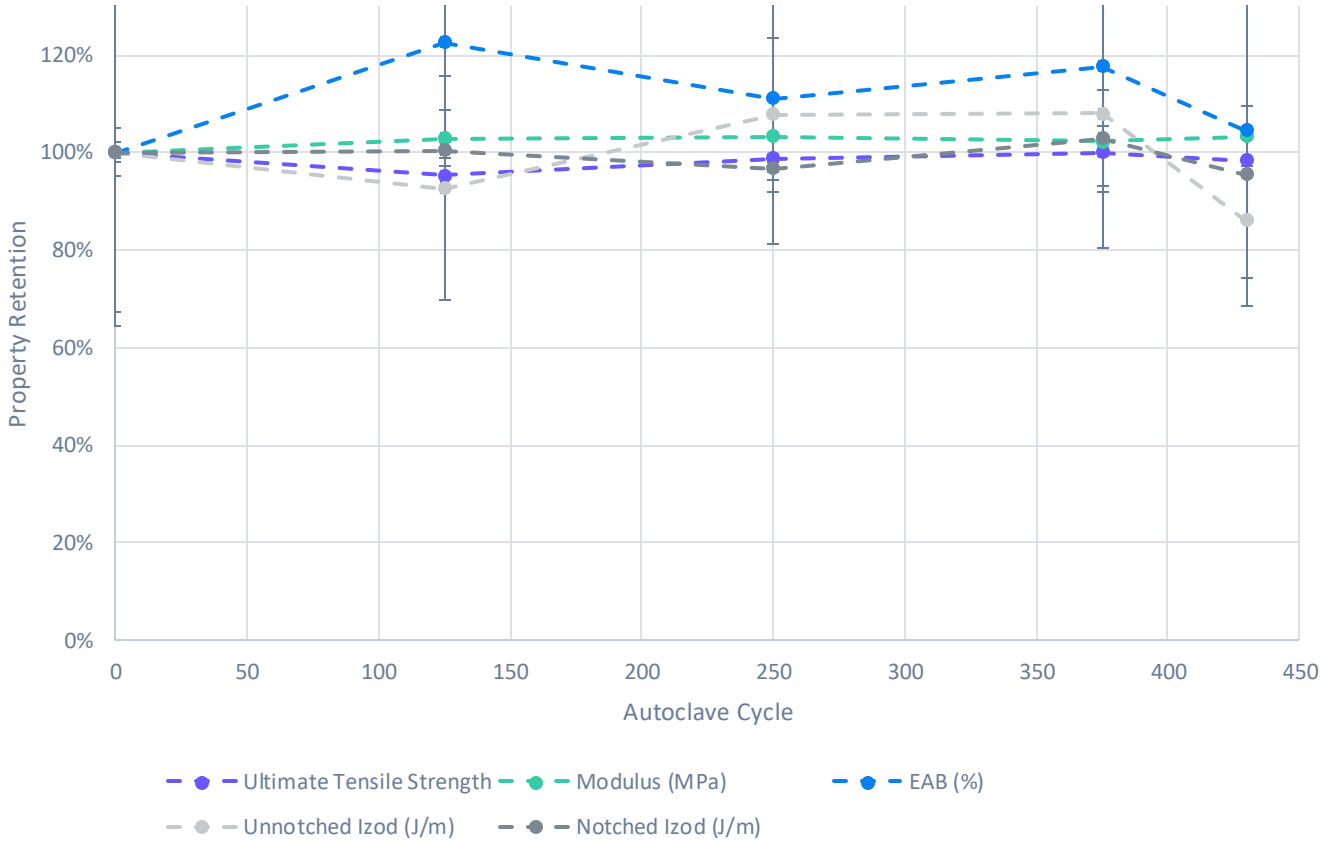
Test Method:
ASTM D638 Type V, 1 mm/min
ASTM D4812, unnotched Izod
ASTM D256, notched Izod (machine notched)

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity.

EPX 150 Extended Endurance

Autoclave Steam Sterilization

EPX 150 can be used for multi- use steam sterilization applications as it demonstrates exceptional stability after 430 cycles of autoclave (134 °C/4 min), showing no significant surface yellowing, blemishes or mechanical properties degradation. Biocompatibility results after autoclave is available on Page 22.



Each cycle consists of a 4 min sterilization at 134°C and 2 min drying time

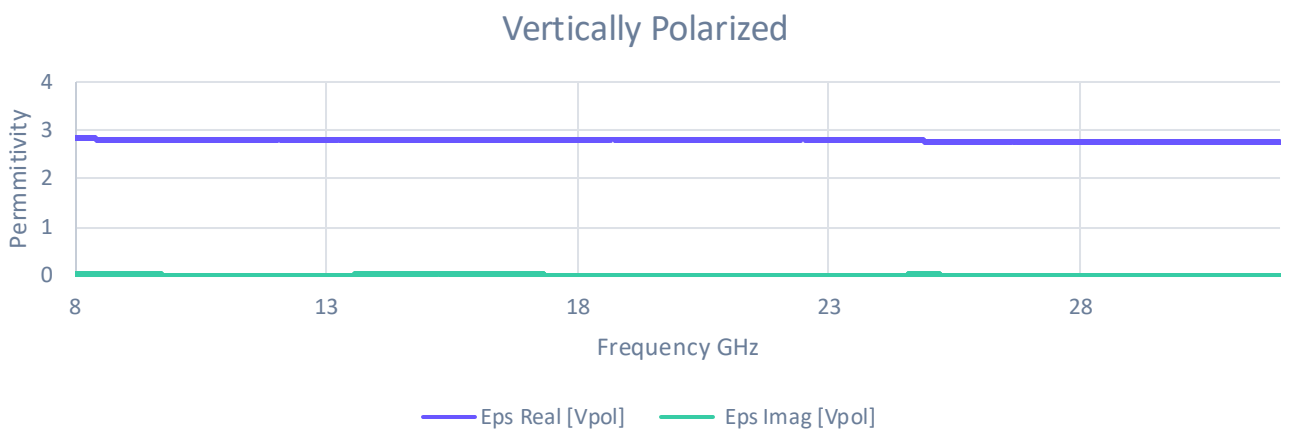
Test Method:
ASTM D638, Type V, 1 mm/min
ASTM D4812, unnotched Izod
ASTM D256, notched Izod (machine notched)

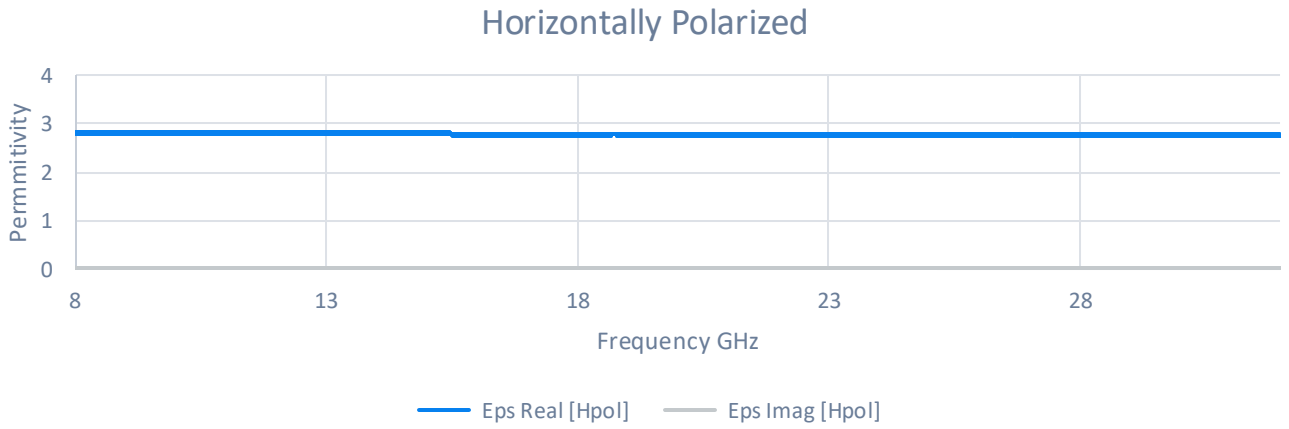
Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity.

EPX 150 Dielectric Properties

Complex Permittivity

Due to the inherent nature of dual cure chemistry used in EPX 150, the material in it's cured state exhibits low dielectric constant, is isotropic and has low loss tangent characteristic across 10-28 GHz which can enable use cases of EPX 150 for wireless communication devices, RF and radome applications.





Test Method:
CTG- TM-0100-2018

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity.

EPX 150 Emissions and Outgassing Performance

EPX 150 passes stringent odor, fogging, and emissions standards required for applications such as interior automotive parts and outer space.

Material Emissions and Outgassing			
	Test Method	**Results**	**General Target**
Odor	VDA 270	Grade: 1.5	< 4
Volatile Organics (VOC)	VDA 278	<1 ppm	< 100 ppm
Fogging	DIN 75201, Method B, Gravimetric	0.14 mg	< 2 mg
Semi-Volatile Organics (FOG)	VDA 278	<1 ppm	< 250 ppm
Total Mass Loss (TML)	ASTM E595-15 (2021) Outgassing (%)	0.96	1.00 MAX
Collected Volatile Condensable Materials (CVCM)	ASTM E595-15 (2021) Outgassing (%)	0.05	0.10 MAX
Water Vapor Regained (WVR)	ASTM E595-15 (2021) Outgassing (%)	0.51	REPORT

Parts were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 in a nitrogen oven. Properties were measured after 1 week conditioning at 23 °C and 50% relative humidity.

EPX 150 Biocompatibility

E-beam Sterilization, Ethylene Oxide Sterilization, and Cytotoxicity

EPX 150 is a great material of choice for a wide range of applications for single and multiple use medical devices. It's compatible with multiple sterilization techniques - Ethylene Oxide (EtO), E-beam and is autoclavable up to 400+ cycles. The material doesn't show any significant changes in mechanical properties pre and post sterilization including no surface cracking or degradation.

E-beam Sterilization

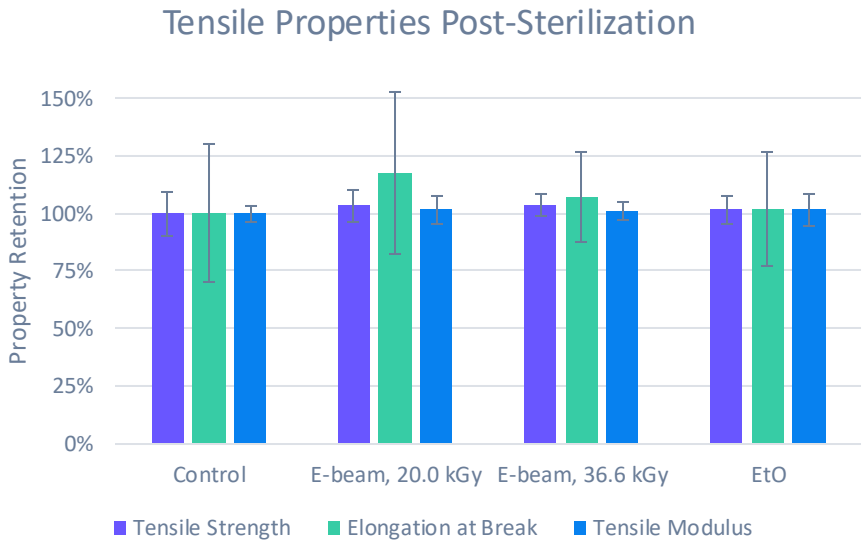
Carbon provided test specimens to E-BEAM Services for material exposure to two electron beam dose levels, 20.0 and 36.6 kGy. [add additional test info]

EPX 150 is compatible with EtO sterilization, exhibiting little change in tensile properties, impact strength, and Tg for both dose levels. Post-sterilization, the 36.6 kGy dosed samples were provided to NAMSA to test for cytotoxicity per ISO 10993-5, *Biological evaluation of medical devices – Part 5: Tests for in vitro cytotoxicity*. The results show that there is no observed cytotoxicity post-sterilization.

Ethylene Oxide (EtO) Sterilization

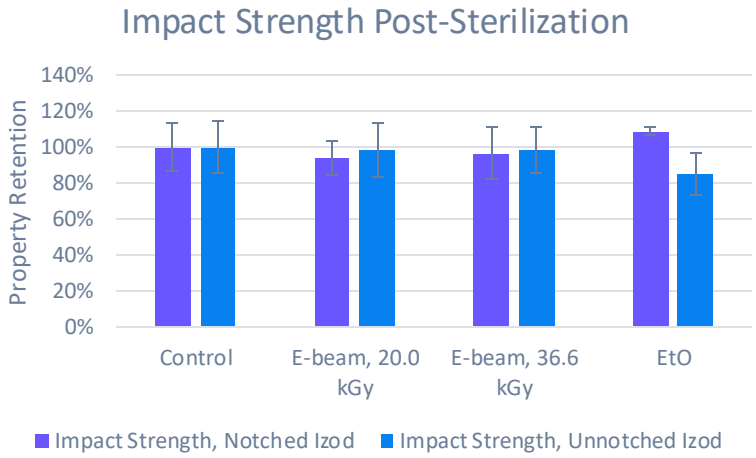
Carbon provided test specimens to Nelson Laboratories for EtO exposure and extraction studies. The specimens were conditioned at 52 °C, 55% relative humidity, and 1.3 psi for 60 minutes. The samples were then exposed to 100% EtO at 52 °C for 240 minutes. The samples were allowed to aerate for 37.9 hours.

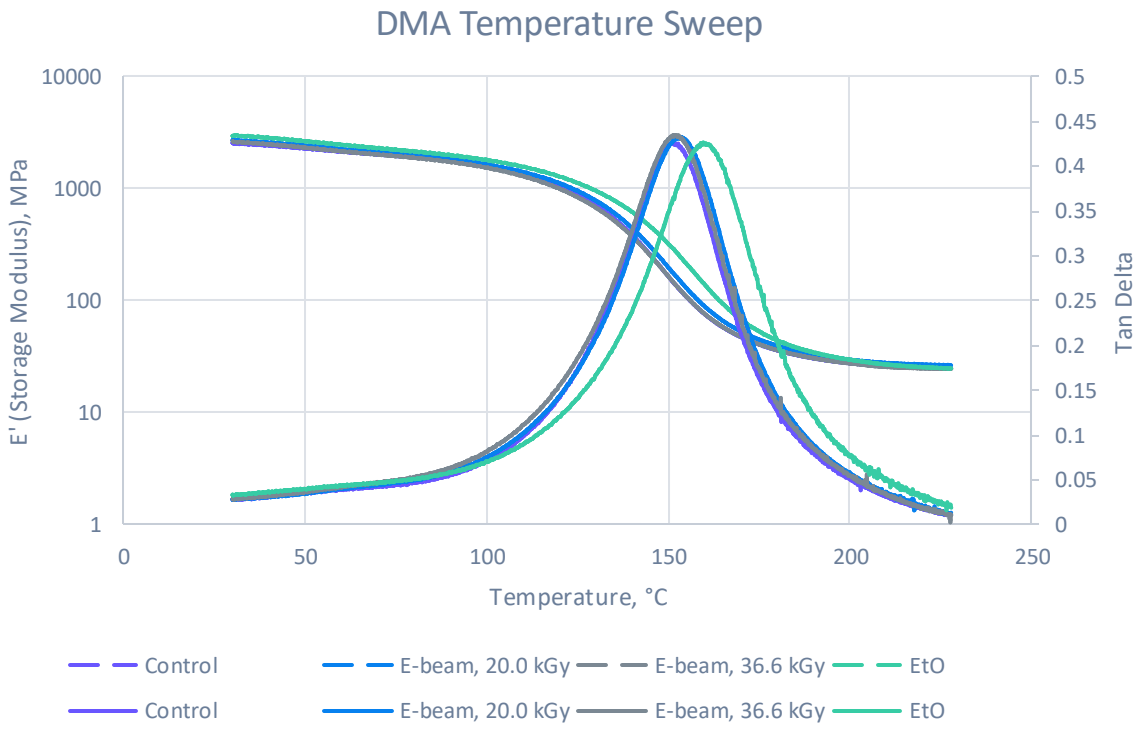
EPX 150 is compatible with EtO sterilization, exhibiting little change in tensile properties, < 15% change in impact strength, and slight shift in Tg. Post-sterilization, the samples were tested for cytotoxicity per ISO 10993-5, *Biological evaluation of medical devices – Part 5: Tests for in vitro cytotoxicity*. The results show that there is no observed cytotoxicity post-sterilization.



EPX 150 Biocompatibility

E-beam Sterilization, Ethylene Oxide Sterilization, and Cytotoxicity





EPX 150 Biocompatibility

Biocompatibility Testing

Test articles in the form of printed parts were provided to NAMSA or Nelson Laboratory for evaluation and met the requirements of each of the following tests:

Biocompatibility Testing*	Test Standard
Cytotoxicity	ISO 10993-5, Biological evaluation of medical devices – Part 5: Tests for *in vitro* cytotoxicity (MEM extract)
Cytotoxicity (after autoclave**)	ISO 10993-5, Biological evaluation of medical devices – Part 5: Tests for *in vitro* cytotoxicity (MEM extract)
Cytotoxicity (after E-beam sterilization at 36.6 kGy dose)	ISO 10993-5, Biological evaluation of medical devices – Part 5: Tests for *in vitro* cytotoxicity (MEM extract)
Cytotoxicity (after EtO sterilization)	ISO 10993-5, Biological evaluation of medical devices – Part 5: Tests for *in vitro* cytotoxicity (MEM extract)
Sensitization	ISO 10993-10: Biological evaluation of medical devices – Part 10: Tests for skin sensitization (Closed patch sensitization study in guinea pigs)
Irritation	ISO 10993-23: Biological evaluation of medical devices – Part 23: Tests for irritation (Intracutaneous study in rabbits)
Hemolysis	ASTM F756: Standard Practice for Assessment of Hemolytic Properties of Materials ISO 10993-4: Biological evaluation of medical devices - Part 4: Selection of tests for interactions with blood
Acute Systemic Toxicity	ISO 10993-11: Biological evaluation of medical devices - Part 11: Tests for systemic toxicity

*Test articles were processed using an M series printer and a Smart Part Washer with DPM as the solvent followed by isopropanol dunk. The washed test articles were baked following the standard baking schedule for EPX 150 (see below) in an inert oven. Additional details about the tests are available upon request.

Baking schedule: Ramp from room temperature to 220 °C at 0.5 °C/min, hold at 220 °C for 1 hour.

**Cytotoxicity (ISO 10993-5) was also conducted on EPX 150 printed parts that went through 430 autoclave sterilization cycles (Each cycle consists of a 4 min sterilization at 134 °C and 2 min drying time).

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