We chose the dragonfly as our UAM/AAM symbol due to its eVTOL-like exceptional maneuverability and its deep heritage as a symbol of transformation, adaptability, and harmony.

The unique flying characteristics of the dragonfly parallel those of the eVTOL aircraft. By the fast and graceful motion created with their wings, they can lift and land vertically, hover, and fly at varying speeds in all directions.

With more than 5,000 dragonfly species in existence, each varying by their unique wing structures, they illustrate how a diverse range of designs can achieve success. Their power, adaptability, and harmony embody the wholistic approach a Toray partnership offers designers to help create their innovative eVTOL designs.

Your Partner for Tomorrow’s Transportation
Toray Advanced Composites 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 aerial 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.

For more product information such as product data sheets, case studies, or technical papers, please use the following resources:

- Search for the Toray TAC Product Selector [www.toraytac.com]
- Go to our online resource center for case studies and technical papers [www.toraytac.com]
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 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.

**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. Toray’s industry-leading thermoset and Cetex® thermoplastic composites meet these needs for eVTOL vehicles.

**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.

**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.

**Platform Protection**
eVTOL exterior surfaces must protect against corrosion and lightning strike. Toray’s 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.

**Platform Protection**
- Corrosion Protection
- Lightning Strike Protection

**Structural**
- Sound Damping
- Out Of Autoclave
- Energy Absorbing
- Fracture Toughness

**Battery System**
- Smooth Surface
- THERMOCYCLE STABLE
- Low FST Values
- High Temperature Resistance

**Interiors**
- SMOOTH SURFACE
- THERMOFORMABLE
- LOW FST VALUES

**Platform Protection**
- SOUND DAMPENING
- DATABASE
- AVAILABILITY
- OUT OF AUTOCLAVE
- WELDABLE
- ENERGY ABSORBING
- FRACTURE TOUGHNESS
# Thermoset Epoxy

<table>
<thead>
<tr>
<th>RESIN MATRIX</th>
<th>NEAT RESIN DRY Tg ONSET (DNA)</th>
<th>CURE TEMPERATURE AND TIME</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>OUT LIFE # DAYS</th>
<th>FREEZER LIFE # MONTHS</th>
<th>DESIGN ALLOWABLES DATABASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy</td>
<td>125°C (257°F)</td>
<td>121°C (250°F)—60 min</td>
<td>Aerospace flight qualified</td>
<td>30</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Epoxy</td>
<td>131°C (268°F)</td>
<td>127°C (260°F)—2 hours</td>
<td>Aerospace flight qualified</td>
<td>30</td>
<td>12</td>
<td>NIAR NCAMP® CHM-17</td>
</tr>
<tr>
<td>Epoxy</td>
<td>n/a</td>
<td>120°C (248°F)—20 min</td>
<td>Short cure cycles &lt; 20 min</td>
<td>21</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Epoxy</td>
<td>140°C (288°F)</td>
<td>130°C (265°F)—2 hours</td>
<td>Aerospace flight qualified</td>
<td>30</td>
<td>12</td>
<td>NIAR NCAMP</td>
</tr>
<tr>
<td>Epoxy</td>
<td>164°C (327°F)</td>
<td>135°C (279°F)—6 hours</td>
<td>Aerospace flight qualified</td>
<td>14</td>
<td>12</td>
<td>NIAR NCAMP® CMH-17</td>
</tr>
<tr>
<td>Epoxy</td>
<td>176°C (345°F)</td>
<td>135°C (279°F)—6 hours</td>
<td>Aerospace flight qualified</td>
<td>28</td>
<td>12</td>
<td>NIAR NCAMP® CMH-17 (in-progress)</td>
</tr>
</tbody>
</table>

1 - Database is FAA and EASA conformed
2 - Database is FAA conformed
3 - Estimated value
<table>
<thead>
<tr>
<th>RESIN MATRIX</th>
<th>POLYMER</th>
<th>MELTING TEMPERATURE $T_m$</th>
<th>TYPICAL CONSOLIDATION TEMPERATURES $T_p$</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>DESIGN ALLOWABLES DATABASE</th>
<th>FORMATS PROCESSING PRODUCT ATTRIBUTES APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC910</td>
<td>PA6</td>
<td>220°C (428°F)</td>
<td>249–271°C (480–520°F)</td>
<td>Lower processing temperature option</td>
<td>-</td>
<td>OEM</td>
</tr>
<tr>
<td>TC1000</td>
<td>PEI</td>
<td>Polyetherimide Amorphous</td>
<td>320–350°C (608–662°F)</td>
<td>Industry-leading mechanical performance</td>
<td>-</td>
<td>OEM</td>
</tr>
<tr>
<td>TC1100</td>
<td>PPS</td>
<td>Polyphenylene Sulfide</td>
<td>280°C (536°F)</td>
<td>Low moisture absorption</td>
<td>-</td>
<td>OEM</td>
</tr>
<tr>
<td>TC1200</td>
<td>PEEK</td>
<td>Polyetheretherketone</td>
<td>343°C (649°F)</td>
<td>Continuous processing temperature</td>
<td>-</td>
<td>OEM</td>
</tr>
<tr>
<td>TC1225</td>
<td>LMPEAK</td>
<td>Low-melt Polyaryletherketone</td>
<td>305°C (581°F)</td>
<td>Outstanding structural performance</td>
<td>-</td>
<td>NIAR NCAMP CMH-17</td>
</tr>
<tr>
<td>TC1320</td>
<td>PEKK</td>
<td>Polyetherketoneketone</td>
<td>337°C (639°F)</td>
<td>Outstanding solvent and impact resistance</td>
<td>-</td>
<td>OEM</td>
</tr>
</tbody>
</table>

1. Database is FAA conformed

Toray Cetex® Portfolio

Our High-performance Thermoplastic Polymers and Product Forms

- UD tape
- Fabric prepreg
- Laminate
- Laminate parts

**High-performance Thermoplastics**
- TC910, PA6
- TC1100, PPS
- TC1200, PEI
- TC1225, Engineered PAEK
- TC1320, PEKK

**Engineering Thermoplastics**
- TC325, FST, PC
- TC350, PMMA

**Standard Thermoplastics**
- TC320, PC/ABS
- TC360, PP
- TC390, HDPE
### Bulk Molding Compounds (BMC)

#### Thermoset BMC

<table>
<thead>
<tr>
<th>RESIN MATRIX</th>
<th>NEAT RESIN Tg ONSET (DMA)</th>
<th>CURE TEMPERATURE AND TIME</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>OUT LIFE # DAYS</th>
<th>FREEZER LIFE # MONTHS</th>
<th>PROCESSING</th>
<th>PRODUCT ATTRIBUTES</th>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS-4H</td>
<td>Epoxy 191°C (375°F) 138°C (280°F) – 15-30 min 180°C (356°F) – 1–2 hours post cure (freestanding)</td>
<td>Aerospace flight qualified  Epoxy-based structural BMC product Economical and lightweight aluminum replacement</td>
<td>14</td>
<td>6</td>
<td>CHOPPED</td>
<td>PEEK-BASED</td>
<td>STRUCTURAL</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
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</table>

#### Thermoplastic BMC

<table>
<thead>
<tr>
<th>RESIN MATRIX</th>
<th>POLYMER</th>
<th>MELTING TEMPERATURE Tm</th>
<th>TYPICAL CONSOLIDATION TEMPERATURES Tp</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>PROCESSING</th>
<th>PRODUCT ATTRIBUTES</th>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC1100</td>
<td>PPS</td>
<td>280°C (536°F) 330°C (626°F)</td>
<td></td>
<td>PPS-based BMC with SM and IM fibers Fire retardant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC1200</td>
<td>PEEK</td>
<td>343°C (649°F) 385°C (725°F)</td>
<td></td>
<td>PEEK-based BMC with SM and IM fibers Fire retardant</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Toray MicroPly™ Surfacing Film, Film Adhesives, and Syntactics

## Resin Matrix | Dry Tg Onset | Cure Temperature and Time | Key Product Characteristics | Out Life | Freezer Life | OOA/VBO | AUTOCLAVE | PRESS FORMING | AFP/PEL | POST CURABLE | THERMORESISTENT | FLAME RETARDANT | CHEMICAL RESISTANT | IMPACT RESISTANT | CORROSION RESISTANT | LIGHTNING STRIKE PROTECTION | PLATFORM PROTECTION
**Surfacing Film Epoxy**

| Resin | Matrix | Dry Tg Onset | Cure Temperature and Time | Key Product Characteristics | Out Life | Freezer Life | OOA/VBO | AUTOCLAVE | PRESS FORMING | AFP/PEL | POST CURABLE | THERMORESISTENT | FLAME RETARDANT | CHEMICAL RESISTANT | IMPACT RESISTANT | CORROSION RESISTANT | LIGHTNING STRIKE PROTECTION | PLATFORM PROTECTION |
| 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**

| Resin | Matrix | Dry Tg Onset | Cure Temperature and Time | Key Product Characteristics | Out Life | Freezer Life | OOA/VBO | AUTOCLAVE | PRESS FORMING | AFP/PEL | POST CURABLE | THERMORESISTENT | FLAME RETARDANT | CHEMICAL RESISTANT | IMPACT RESISTANT | CORROSION RESISTANT | LIGHTNING STRIKE PROTECTION | PLATFORM PROTECTION |
| RS-15H | Epoxy | 99°C (211°F) | 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**

| Resin | Matrix | Dry Tg Onset | Cure Temperature and Time | Key Product Characteristics | Out Life | Freezer Life | OOA/VBO | AUTOCLAVE | PRESS FORMING | AFP/PEL | POST CURABLE | THERMORESISTENT | FLAME RETARDANT | CHEMICAL RESISTANT | IMPACT RESISTANT | CORROSION RESISTANT | LIGHTNING STRIKE PROTECTION | PLATFORM PROTECTION |
| EM-3 | Epoxy | 116°C (240°F) | 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 Tg | 30 | 12 | | | | | | | | | | | | | | |
| TCF4045 | Modified Epoxy | 180°C (356°F) | 179°C (355°F)—3 hours | Excellent low dielectric constant and loss | 14 | 6 | | | | | | | | | | | | | | |

1. Tg estimated from base resin data
## Toray AmberTool® Composite Tooling Prepregs

<table>
<thead>
<tr>
<th>RESIN MATRIX</th>
<th>DRY Tg, ONSET (AFTER POSTCURE)</th>
<th>MIN CURE TEMP</th>
<th>TYPICAL CURE TIME AND TEMPERATURE</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>OUT LIFE # DAYS</th>
<th>FREEZER LIFE # MONTHS</th>
<th>PROCESSING</th>
<th>PRODUCT ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>HX40 Epoxy</td>
<td>203°C (397°F)</td>
<td>50°C (122°F)</td>
<td>12 hours at 65°C (149°F)</td>
<td>Large tooling applications</td>
<td>8</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HX42 Epoxy</td>
<td>200°C (392°F)</td>
<td>50°C (122°F)</td>
<td>60°C (140°F)—8 hours</td>
<td>Proven system for aerospace</td>
<td>5</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HX56 Epoxy</td>
<td>185°C (365°F)</td>
<td>40°C (104°F)</td>
<td>50°C (122°F)—8.5 hours</td>
<td>Improved handleability</td>
<td>60 hours</td>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Processing**: OOA/VBO, AUTOCLAVE, PRESS FORMING, AFP/ATL, POST CURABLE, TOUGHENED
- **Product Attributes**: CHEMICAL RESISTANT, CORROSION RESISTANT, IMPACT RESISTANT, HIGH TEMPERATURE PERFORMANCE, LOW MOISTURE ABSORPTION, LIGHTNING STRIKE PROTECTION, HIGH TEMP PERFORMANCE, CORROSION RESISTANCE
LOCATIONS AND CAPABILITIES

SOLUTIONS
- Thermoplastic composites
- Thermoplastic laminates
- Thermoset composites
- Carbon-free manufacturing
- Parts manufacture
- Sales office

CERTIFICATIONS
- ISO 9001:2015
- AS9100D
- ISO 14001:2015
- ISO 45001:2018

For more product information such as product data sheets, case studies, or technical papers, please use the following resources:

Search for the Toray TAC Product Selector

Go to our online resource center for case studies and technical papers

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