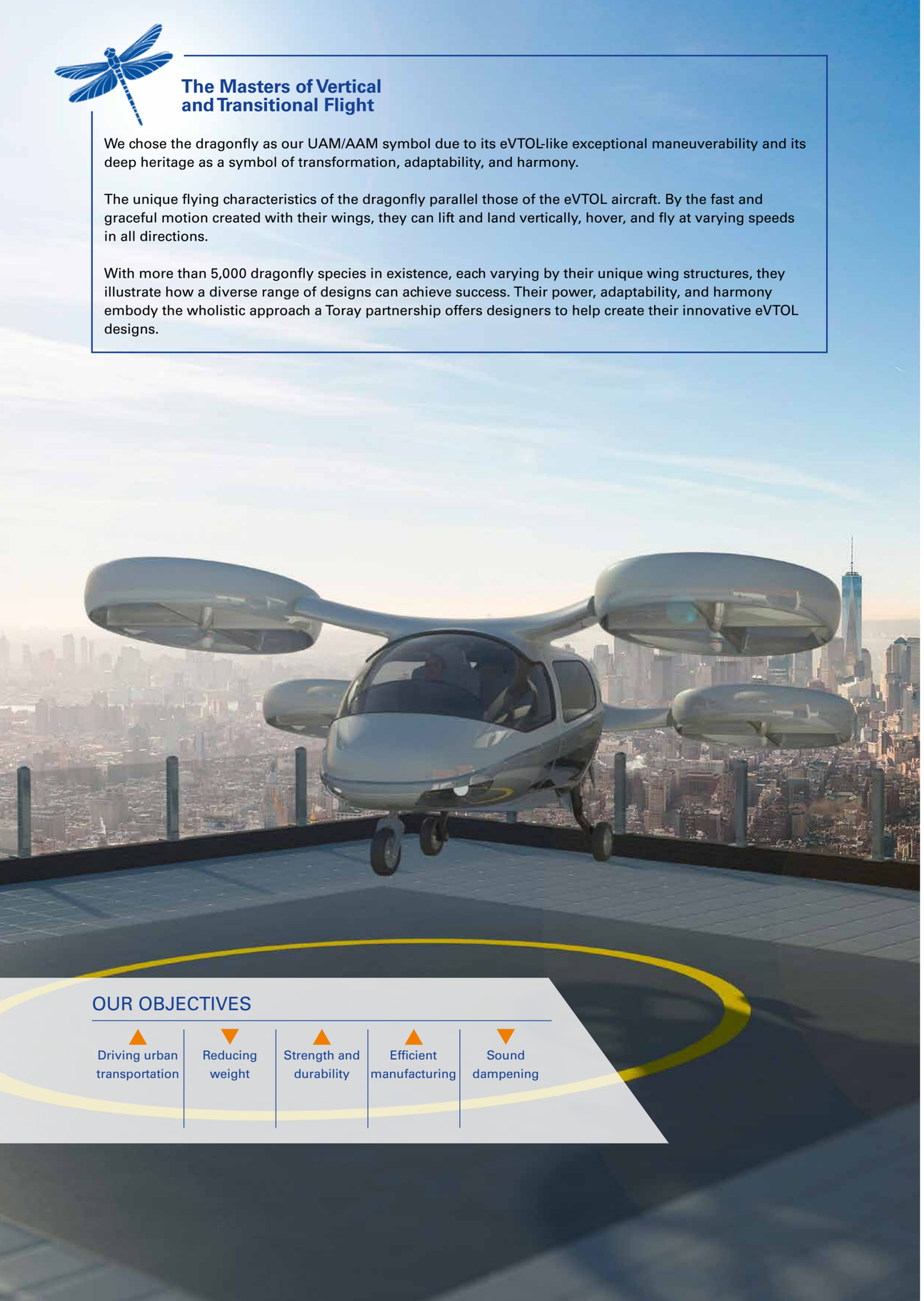
Urban Air Mobility

Advanced Composite Materials Selector Guide

Lightweight to elevate

TORAY

Innovation by Chemistry



Urban Air Mobility

Introduction

Your Partner for Tomorrow's Transportation

Toray is ideally positioned to help eVTOL designers and manufacturers create cost-effective prototypes today and prepare for high-rate productions of the future. Our history of successful partnerships in traditional aerospace as well as emerging high-performance industrial and aviation markets provides the confidence needed from a material supplier in an industry with rapid growth and fluid market dynamics. Active collaborations are advancing and demonstrating material and process maturity. A broad portfolio of proven thermoset and thermoplastic materials allow choices and flexibility for applications in this nascent but evolving market. With global locations and an unmatched carbon fiber supply chain, we can ensure your chosen materials are available whenever and wherever they are needed.

Why Do eVTOLS Need Composites?

Without advanced composites, eVTOLs would not be possible. Advanced fiber reinforced composite materials are extremely lightweight and are incredibly strong. These inherent material properties enable today's battery technology to effectively manage the power loads needed for vertical and forward propulsion for a variety of vehicle flight ranges.

From Prototype to Production

Initial designs with low-rate production, minimal nonrecurring cost investment, and a broad knowledge base will drive prototypes toward thermoset solutions.

Our industry-leading thermosets are used on general aviation aircraft, business jets, unmanned areal vehicles (UAV), and traditional vertical lift vehicles. These materials meet the demanding mechanical and environmental requirements and safety standards needed in this early market phase. Initial production rates that mirror current aerospace rates will continue to rely on trusted thermoset composites.

As the market matures beyond aerospace production rates, eVTOL manufacturers will have validated and refined designs to demonstrate crashworthiness and impact resistance. Volume production can begin and the transition to higher rates and reduced operating costs will drive a material shift to thermoplastic composites. Processing methods will shift from autoclave and hand lay-up benchmarks to Out of Autoclave (OOA) and Vacuum Bag Only (VBO), ATL/AFP, stamp and press forming, and continuous compression molding where cut/pick/place steps can be highly automated.

Our Experts Are Here

Toray's experience with primary and secondary aerospace structures, interior applications, high-end automotive, and tooling knowledge means your engineers will be in the best of company. Our Experts Services team will guide your composite material development choices to accommodate the needs of each bespoke eVTOL design.

Urban Air Mobility

Product Applications

Propulsion System

eVTOL propulsion systems will consist of a combination of rotor blades, propellers, and nacelles structures that must be lightweight and durable. Toray intermediate modulus carbon fiber thermosets are well suited for these applications. Toray Cetex® thermoplastics also provide sound dampening characteristics that minimize noise in the surrounding environment as well as in the passenger compartment.

DATABASE AVAILABILITY | SOUND DAMPENING | FRACTURE TOUGHNESS | OUT OF AUTOCLAVE | RESILIENT | ENERGY ABSORBING

Platform Protection

eVTOL exterior surfaces must protect against corrosion and lightning strike. Toray MicroPly® surface films deliver a strong paintable surface that, when integrated with conductive reinforcements, also provide lightning strike protection. Toray's fiberglass scrim reinforced films offer excellent galvanic barriers.

GALVANIC CORROSION PROTECTION | LIGHTNING STRIKE PROTECTION

Structural

Structural components such as fuselages, wings, landing gear, and flight control structures such as flaps, ailerons, spoilers/speed brakes, elevators, and ruddervators need high-strength and lightweight materials that can meet both rapid and high-volume manufacturing demands.

DATABASE AVAILABILITY | SOUND DAMPENING | OUT OF AUTOCLAVE | WELDABLE | ENERGY ABSORBING

Panels, Covers, and Communication

Ideal for panels and component covers, Toray thermosets, Cetex® thermoplastics, and bulk molding compounds are lightweight and can be rapidly manufactured in high volume. Toray's industry-leading low dielectric products provide low loss and high signal clarity for communication radomes.

SCALABLE MANUFACTURING | DESIGN FREEDOM

Battery System

Toray's product portfolio of thermosets, Cetex® thermoplastics, and bulk molding compounds can be used for battery racks and boxes that must withstand high temperatures while remaining lightweight and incredibly durable.

THERMOCYCLE STABLE | LOW FST VALUES | HIGH TEMPERATURE RESISTANT

Interiors

Interior eVTOL components must be strong, light, flame-retardant, and visually pleasing while meeting high crashworthiness standards. Toray's Cetex® thermoplastics are well suited for interiors and can be rapidly processed for high-rate production.

SMOOTH SURFACE | THERMOFORMABLE | LOW FST VALUES

Thermoset Epoxy

	Resin Matrix	Neat Resin Dry T_g Onset (DMA)	Cure Temperature and Time	Key Product Characteristics	Out Life # Days	Freezer Life # Months	Design Allowables Database	Formats: UD Tape	Formats: Woven Prepreg	Formats: Slit Tape	Processing: OOA/VBO	Processing: Autoclave	Processing: Press Forming	Processing: Flexilbe Cure	Processing: Freestanding Post cure	Processing: AFP/ATL	Product Attributes: Toughened	Product Attributes: Flame Retardant	Product Attributes: Chemical Resistant	Product Attributes: Corrosion Resistant	Product Attributes: Impact Resistant	Product Attributes: High Temperature Peformance	Product Attributes: Low Moisture Absorbtion	Applications: Structural	Applications: Propulsion System	Applications: Interiors	Applications: Battery System	Applications: Panels, Covers, Communication
BT250E-6	Epoxy	131°C (268°F)	127°C (260°F)—2 hours	• Aerospace flight qualified • 71°C (160°F) hot/wet service	30	12	NIAR NCAMP[1] CHM-17	●	●		●	●	●						●	●				●	●	●		●
2510	Epoxy	131°C (294°F)	132°C (270°F)—2 hours	• Qualified to AMS 3960, 3914, and 3915 • In stock and ready to ship • Long freezer life	28	24	AGATE	●	●		●	●		●					●	●				●	●			●
E732	Epoxy	n/a 159°C (318°F) 170°C (338°F)	120°C (248°F)—20 min 140°C (284°F)—10 min 160°C (320°F)—4 min	• Short cure cycles < 20 min • Hot-in hot-out press processing	21	6		●	●		●	●	●	●			●		●	●				●	●	●		●
2511	Epoxy	162°C (324°F)	132°C (270°F)—2 hours	• Qualified to AMS 3962 • Low void content with OOA/VBO • Long freezer life	28	24	CMH-17	●	●	●	●	●		●			●		●	●	●		●	●	●			●
2700	Epoxy	163°C (326°F) 200°C (392°F) with post cure	160°C (320°F)—5 minutes (press) 132°C (270°F)—2 hours	• Multi-process flexible system for high volume • Short cure cycles < 5 min • Low void content and optimized tack	28	24		●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●			●
TC275-1	Epoxy	164°C (327°F) 174°C (345°F) with post cure 183°C (362°F)	135°C (275°F)—6 hours 180°C (356°F)—2 hours post cure (optional) 180°C (356°F)—2 hours	• Aerospace flight qualified • Excellent hot/wet strength retention • Flexible cure • 121°C (250°F) hot/wet service	14	12	NIAR NCAMP[1] CMH-17	●	●	●	●	●	●	●	●	●	●		●	●	●		●	●	●	●	●	●
TC380	Epoxy	176°C (349°F) 190°C (374°F) with post cure[3] 201°C (394°F)	135°C (275°F)—6 hours 180°C (356°F)—2 hours post cure (optional) 180°C (356°F)—2 hours	• Aerospace flight qualified • Outstanding toughness • Excellent balance of OHC and CAI properties • 121°C (250°F) hot/wet service	28	12	NIAR NCAMP[2] CMH-17 (in-progress)	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●
3900	Epoxy	204°C (400°F)	177°C (350°F) - 2 hours	• Qualified to AMS 6891 • In stock and ready to ship • Long out life • Legacy commercial aerospace material • 121°C (250°F) hot/wet service • Outstanding toughness	42	24	CMH-17	●	●	●		●				●	●		●	●	●	●	●	●	●			●
3960	Epoxy	204°C (400°F)	177°C (350°F) - 2 hours	• Combined with high performance T1100G IM+ fiber • Long out life, Extremely long freezer life • Excellent balance of CAI and OHC properties • 121°C (250°F) hot/wet service • Outstanding toughness	42	36	NCAMP (in progress)	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●			●

1 - Database is FAA and EASA accepted
2 - Database is FAA accepted
3 - Estimated value

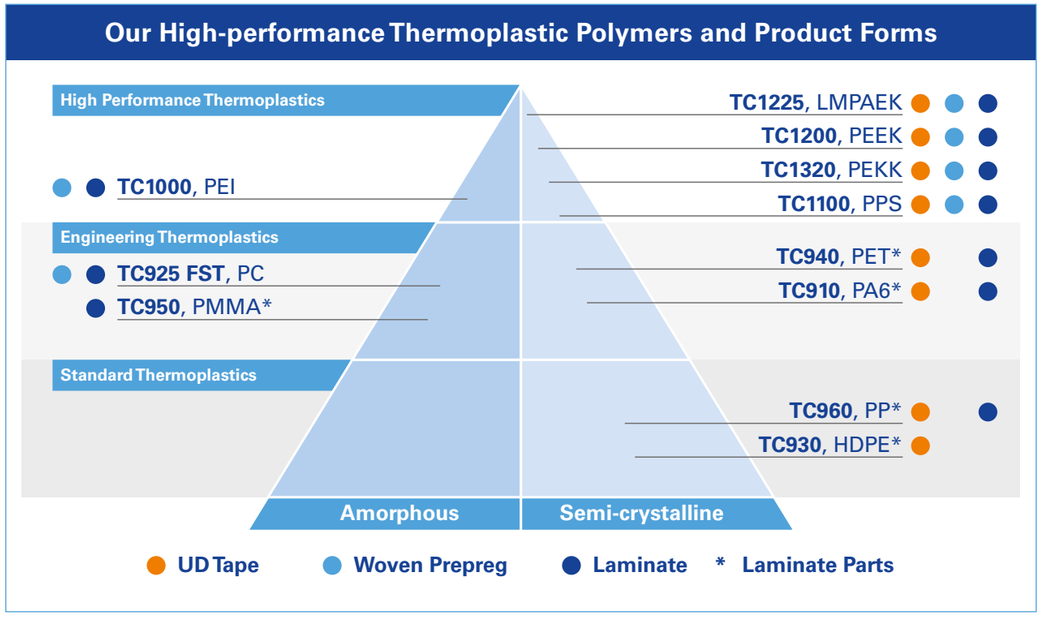
Toray Cetex® Thermoplastic

Cetex®

	Resin Matrix	Polymer	Melting Temperature T_m	Typical Consolidation Temperatures T_p	Key Product Characteristics	Design Allowables Database	Formats: UD Tape	Woven Prepreg	Slit Tape	RTL Laminate	Chopped	Processing: Weldable/Jointing	Autoclave	Press Forming	AFP/ATL	Product Attributes: Toughened	Flame Retardant	Chemical Resistant	Corrosion Resistant	Impact Resistant	High Temperature Performance	Low Moisture Absorption	Applications: Structural	Propulsion System	Interiors	Battery System	Panels, Covers, Communication
TC910	PA6	Nylon 6	220°C (428°F)	249–271°C (480–520°F)	• Lower processing temperature option		●	●	●	●	●	●	●	●	●	●			●	●				●	●		●
TC1000	PEI	Polyetherimide	Amorphous	320–350°C (608–662°F)	• Industry-leading mechanical performance • Excellent FST properties	OEM	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●			●	●	●
TC1100	PPS	Polyphenylene Sulfide	280°C (536°F)	300–330°C (572–626°F)	• Low moisture absorption • Ideal for leading edges, beams, clips, and floor panels	OEM	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
TC1200	PEEK	Polyetheretherketone	343°C (649°F)	370–400°C (698–752°F)	• Continuous processing temperature • Good high-temperature properties	OEM	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●					
TC1225	LMPAEK	Low-melt Polyaryletherketone	305°C (581°F)	340–385°C (644–725°F)	• Outstanding structural performance • Compatible with PEEK for overmolding and welding	NIAR NCAMP[1] CMH-17	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
TC1320	PEKK	Polyetherketoneketone	337°C (639°F)	370–400°C (698–752°F)	• Outstanding solvent and impact resistance • Excellent mechanical properties	OEM	●		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

1 - Database is FAA accepted

Toray Cetex® Portfolio



Bulk Molding Compounds (BMC)

Thermoset BMC

	Resin Matrix	Neat Resin Dry T_g Onset (DMA)	Cure Temperature and Time	Key Product Characteristics	Out Life # Days	Freezer Life # Months	Chopped	Processing: OOA/VBO	Processing: Autoclave	Processing: Press Forming	Processing: Flexible Cure	Processing: Freestanding Post Cure	Product Attributes: Toughened	Product Attributes: Flame Retardant	Product Attributes: Chemical Resistant	Product Attributes: Corrosion Resistant	Product Attributes: Impact Resistant	Product Attributes: High Temperature Performance	Product Attributes: Low Moisture Absorption	Product Attributes: Lightning Strike Protection	Applications: Structural	Applications: Propulsion System	Applications: Interiors	Applications: Battery System	Applications: Panels, Covers, Communication
MS-4H	Epoxy	191°C (375°F)	138°C (280°F)—15–30 min 180°C (356°F)—1–2 hours post cure (freestanding)	• Aerospace flight qualified • Epoxy-based structural BMC product • Economical and lightweight aluminum replacement	14	6	●			●		●	●	●	●	●	●		●		●	●		●	●

Thermoplastic BMC

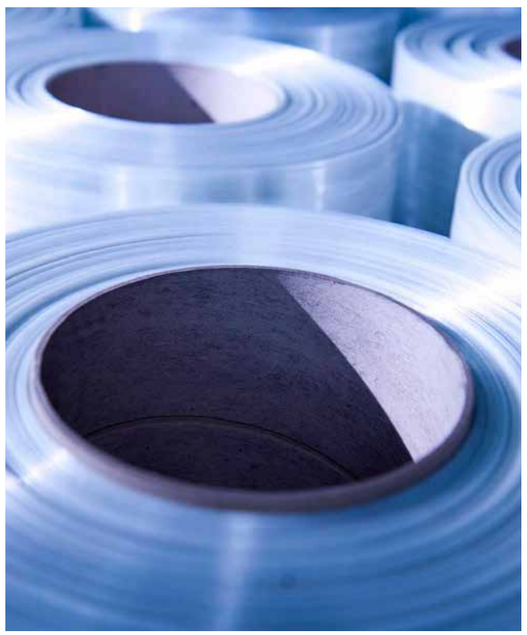
	Resin Matrix	Polymer	Melting Temperature T_m	Typical Consolidation Temperatures T_p	Key Product Characteristics	Chopped	Processing: Weldable/Jointing	Processing: Autoclave	Processing: Press Forming	Product Attributes: Toughened	Product Attributes: Flame Retardant	Product Attributes: Chemical Resistant	Product Attributes: Corrosion Resistant	Product Attributes: Impact Resistant	Product Attributes: High Temperature Performance	Product Attributes: Low Moisture Absorption	Product Attributes: Lightning Strike Protection	Applications: Structural	Applications: Propulsion System	Applications: Interiors	Applications: Battery System	Applications: Panels, Covers, Communication
MC1100	PPS	Polyphenylene Sulfide	280°C (536°F)	330°C (626°F)	• PPS-based BMC with SM and IM fibers • Fire retardant	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●
MC1200	PEEK	Polyetherketoneketone	343°C (649°F)	385°C (725°F)	• PEEK-based BMC with SM and IM fibers • Fire retardant	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●

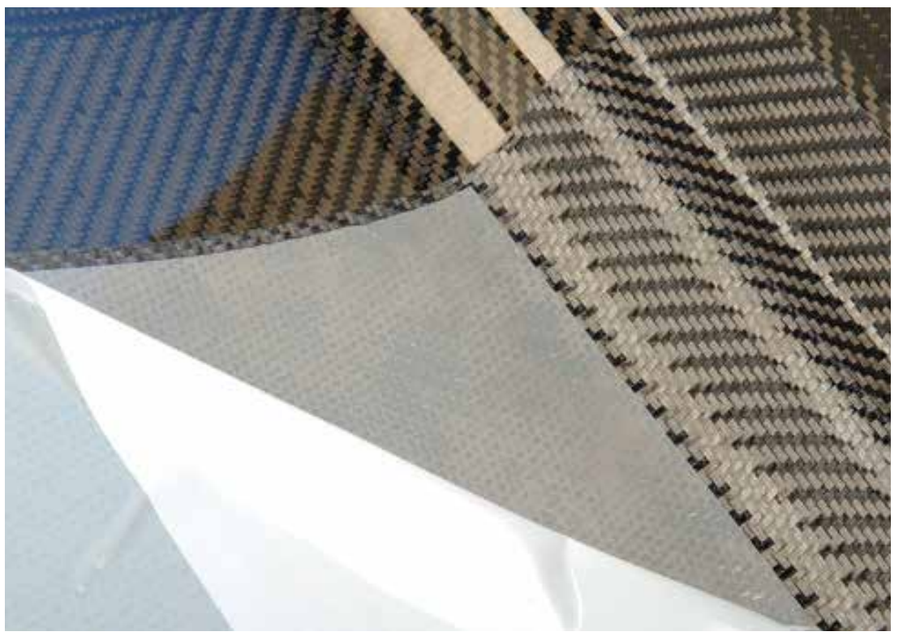
Toray MicroPly™ Surfacing Film, Film Adhesives, and Syntactics

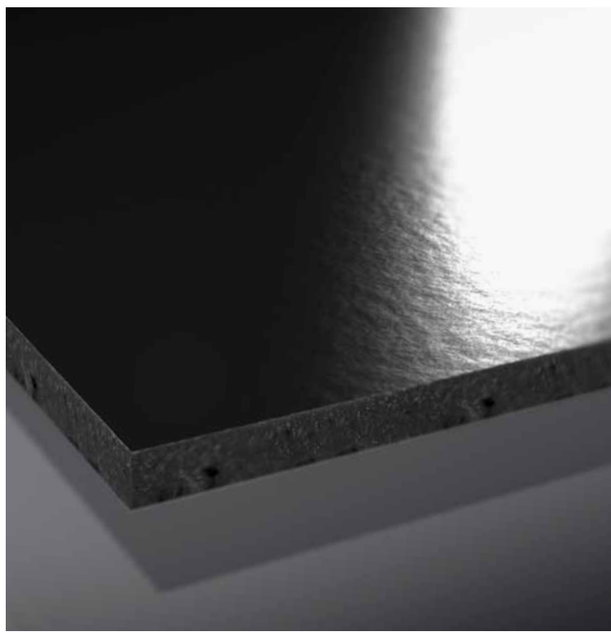
MicroPly™

	Resin Matrix	Dry T_g Onset	Cure Temperature and Time	Key Product Characteristics	Out Life # Days	Freezer Life # Months	Processing: OOA/VBO	Processing: Autoclave	Processing: Press Forming	Processing: AFP/ATL	Processing: Post Curable	Product attributes: Toughened	Product attributes: Flame Retardant	Product attributes: Chemical Resistant	Product attributes: Corrosion Resistant	Product attributes: Impact Resistant	Product attributes: High Temperature Performance	Product attributes: Low Moisture Absorption	Product attributes: Lightning Strike Protection	Appl.: Platform Protection
Surfacing Film Epoxy																				
TC235SF-1	Epoxy	119°C (246°F)	121°C (250°F)—60 minutes	• Excellent protective surface finish Available with embedded lightning strike foils • Reduces shop floor finishing for productivity savings	30	12	●	●	●			●		●	●				●	●
Film Adhesives Epoxy																				
RS-15H	Epoxy	99°C (211°F)[1]	93°C (200°F)—6 hours Alternate cures are available	• Low temperature curing adhesive	30	12	●	●	●			●		●	●					
TC263	Epoxy	110°C (230°F)	121°C (250°F)—2 hours	• Ideal for metal or composite bonding	21	12	●	●	●			●		●	●					
TC310	Epoxy	157°C (315°F)	177°C (350°F)—2 hours	• Ideal for metal or composite bonding	30	12	●	●	●			●		●	●					
Syntactics Epoxy																				
EM-3	Epoxy	116°C (240°F)[1]	121°C (250°F)—60 minutes	• Expanding syntactic coresplice • High expansion (8–10 x)	14	12		●				●		●	●					
TCF4035	Epoxy	140°C (284°F)	130°C (265°F)—2 hours	• Compatible with TAC 121/135°C (250/275°F) curing materials • May be post cured for higher T_g	30	12	●	●			●	●		●	●					
TCF4045	Modified Epoxy	180°C (356°F)	179°C (355°F)—3 hours	• Excellent low dielectric constant and loss	14	6	●	●				●		●	●					

1 - T_g estimated from base resin data



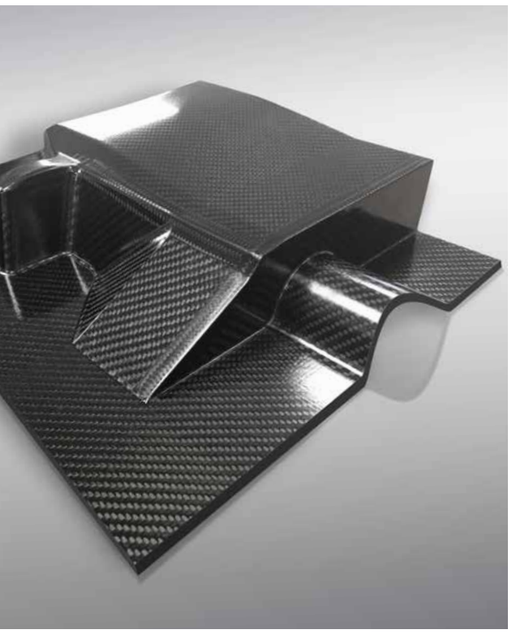


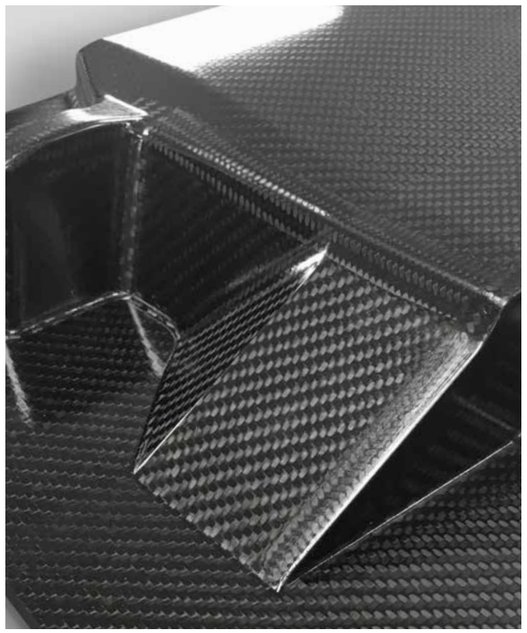


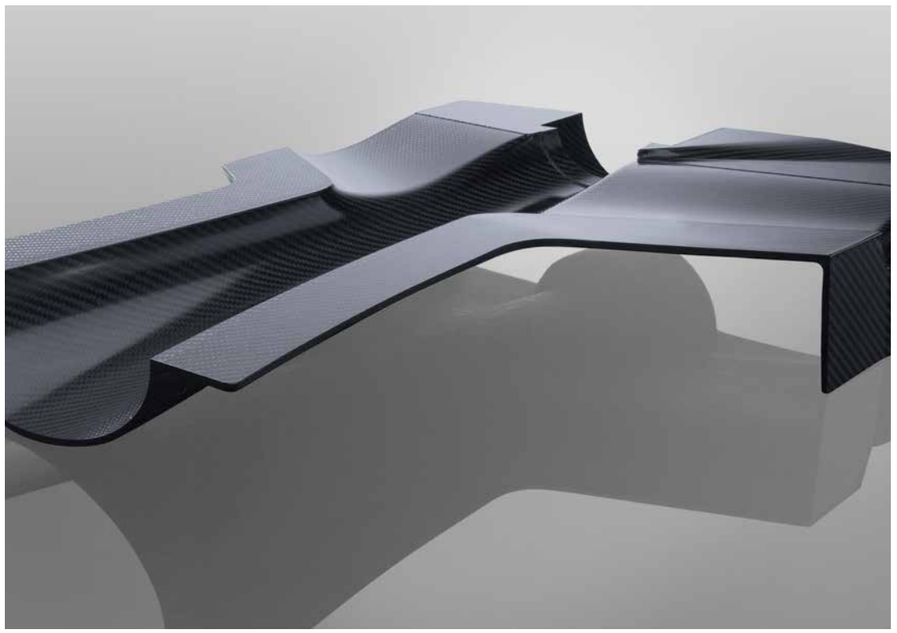
Toray AmberTool® Composite Tooling Prepregs

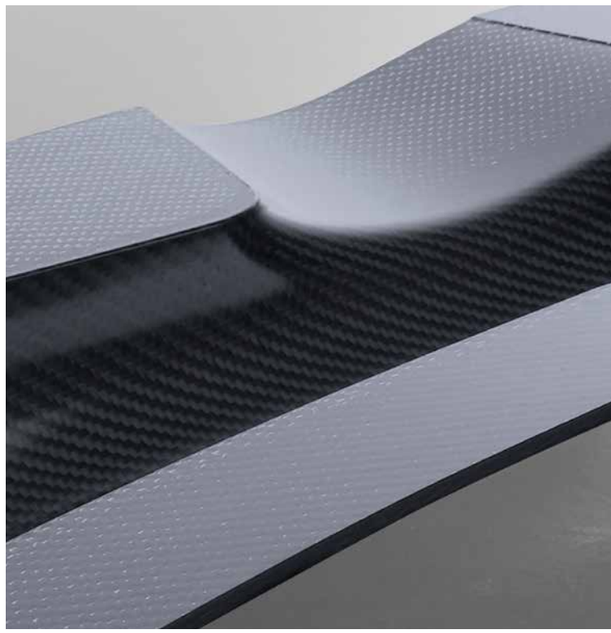
AmberTool®

	Resin Matrix	Dry T_g Onset (After Postcure)	Min Cure Temp	Typical Cure Time and Temperature	Key Product Characteristics	Out Life # Days	Freezer Life # Months	Processing					Product attributes								
								OOA/VBO	Autoclave	Press Forming	AFP/ATL	Post Curable	Toughened	Flame Retardant	Chemical Resistant	Corrosion Resistant	Impact Resistant	High Temperature Performance	Low Moisture Absorption	Lightning Strike Protection
HX40	Epoxy	203°C (397°F)	50°C (122°F)	12 hours at 65°C (149°F)	• Large tooling applications	8	12		●			●			●	●				
HX42	Epoxy	200°C (392°F)	50°C (122°F)	60°C (140°F)—8 hours	• Proven system for aerospace • Excellent surface finish	5	12		●			●			●	●				
HX56	Epoxy	185°C (365°F)	40°C (104°F)	50°C (122°F)—8.5 hours	• Improved handleability • Excellent surface finish • Excellent drape for complex shapes	60 hours	6		●			●			●	●				









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Innovation by Chemistry

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Enquiries
North America/APAC: **uam@toraytac-usa.com**
EMEA: **uam@toraytac-europe.com**