WE’VE BEEN TO MARS. MORE THAN ONCE.
SPACE, SATELLITE, & LAUNCH

SPACE FLIGHT HERITAGE
With more than 25 years of space flight heritage, Toray Advanced Composites is the undisputed leader in developing and manufacturing cutting-edge, high-reliability materials for the space market. Our products are found on most satellites, spacecraft, and planetary rovers launched from the Western world. No other materials company offers the pedigree, experience, or breadth of product knowledge to meet the demanding needs of the space, launch, and satellite industry.

In partnership with our customers and with a close eye to evolving market needs, we have developed a comprehensive product portfolio of industry-leading resin systems for use on high-modulus PAN and pitch carbon fiber and specialty fabrics, as well as standard reinforcements.

COMMERCIAL SATELLITES AND LAUNCH VEHICLES
We continue to develop and serve our long-standing customers, who are building ever larger telecommunications satellites to accommodate more powerful and sophisticated payloads - offering higher resolution, more deployable structures, and larger, more accurate reflectors.

Toray also offers a full range of products to meet the demands of today’s heavy-lift commercial launch vehicles being utilized today to send high-value missions reliably into space.

SCIENCE AND EXPLORATION
Our next generation materials support science missions, going further than ever before to unlock the secrets of the universe. Tomorrow’s spacecraft will journey to more aggressive, hotter, and colder environments, and with greater numbers of planetary rovers and landers. Toray’s materials are also playing a key role in sending humans to Mars.

NEW SPACE
Today’s rapidly emerging New Space market is bringing new opportunities to meet material demands for mass-produced satellite constellations, small launch-on-demand vehicles, and swarms of high-flying pseudo-satellite drones. New Space will bring internet connectivity, new science, and big data to billions more people.

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/space

Go to our online resource center for product data sheets and technical resources.

OUR OBJECTIVES
Connecting the planet
Furthering scientific understanding
Reducing weight
High reliability

To confine our attention to terrestrial matters would be to limit the human spirit.

Stephen Hawking
HEAT SINKS Composite plates and tubes are manufactured with Toray highly conductive pitch-based carbon fiber prepregs. These unique materials provide superior thermal conductivity to channel heat from electrical components. Toray prepreg systems for these applications are designed to withstand high temperatures while providing exceptional resistance to the effects of thermocycling.

REFLECTORS AND ANTENNAS Toray space flight approved cyanate ester and epoxy systems utilize high-modulus carbon fiber and specialized weaves. These materials are designed to deliver low CTE on reflectors, antennas, and deployable structures over space temperature extremes.

HIGH TEMPERATURE RESISTANT SOLAR ARRAY, BOOMS, AND TRUSSES These satellite applications utilize Toray high-modulus carbon fibers with resins that provide low coefficients of thermal expansion (CTE), low coefficients of moisture expansion (CME), low outgassing, and radiation resistance.

LIGHTWEIGHT HIGH TEMPERATURE RESISTANT THERMOCYCLE STABILITY PRECISION STRUCTURES Toray materials protect the payload during launch and resist moisture to prevent outgassing in orbit. Toray high-modulus PAN or pitch-based carbon fiber prepregs are utilized for strength, stiffness, and light weight. Structures made from Toray products, including benches for optics and instrumentation, withstand extreme conditions in space, including thermal cycling, atomic oxygen, and radiation.

SOLAR ARRAY, BOOMS, AND TRUSSES These satellite applications utilize Toray high-modulus carbon fibers with resins that provide low coefficients of thermal expansion (CTE), low coefficients of moisture expansion (CME), low outgassing, and radiation resistance.
## THERMOSET PREPREGS

### EPOXY

<table>
<thead>
<tr>
<th>Resin Matrix</th>
<th>Dry T&lt;sub&gt;i&lt;/sub&gt;, Onset</th>
<th>Cure Time and Temperature</th>
<th>Key Product Characteristics</th>
<th>Outgassing, CTE, CM, OR, OUT/WAT Data</th>
<th>Heatshield</th>
<th>OOA/VBO</th>
<th>Toughened</th>
<th>Low Moisture Absorption</th>
<th>Good Hot/Wet Properties</th>
<th>Large Structure</th>
<th>OOA/VBO Processable</th>
<th>Space/Satellite</th>
<th>Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX-1522 Modified Epoxy</td>
<td>180°C (356°F)</td>
<td>2 hours at 177°C (350°F)</td>
<td>Excellent mechanical properties</td>
<td>TML 0.28 %</td>
<td>OOA/VBO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>TC250 Epoxy</td>
<td>140°C (285°F) or 180°C (356°F) with post cure</td>
<td>60 minutes at 188°C (365°F), followed by 2 hours at 130°C (265°F)</td>
<td>NCAMP qualified</td>
<td>Wet T&lt;sub&gt;c&lt;/sub&gt; 125°C (257°F) Cured at 130°C (265°F)</td>
<td>OOA/VBO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>RS-36 / RS-36-1 Epoxy</td>
<td>181°C (358°F) or 190°C (374°F)</td>
<td>90 minutes at 177°C (350°F)</td>
<td>ESA qualified for solar array</td>
<td>TML 0.4 %</td>
<td>OOA/VBO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>TC275-1 Epoxy</td>
<td>164°C (327°F)</td>
<td>6 hours at 130°C (253°F) optional post cure of 2 hours at 177°C (350°F)</td>
<td>Ideal for large structure fabrication</td>
<td>Wet T&lt;sub&gt;c&lt;/sub&gt; 136°C (277°F)</td>
<td>OOA/VBO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>TC275-1E NEW Epoxy</td>
<td>168°C (334°F)</td>
<td>6 hours at 130°C (253°F) optional post cure of 2 hours at 177°C (350°F)</td>
<td>Long out time version of TC275-1</td>
<td>Wet T&lt;sub&gt;c&lt;/sub&gt; 160°C (320°F)</td>
<td>OOA/VBO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>TC285-1 Epoxy</td>
<td>191°C (378°F)</td>
<td>2 hours at 177°C (350°F)</td>
<td>OOA/VBO processable</td>
<td>Wet T&lt;sub&gt;c&lt;/sub&gt; 160°C (320°F)</td>
<td>OOA/VBO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
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</tr>
<tr>
<td>TC380 NEW Epoxy</td>
<td>204°C (399°F)</td>
<td>2 hours at 177°C (350°F)</td>
<td>Extreme toughness for structural and cryogenic applications</td>
<td>TML 0.83 %</td>
<td>OOA/VBO</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
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</tbody>
</table>

### BMI

<table>
<thead>
<tr>
<th>Resin Matrix</th>
<th>Dry T&lt;sub&gt;i&lt;/sub&gt;, Onset</th>
<th>Cure Time and Temperature</th>
<th>Key Product Characteristics</th>
<th>Outgassing, CTE, CM, OR, OUT/WAT Data</th>
<th>Space/Satellite</th>
<th>Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS-8HT BMI</td>
<td>203°C (396°F) or 265°C (503°F) with post cure</td>
<td>2 hours at 204°C (400°F) followed by 6 hours at 210°C (410°F)</td>
<td>Excellent elevated temperature performance</td>
<td>OOA/VBO</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

**LAUNCH VEHICLE**

**Product Applications**

**Barrel Fuselage Assemblies, Payload Shrouds, and Fairings**
The latest generation of launch vehicles utilize Toray out-of-autoclave (OOA) processable prepreg systems for cost-competitive vehicle barrel assemblies, inner and outer stages, payload shrouds, and fairings for weight and cost savings.

**Cryotanks**
Launched vehicle cryotanks utilize Toray toughened epoxies to provide high strength, low weight tanks.

**Heatshields**
Toray high-temperature cyanate ester prepregs create lightweight, thermally stable structures.

**Struts and Tubes**
Toray exceptionally durable and microcrack-resistant thermosets deliver a lightweight, high-strength structure for landing leg assemblies, secondary tubes, and struts and conduits.

**Space, Satellite, & Launch**

**Product Overview**

**Thermoset Prepregs**

**Epoxy**

- **EX-1522 Modified Epoxy**
  - 180°C (356°F)
  - 2 hours at 177°C (350°F)
  - Excellent mechanical properties
  - Good balance of properties between cyanate ester and epoxy
  - Low D<sub>1</sub> and D<sub>2</sub>

- **TC250 Epoxy**
  - 140°C (285°F) or 180°C (356°F) with post cure
  - 60 minutes at 188°C (365°F), followed by 2 hours at 130°C (265°F)
  - NCAMP qualified
  - Long out life of 60 days

- **RS-36 / RS-36-1 Epoxy**
  - 181°C (358°F) or 190°C (374°F)
  - 90 minutes at 177°C (350°F)
  - ESA qualified for solar array
  - High toughness
  - Low moisture absorption

- **TC275-1 Epoxy**
  - 164°C (327°F) or 183°C (362°F) with post cure
  - 6 hours at 130°C (253°F)
  - Ideal for large structure fabrication
  - Low density
  - Excellent toughness for impact resistance

- **TC275-1E NEW Epoxy**
  - 168°C (334°F)
  - 6 hours at 130°C (253°F)
  - Long out time version of TC275-1
  - Allows construction of thick or larger composites structures
  - OOA/VBO processable

- **TC285-1 Epoxy**
  - 191°C (378°F)
  - 2 hours at 177°C (350°F)
  - OOA/VBO processable
  - Good hot/wet properties

- **TC380 NEW Epoxy**
  - 204°C (399°F)
  - 2 hours at 177°C (350°F)
  - Extreme toughness for structural and cryogenic applications
  - Excellent balance of CAI, OHC, and hot/wet properties

**BMI**

- **RS-8HT BMI**
  - 203°C (396°F) or 265°C (503°F) with post cure
  - 2 hours at 204°C (400°F) followed by 6 hours at 210°C (410°F)
  - Excellent elevated temperature performance
  - Good moisture resistance

**Outgassing, CTE, CM, OR, OUT/WAT Data**

- TML 0.28 %
- CVCM 0.01 %
- WVR 0.16 %
- TML-WVR 0.12 %
**Thermoset Prepregs: Cyanate Ester**

<table>
<thead>
<tr>
<th>RESIN/MATRIX</th>
<th>DRY Tg, ONSET</th>
<th>CURE TIME AND TEMPERATURE</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>OUTGASSING, CTE/OMI, ON HOTMIL DATA</th>
<th>SOLID</th>
<th>TOUGHED</th>
<th>LOW-MOBILITY ABBREVIATION</th>
<th>SPACE</th>
<th>SATELLITE</th>
<th>LAUNCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX-1515 Cyanate Ester</td>
<td>121°C (250°F) or 177°C (350°F) with post cure</td>
<td>3 hours at 121°C (250°F) Optional post cure of 2 hours at 177°C (350°F)</td>
<td>Low density • Resistant to microcracking • Low residual stress with 121°C (250°F) cure</td>
<td>TML 0.18% CVM 0.01% CTE 61 ppm/°C</td>
<td>o</td>
<td>o</td>
<td>o</td>
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<tr>
<td>TC410 Cyanate Ester</td>
<td>112°C (234°F) or 181°C (358°F) with post cure</td>
<td>3 hours at 121°C (250°F) Optional post cure at 177°C (350°F)</td>
<td>Low CTE 58.4 μm/m°C • Extremely low CME 1205 μm/m°C • Ideal system for stable structures</td>
<td>TML 0.29% CVM &lt; 0.01% WVR 0.17% TML-WVR 0.12%</td>
<td>o</td>
<td>o</td>
<td>o</td>
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<tr>
<td>BTCy-1A Cyanate Ester</td>
<td>165°C (329°F) or 207°C (400°F) with post cure</td>
<td>2 hours at 177°C (350°F) Optional post cure of 60 minutes at 232°C (450°F)</td>
<td>Tough • High Tg</td>
<td>CTE 77 ppm/°C</td>
<td>o</td>
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<tr>
<td>RS-3/RS-3C Cyanate Ester</td>
<td>191°C (378°F) or 254°C (480°F) with post cure</td>
<td>2 hours at 177°C (350°F) Optional post cure of 60 minutes at 232°C (450°F)</td>
<td>Extensive qualification portfolio • Low CTE, CME • High stability • RS-3C is controlled-flow version</td>
<td>TML 0.22% CVM 0.01%</td>
<td>o</td>
<td>o</td>
<td>o</td>
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<tr>
<td>TC401 Cyanate Ester</td>
<td>176°C (348°F) or 348°C (658°F) with post cure</td>
<td>3 hours at 177°C (350°F) Optional post cure at 260°C (500°F)</td>
<td>Good resistance to microcracking • Capable of high-temperature service • Ideal for heat shield and ablative applications</td>
<td>TML 0.41% CVM &lt; 0.01% WVR 0.29% CTE 56 ppm/°C</td>
<td>o</td>
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**RTM Resins**

<table>
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<tr>
<th>RESIN</th>
<th>DRY Tg, ONSET</th>
<th>CURE TIME AND TEMPERATURE</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>OUTGASSING, CTE/OMI, ON HOTMIL DATA</th>
<th>SOLID</th>
<th>TOUGHED</th>
<th>LOW-MOBILITY ABBREVIATION</th>
<th>SPACE</th>
<th>SATELLITE</th>
<th>LAUNCH</th>
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</thead>
<tbody>
<tr>
<td>EX-1545 Cyanate Ester</td>
<td>177°C (345°F)</td>
<td>2 hours at 177°C (350°F)</td>
<td>Toughened resin system with low viscosity of 140 cPs at 43°C (110°F) • Long post life for complex parts</td>
<td>o</td>
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<tr>
<td>RS-16 Cyanate Ester</td>
<td>167°C (332°F) or 211°C (412°F) with post cure</td>
<td>2 hours at 135°C (275°F) followed by 2 hours at 150°C (300°F)</td>
<td>Low-temperature cure resin system • Post curable for higher Tg</td>
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<tr>
<td>EX-1510 Cyanate Ester</td>
<td>183°C (363°F)</td>
<td>2 hours at 177°C (350°F)</td>
<td>Low room temperature viscosity of 150 cPs • Post curable for higher Tg</td>
<td>o</td>
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**Toray Microply™ Film Adhesives: Epoxy**

<table>
<thead>
<tr>
<th>RESIN MATRIX</th>
<th>DRY Tg, ONSET</th>
<th>CURE TIME AND TEMPERATURE</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>OUTGASSING, CTE/OMI, ON HOTMIL DATA</th>
<th>SOLID</th>
<th>TOUGHED</th>
<th>LOW-MOBILITY ABBREVIATION</th>
<th>SPACE</th>
<th>SATELLITE</th>
<th>LAUNCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS-15H Epoxy</td>
<td>99°C (210°F)</td>
<td>6 hours at 93°C (200°F)</td>
<td>Low-temperature curing adhesive</td>
<td>o</td>
<td>o</td>
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</tr>
<tr>
<td>TC263 Epoxy</td>
<td>110°C (230°F)</td>
<td>2 hours at 121°C (250°F)</td>
<td>High peel strength • Ideal for metal or composite bonding</td>
<td>o</td>
<td>o</td>
<td>o</td>
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<tr>
<td>TC310 Epoxy</td>
<td>153°C (315°F)</td>
<td>2 hours at 177°C (350°F)</td>
<td>Ideal composite bonding film adhesive</td>
<td>o</td>
<td>o</td>
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**Toray Microply™ Film Adhesives: Cyanate Ester**

<table>
<thead>
<tr>
<th>RESIN MATRIX</th>
<th>DRY Tg, ONSET</th>
<th>CURE TIME AND TEMPERATURE</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>OUTGASSING, CTE/OMI, ON HOTMIL DATA</th>
<th>SOLID</th>
<th>TOUGHED</th>
<th>LOW-MOBILITY ABBREVIATION</th>
<th>SPACE</th>
<th>SATELLITE</th>
<th>LAUNCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX-1516 Cyanate Ester</td>
<td>128°C (260°F)</td>
<td>5 hours at 121°C (250°F)</td>
<td>Compatible with Toray EX-1515 prepreg</td>
<td>o</td>
<td>o</td>
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<tr>
<td>RS-4A Cyanate Ester</td>
<td>195°C (383°F) or 238°C (460°F) with post cure</td>
<td>2 hours at 177°C (350°F) Optional post cure of 1.5-2 hours at 232°C (450°F)</td>
<td>Moisture resistant</td>
<td>o</td>
<td>o</td>
<td>o</td>
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</tr>
<tr>
<td>EX-1543 Cyanate Ester</td>
<td>191°C (378°F) or 211°C (412°F) with post cure</td>
<td>2 hours at 177°C (350°F)</td>
<td>Compatible with 177°C (350°F) curing cyanate ester prepreg • Low shrinkage • Low outgassing</td>
<td>o</td>
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<tr>
<td>TC4015 Cyanate Ester</td>
<td>176°C (348°F) or 321°C (610°F) with post cure</td>
<td>2 hours at 177°C (350°F) Optional post cure of &gt; 60 minutes at 232°C (450°F)</td>
<td>Excellent high-temperature properties • Compatible with TC420</td>
<td>o</td>
<td>o</td>
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**Toray Microply™ Syntactics: Epoxy**

<table>
<thead>
<tr>
<th>RESIN MATRIX</th>
<th>DRY Tg, ONSET</th>
<th>CURE TIME AND TEMPERATURE</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>OUTGASSING, CTE/OMI, ON HOTMIL DATA</th>
<th>SOLID</th>
<th>TOUGHED</th>
<th>LOW-MOBILITY ABBREVIATION</th>
<th>SPACE</th>
<th>SATELLITE</th>
<th>LAUNCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>EM-3 Epoxy</td>
<td>~10°C (50°F)</td>
<td>60 minutes at 121°C (250°F)</td>
<td>High expansion (8-10 x) • 0.64 g/cc (40 pcf) density • Tg estimated from base resin data</td>
<td>o</td>
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<tr>
<td>TCF4005 Epoxy</td>
<td>140°C (284°F)</td>
<td>3 hours at 130°C (265°F)</td>
<td>Low density 0.64 g/cc (40 pcf) • Compatible with TCF56, may be post cured for higher Tg</td>
<td>o</td>
<td>o</td>
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Advanced Thermoset Composite Products for Space, Satellite, & Launch
Toray Microply™ Syntactics Cyanate Ester

<table>
<thead>
<tr>
<th>RESIN MATRIX</th>
<th>DRY T onset</th>
<th>CURVE TIME AND TEMPERATURE</th>
<th>KEY PRODUCT CHARACTERISTICS</th>
<th>DRY</th>
<th>THICKENED</th>
<th>LOW MOISTURE</th>
<th>SATIN</th>
<th>SATURAL</th>
<th>LAUNCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCF4001 Cyanate Ester</td>
<td>176°C (349°F)</td>
<td>2 hours at 177°C (350°F)</td>
<td>Low density 0.38 g/cc (24 pcf)</td>
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<td></td>
<td>Optional post cure of 60-90 minutes at 232°C (450°F)</td>
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<tr>
<td>TCF4060 Cyanate Ester</td>
<td>176°C (349°F) or 232°C (450°F) with post cure</td>
<td>2 hours at 177°C (350°F)</td>
<td>Expanding syntactic film/core splice</td>
<td>○</td>
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<tr>
<td></td>
<td></td>
<td>Optional post cure of 60-90 minutes at 232°C (450°F)</td>
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<td></td>
</tr>
<tr>
<td>EM-5A Cyanate Ester</td>
<td>204°C (400°F)</td>
<td>2 hours at 177°C (350°F)</td>
<td>Expansion ratio of 4 x</td>
<td>○</td>
<td>○</td>
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<td>Optional post cure of 60-90 minutes at 232°C (450°F)</td>
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- AS9100D
- ISO 14001:2015
- ISO 45001:2018

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