

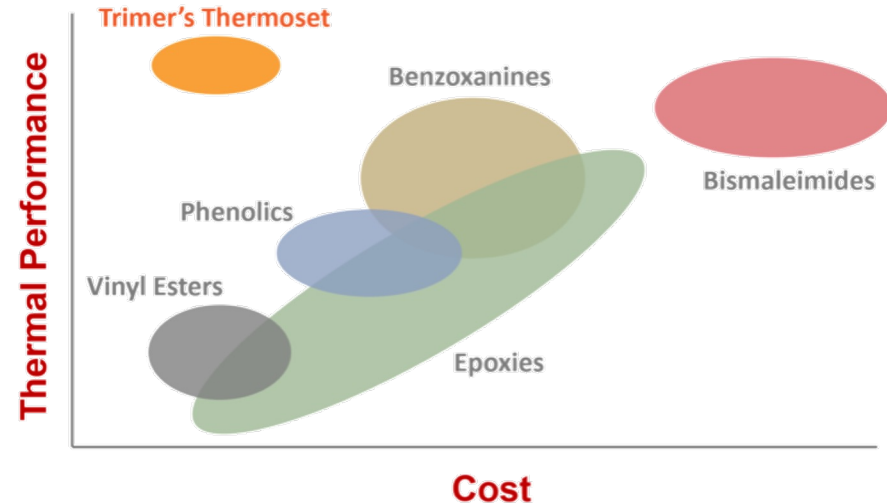
# SNAP CURE RESIN FOR HIGH RATE FST RATED AUTOMOTIVE COMPOSITES

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President / CEO  
Trimer Technologies, LLC



# Advanced Resin Technology

- Trimer has developed low-cost high strength polymers which can enable reduced cycle times
- Polymer exhibits:
  - Low viscosity for rapid infusion
  - Rapid Cure - as fast as 30 sec at 140°C
  - High strength, stiffness and toughness
  - Non-flammable
  - High glass transition temperature >400°C



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# Resin Performance Comparison

- Trimer has developed low cost, low viscosity and high strength polymers which outperform competing resins while enabling reduced cycle times

Material Property	Trimer Technologies' RTM Resin	Dow Voraforce 5300	Huntsman Araldite LY 3585 / Aradur 3475	AOC VIPEL FO10 BIS-A VE	Reichhold DION IMPACT 9102-75
Polymer Type/Chemistry	-	Epoxy	Epoxy	Vinyl Ester	Vinyl Ester
Glass Transition, T <sub>g</sub> Dry °C	225	120	110	130	99
Tensile Strength (MPa)	105	68	77.5	88	79.2
Tensile Modulus (GPa)	4.0	2.8	2.8	3.2	2.9
Tensile Strain to Failure, %	4.0	7	9	6.2	4.5
Compressive Strength (MPa)	149	-	-	121	108.9
Flexural Strength (MPa)	140	-	-	153	144
Fracture Toughness, K <sub>1C</sub> (MPa/m <sup>1/2</sup> )	1.03	1.22	0.85	0.6	-
Viscosity (cP at 23 °C)	200	500	1,000	3,200	170

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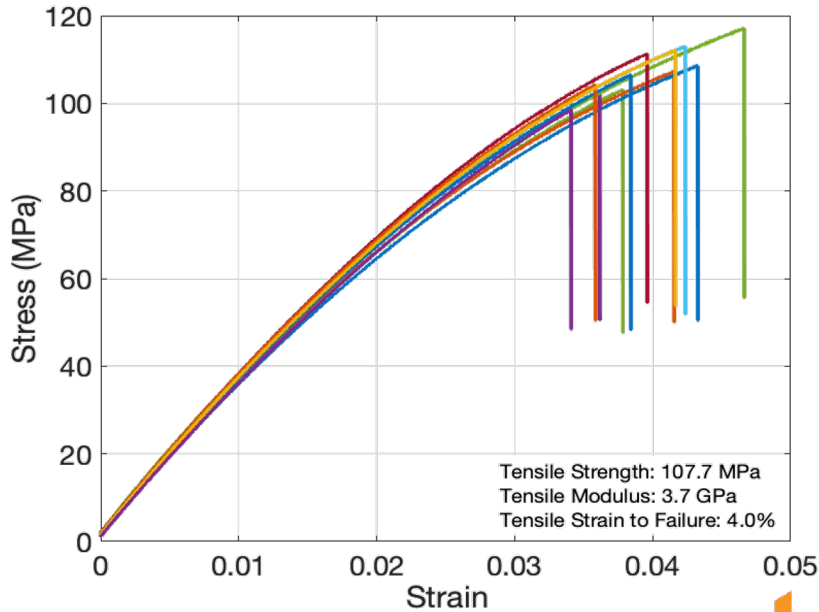
# Resin Performance Comparison

- Trimer's resin outperforms competing 350° F autoclave cured resins while enabling reduced cycle times

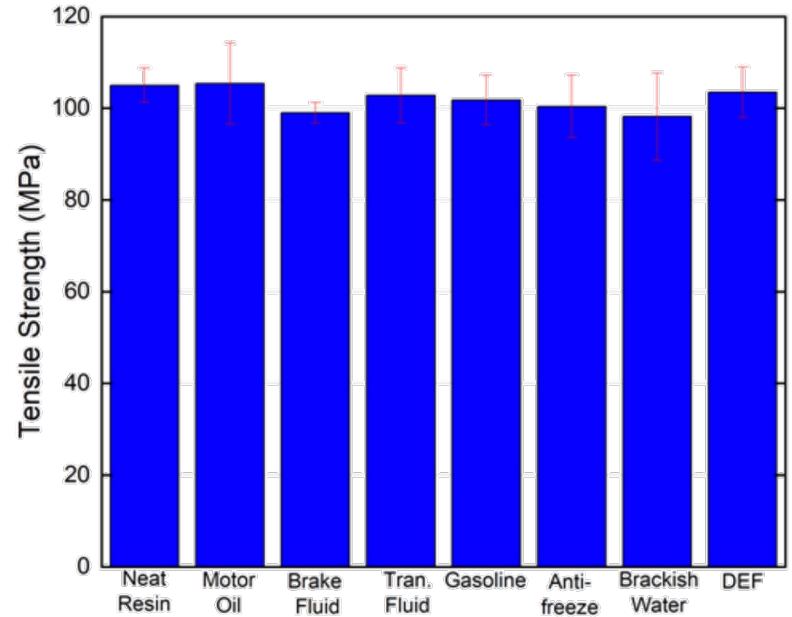
Material Property	Trimer's Resin	Hexcel 8552	Hexcel M74	Hexcel 3501-6	Cytec 5250 BMI	Hexcel F650 BMI	Cytec 2237
Polymer Type/Chemistry	-	Epoxy	Epoxy	Epoxy	BMI	BMI	Polyimide
Glass Transition, Tg Dry °C	225	200	194	210	271	316	338
Tensile Strength (MPa)	105	120	83	45.5	103	-	38.6
Tensile Modulus (GPa)	4.0	4.6	4.1	4.2	4.6	-	3.9
Tensile Strain to Failure, %	4.0	1.7	-	1.15	4.8	-	1.5
Fracture Toughness, K <sub>1C</sub> (MPa/m <sup>1/2</sup> )	1.03	1.34	-	0.67	0.85	0.46	0.33
Flexural Strength (MPa)	140	-	69	-	163	-	-
Compressive Strength (MPa)	149	-	-	-	-	-	-
H <sub>2</sub> O Equilibrium Absorption	2.5%	3.1%	-	3.1%	4.2%	4.3%	4.4%
Cure Schedule	<60 sec at 250 °F	1h at 250°F then 2h at 350°F	2h at 350°F	1h at 240°F then 2h at 350°F	6h at 375°F then 6h at 440°F	4h at 350°F then 8h at 450°F	3.5h at 425°F then 475 °F for 1h then 600 °F for 3.5h

# Resin Properties

- Resin exhibits aerospace grade properties and high strain to failure



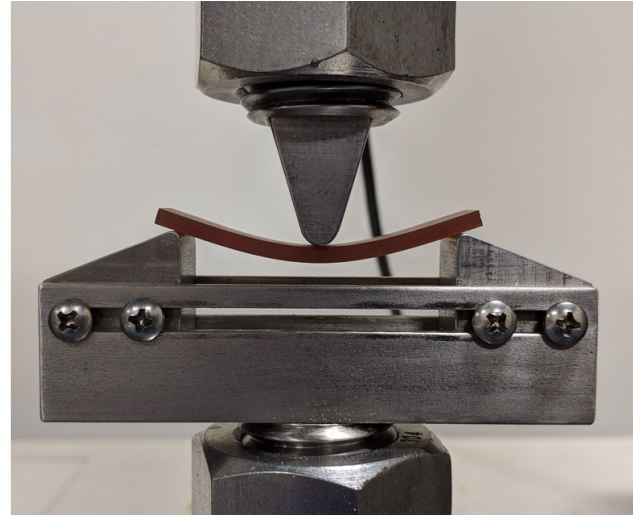
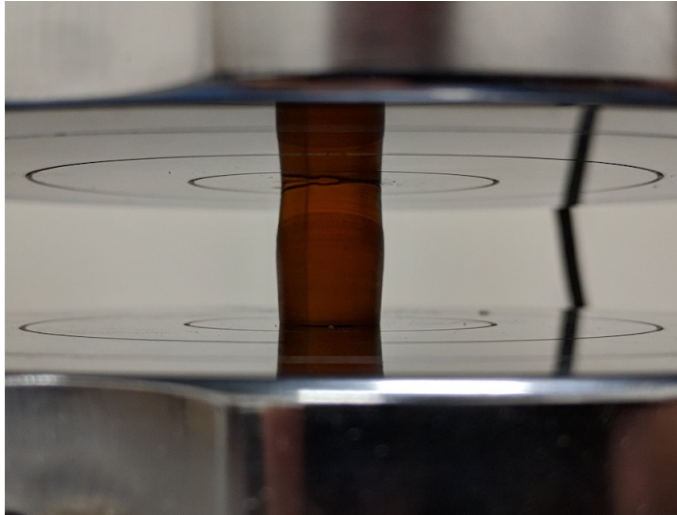
- Common automotive fluids show no impact on resin properties



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# High Strength and Strain to Failure

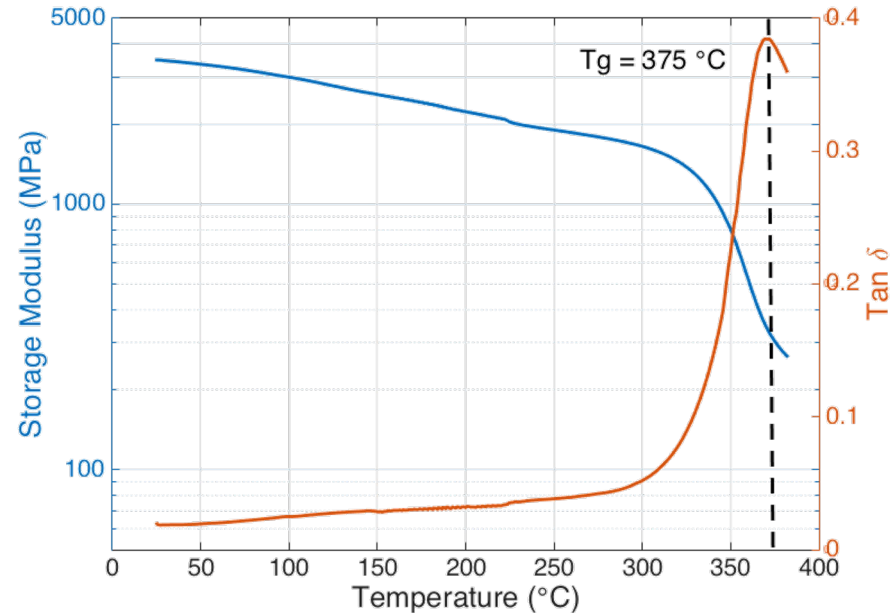
- High flexural strength and compressive strength with high strain to failure
  - Compressive strain to failure ~9%
  - Flexural strain to failure ~5%



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# Thermally Stable Composites

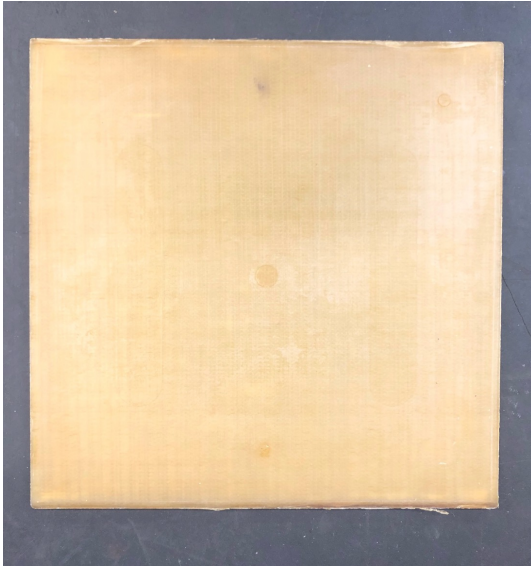
- Dynamic mechanical analysis (DMA) used to evaluate the glass transition temperature of the polymer
- Polymers exhibit high glass transition temperature of 707° F ( $T_g = 375^\circ \text{C}$ )
- Storage modulus  $\sim 2.5 \text{ GPa}$  at  $300^\circ \text{C}$
- $T_g$  in the range of polyimides yet cure schedule enables low-cost manufacturing
- Trimer has developed a technology which decouples the glass transition temperature from the cure temperature



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# Liquid Compression Molding

- Trimer has used liquid compression molding to demonstrate rapid molding of composites
- Cure monitoring used to study the polymerization and optimize the cycle time

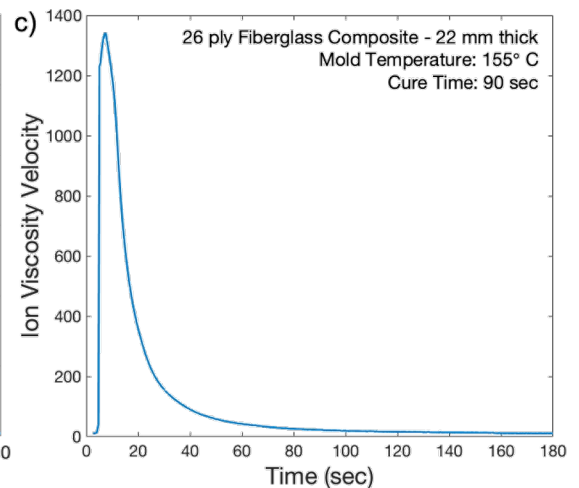
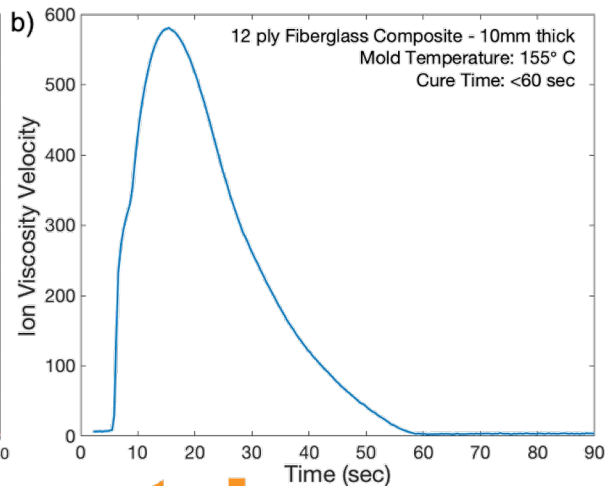
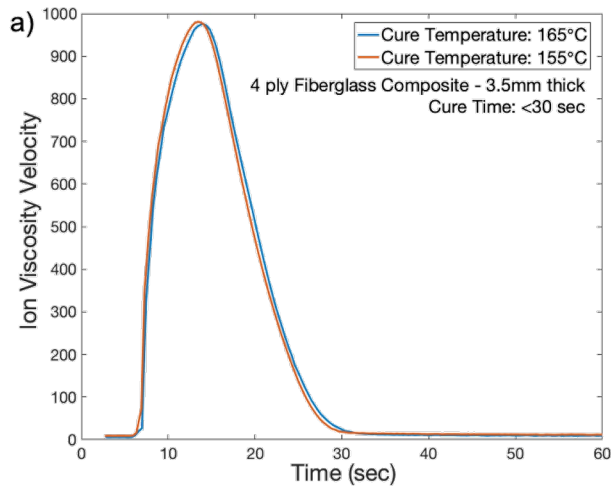


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# Low Cycle Time Composites

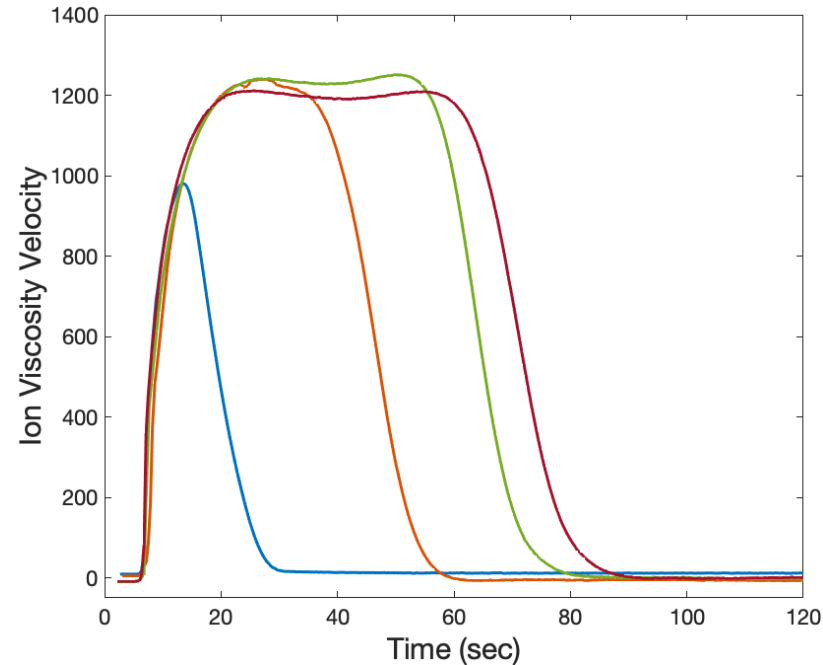
- Trimer demonstrated 3.5 mm thick composites could be cured in ~25 seconds with a 30 second cycle time
- 10mm thick composites were cured in under 60sec and 22mm thick composites were cured in under 120 sec with an unheated resin



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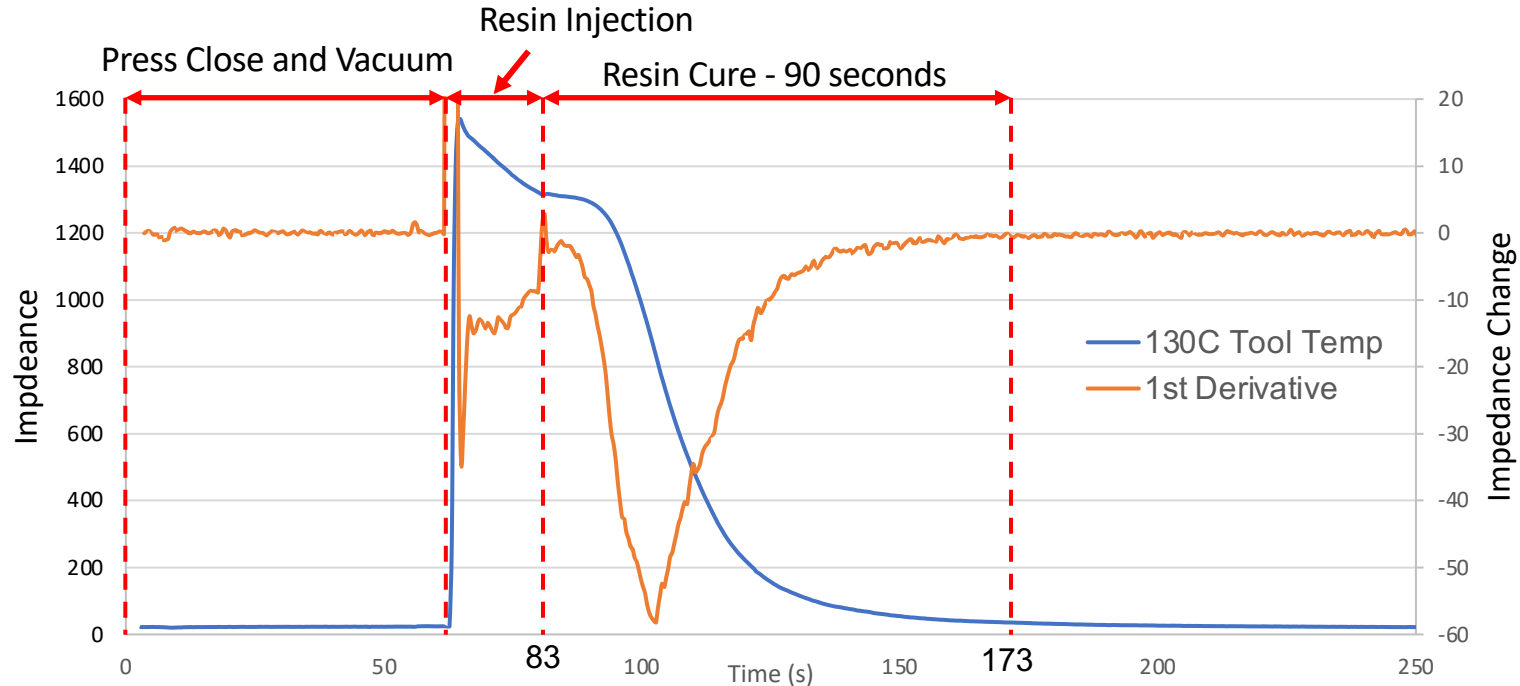
# Cure Kinetics

- Trimer wet compression molded 3.5 mm thick fiberglass panels in 30 seconds
- Full cycle time of 30 sec. which exceeds DOE 2050 goal for automotive composites of <1 minute
- Many currently used molding tools are designed for slower curing resins where low cycle time may lead to polymerization prior to full infusion of the resin
- Trimer has developed the chemistry to enable the cure rate to be tailored for a particular application
- Increased the cure time of a 3.5mm panel from 30 sec to 90 sec



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# RTM processing of 28 mm Thick Composite

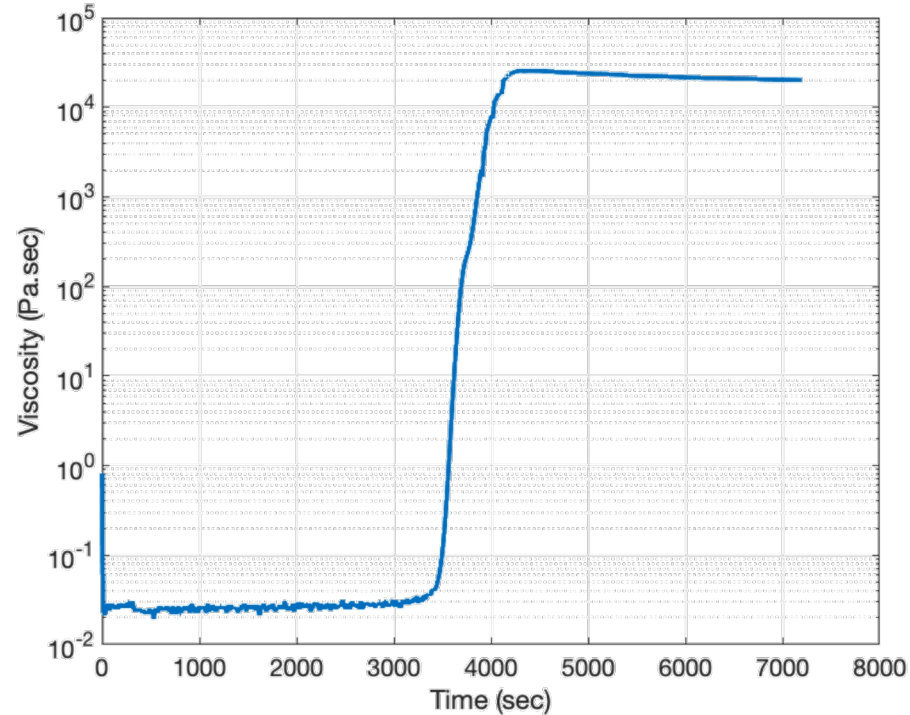


Demolding at between a 200-250s cycle time should be feasible (120-150s resin cure time)  
Minimal change in material impedance or rate of change during this time frame



# Long Working Life Resins

- Trimer was challenged to design the resin with sufficient latency to allow hot infusion of a wing
- Requested at least 30 min at cure temperature followed by snap cure
- Trimer created resin system with 1 hour gel time at 85C followed by a snap cure
- Trimer can provide resins with ambient gel times exceeded 16 hours



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# High Rate Pultrusion

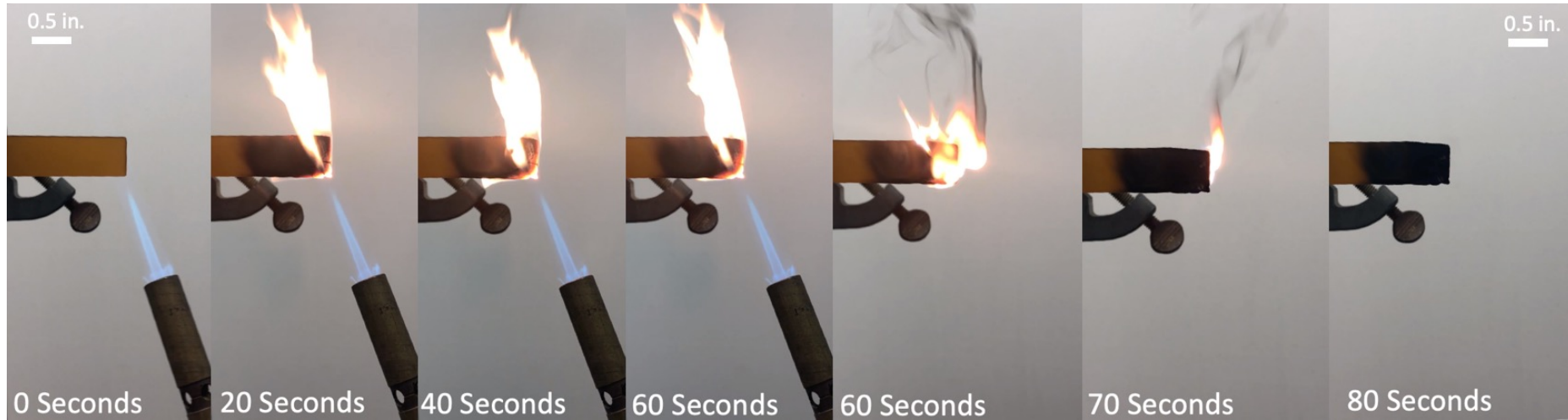
- Trimer has used both direct die injection and resin bath techniques
- Demonstrated the ability to run continuously at over 120 in/min
- High thermal stability and allows pultrusion with a higher die temperature profile
- Die typically run at 390° F although die temperature can be varied greatly



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# Fire Resistant Polymers

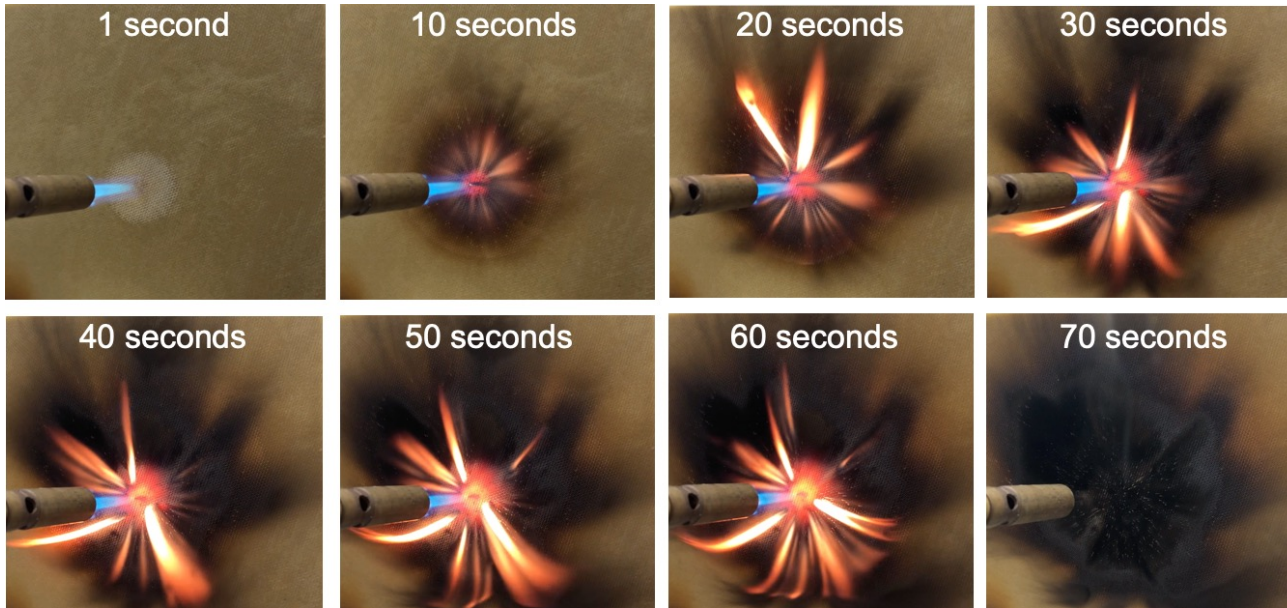
- Trimer tested the neat polymer for horizontal flame spread (ASTM D635) and passed the horizontal burning test after 30 sec exposure to flame
- To further demonstrate the polymer's nonflammable properties the polymer was subjected to a 60 second burn time under more intense flux than the ASTM



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# Fire Resistant Polymers

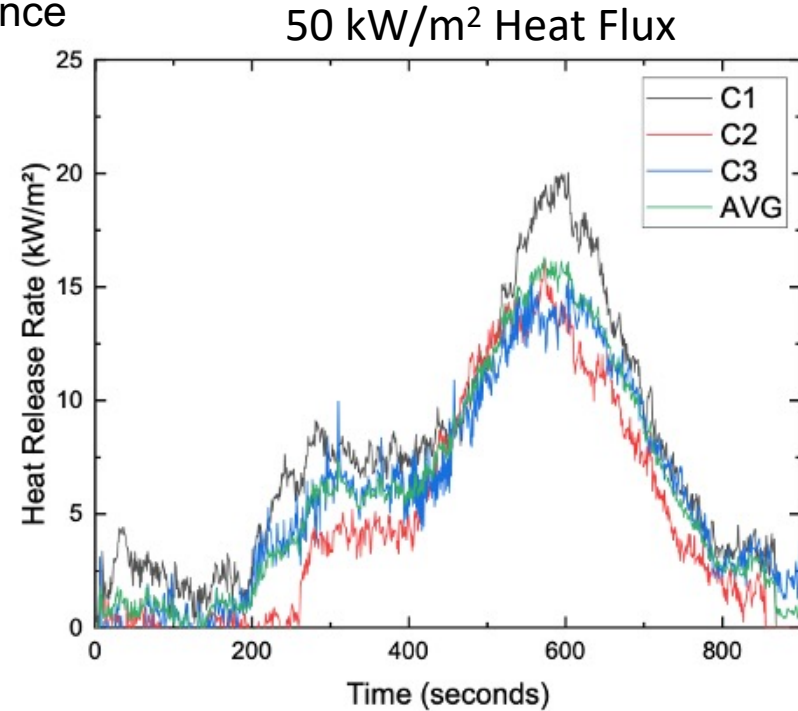
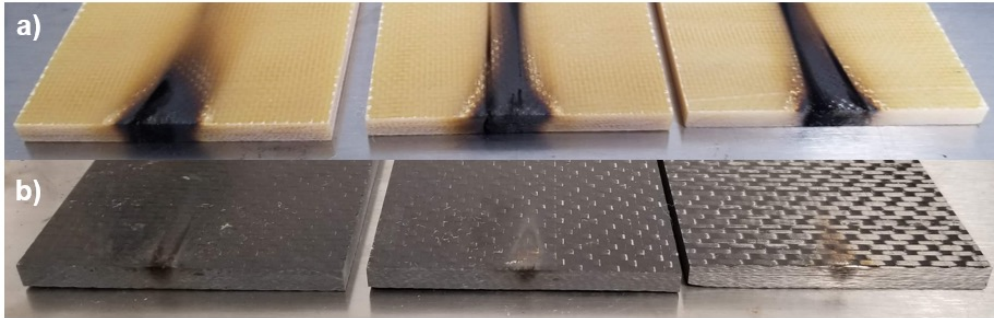
- Fiberglass reinforced composite panel (3mm thick) exposed to propane torch for 60 sec then allowed to self extinguish



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# Fire Resistant Polymers

- Fiberglass panels tested at UDRI and SGS in accordance with ASTM E-1354/ISO 5660
- Cone calorimeter with 50 kW/m<sup>2</sup>
- Results showed a peak heat release rate of 17 kW/m<sup>2</sup>
- Time to ignition was measured at 155 sec.
- Average heat release rate was 17 kW/m<sup>2</sup>
- Aeroblaze Laboratory tested vertical flame spread according to ASTM D3801



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# OSU Heat Release Testing

- Trimer has worked to demonstrate fire resistance for transportation applications
- Trimer's resin systems can greatly exceed FAR 25.853 for Aircraft Interiors
- Resin provides very low heat release with a low smoke density while providing high strength and stiffness

TEST REQUIREMENTS (MAXIMUM AVERAGE)				TOTAL (2 MINUTE) HEAT RELEASE	MAXIMUM (PEAK) HEAT RELEASE
Per Title 14 CFR/JAR/CS Part 25 Appendix F Part IV (g) [Amdt. 25-66] & ABD0031 (issue G, June 2014)				65 kW Min./m <sup>2</sup>	65 kW/m <sup>2</sup>
Sample	Total	Peak	Time	Comments	
1	11.9	21.4	62	MELTING: NONE SAGGING: NONE DELAMINATION: NONE OTHER OBSERVATIONS: NONE OTHER COMMENTS: NONE	
2	21.4	32.3	158	MELTING: NONE SAGGING: NONE DELAMINATION: NONE OTHER OBSERVATIONS: NONE OTHER COMMENTS: NONE	
3	15.3	31.6	135	MELTING: NONE SAGGING: NONE DELAMINATION: NONE OTHER OBSERVATIONS: NONE OTHER COMMENTS: NONE	
Average	16.2	28.4	118		
Pass/Fail	PASS	PASS			

TEST REQUIREMENTS (MAXIMUM AVERAGE)			MAXIMUM (PEAK) SMOKE DENSITY
Per Title 14 CFR/JAR/CS Part 25 Appendix F Part V (b) [Amdt. 25-66] & ABD0031 (issue G, August 2014)			200 Ds
Sample	Maximum Smoke Ds	Time	Comments
1	4.8	235	MELTING: NONE SAGGING: NONE DELAMINATION: NONE OTHER OBSERVATIONS: NONE OTHER COMMENTS: NONE
2	3.9	236	MELTING: NONE SAGGING: NONE DELAMINATION: NONE OTHER OBSERVATIONS: NONE OTHER COMMENTS: NONE
3	6.0	240	MELTING: NONE SAGGING: NONE DELAMINATION: NONE OTHER OBSERVATIONS: NONE OTHER COMMENTS: NONE
Average	4.9	237	
Pass/Fail	PASS		



# Smoke Density

- Trimer's resin generates very low smoke density
- Meets ASTM E662 for smoke density without intumescent coating
- Have received an ASTM E84 Class A rating with a FSI of 15 and SDI of 250
- E84 testing of panel with Technofire intumescent veil showed equivalent FSI but nearly double SDI

Specimen	Flaming Mode		Non-Flaming Mode	
	90 Second Maximum Specific Optical Smoke Density	4 Minute Maximum Specific Optical Smoke Density	90 Second Maximum Specific Optical Smoke Density	4 Minute Maximum Specific Optical Smoke Density
A	0	17.0	0	0
B	0	5	0	0



# SMP 800 Testing

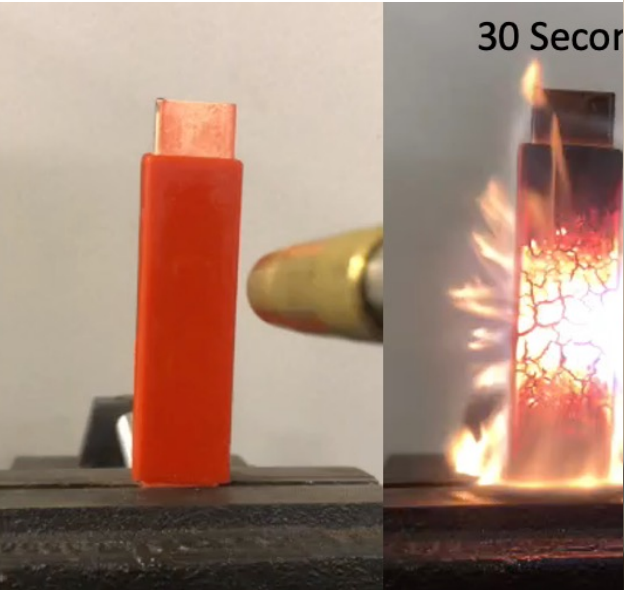
- Trimer's resin is non-halogenated
- Minimizes toxic fumes during combustion processes
- Resin system is well suited for aircraft interiors and mass transit applications

Results:	Toxic Gas Generation		Specified Maximum
	Flaming Mode	Non-Flaming Mode	
Carbon Monoxide (CO ppm)			
At 1.5 Minutes	LT 1	LT 1	-
At 4.0 Minutes	17	LT 1	-
At Maximum	398	LT 1	3500
Carbon Dioxide (CO2 ppm)			
At 1.5 Minutes	114	LT 10	-
At 4.0 Minutes	1,033	LT 10	-
At Maximum	10,952	804	90,000
Nitrogen Oxides (as NO@ ppm)	LT 1	22	100
Sulfur Dioxide (SO2 ppm)	LT 1	LT 1	100
Hydrogen Chloride (HCL ppm)	20	12	500
Hydrogen Bromide (HBr ppm)	LT 1	LT1	100
Hydrogen Fluoride (HF ppm)	LT 2	LT2	100
Hydrogen Cyanide (HCN ppm)	15	1	100



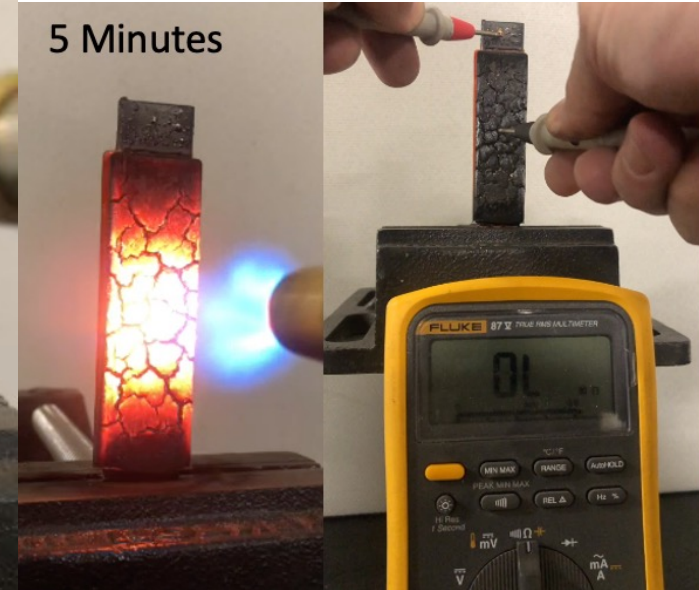
# Fire Resistant

- Have demonstrated pi fire and maintain isula



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# Composite Properties

- Trimer to perform testing of composite for MAT261 card with pultrusion resins
- Testing performed on Crestapol 1250, a urethane acrylate pultrusion resin used for the new Corvette bumper
- Trimer's Resin cured in 3 minutes compared to 45 min for Crestapol 1250
- Results showed Trimer's resin greatly outperformed Scott Baders' Crestapol 1250
- 0° compressive strength increased by 70% while 90° compressive strength increased by 85.2%
- 90° tensile strength was increased by 86.7%
- Much greater heat deflection temperature

Property	Trimer Rapid	Crestapol 1250
0° Tensile Strength, GPa (ASTM D3039)	<b>1.04</b>	1.03
0° Tensile Modulus, GPa (ASTM D3039)	44.2	46.45
0° Compression Strength, MPa (ASTM D6641)	<b>966.0</b>	568.7
0° Compression Modulus, GPa (ASTM D6641)	<b>47.2</b>	43.9
90° Tensile Strength, MPa (ASTM D3039)	<b>36.4</b>	19.5
90° Tensile Modulus, GPa (ASTM D3039)	14.3	14.9
90° Compression Strength, MPa (ASTM D6641)	<b>184.3</b>	99.5
90° Compression Modulus, GPa (ASTM D6641)	<b>31.0</b>	12.9
In-Plane Shear Strength, MPa (ASTM D3518)	<b>64.7</b>	57.77
In-Plane Shear Modulus, GPa (ASTM D3518)	<b>3.4</b>	2.66
Mode I Fracture Toughness, J/m <sup>2</sup> , (ASTM D5528)*	437	809
Mode I Fracture Toughness, J/m <sup>2</sup> , (ASTM D7905)†	1,510	1,640
Translaminar Fracture Toughness, MPa·m <sup>1/2</sup> (ASTM E1922)	<b>60.64</b>	51.87

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# Revolutionary FST Polymers

- Trimer Technologies has developed a revolutionary thermosetting polymer
- **Aerospace thermal and mechanical properties through automotive manufacturing cycle time**
- Have demonstrated aerospace grade composites manufactured faster than the DOE's 2050 goal for automotive composites

## Benefits

- Rapid cure can reduce manufacturing time and cost
- Roughly an order of magnitude lower viscosity than current HP-RTM resins
- Long gel-time enable the manufacture of large structures
- Tg more than twice the value of current state of the art materials
- Resin has high fire resistance and easily meets FAR 25.853



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# Questions?

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