Advanced Materials

Raising performance with building blocks

Quarter 4, 2012 - Selection for Composites Europe
## Table of contents

### High performance epoxy resins

<table>
<thead>
<tr>
<th>Resin Type</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tactix</strong> 123</td>
<td>Distilled BPA resin - Lowest viscosity among BPA resins</td>
</tr>
<tr>
<td><strong>Tactix</strong> 556</td>
<td>Specialty Phenol Novolac resin - Low moisture absorption</td>
</tr>
<tr>
<td><strong>Araldite</strong> MY 0610</td>
<td>Distilled TGMAP - Low viscosity, high modulus and Tg</td>
</tr>
<tr>
<td><strong>Tactix</strong> 742</td>
<td>Tri-functional epoxy resin - Highest temperature resistance</td>
</tr>
<tr>
<td><strong>Araldite</strong> MY 0816</td>
<td>Naphthalene based epoxy resin - Liquid, bi-functional and high Tg</td>
</tr>
<tr>
<td><strong>LME 10169</strong></td>
<td>Fluoren based epoxy resin - Bi-functional, high Tg</td>
</tr>
</tbody>
</table>

### Specialty hardeners and accelerators

<table>
<thead>
<tr>
<th>Hardener/Accelerator Type</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LME 10638</strong></td>
<td>Modified DDS curing agent - Easier processing</td>
</tr>
<tr>
<td><strong>Aradur</strong> 1571</td>
<td>Latent curing agent in dispersion - Easier processing</td>
</tr>
<tr>
<td><strong>Aradur</strong> 3123 and <strong>Aradur</strong> 9506</td>
<td>Latent hardeners - “Snap-shot” curing behavior</td>
</tr>
</tbody>
</table>

### Tougheners and flexibilizers

<table>
<thead>
<tr>
<th>Flexibilizer Type</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Araldite</strong> LY 1108</td>
<td>Liquid epoxy rubber adduct - Easy processing, adhesion promoter</td>
</tr>
<tr>
<td><strong>Flexibilizer</strong> DY 965</td>
<td>Special PU adduct - Synergistic effect with epoxy-rubber adducts</td>
</tr>
<tr>
<td><strong>Tactix</strong> 695</td>
<td>Single phase toughened and self reactive epoxy resin</td>
</tr>
<tr>
<td><strong>Resin XU 3508</strong></td>
<td>Multi-phase toughened epoxy resin</td>
</tr>
</tbody>
</table>

### Benzoxazine resins

<table>
<thead>
<tr>
<th>Resin Type</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Araldite</strong> MT 35600</td>
<td>BPA based benzoxazine resin - Mechanical and Flame resistance</td>
</tr>
</tbody>
</table>
Distilled BPA resin - Lowest viscosity among BPA resins
Tactix® 123

Description
- Distilled Bisphenol–A epoxy resin

Typical characteristics
- Aspect: clear liquid
- Epoxy equivalent weight: 172 – 176 g/Eq
- Viscosity at 25°C: 4 400 – 5 600 mPa.s

Main features
- Distilled product
- Lowest viscosity within the Bisphenol–A epoxy range

Applications and benefits
- Aero type grade
- Recommended for applications and processes requiring low viscosity such as filament winding, infusion, resin transfer molding
- Similar Tg as standard liquid Bisphenol–A epoxy resins
### Associated products

<table>
<thead>
<tr>
<th>Description</th>
<th>Viscosity at 25°C</th>
<th>Epoxy equivalent weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
<td>mPa.s</td>
<td>g/Eq</td>
</tr>
<tr>
<td><strong>Araldite® PY 306</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distilled Bis–F epoxy resin</td>
<td>1 200 – 1 600</td>
<td>156 – 167</td>
</tr>
<tr>
<td><strong>Araldite® MY 790</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distilled Bis–A epoxy resin</td>
<td>4 000 – 6 000</td>
<td>169 – 178</td>
</tr>
<tr>
<td><strong>Developmental LME 10872</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distilled Bis–A epoxy resin, low EHC (&lt;150 ppm)</td>
<td>4 000 – 6 000</td>
<td>169 – 178</td>
</tr>
</tbody>
</table>
Comparison between distilled resins and standard resins
Viscosity at 23°C (mPa.s)
Comparison between distilled resins and standard resins
Epoxy equivalent weight (g/Eq)
Tactix® 556

High performance epoxy resins

Specialty Phenol Novolac resin - Low moisture absorption
**Tactix® 556**

**High performance epoxy resins**

**Description**
- Dicyclopentadiene based epoxy novolac

**Typical characteristics**
- Aspect: amber to dark, semi-solid
- Epoxy equivalent weight: 215 – 240 g/Eq
- Softening point: 53°C
- Viscosity at 85°C: 1 000 – 1 500 mPa.s
- Hydrolisable chlorine: 0 – 300 ppm

**Main features**
- Hydrophobic backbone
- Melts at medium temperature

**Applications and benefits**
- Lower moisture absorption than many multifunctional epoxies commonly used in advanced composites
- Equivalent glass transition temperatures in dry conditions as standard epoxy novolac resins
- Tactix® 556 resin is ideal for new use where retention of properties under hot and wet conditions is critical
## Associated products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Epoxy equivalent weight</th>
<th>Softening point</th>
<th>Hydrolisable chlorine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dicyclopentadiene based epoxy novolac</td>
<td>250 – 274</td>
<td>78 – 90</td>
<td>0 – 100</td>
<td></td>
</tr>
</tbody>
</table>
Ultimate Tg (°C) and water absorption (%)
Distilled TGMAP - Low viscosity, high modulus and Tg
**Araldite® MY 0610**

### Description
- Distilled triglycidylether of meta-amino phenol
- Typical characteristics
- Aspect: clear liquid
- Epoxy equivalent weight: 94 – 102 g/Eq
- Viscosity at 25°C: 1 500 – 4 800 mPa.s
- Hydrolisable chlorine: 0 – 2 000 ppm

### Main features
- Liquid
- High monomer content and high purity
- Non symmetrical backbone
- Good solvent for Polyethersulfone

### Applications and benefits
- Facilitate processing, especially of PES toughened compositions
- Higher stability (reactivity) than non distilled version
- Provides higher modulus than p-amino phenol based resins
- Provides higher toughness than p-amino phenol based resins
- Provides similar level of glass transition temperature
# Araldite® MY 0610

## High performance epoxy resins

### Associated products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Viscosity at 25°C</th>
<th>Epoxy equivalent weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td></td>
<td>mPa.s</td>
<td>g/Eq</td>
</tr>
<tr>
<td>Araldite® MY 0600</td>
<td>Triglycidylether of meta-aminophenol (TGMAP)</td>
<td>7 000 – 13 000</td>
<td>101 – 111</td>
</tr>
<tr>
<td>Araldite® MY 0500</td>
<td>Triglycidylether of para-aminophenol (TGPAP)</td>
<td>2 000 – 5 000</td>
<td>100 – 115</td>
</tr>
<tr>
<td>Araldite® MY 0510</td>
<td>Triglycidylether of para-aminophenol (TGPAP) distilled grade</td>
<td>550 – 850</td>
<td>96 – 106</td>
</tr>
</tbody>
</table>
Comparison between TGPAP and TGMAP
Flexural modulus and strength (MPa)

Stoechiometric cure with 4,4'-DDS - Water absorption after 48h in boiling water
Cure cycle: 0.5h at 80°C + 0.5h at 100°C + 1.5h at 120°C + 2h at 180°C
Comparison between TGPAP and TGMAP

Glass transition temperature - Tg DMA (°C)

Stoechiometric cure with 4,4'-DDS - Water absorption after 48h in boiling water

Cure cycle: 0.5h at 80°C + 0.5h at 100°C + 1.5h at 120°C + 2h at 180°C
Araldite® MY 0610

High performance epoxy resins

Comparison between TGPAP, TGMAP and TGMDA
Glass transition temperature (°C) and modulus (MPa)

Stoechiometric cure with 4,4’-DDS
Cure cycle : 0.5h at 80°C + 0.5h at 100°C + 1.5h at 120°C + 2h at 180°C
Comparison with DGEBA
Glass transition temperature (°C) by DMA

Stoechiometric cure with 4,4’-DDS
Cure cycle : 0.5h at 80°C + 0.5h at 100°C + 1.5h at 120°C + 2h at 180°C
Tri-functional epoxy resin - Highest temperature resistance
Description

- Tris-(hydroxyl phenyl) methane-based epoxy

Typical characteristics

- Aspect: yellow, semi-solid
- Epoxy equivalent weight: 150 - 170 g/Eq
- Softening point: 45 - 55°C
- Viscosity at 80°C: 600 – 700 mPa.s
- Hydrolisable chlorine: 0 – 500 ppm

Main features

- Tri-functional
- Symmetrical and rigid backbone
- Large distance between epoxy reactive groups

Applications and benefits

- Provides very high glass transition temperatures
- Most commonly used in adhesive and composite formulation, especially for parts and components near high-heat zones
## Associated products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Aspect</th>
<th>Epoxy equivalent weight</th>
<th>Hydrolisable chlorine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td></td>
<td>g/Eq</td>
<td></td>
<td>ppm</td>
</tr>
<tr>
<td>XB 4399-3</td>
<td>Tetrafunctional epoxy resin</td>
<td>Brown flaked, solid</td>
<td>213 – 244</td>
<td>300 – 1 100</td>
</tr>
</tbody>
</table>
Tactix® 742

High performance epoxy resins

Tg comparison - Ultimate Tg DMA (°C)

Stoechiometric cure with 4,4'-DDS
Cure cycle: 3h at 180°C + 2h at 230°C
Tactix® 742

High performance epoxy resins

Molecular structure comparison

![Molecular structure comparison]

Tactix® 742  
XB 4399-3
Naphthalene based epoxy resin - Liquid, bi-functional and high Tg
Araldite® MY 0816

**High performance epoxy resins**

**Description**
- 1,6 – naphthalene diepoxy

**Typical characteristics**
- Aspect: clear, red liquid
- Epoxy equivalent weight: 133 – 154 g/eq
- Viscosity at 25°C: 25 000 – 80 000 mPa.s
- Viscosity at 50°C: 1500 – 2500 mPa.s
- Hydrolisable chlorine: 0 – 2 000 ppm

**Main features**
- Low viscosity
- Di functional
- Flat rigid core facilitating multimolecular association leading to highly compact network
- Strong aromatic character and low polarity backbone

**Applications and benefits**
- Easy processing (liquid), helps to control tack
- Provides higher glass transition temperatures than Bisphenol-A epoxy resins, close to glycidylamines epoxy resins
- Contributes to toughness improvement via reduction of cross-linking density
- Lower contribution to water uptake compared to other high performance resins
<table>
<thead>
<tr>
<th>Neat resin properties*</th>
<th>Araldite® MY 721</th>
<th>Araldite® MY 0816</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity at 80°C</td>
<td>260 mPa.s</td>
<td>110 mPa.s</td>
</tr>
<tr>
<td>Tg (DMA, onset) - DRY/WET**</td>
<td>260 / 250 °C</td>
<td>223 / 220 °C</td>
</tr>
<tr>
<td>Δ Tg Dry-Wet</td>
<td>10 °C</td>
<td>3 °C</td>
</tr>
<tr>
<td>Flexural modulus / strength</td>
<td>3 575 / 146 MPa</td>
<td>3 550 / 140 MPa</td>
</tr>
<tr>
<td>KIC</td>
<td>0.6 MPa √m</td>
<td>0.8 MPa √m</td>
</tr>
<tr>
<td>GIC</td>
<td>85 J/m²</td>
<td>145 J/m²</td>
</tr>
</tbody>
</table>

*Stoechiometric cure with 4,4’-DDS, 2h at 150°C + 4h at 180°C + 2h at 200°C

**Wet = 1 month in boiling water
Fluoren based epoxy resin - Bi-functional, high Tg
Developmental Resin LME 10169

Description
- Fluoren di-epoxy

Typical characteristics
- Aspect: white powder
- Epoxy equivalent weight: 245 - 255 g/Eq
- Melting point: 130 – 160°C

Main features
- Di-functional epoxy
- Large / bulky backbone showing structural rigidity
- High aromatic content

Applications and benefits
- Proposed for structural composite matrices and adhesives
- Provides glass transition temperatures similar to tri and tetra functional glycidylamine epoxies
- Contributes to toughness improvement via reduction of cross-linking density (in comparison to glycidylamine epoxies)
- Aromatic character will favor charring in case of fire
## Developmental Resin LME 10169

### Associated products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Epoxy equivalent</th>
<th>Softening point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td></td>
<td>g/Eq</td>
<td>°C</td>
</tr>
<tr>
<td>Developmental LME 10889</td>
<td>Bisphenol-R based epoxy</td>
<td>255 – 265</td>
<td>135 – 160</td>
</tr>
<tr>
<td></td>
<td>Bulky aromatic backbone</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Developmental Resin LME 10169

High performance epoxy resins

Melt viscosity comparison

Melt viscosity (mPa·s)

Temperature (°C)

LME 10169
LME 10889

Advanced Materials
Developmental Hardener LME 10638

Specialty hardeners and accelerators

Modified DDS curing agent - Easier processing
Developmental Hardener LME 10638

Description
- Modified DDS

Typical characteristics
- Aspect: brown, semi-solid
- H⁺ active equivalent (theory): 84 g/Eq
- Melting point: 65 - 80°C
- Viscosity at 120°C: 2 000 – 2 500 mPa.s

Main features
- Low softening temperature
- Low melt viscosity
- DDS like structure and behavior
- Faster reactivity than 3,3'-DDS
- Patented

Applications and benefits
- Dissolves easily in epoxy resins
- When cured with glycidylamine based epoxies or Bisphenol-A epoxies, brings glass transition temperature and thermal resistance nearly at the same level as 3,3'-DDS
- Would allow DDS-type curative to be used in RTM process
- Contributes to improve chemical resistance
### Developmental Hardener LME 10638

**Specialty hardeners and accelerators**

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Aspect</th>
<th>Tg DSC °C</th>
<th>Viscosity at 120°C mPa.s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developmental LME 10477</td>
<td>Modified DDS, “high modulus”</td>
<td>Brown, amorphous powder</td>
<td>20 – 30</td>
<td>~190</td>
</tr>
<tr>
<td>Developmental LME 10478</td>
<td>Modified DDS</td>
<td>Brown, amorphous powder</td>
<td>20 – 30</td>
<td>~190</td>
</tr>
</tbody>
</table>
Developmental Hardener LME 10638

LME 10638 vs. 3,3'-DDS
Higher reactivity, comparable temperature resistance

<table>
<thead>
<tr>
<th></th>
<th>Araldite® MY 721</th>
<th>LME 10638</th>
<th>Tactix® 123</th>
<th>LME 10638</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3,3'-DDS</strong></td>
<td>190°C</td>
<td>175°C</td>
<td>171°C</td>
<td>147°C</td>
</tr>
<tr>
<td><strong>Reactivity, DSC onset</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reactivity, DSC peak</strong></td>
<td>223°C</td>
<td>216°C</td>
<td>211°C</td>
<td>200°C</td>
</tr>
<tr>
<td><strong>Tg DMA, onset, DRY</strong></td>
<td>231°C</td>
<td>232°C</td>
<td>186°C</td>
<td>171°C</td>
</tr>
<tr>
<td><strong>Tg DMA, WET</strong></td>
<td>195°C</td>
<td>185°C</td>
<td>154°C</td>
<td>135°C</td>
</tr>
</tbody>
</table>

Wet: 48h in boiling water
LME 10477 & LME 10478 vs. 4,4'-DDS
Viscosity build up at 80°C - Araldite® MY 721 / Araldite® MY 0510 (40/60) + Hardener

Melt viscosity (mPa.s)

Process temperature for mixing: 4,4’ DDS: 130°C / LME 10477: 80°C / LME 10478: 80°C
Developmental Hardener LME 10638

**LME 10478 - Carbon composite data - Comparison to aero reference system**

60% FV - Process RTM - Cure cycle: 2h at 180°C

<table>
<thead>
<tr>
<th></th>
<th>Tg DMA, onset, dry</th>
<th>Tg DMA, onset, wet</th>
<th>ILSS dry</th>
<th>ILSS wet</th>
<th>Flexural modulus dry</th>
<th>Compression modulus dry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Araldite® MY 721 / Araldite® MY 0510 / LME 10478</strong></td>
<td>193 °C</td>
<td>162 °C</td>
<td>100 MPa</td>
<td>90 MPa</td>
<td>108 GPa</td>
<td>115 GPa</td>
</tr>
<tr>
<td><strong>Aero. Reference</strong></td>
<td>190 °C</td>
<td>175 °C</td>
<td>95 MPa</td>
<td>85 MPa</td>
<td>109 GPa</td>
<td>115 GPa</td>
</tr>
</tbody>
</table>

Wet: 3 days in boiling water

---

Advanced Materials
Latent curing agent in dispersion - Easier processing
Aradur® 1571

Description
- Dispersion of dicyandiamide in liquid epoxy resins

Typical characteristics
- Aspect: white viscous paste
- Viscosity at 25°C: 28 000 – 40 000 mPa.s
- Dicyandiamide content: 28% bw

Main features
- Dicyandiamide particle size: 98% < 10 μm
- Accurate and consistent content of dicyandiamide
- Complies with “one component” transportation constraints

Applications and benefits
- Eliminate manipulation of dicyandiamide in powder form
- Eliminate the need for heavy dispersion equipments
- Homogeneous, agglomerate-free dispersion
- Easy to manipulate and introduce in epoxy resins formulations
## Associated products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Aspect</th>
<th>Viscosity at 25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td></td>
<td></td>
<td>mPa.s</td>
</tr>
<tr>
<td><strong>Accelerator 1573</strong></td>
<td>Dispersion of solid accelerator in liquid epoxy resin</td>
<td>White viscous paste</td>
<td>60 000 – 90 000</td>
</tr>
</tbody>
</table>
Aradur® 1571 and Aradur® 1573

Typical particle size characteristics measured by laser diffraction (dilution in MEK)

<table>
<thead>
<tr>
<th></th>
<th>d(0.1)</th>
<th>d(0.5)</th>
<th>d(0.9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aradur® 1571</td>
<td>1.3 - 1.4</td>
<td>3.9 - 4.1</td>
<td>7.7 - 7.9</td>
</tr>
<tr>
<td>Aradur® 1573</td>
<td>0.9 - 1.1</td>
<td>2.9 - 3.1</td>
<td>6.0 - 6.2</td>
</tr>
</tbody>
</table>

*d(0.X) : X% of the particles have a diameter below d(0.X)*
Typical particle size distribution of Aradur® 1571 (% volume)

Light diffraction - dilution in MEK
Latent hardeners - “Snap-shot” curing behavior
**Aradur® 3123**

**Specialty hardeners and accelerators**

**Description**
- Substituted Imidazole accelerator

**Typical characteristics**
- Aspect: white fine powder
- Melting point: ~210°C
- Volatile matter: 0.0 – 0.5%

**Main features**
- Free flowing and fine powder
- Very low solubility in epoxy resins and solvents at RT

**Applications and benefits**
- Easily dispersible in liquid resins
- Recommended as latent catalytic curing agent for liquid epoxy resins or as latent accelerator for anhydride or amine cured epoxy resins
- Very good latency up to 100 - 110°C
- Snap-cure type behavior at temperature above 110°C
Typical particle size distribution of Aradur® 3123
Measured by laser diffraction

<table>
<thead>
<tr>
<th>Typical particle size distribution (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (10%)</td>
</tr>
<tr>
<td>D (50%)</td>
</tr>
<tr>
<td>D (90%)</td>
</tr>
</tbody>
</table>
Reactivity of Araldite® GY 250 / Aradur® 3123
8.0 pbw of Aradur® 3123 in 100 parts of epoxy resin - Time to cure (min) / Curing temperature (°C)
Aradur® 9506

Specialty hardeners and accelerators

Description
- Cyclic polyamidoamine

Typical characteristics
- Aspect: pale yellow fine powder
- Melting point: ~105°C
- Amine equivalent weight: 65 – 70 g/eq

Main features
- Free flowing and fine powder
- Very low solubility in epoxy resins at RT

Applications and benefits
- Easily dispersible in liquid resins
- Outstanding latency at 25°C
- High reactivity at temperature > 100°C
- Recommended as latent curing agent for epoxy based adhesives
Typical particle size distribution of Aradur® 9506
Measured by laser diffraction

Volume (%)

Particle size (μm)

<table>
<thead>
<tr>
<th>Typical particle size distribution (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (10%)</td>
</tr>
<tr>
<td>D (50%)</td>
</tr>
<tr>
<td>D (90%)</td>
</tr>
<tr>
<td>D (100%)</td>
</tr>
</tbody>
</table>
Time to cure with Araldite® GY 250

- **Araldite® GY 250 / Aradur® 3123 (8 phr)**
- **Araldite® GY 250 / Aradur® 9506 (30 phr)**

The graph shows the time to cure (in minutes) at different curing temperatures (in °C). The dark blue bar represents Araldite® GY 250 / Aradur® 3123 (8 phr), and the light blue bar represents Araldite® GY 250 / Aradur® 9506 (30 phr).
Araldite® LY 1108

Tougheners and flexibilizers

Liquid epoxy rubber adduct - Easy processing, adhesion promoter
Araldite® LY 1108

Description
- Modified CTBN / Bisphenol-F epoxy adduct
- Typical characteristics
  - Aspect: reddish brown liquid
  - Epoxy equivalent weight: 269 - 301 g/Eq
  - Viscosity at 25°C: 22 - 51 mPa.s
  - Rubber content: ~ 30%

Main features
- Liquid
- Low viscosity at RT
- Contains special modifier within the polymer chain

Applications and benefits
- Easy processing/incorporation
- Reactive toughener, efficient under low to medium service temperatures
- Proposed for adhesives, composite and any other formulation when high glass transition temperature is not a must
- Co-reacted modifier contributes to adhesion improvement, especially on contaminated surfaces and also helps in corrosion resistance
**Araldite® LY 1108**

### Associated products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Epoxy equivalent weight</th>
<th>Viscosity</th>
<th>Rubber content</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Araldite® LY 1146</strong></td>
<td>Modified CTBN / Bis-A epoxy adduct</td>
<td>833 – 1 116</td>
<td>350 – 1 100 at 25°C</td>
<td>~ 40</td>
</tr>
<tr>
<td><strong>Araldite® LY 1115</strong></td>
<td>CTBN / Bis-F epoxy adduct</td>
<td>238 – 250</td>
<td>250 – 400 at 25°C</td>
<td>~ 20</td>
</tr>
<tr>
<td><strong>Araldite® LY 1134</strong></td>
<td>CTBN / Bis-A epoxy adduct</td>
<td>286 – 323</td>
<td>200 – 500 at 40°C</td>
<td>~ 20</td>
</tr>
<tr>
<td><strong>Araldite® LT 1522</strong></td>
<td>CTBN / Bis-A epoxy adduct</td>
<td>1 562 – 1 818</td>
<td>Solid material</td>
<td>~ 30</td>
</tr>
</tbody>
</table>
Effect of CTBN on $T_g$ in an epoxy matrix

![Graph showing the effect of CTBN on $T_g$ in an epoxy matrix.](image-url)
Araldite® LY 1108

Tougheners and flexibilizers

Araldite® CTBN-epoxy adducts
Main characteristics comparison

- EEW (g/Eq)
- Viscosity (Pa·s)

CTBN content (%)
Special PU adduct - Synergistic effect with epoxy-rubber adducts
Flexibilizer DY 965

Description
- Phenol terminated polyurethane adduct

Typical characteristics
- Aspect: clear yellow / brownish viscous liquid
- Hydroxyl eq.: 1.00 – 1.15 Eq/Kg
- Viscosity at 40°C: 440 – 1300 Pa.s

Main features
- Toughening and flexibilizing effect
- Adhesion promoter
- Reactive through OH groups
- High compatibility with epoxy resins and various solvents
- Liquid

Applications and benefits
- Preparation of high impact resistant epoxy resin compositions (composite and adhesives)
- Improvement of adhesion on metals, especially for low temperature applications
- Easy processing (incorporation)
## Tougheners and flexibilizers

### Associated products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Hydroxy equivalent</th>
<th>Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Araldite® DY 1186</strong></td>
<td>Phenol terminated polyether adduct</td>
<td>1.4 - 2.0 Eq/Kg</td>
<td>5600 – 8400 mPa.s at 25°C</td>
</tr>
<tr>
<td><strong>Flexibilizer XB 3333</strong></td>
<td>Phenol terminated polyurethane adduct</td>
<td>1.0 - 1.2 Eq/Kg</td>
<td>400 – 1300 Pa.s at 40°C</td>
</tr>
</tbody>
</table>
**Flexibilizer DY 965**

Toughening / flexibilizing effect of Flexibilizer DY 0965 in Tactix® 556 / Aradur® 9664-1

Stoechiometric cure with 4,4’-DDS - Water absorption after 48h in boiling water
Effect of Flexibilizer DY 965 on peel strength
2K-epoxy adhesive, aluminium substrate

![Graph showing the effect of Flexibilizer DY 965 on peel strength. The graph includes lines for Tg DMA Peak, Tg DMA Onset, Peel strength Acid etched Al, and Peel strength Sand-blasted Al. The x-axis represents Flexibilizer DY 965 loading (%), and the y-axis represents Peel strength (N/mm).]
Flexibilizer DY 965

Synergistic behavior of Flexibilizer DY 965 + conventional nitril rubbers *

T-Peel (N/mm)

* XB 3333: similar trend as Flexibilizer DY 965
Synergistic behavior of Flexibilizer DY 965 + conventional nitril rubbers *

$G_{1C}$ (KJ/m$^2$)

* XB 3333: similar trend as Flexibilizer DY 965
## Conventional nitril rubber based tougheners

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Epoxy equivalent weight</th>
<th>Viscosity</th>
<th>Rubber content</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Araldite® LY 1108</strong></td>
<td>Modified CTBN / Bis-F epoxy adduct</td>
<td>269 - 301</td>
<td>22 - 51 at 25°C</td>
<td>~ 30</td>
</tr>
<tr>
<td><strong>Araldite® LY 1146</strong></td>
<td>Modified CTBN / Bis-A epoxy adduct</td>
<td>833 - 1 116</td>
<td>350 - 1 100 at 25°C</td>
<td>~ 40</td>
</tr>
<tr>
<td><strong>Araldite® LY 1115</strong></td>
<td>CTBN / Bis-F epoxy adduct</td>
<td>238 - 250</td>
<td>250 - 400 at 25°C</td>
<td>~ 20</td>
</tr>
<tr>
<td><strong>Araldite® LY 1134</strong></td>
<td>CTBN / Bis-A epoxy adduct</td>
<td>286 - 323</td>
<td>200 - 500 at 40°C</td>
<td>~ 20</td>
</tr>
<tr>
<td><strong>Araldite® LT 1522</strong></td>
<td>CTBN / Bis-A epoxy adduct</td>
<td>1 562 - 1 818</td>
<td>Solid material</td>
<td>~ 30</td>
</tr>
</tbody>
</table>
Tactix® 695

Tougheners and flexibilizers

Single phase toughened and self reactive epoxy resin
Tactix® 695

Description
- Single phase toughened epoxy resin

Typical characteristics
- Aspect: clear semi-solid
- Epoxy equivalent weight: 330 - 420 g/Eq
- Viscosity at 70°C: 1500 – 5500 mPa.s
- Shelf life at 5°C: 1 year

Main features
- Single has in-situ toughened epoxy resin
- Contains a proprietary blocked catalyst
- Catalyst is irreversibly deblocked at 80°C or above

Applications and benefits
- Can be used alone or as an additive to other resin systems to increase toughness
- Outstanding fracture toughness along with thermal and mechanical properties of standard epoxy resins
- Equilibrium moisture absorption about 1/3 to 1/2 of standard resins
- Suggested for highly damage-tolerant composites or high peel strength adhesive applications
**Tactix® 695**

**Tougheners and flexibilizers**

**Typical DSC trace**

*Method: 10°C/min*

- **Onset:** 167°C
- **Endset:** 227°C
- **Peak:** 206°C

---

*Huntsman*

Enriching lives through innovation
Viscosity increase at 80°C
### Tactix® 695

**Tougheners and flexibilizers**

**Typical matrix properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gel time at 150°C</td>
<td>75 min</td>
</tr>
<tr>
<td>Tg DMA, onset – DRY</td>
<td>160°C</td>
</tr>
<tr>
<td>Moisture absorption, 14 days in boiling water</td>
<td>1.4 %</td>
</tr>
<tr>
<td>Flexural modulus</td>
<td>3 100 MPa</td>
</tr>
<tr>
<td>Tensile modulus</td>
<td>3 070 MPa</td>
</tr>
<tr>
<td>Tensile elongation at break</td>
<td>6 %</td>
</tr>
</tbody>
</table>

Stoechiometric cure with 4,4'-DDS
Resin XU 3508

Tougheners and flexibilizers

Multi-phase toughened epoxy resin
Resin XU 3508

Toughened epoxy resin

Typical characteristics
- Aspect: white liquid
- Epoxy equivalent weight: 191 - 206 g/Eq
- Viscosity at 25°C: 11 000 – 20 000 mPa.s

Main features
- Similar viscosity as standard liquid Bisphenol-A based epoxy resins
- Similar epoxy equivalent weight range
- Unique multi-phase toughening technology

Applications and benefits
- Can replace totally or partly standard liquid Bisphenol-A based epoxy resins
- Increasing toughness characteristics \( (K_{IC}, G_{IC}) \) by factor greater than 2
- Without decrease in glass transition temperature
Resin XU 3508

Comparison to standard liquid Bisphenol-A based epoxy resins
Viscosity and epoxy equivalent weight

![Graph showing viscosity and epoxy equivalent weight comparison between XU 3508, Araldite® GY 240, Araldite® GY 250, and Araldite® GY 260. The graph compares viscosity (mPas·s) and epoxy equivalent weight (g/eq).]
# Resin XU 3508

## Tougheners and flexibilizers

### Comparison to standard liquid Bisphenol-A based epoxy resins

<table>
<thead>
<tr>
<th></th>
<th>Araldite® GY 250</th>
<th>XU 3508</th>
<th>Araldite® GY 250</th>
<th>XU 3508</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed viscosity at RT</td>
<td>1800 - 2000</td>
<td>1900 - 2100</td>
<td>600 - 900</td>
<td>700 - 1000</td>
</tr>
<tr>
<td>Cure cycle</td>
<td>15 min at 120°C + 2h at 150°C</td>
<td></td>
<td>4h at 80°C + 8h at 140°C</td>
<td></td>
</tr>
<tr>
<td>Tg DSC</td>
<td>155°C</td>
<td>150°C</td>
<td>150°C</td>
<td>140°C</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>130 - 136 MPa</td>
<td>120 - 135</td>
<td>130 - 150</td>
<td>140 - 150</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>7.5 - 10.0 %</td>
<td>8.0 - 10.0</td>
<td>7.0 - 8.5</td>
<td>5.7 - 6.7</td>
</tr>
<tr>
<td>$K_{IC}$</td>
<td>0.68 - 0.78 MPa.m1/2</td>
<td>0.95 - 1.15</td>
<td>0.56 - 0.60</td>
<td>0.85 - 0.95</td>
</tr>
<tr>
<td>$G_{IC}$</td>
<td>140 - 175 J/m²</td>
<td>340 - 380</td>
<td>88 - 96</td>
<td>210 - 240</td>
</tr>
</tbody>
</table>
Soluble thermoplastic Polyimide - Very high Tg and toughening effect
Matrimid® 5218

Description
- Thermoplastic Polyimide polymer based on 5(6)-amino-1-(4’ aminophenyl)-1,3,,-trimethylindane

Typical characteristics
- Aspect: yellow powder
- Volatile content: < 1.5%

Main features
- Fully imidized polymer
- Soluble in various solvents such as NEP, NMP, γBL, THF
- Very high glass transition temperature (Tg DMA >300°C)
- Very strong adhesion on various substrates such as metals, engineering plastics (acid etched), glass…
- Compatible with epoxies and other chemistries

Applications and benefits
- Temperature resistant adhesives
- Toughening of adhesives and composites matrices when high temperature resistance is key
- Temperature resistant coatings
# Matrimid® 5218

## Tougheners and flexibilizers

### Associated products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Particles size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrimid® 9725</td>
<td>Micronized version of Matrimid® 5218</td>
<td>&gt;70% &lt; 100 µm</td>
</tr>
</tbody>
</table>
Matrimid® 5218

Tougheners and flexibilizers

Tg by DMA > 300°C
Efficiency in composite toughening
CAI* strength (MPa)

* Compression After Impact
20% Thermoplastic b.w. in 180°C epoxy matrix - Impact Energy : 25 J / 4mm laminate thickness
Unidirectional intermediate modulus carbon fiber - Quasi-Iso lay-up : +45/0/-45/90
Source: US Pat. 5,242,748
Gas membrane application

Polyimides have proven useful for the formation of gas separation membranes because of their attractive combination properties: high gas permeability as well as high intrinsic permselectivity in comparison to polycarbonate, polysulfone and other materials.

<table>
<thead>
<tr>
<th>Solution</th>
<th>H₂ permeance (m³/m².h * bar)</th>
<th>α (H₂/CH₄)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5% Matrimid® 5218 in CHCl₃</td>
<td>0.156</td>
<td>86.71</td>
</tr>
<tr>
<td></td>
<td>0.148</td>
<td>82.28</td>
</tr>
<tr>
<td></td>
<td>0.164</td>
<td>83.13</td>
</tr>
<tr>
<td></td>
<td>0.169</td>
<td>81.78</td>
</tr>
<tr>
<td>2% Jeffamine® to Matrimid® 5218 0.5%CHCl₃</td>
<td>0.278</td>
<td>88.74</td>
</tr>
<tr>
<td></td>
<td>0.284</td>
<td>82.00</td>
</tr>
<tr>
<td></td>
<td>0.289</td>
<td>85.57</td>
</tr>
<tr>
<td></td>
<td>0.247</td>
<td>92.65</td>
</tr>
</tbody>
</table>

Table showing gas transport properties for Matrimid® 5218 membranes prepared without and with cross-linking agent.  
BPA based benzoxazine resin - Mechanical and Flame resistance
Araldite® MT 35600

Benzoxazine resins

Description
- Bisphenol-A benzoxazine resin

Typical characteristics
- Aspect: yellowish solid
- Melting point: 58 - 70°C
- Viscosity at 125°C: 50 – 500 mPa.s
- Volatile content: < 1%

Main features
- Di-functional thermosetting molecule
- Reacts at high temperature through addition reaction, without gas release and with “near-zero” shrinkage
- Creates on curing a phenolic-type network, showing very low moisture absorption
- High glass transition temperature and high modulus network
- Compatible with various other chemistries including epoxies, bis-maleimides, phenolics…

Applications and benefits
- High stability on storage at room temperature
- Provides matrices with higher modulus than epoxy resins, with equivalent glass transition temperature, lower water sensitivity, and better flame resistance
- Proposed for advanced composites, structural adhesives, laminates for printed wiring boards, high performance coatings, encapsulating and molding compounds
## Araldite® MT 35600

### Associated products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Aspect</th>
<th>Viscosity</th>
<th>Melting point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td></td>
<td></td>
<td>mPa.s</td>
<td>°C</td>
</tr>
<tr>
<td><strong>Araldite® 35700</strong></td>
<td>N-Phenyl Bis-F benzoxazine</td>
<td>Yellowish solid</td>
<td>1 000 – 7 000 at 100°C</td>
<td>~ 60</td>
</tr>
<tr>
<td><strong>Developmental LMB 6659</strong></td>
<td>Araldite® MT 35700 in solution</td>
<td>Solution (75% in MEK)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>XU 8282-1</strong></td>
<td>Phenolphthaleine benzoxazine based</td>
<td>Amber liquid</td>
<td>500 – 3000 at 25°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solution (70% in MEK)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Developmental LME 10640</strong></td>
<td>Cardanol based benzoxazine</td>
<td>Clear liquid Solvent-free</td>
<td>50 – 150 at 25°C</td>
<td></td>
</tr>
<tr>
<td><strong>DT 300 / DT310</strong></td>
<td>Accelerators for benzoxazines</td>
<td>White crystal</td>
<td></td>
<td>~155 / ~130</td>
</tr>
</tbody>
</table>
## Benzoxazine resins

### Benzoxazines: high modulus thermosets

Comparison to TGMAP epoxy resin (reference in high modulus epoxy resins)

<table>
<thead>
<tr>
<th></th>
<th>Tg DMA Onset</th>
<th>Flexural modulus</th>
<th>Tensile modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°C</td>
<td>MPa</td>
<td>MPa</td>
</tr>
<tr>
<td><strong>Araldite® MT 35600</strong></td>
<td>190</td>
<td>4 600</td>
<td>5 000</td>
</tr>
<tr>
<td><strong>Araldite® MY 0610</strong></td>
<td>220</td>
<td>4 150</td>
<td>4 000</td>
</tr>
</tbody>
</table>
**Araldite® MT 35600**

**Benzoxazine resins** | < Table of content> | < Previous product>
---|---|---

### Flammability behavior

**Comparison benzoxazine vs. phenolic (tests by Airbus Bremen)**

<table>
<thead>
<tr>
<th>Test methods</th>
<th>Units</th>
<th>Phenolic prepreg</th>
<th>Benzoxazine prepreg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aero qualified reference</td>
<td></td>
<td>XU 8282-1</td>
<td>XU 8282-1 + Catalyst</td>
</tr>
<tr>
<td><strong>E-glass</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepreg resin content</td>
<td></td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>Curing conditions</td>
<td></td>
<td>-</td>
<td>180°C, 120 min, 1.0 bar 150°C, 120 min, 1.0 bar</td>
</tr>
<tr>
<td>Resin content (cured)</td>
<td></td>
<td>%</td>
<td>40% ± 2</td>
</tr>
<tr>
<td>Flammability (12 s)</td>
<td>AITM 2.0002 B</td>
<td>mm/s/s</td>
<td>128 / 0 / 0 142 / 2 / 0</td>
</tr>
<tr>
<td>Flammability (60 s)</td>
<td>AITM 2.0002 A</td>
<td>mm/s/s</td>
<td>144 / 0 / 0 167 / 0 / 0</td>
</tr>
<tr>
<td>Smoke density (Flaming)</td>
<td>AITM 2.0007</td>
<td>Ds</td>
<td>6 6</td>
</tr>
<tr>
<td>Toxicty (Flaming)</td>
<td>AITM 3.0005</td>
<td>ppm HCN</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ppm CO</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ppm NOx</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ppm SO2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ppm HF</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ppm HCl</td>
<td>0</td>
</tr>
<tr>
<td>Heat release test (HRR / HR)</td>
<td>AITM 2.0006</td>
<td>kw/m² . kw*min/m²</td>
<td>65 / 40 58 / 34 63 / 33</td>
</tr>
</tbody>
</table>

---

**Advanced Materials**
Effect of accelerators DT 300 and DT 310 on gel time of Araldite® MT 35600

The graph shows the gel time (s) of Araldite® MT 35600 with different accelerators. The gel time decreases as the temperature increases. The graph compares three scenarios:
- No Accelerator
- 10 phr DT300
- 10 phr DT310

As the temperature increases from 130°C to 210°C, the gel time decreases for all three scenarios, but the rate of decrease varies. The 10 phr DT300 and DT310 show a more significant decrease in gel time compared to the no accelerator case.
Keep our products at your fingertips

View the brochure on SlideShare
With this brochure get an overview of our comprehensive range of building blocks for formulators.

Download our mobile apps on your smartphone
With these apps select immediately the right:
- Araldite® industrial adhesive for your specific need
- Araldite® composite formulated system for your process / application
Access the product description or send us an email to request the technical data sheet.

Araldite® - Adhesives (Europe)
Download on iPhone | Android | BlackBerry

Huntsman - Composite resins (Europe)
Download on iPhone | Android | BlackBerry
For more information

www.huntsman.com/advanced_materials
advanced_materials@huntsman.com

Europe
Huntsman Advanced Materials (Switzerland) GmbH
Klybeckstrasse 200
P.O. Box - 4002 Basel
Switzerland
Tel. +41 61 299 20 41
Fax +41 61 299 20 40

Registered for REACH

Responsible Care®
OUR COMMITMENT TO SUSTAINABILITY
Legal Disclaimer

Copyright © 2012 Huntsman Corporation or an affiliate thereof. All rights reserved.

The use of the symbol ® herein signifies the registration of the associated trademark in one or more, but not all, countries. While the information and recommendations included in this publication are, to the best of Huntsman’s knowledge, accurate as of the date of publication, nothing contained herein is to be construed as a representation or warranty of any kind, express or implied.