EVONIK FOR COMPOSITES
Products for efficiency and performance
Evonik products for composites

Composites consist mainly of a combination of polymers that have endless fibers imbedded in them. The polymer serves to protect the load-bearing fibers against all environmental influences and to transfer loads evenly over the fibers. For this reason, the polymer for this matrix plays a pivotal role in composites.

Examples of composites include laminates that consist of fiber-matrix combinations, or sandwich constructions that feature a combination of two very thin composite laminates with a lightweight core material between them.

Evonik itself does not offer composites, but unidirectional tapes, specialty foams for sandwich construction cores, and the components that go into composites. Evonik’s broad product portfolio includes different types of matrices or matrix-related products, such as hardeners and additives. This brochure aims to provide manufacturers of composite prepregs or parts a comprehensive overview of the products available to them.

You are more than welcome to ask our experts for further information about specific products.
A growing number of challenges presented by renewable energy, efficient resource management and ecological aspects can only be mastered now and in the future by using lightweight construction. Fiber-reinforced composites will play a major role in this regard as one of the key technologies for the 21st century.

Evonik manufactures a range of products that can be found in almost all components of fiber-reinforced composites. We supply unidirectional tapes, core materials for sandwich construction, thermoplastic and thermosetting resin matrices, as well as the essential components for matrices such as crosslinkers, catalysts, impact strength modifiers or processing and process additives. Some of these products are used in sizings for glass or carbon fibers, and in adhesives for joining fiber-reinforced composites.

**EVONIK’S STRENGTH IS DIVERSITY**

Our experts in fiber-reinforced composites think “systems,” not “products”. Even in cases of applications where products from their own department are not the material of choice, our experts involve the specialists from other departments to identify the optimal solution for the customer. According to the philosophy: when you work with us, you have the support of the entire team of specialists at Evonik. In short, you talk to one, you talk to all.

The fact that composite specialists within Evonik are closely connected to each other across the respective business divisions is an enormous advantage for our customers. A result of this cooperation is the platform that serves to exchange technical information between experts and the group-wide Composites Industry Team. This ensures that specialist knowledge is available to our customers at all locations.

**CROSS SECTIONAL VIEW**

```
THERMOPLASTICS
VESTAKEEP®
VESTAMID®

UD TAPES
VESTAPE®

FOAM CORES
ROHACELL®

ADDITIVES/
RHEOLOGICAL MODIFIER
AEROSIL®
Dynasylan®
TEGOMER®

CROSSLINKER
Amicure®
Ancamine®
Ancamide®
Dicyanex®
Imicure®

THERMOSET MODIFIER
ALBIPOX®
NANOPOX®
P84®

```
Composites market overview

WORKING IN MANY DIFFERENT MARKETS

With its wide range of products, Evonik Industries provides product solutions for a variety of different applications to the end markets for fiber-reinforced composites. The group’s composite activities are focused on the automotive, aviation, wind power, construction and oil & gas markets. In addition composites with Evonik materials are used in medical applications and sports equipment.
Matrix systems

The matrix in a fiber-reinforced composite serves to:

• Keep the fibers in place
• Transfer stresses evenly over the fibers
• Provide a barrier under adverse conditions such as chemicals and moisture
• Protect the surface of the fibers from mechanical degradation, for example, as a result of abrasion

The matrix you select has a major impact on the compressive, interlaminar shear, and in-plane shear properties of the composite material.

Polymer matrix systems fall into two broad categories: thermosets and thermoplastics. A thermoset matrix has a three-dimensional network structure, where the molecular chains are permanently crosslinked. The transformation is irreversible, and the original properties of the material cannot be restored. The advantage of thermoset resins is that they are easy to formulate and use.

When selecting a matrix, a manufacturer considers primarily its basic mechanical properties. For high-performance composites, the most desirable mechanical properties of a matrix are:

• High tensile modulus, which influences the compressive strength of the composite
• High tensile strength, which controls the intraply cracking in a composite laminate
• High fracture toughness, which controls ply delamination and crack growth
• Good dimensional stability at elevated temperatures (glass transition temperature higher than maximum use temperature)
• Resistance to moisture and solvents, for example, fuels and gasoline, motor oil, deicing fluids and anti-freeze, and paint strippers (polymer should not swell, crack or degrade)

Evonik is one of the leading suppliers of high-performance resins and crosslinkers to the composite industry: resin modifiers and curing agents for epoxy systems, PBO crosslinked phenolic resins, bismaleimide resins (BMI) for high temperature composites, polyimides as BMI modifiers, polyetheretherketones (PEEK) and polyamides for thermoplastic matrices, and special acrylics.

The following are the most important thermoset resins:

**Epoxies:** principally used in high-performance composite applications, for example, aerospace and aeronautics, automotive, wind energy (rotor blades), composite pipes, and high-performance boats.

**Polyesters, vinyl esters:** used mostly in commodity composite applications, for example, automotive, marine, and electrical applications.

**Polyimides:** used for high-temperature aerospace applications.

**Phenolics:** used almost exclusively because of their flame-retardant properties, for example, in the aircraft industry.

**Polyurethanes:** used for their in-situ moldability, high weathering stability (aliphatics).

**Bismaleimides:** provide outstanding performance in advanced composites for high temperature applications due to their high glass transition temperature (Tg) and excellent retention of mechanical properties up to 250 °C under hot/wet conditions.

**EPOXY COMPOSITES**

Common epoxy matrix resins are based on diglycidyl ether of bisphenol A (DGEBA), which contains two epoxy groups, one at each end of the molecule. They are low-molecular-weight liquids. Typically, amines are used to cure the epoxy resins, after which a three-dimensional network is achieved.

**DIAMINES**

Evonik is one of the leading suppliers of high-performance crosslinkers to the composite industry. Evonik crosslinkers play an important role in a majority of advanced composite applications.

**VESTAMIN® IPD**, a cycloaliphatic diamine, is regarded as the industry standard for crosslinkers and is formulated for epoxy composite systems. The cycloaliphatic structure and medium reactive amino groups offer the following advantages:
• Good processability of the liquid matrix system
• High-performance composites with high glass transition temperatures
• High mechanical strength
• Improved mechanical properties
• Good temperature performance
• Resistance to impact stress
• Moisture and hot-water resistance
• Good chemical resistance

Typical applications are fiber-reinforced composites for rotor blades, pipes, leaf springs, pump cases, high-performance boats, light airplanes, sporting goods, printed circuit boards, automotive parts, construction profiles, and housings for office machines.

VESTAMIN® PACM, also a cycloaliphatic diamine, shows a similar behavior as VESTAMIN® IPD in epoxy composites regarding the mechanical properties. An additional advantage is its lower exothermic behavior during curing as well as the lower water uptake of PACM based epoxy matrix systems when exposed to water.

VESTAMIN® TMD, an aliphatic diamine, provides higher impact resistance to composites due to its linear structure. It’s high reactivity makes it suitable for ultra fast cured epoxy composites.

VESTAMIN® product group comprises the following amines

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DELIVERY FORM</th>
<th>CHARACTERISTICS</th>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>VESTAMIN® IPD</td>
<td>Liquid, 100%</td>
<td>Isophorone diamine, cycloaliphatic diamine</td>
<td>Hardener component for epoxy resins for rotor blades, pipes, leaf springs, pump cases, high-performance boats, sporting goods</td>
</tr>
<tr>
<td>VESTAMIN® PACM</td>
<td>Liquid, 100%</td>
<td>4,4’-Diaminodicyclohexyl-methane, cycloaliphatic diamine</td>
<td>Hardener component for epoxy resins for composites</td>
</tr>
<tr>
<td>VESTAMIN® TMD</td>
<td>Liquid, 100%</td>
<td>Trimethyl hexamethylene diamine, aliphatic diamine</td>
<td>Fast curing hardener component for epoxy resins for composites</td>
</tr>
</tbody>
</table>

REACTIVE RESIN MODIFIERS

VESTAMIN® PACM

Evonik is the leading manufacturer of surface modified silica nanoparticles in epoxy resins. Using nanosilica several important properties of fiber reinforced composites can be improved:
• Significantly improved modulus and flexural strength
• Dramatically improved fatigue performance
• Increased toughness
• Improved surface quality (reduced print through)
• Reduced microcrack formation

The nanoparticles are chemically synthesized from aqueous sodium silicate solution. In this unique process the epoxy matrix resin is not altered, in contrast to processes in which powdered fillers are dispersed with dissolvers or other equipment using high shear energy.

These products are concentrates and, for most composite applications, are diluted with standard epoxy resins. Typical nanosilica levels in, e.g., VARTM resin systems are 10 percent.

The NANOPOX® products are suitable for all hardeners and all manufacturing processes. As the silica nanoparticles do not sediment, even solvent-based preprepping does not pose a problem. Due to their small size and the absence of any larger aggregates, the nanoparticles can easily penetrate all fiber structures without compromising the impregnation by excessive viscosity, thereby enabling all the state-of-the-art process technologies like resin infusion, RTM, or resin injection. In addition to significantly improved mechanical properties (modulus, fracture toughness), the thermal expansion, shrinkage and electrical properties can also be improved.

The standard grades of the NANOPOX® product group

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>BASE RESIN</th>
<th>EEW [G/EQUIV]</th>
<th>DYN. VISCOSITY, 25 °C [MPA·S]</th>
<th>CHARACTERIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NANOPOX® F 400</td>
<td>DGEBA</td>
<td>295</td>
<td>60,000</td>
<td>Special for glass, aramide and carbon fibers; 40% SiO₂-nanoparticles</td>
</tr>
<tr>
<td>NANOPOX® F 520</td>
<td>DGEBF</td>
<td>275</td>
<td>20,000</td>
<td>Low viscous; 40% SiO₂-nanoparticles</td>
</tr>
<tr>
<td>NANOPOX® F 631</td>
<td>EECC</td>
<td>220</td>
<td>5,500</td>
<td>Cycloaliphatic formulations; 40% SiO₂-nanoparticles</td>
</tr>
<tr>
<td>NANOPOX® F 700</td>
<td>epoxidized novolac</td>
<td>310</td>
<td>20,000 (at 50 °C)</td>
<td>High performance novolac, high Ty</td>
</tr>
</tbody>
</table>

15 % nanosilica 4 % nanosilica – TEM-Pictures of GFRCs with different levels of SiO₂-nanoparticles (based on NANOPOX® F 400)
ALBIPOX®
Epoxy resins have a substantial disadvantage: their brittleness. This disadvantage can be more than compensated by an elastomer modification (so-called “toughening” or impact resistance modification). In contrast to an elastification, the elongation at break of the cured modified resin normally remains under 10 percent.

The toughening of epoxy resins proves to be difficult, however. Thus, for example, the use of flexible hardeners or the addition of non-reactive flexibilizers significantly impairs a number of important properties such as tensile strength and modulus, thermal and chemical resistance as well as thermodimensional stability.

These negative effects can be avoided by toughening with copolymers based on reactive elastomers. However, the pure liquid elastomers are only slightly miscible with epoxy resins, if at all.

The different ALBIPOX® grades are reaction products between epoxy resins and an elastomeric copolymer. Hereby, an epoxy resin is reacted with an excess amount of the reactive liquid elastomer. After the reaction, the elastomer molecules are epoxy functional and will be chemically bonded to the resin matrix during curing.

ALBIPOX® products can be used by epoxy resin formulators like a modular system. There are no limitations in respect to the resins and hardeners that can be used. Typical addition levels are 25–40 percent.

As a synergy exists between the modification with NBR and nanosilica, several products contain both modifications.

An additional advantage is the improved processability of the modified laminates, thereby avoiding splintering on mechanical finishing. The shrinkage is also reduced, as the rubber domains formed upon cure can absorb the internal stresses arising during curing.

### The standard grades of the ALBIPOX® product group

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>BASE RESIN</th>
<th>EBW [G/EQUIV]</th>
<th>DYN. VISCOSITY, 25 °C [MPA·S]</th>
<th>CHARACTERIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALBIPOX® 1000</td>
<td>DGEBA</td>
<td>330</td>
<td>200,000</td>
<td>Standard type, 40% NBR</td>
</tr>
<tr>
<td>ALBIPOX® 3001</td>
<td>DGEBA/DGEBF</td>
<td>215</td>
<td>22,000</td>
<td>Application-ready resin</td>
</tr>
<tr>
<td>ALBIPOX® 8001</td>
<td>DGEBA</td>
<td>210</td>
<td>400,000; 4,000 (at 80 °C)</td>
<td>Extremely efficient tackifier (addition level 3–5 %)</td>
</tr>
<tr>
<td>ALBIPOX® F 080</td>
<td>DGEBA/DGEBF</td>
<td>330</td>
<td>70,000</td>
<td>Contains NBR(*) and nanoparticles</td>
</tr>
<tr>
<td>ALBIPOX® F 081</td>
<td>DGEBA/DGEBF</td>
<td>240</td>
<td>35,000</td>
<td>Contains NBR(*) and nanoparticles</td>
</tr>
</tbody>
</table>
Albidur®

One of the drawbacks of rubber toughening is the increase in viscosity, which cannot be tolerated in some injection methods. By using core shell elastomers as tougheners, the viscosity increase becomes minimal.

Albidur® products consist of a reactive resin in which silicone elastomer particles of a defined size (0.1–3 µm) are finely distributed. The silicone elastomer particles have an organic shell structure comprising reactive groups. The toughening mechanism is the same as for reactive liquid rubbers; however, the rubber domains are already preformed and not built during the curing process.

The typical addition levels are 10 percent and result in a substantially improved toughness over a very broad temperature range, reduced shrink and no or minimal loss of modulus and Tg.

In contrast to the AlbiPox® products, unsaturated polyester resins and vinyl ester resins can also be modified with Albidur® based on such resins. Please refer to the separate Albidur® brochure.

Matrix Systems

The standard grades of the Albidur® product group

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>BASE RESIN</th>
<th>CORE SHELL CONTENT [WT%]</th>
<th>DYN. VISCOSITY, 25 °C [mPas]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albidur® EP 2240 A</td>
<td>DGEBA epoxy resin</td>
<td>40</td>
<td>33,000</td>
</tr>
<tr>
<td>Albidur® VE 3940</td>
<td>Vinyl ester resin/styrene</td>
<td>40</td>
<td>6,000</td>
</tr>
<tr>
<td>Albidur® PU 5640</td>
<td>Propylenglycol (triol)</td>
<td>40</td>
<td>2,500</td>
</tr>
</tbody>
</table>

Process Additives for Epoxy Resins, Vinyl Ester Resins and Unsaturated Polyester Resins

Tegopren®, Tegomer®, Tego® Antifoam

Property and Processing Improvements

By using small amounts of these additives in thermosetting resin formulations (typically 0.1 – 0.8 %) the manufacturing process of fiber-reinforced composites can be made easier. If such an additive is used as internal release agent, demolding even without using an external mold release agent is no problem anymore. Surface properties like scratch resistance can be increased significantly. The use of defoamers reduces the amount of bubbles or pores in a fiber-reinforced composite, which consequently exhibits better mechanical performance.

Technical data

<table>
<thead>
<tr>
<th>PRODUCT NAME</th>
<th>CHEMICAL COMPOSITION</th>
<th>CHARACTERIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tegomer® DA 626</td>
<td>Polymeric structure</td>
<td>dispersing agent, defoamer</td>
</tr>
<tr>
<td>Tegomer® Antifoam D 2340, Tegomer® Antifoam D 2345</td>
<td>Polymer solution</td>
<td>defoamer</td>
</tr>
<tr>
<td>Tegopren® 6875</td>
<td>Alkyl-modified siloxane</td>
<td>dispersing agent, improved scratch resistance</td>
</tr>
<tr>
<td>Tegomer® M-SI 2650</td>
<td>Organos-modified siloxane containing non-reactive aromatic groups</td>
<td>internal release agent, dispersing agent</td>
</tr>
</tbody>
</table>

Internal Release Agent

Especially in fast manufacturing processes like VARTM efficient demolding is necessary. Time and cost-intensive external mold release agents cannot be used. Therefore internal release agents are part of the epoxy resin formulation. They offer several advantages:

- fast demolding of the composite part
- superior surface appearance of the composite part
- no negative effects on paintability of the composite part
- no negative effects on processability of the epoxy resin

1 no specification
**DEFOAMERS**

Air trapping and bubble formation can be a nasty problem in several composite manufacturing processes like pultrusion or RTM processes.

<table>
<thead>
<tr>
<th>Internal release agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESIN</td>
</tr>
<tr>
<td>Standard epoxy resins</td>
</tr>
<tr>
<td>Standard UP resins</td>
</tr>
</tbody>
</table>

**DEFoAMERS**

Air trapping and bubble formation can be a nasty problem in several composite manufacturing processes like pultrusion or RTM processes.

<table>
<thead>
<tr>
<th>Defoamers</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESIN/HARDENER</td>
</tr>
<tr>
<td>Epoxy, anhydride cure</td>
</tr>
<tr>
<td>Epoxy, amine cure</td>
</tr>
<tr>
<td>UP resin, BPO or MEKP cured</td>
</tr>
</tbody>
</table>

**MATRIX SYSTEMS**

**SCRATCH RESISTANCE**

Just think about public transportation – and the scratch resistance of panels made from SMC becomes an imminent issue. The figure shows the possible improvements.

Low addition levels of 0.3 – 0.6 % can already yield significant improvements. For the modification of unsaturated polyester resins based on orthophthalic acid we recommend these products:

<table>
<thead>
<tr>
<th>Scratch resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURING AGENT</td>
</tr>
<tr>
<td>Methyl ethyl ketone peroxide (MEKP)</td>
</tr>
<tr>
<td>Dihydroxy naphthalene (DHP)</td>
</tr>
</tbody>
</table>

**HOW IT WORKS**

Organosilanes (OMS) consist of a siloxane backbone with attached organic groups. The organic groups ensure a permanent functionalization of the polymer without bleeding of the OMS. Different molecular architectures of OMS derivatives are available. The figure shows the comb-like as well as the linear structure of the OMS together with the possible functional groups. By varying the density and nature of the attached organic groups the OMS called TEGOMER® or TEGOPREN® are tailor-made products to the final application. The figure below shows the functionalization of a polymer matrix with OMS. These derivatives can either work for bulk modification (case A) or for surface modification (case B).
EPOXY CURING AGENTS
Evonik is the leading supplier of high-performance epoxy curing agents to advance composite manufacturing and adhesive bonding of composites.

The portfolio contains a full range of high quality amine hardeners, catalysts and accelerators for a wide range of applications, including infusion technologies, filament winding and prepreg applications.

Ancamine® curing agents are mostly cycloaliphatic amines used across many different composite applications, including filament winding and pipe rehabilitation applications. Modified amines are also employed as anhydride and epoxy accelerators in heat curing. Ancamide® curing agents can be divided into two major classes: amidoamines and polyamides. Amidoamines are known for low viscosity, excellent fiber wet-out and long pot life. They are recommended for wet lay-up laminating and filament winding applications. Polyamides are known for low toxicity, very good adhesion to multiple substrates and good flexibility. Evonik offers a range of polyamides and adducts that include standard grades as well as grades that do not require an induction time, improved chemical resistance, lower viscosity and faster cure speed.

Amicure® and Dicyanex® products are Dicyandiamide (DICY) catalysts and substituted ureas for one component heat cure high-performance composites and adhesives. Imicure® and Curezol® products are imidazoles which are tailor-made to accelerate anhydride and amine curing epoxy resins. They offer a broad range of latency, rapid cure beyond activation temperatures as well as high thermal and chemical resistance in prepreg applications and bonding of composites.
## Top Recommendations

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>Curing Agent</th>
<th>BENEFITS</th>
<th>COMPOSITES PROCESSING ROUTES/ APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycloaliphatics</td>
<td>Ancamine® 2167</td>
<td><img src="image" alt="" /> O <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> O <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Ancamine® 2927</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>Amidazine</td>
<td>Ancamide® 506</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Ancamide® 552</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Ancamide® 2798</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>Polyamide</td>
<td>Ancamide® 351A</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Ancamide® 3030</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Ancamide® 910</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>Anhydride Acid</td>
<td>Ancamine® 2908A*</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>Dicyandiamide</td>
<td>Ancamine® 1200G**</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Dispamet® 1400B**</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Amicure® UK1T</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>Imidazoles</td>
<td>Imicure® EM24</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Imicure® AMI1*</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Curex® 2MG Azine</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td>Accelerators for heat cure</td>
<td>Ancamine® 2014 AS/FG</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
<tr>
<td></td>
<td>Ancamine® K 54</td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
<td><img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /> <img src="image" alt="" /></td>
</tr>
</tbody>
</table>

* not commercially available in EMEA
** Benefits depending on formulations

- Excellent
- Highly recommended
- Recommended
BISMALEIMIDES COMPIMIDE®

High performance materials helping you to meet your future requirements for advanced composites today.

The COMPIMIDE® bismaleimide resin family represents a full range of proprietary thermosetting resins and specialties that have been developed for the production of high-performance composites, adhesives, and moldings.

Evonik offers more than 40 years of experience in bismaleimide resins. Our products are certified and referenced throughout the industry.

COMPIMIDE® bismaleimide matrix resins are characterized by their high glass transition temperature (Tg). They offer improved high temperature performance over epoxies and cyanate esters. Other outstanding features are:

- Easy processing by autoclave, plates press, and compression molding techniques
- Retention of excellent mechanical properties up to 250 °C
- Good solvent resistance
- Excellent performance under hot/wet conditions
- Superior flame and radiation resistance, low smoke and toxicant emissions

The COMPIMIDE® BMI product group offers the most complete portfolio of bismaleimide products in the market:

- Monomers
- Co-monomers
- Pre-formulated resin blends
- Resin solutions
- RTM resins

Applications

COMPIMIDE® thermosetting BMI resins and formulations have been developed for the use in all relevant processing techniques

- Prepregging
- Resin Transfer Molding (RTM)
- Vacuum Assisted Resin Infusion (VARI)
- Filament Winding (FW)
- Compression Molding
- And many more

EPOXY CURING AGENT AND PU RESIN FORMULATIONS FOR AUTOMOTIVE LIGHTWEIGHT SOLUTIONS VESTALITE®

VESTALITE® products are tailor-made solutions for high performance composite parts based on epoxies and polyurethanes.

VESTALITE® products allow for cost-efficient and fast processing for high performance composite parts which makes them particularly suitable for next generation automotive composite applications.

VESTALITE® products are support-ed by VESTARO to bring next generation composites onto the road with you. VESTARO combines Evonik’s chemistry with automotive engineering.

VESTALITE® P

VESTALITE® P resin formulations yield non-toxic, reversibly shapeable prepregs for fast and automated prepreg compression molding with low investment costs.

VESTALITE® P is a matrix system for prepregs based on aliphatic diisocyanates VESTANAT® IPDI. The resin allows for excellent surface qualities including high UV stability and ductility. Due to low reaction heat upon curing even thick parts can be cured within 5 – 10 min at 140 – 150°C.

Its unique properties make VESTALITE® P suitable for large scale automated manufacturing. Due to Evonik’s blocking-agent free uretdione chemistry the prepreg resins exhibit long shelf life at ambient conditions, manufacturing of form stable pre-forms and easy handling with robots.

Applications

- Exterior panels
- Exposed interior parts
Benefits
- Reduction of painting costs
- Outstanding toughness and flexibility
- Low exothermic curing reaction

**VESTALITE® S**
VESTALITE® S curing agent is a high performance solution for sheet molding compound (SMC) material with low VOC when combined with a liquid epoxy resin.

VESTALITE® S is a curing agent for sheet molding compounds based on Evonik’s diamine chemistry. Its unique properties make VESTALITE® S suitable for large scale automated manufacturing. Due to Evonik’s diamine chemistry the resulting epoxy system exhibits a low initial viscosity, storage stability, fast curing and best in class mechanical performance. Due to the EP chemistry VESTALITE® S based SMC have lowest VOCs and no styrene emissions.

Applications
- Semi-structural parts
- Supporting structures
- Exterior / Interior parts

**Benefits**
- Low initial viscosity for high fiber volumes and excellent fiber wetting
- High storage stability (> 30 days) of intermediate SMC
- Excellent mold flow combined with fast curing (3 min at 150°C)
- Best in class mechanical performance
- Low VOCs and no styrene emissions

**POLYURETHANE COMPOSITES**
Evonik is one of the leading suppliers of high-performance crosslinkers to the composite industry. Evonik provides colorless and UV stable isocyanates as hardeners for polyurethane systems.

Polyurethanes are based on polydiols and diisocyanates. Common polyols are polyethers and polyesters which differ in their chemical backbone, functionality, molecular weight and viscosity.

Evonik’s portfolio contains monomeric diisocyanates as well as polyisocyanates (isocyanurates) based on isophorone disocyanate or hexamethylene diisocyanate.

These products are used for applications such as composites, gel coats, coatings, adhesives and elastomers. VESTANAT® T 1890/100 is the isocyanurate of isophorone disocyanate. It is solid at room temperature. It is typically blended with liquid isocyanurates for easy processing.

The cycloaliphatic structure of VESTANAT® T 1890/100 provides:
- easy processing of liquid matrix systems
- high glass transition temperatures
- excellent mechanical properties
- extremely short cycle times
- light and weathering stability
- good chemical resistance

**VESTALITE® epoxy curing agent and PU resin formulations for automotive lightweight solutions**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>APPLICATION</th>
<th>BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>VESTALITE® S</td>
<td>Epoxy Curing Agent Sheet Molding Compound</td>
<td>Fast curing (&lt; 3 min) High mechanical performance Low VOC</td>
</tr>
<tr>
<td>VESTALITE® P</td>
<td>PU Formulation Prepreg</td>
<td>UV stable Fast curing High toughness</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>PHYSICAL FORM</th>
<th>VISCOSITY</th>
<th>CHARACTERISTICS</th>
<th>BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>VESTANAT® T 1890/100</td>
<td>pellets, 100%</td>
<td>–</td>
<td>Polyisocyanate based on isophorone disocyanate Crosslinker for high Tg (&gt;100°C)</td>
<td></td>
</tr>
</tbody>
</table>
THERMOPLASTICS

COMPOSITES WITH THERMOPLASTIC MATRIX

Matrices for composites have so far been mainly thermoset matrices used in established processes that draw on many years of experience. Used with the same reinforcing fibers, thermoplastic matrices allow significantly shorter cycle times in component production, can be stored indefinitely at room temperature, absorb less water (depending on the matrix), and are particularly suitable for medium- and large-scale production. Also particularly noteworthy are the simpler bonding technique (fusion) and the significantly higher continuous working temperatures (up to 200 °C, depending on the polymer) and impact tolerance of components with a thermoplastic matrix.

In VESTAKEEP® (PEEK) and VESTAMID® L (PA12), Evonik offers thermoplastic polymers that have proven their worth as matrices and can be selected for different requirements in regard to continuous working temperature and mechanical properties. Prepregs (preimpregnated reinforcing materials) in the form of coated woven fabrics and unidirectional tapes are sheet products produced using Evonik matrices. These polymers are available as granules, powders of various particle size distribution, and films for further processing by melt impregnation, powder coating, or suspension impregnation, and even for the film stacking process.

In addition, Evonik offers unidirectional (UD) tapes branded VESTAPE®.

VESTAKEEP®, the PEEK from Evonik as a matrix for thermoplastic composites

Evonik, which has been producing high performance polymers for more than 50 years, is known for its powder technology expertise in development, production, application, and customer service. VESTAKEEP® molding compounds and powders are particularly suitable for applications where extreme mechanical, thermal, and chemical requirements must be satisfied.

VESTAKEEP® is suitable as a matrix for unidirectional fiber layouts or woven fabrics of glass, carbon or aramid fibers, and thus makes it possible to produce fiber composite materials with a thermoplastic matrix. The thermoplastic fiber composite materials are produced by a powder-coating or dispersion-coating process. Evonik has developed optimized powders suited specifically to these processes, thus confirming its eligibility for production of composites. Its VESTAKEEP® 2000 powder line with different particle sizes is established as the ideal polymer for this application.

The semi-crystalline polymer features superior, thermal and chemical resistance.

- High Tg
- Self-extinguishing parts
- Very high heat deflection temperature
- High stiffness
- Low water absorption and therefore high dimensional stability
- Excellent chemical resistance
- Excellent hydrolytic stability
- Good processability
- No tendency to stress cracks

VESTAKEEP® POLYETHERETHERKETONE

VESTAKEEP®, the PEEK from Evonik as a matrix for thermoplastic composites

Our powder grades

<table>
<thead>
<tr>
<th>VESTAKEEP®</th>
<th>POLYETHERETHERKETONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 P</td>
<td>Unreinforced, medium viscosity</td>
</tr>
<tr>
<td>2000 FP</td>
<td></td>
</tr>
<tr>
<td>2000 UFP</td>
<td></td>
</tr>
</tbody>
</table>

P | Powder, 500 µm
FP | Fine powder, 55 µm
UFP | Ultra fine powder, 20 µm
POLYAMIDE VESTAMID® L

VESTAMID® L (PA12) has been used very successfully for decades in manifold automotive, sports and industrial applications. As a matrix material it is extremely suitable to be used in demanding applications of the oil and gas industry. Composites with VESTAMID® L as the matrix are processable at a lower temperature. Compared to high temperature-resistant matrices such as PEEK, PPA, and PPS, this presents an advantage, thus significantly shortening cycle times for mass-production.

Further general properties:
- Low weight
- High impact resistance
- High elongation and high abrasion resistance, even at low temperatures
- Low water absorption
- Good electrical isolation and dielectric strength

Properties of PA12 and PEEK matrix materials for UD tapes

<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>UNIT</th>
<th>VESTAMID® PA12</th>
<th>VESTAKEEP® PEEK</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer</td>
<td>–</td>
<td>Polyamide 12</td>
<td>Polyetheretherketone</td>
<td>–</td>
</tr>
<tr>
<td>Density</td>
<td>23°C</td>
<td>g/cm³</td>
<td>1.01</td>
<td>1.30</td>
</tr>
<tr>
<td>Melting temperature DSC</td>
<td>2nd heating</td>
<td>°C</td>
<td>178</td>
<td>340</td>
</tr>
<tr>
<td>Tensile test</td>
<td>ISO 527-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress at yield</td>
<td>MPa</td>
<td>46</td>
<td>100</td>
<td>ISO 527-2</td>
</tr>
<tr>
<td>Strain at yield</td>
<td>%</td>
<td>5</td>
<td>5</td>
<td>ISO 527-2</td>
</tr>
<tr>
<td>Strain at break</td>
<td>%</td>
<td>&gt;200</td>
<td>30</td>
<td>ISO 527-2</td>
</tr>
<tr>
<td>Tensile Modulus</td>
<td>MPa</td>
<td>1400</td>
<td>3700</td>
<td>ISO 527-1</td>
</tr>
<tr>
<td>CHARPY notched impact strength</td>
<td>23 °C</td>
<td>kJ/m²</td>
<td>5C</td>
<td>6C</td>
</tr>
<tr>
<td>CHARPY notched impact strength</td>
<td>-30°C</td>
<td>kJ/m²</td>
<td>4C</td>
<td>6C</td>
</tr>
</tbody>
</table>

C1: complete break

Relative comparison of PA12 and PEEK recommended for composites
SPECIALTIES

THE DEGAPLAST® REACTIVE SYSTEM

Thanks to modern prosthetics, disabled people can scale mountains and break records at the Paralympic Games. In everyday life, too, prostheses provide high mobility and freedom of movement to the people who wear them, thanks to the perfect interaction of technology, electronics, and innovative materials.

Besides metals, plastics play an important role here, too, with DEGAPLAST® based lamination systems occupying a prominent position, particularly in the hand-crafting industry. Despite mechanization, certain components such as shafts, which have to be adapted individually, still have to be customized by hand.

Like aircraft and automotive designers, prosthetists value the high strength of these resins, not to mention their low weight and dimensional stability, even at slight thicknesses. Another important fact fueling the popularity of these materials is the ease of care and maintenance of the end products, which perfectly fits in with today’s increased demands on hygiene.

DEGAPLAST® is based on methyl methacrylate (MMA), solved polymethyl methacrylate (PMMA) and special modifiers. The cured parts are thermoplastic and will not become brittle.

DEGAPLAST® LH is a reactive resin for casting purposes. In the orthopedic technology, it is used for manufacturing softly adjusted shanks, protective sleeves, soft sockets, and a soft adjustment of other DEGAPLAST® resins.

DEGAPLAST® LH 80:20 works satisfactorily as the “number one laminating product for the orthopedic manufacturing industry”. It is suitable with almost all common materials such as wood, leather and different kinds of canvas as well as DEGAPLAST® Resins. Producing inlays by casting, it can be adjusted with 20 percent (m/m) DEGAPLAST® GH for a higher flexibility. Special features are a short curing time, fast and safe impregnating of the filling fabric and a tack-free hardening. DEGAPLAST® LHC is a specially developed reactive resin for laminating carbon-fibers.

DEGAPLAST® SH is a reactive resin for sealing purposes. It is used for sealing virtually all porous materials.

UD TAPES

Endless fiber-reinforced plastics offer a promising and innovative solution with high potential for lightweight construction.

Our composites of endless fiber-reinforced plastics consist of carbon fibers and a matrix made of high performance polymers. In a UD tape, the properties of both materials combine ideally to create innovative construction materials for new paths in component design.

Several layers of UD tapes in a laminate form “organosheets,” which significantly outperform the mechanical properties of metal sheets of the same thickness. Organosheets can be thermoformed and, therefore, adopt a variety of component geometries. They also offer the opportunity of integrating additional functions or components, as the parts can be over-molded with a fiber-reinforced compound. Naturally, using the same polymer class as for the matrix in the UD tape ensures a good connection between the two components, which is essential for dynamic load conditions.

VESTAPE®

The matrix of VESTAPE® UD tapes is made from specially developed high-performance polymers with, e.g., a high glass transition temperature and therefore features good heat resistance. It is customized to high-strength endless fibers and allows production of parts that can be used even in areas exposed to extreme temperatures. Evonik is one of the leading suppliers of high performance thermoplastic resins such as specialty polyamides for use under adverse environmental conditions and polyetheretherketones (PEEK).

APPLICATIONS

Oil and gas industry

VESTAPE® is the material of choice for the production of hybrid liners for the oil recovery from deep sea oilfields. Hybrid liners or full TCPs (Thermoplastic Composite Pipes) replace heavy steel solutions and allow for reaching deeper oilfields than before. The lightweight construction of the extruded polymer in combination with wound UD tapes offers weight savings up to 60% compared to conventional solutions.
AIRCRAFT

Large aircraft manufacturers are using more and more thermoplastic composites to reach the lightweight design targets which are substantial to keep competitive. VESTAPE® composites with a PEEK matrix are best suited for applications where extreme mechanical, thermal and chemical requirements must be satisfied. Their mechanical properties stay unchanged over a wide range of service temperature.

Properties of UD tapes with PA12 and PEEK matrices

<table>
<thead>
<tr>
<th>UNIT</th>
<th>VESTAPE® PA12-CF45 10141</th>
<th>VESTAPE® PEEK-CF45 24241</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAPE PROPERTIES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polymer</td>
<td>–</td>
<td>polyamide 12</td>
<td>PEEK</td>
</tr>
<tr>
<td>Fiber</td>
<td>–</td>
<td>HT carbon fiber</td>
<td>HT carbon fiber</td>
</tr>
<tr>
<td>Fiber volume fraction % by vol.</td>
<td>45</td>
<td>45</td>
<td>EN 2559</td>
</tr>
<tr>
<td>Fiber weight fraction % by weight</td>
<td>59</td>
<td>53</td>
<td>EN 2559</td>
</tr>
<tr>
<td>Tape areal weight g/m²</td>
<td>343</td>
<td>381</td>
<td></td>
</tr>
<tr>
<td>Tape density g/cm³</td>
<td>1.36</td>
<td>1.51</td>
<td>ISO 1183</td>
</tr>
<tr>
<td>Tape thickness mm</td>
<td>0.25</td>
<td>0.25</td>
<td>–</td>
</tr>
<tr>
<td>Tape width mm</td>
<td>150</td>
<td>150</td>
<td>–</td>
</tr>
<tr>
<td>LAMINATE PROPERTIES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile modulus (0°) GPa</td>
<td>100</td>
<td>100</td>
<td>ISO 527</td>
</tr>
<tr>
<td>Tensile strength (0°) MPa</td>
<td>1750</td>
<td>1750</td>
<td>ISO 527</td>
</tr>
<tr>
<td>In plane shear modulus G12 GPa</td>
<td>1.4</td>
<td>approx. 3.45</td>
<td>ISO 14129</td>
</tr>
<tr>
<td>In plane shear strength 1206 MPa</td>
<td>30</td>
<td>approx. 145</td>
<td>ISO 14129</td>
</tr>
<tr>
<td>PROCESSING PROPERTIES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melt temperature °C</td>
<td>approx. 176</td>
<td>370–410</td>
<td>ISO 11357</td>
</tr>
<tr>
<td>Glass transition temperature °C</td>
<td>approx. 45</td>
<td></td>
<td>ISO 11357</td>
</tr>
<tr>
<td>Typical processing temperature °C</td>
<td>210–240</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ROHACELL®, a polymethacrylimide-based structural foam, has been used in the composites industry for almost 50 years.

Unique performance:

- Low weight
- Excellent mechanical properties and stability over a wide temperature range, even at low densities
- High temperature resistance up to 210 °C (410 °F) in pressure-free post-cure processes
- Unique compressive creep behavior for processing up to 190 °C (374 °F) and 0.7 MPa
- Excellent dynamic strength
- Cell sizes customizable to a variety of processing methods
- Featuring closed cells, ROHACELL® is manufactured without CFC or heavy metals
- It can also be foamed directly inside a mold to create complex geometric parts for high volume serial production. Because of its high thermal and creep resistance, ROHACELL® Triple F can be cured at elevated temperatures in almost no-time at all. No other core material offers such easy and fast curing for autoclave, resin infusion, or press molding processes.

ROHACELL® can be shaped easily on common CNC-machines or thermoformed within minutes without special outgassing or surface preparation.

The ROHACELL® product range offers process temperatures up to 190 °C (374 °F) across a full line of grades. Customers can choose from products with various cell sizes and densities – from 32 to 200 kg/m² (2 lb/ft² to 12.5 lb/ft²) – making it possible for their specific mechanical and weight targets to be met.

### Structural foams

The right product for your success

<table>
<thead>
<tr>
<th>PRODUCT GRADE</th>
<th>APPLICATION INDUSTRY</th>
<th>CELL SIZE</th>
<th>CURING TEMPERATURE</th>
<th>SPECIAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Aircraft Coarse</td>
<td>≤130 °C/266 °F</td>
<td>Low temperature curing/standard aircraft grade</td>
<td></td>
</tr>
<tr>
<td>HERO</td>
<td>Aircraft Medium</td>
<td>≤180 °C/356 °F</td>
<td>Highest elongation at break/excellent damage tolerance</td>
<td></td>
</tr>
<tr>
<td>RIST-HT</td>
<td>Aircraft Medium</td>
<td>≤180 °C/356 °F</td>
<td>Designed for resin infusion/small cells</td>
<td></td>
</tr>
<tr>
<td>RIMA</td>
<td>Aircraft Fine</td>
<td>≤190 °C/374 °F</td>
<td>Designed for resin infusion/smaller cells</td>
<td></td>
</tr>
<tr>
<td>XT</td>
<td>Aircraft Coarse</td>
<td>≤190 °C/374 °F</td>
<td>Highest temperature resistance/usable with BMI resins</td>
<td></td>
</tr>
<tr>
<td>WF</td>
<td>Aircraft Radomes Coarse</td>
<td>≤180 °C/356 °F</td>
<td>Most frequently qualified aircraft grade</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Aircraft Railway Shipbuilding Coarse</td>
<td>≤130 °C/266 °F</td>
<td>Good fire behavior for railcars/ships/small aircraft (no OSU)</td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>Aircraft Electronics</td>
<td>≤180 °C/356 °F</td>
<td>Electrically conductive/designated for UAVs and other stealth applications</td>
<td></td>
</tr>
<tr>
<td>HF</td>
<td>Radomes Medical Fine</td>
<td>≤130 °C/266 °F</td>
<td>High frequency transparency/designated for radome and medical x-ray table applications</td>
<td></td>
</tr>
<tr>
<td>SL</td>
<td>Sport Automotive</td>
<td>≤180 °C/356 °F</td>
<td>Increased elongation at break</td>
<td></td>
</tr>
<tr>
<td>IG- F</td>
<td>Automotive Medical Sport Electronics</td>
<td>≤130 °C/266 °F</td>
<td>Standard grade for non-qualified applications</td>
<td></td>
</tr>
<tr>
<td>WIND- F</td>
<td>Wind Medium</td>
<td>≤130 °C/266 °F</td>
<td>Reduce blade mass and turbine loads</td>
<td></td>
</tr>
</tbody>
</table>

* only with HT version
BUILD SANDWICH COMPONENTS THAT ARE LIGHTWEIGHT, YET HIGHLY DURABLE.

EXPLORING SANDWICH CONSTRUCTION

A lightweight core of polymeric foam can be sandwiched between two skins of fiber composite, sheet metal, or film to create structural components that deliver superior mechanical performance at a very low weight.

The core lends the skins their shape, spacing them apart from each other evenly. Because of the distance between the skins, the core significantly increases the rigidity of the composite: the greater the distance, the better the rigidity. The weight of the core material is, however, significantly lower than that of the additional skins that would be necessary to achieve comparable rigidity in the absence of a core.

The core material must nevertheless be able to withstand high stresses. All impact must be transmitted from one skin to the other and the compressive forces fully absorbed.

Foams based on polymethacrylimide (PMI) have proven their worth, particularly at high processing temperatures and pressures. They are easily processed and offer considerable cost savings in the manufacture of the complete component.

<table>
<thead>
<tr>
<th>Sandwich design</th>
<th>CONSTRUCTION CONCEPT</th>
<th>SKETCH</th>
<th>RIGIDITY</th>
<th>WEIGHT</th>
<th>LAYUP COST</th>
<th>ASSEMBLY COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full sandwich design</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin sandwich</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profile reinforcement</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPLORING SANDWICH CONSTRUCTION

ROHACELL® Cover layer, e.g. CFRP

++ Very good
+ Good
0 Satisfactory

We are always ready to support our customers in their challenges to design optimal solutions for their applications. We work together with them to evaluate a number of options for incorporating ROHACELL® more efficiently in their sandwich designs.

FROM PROJECT DESIGNS TO PROTOTYPES AND MORE

At our Sandwich Technology Center (STC), we arrange prototype construction, small production runs and conduct sandwich core testing. Our experienced team is able to demonstrate the use of ROHACELL® in common curing techniques such as liquid composite molding and autoclaving. In addition, we provide samples to customers and offer hands-on training in handling and thermoforming our products.

ENJOY THE ADVANTAGES OF READY-TO-USE FOAM CORES

Evonik offers a full range of foam shaping services to provide convenient delivery of foam cores that are pre-shaped and ready for use in sandwich components.

Our professional shaping capabilities and experience with ROHACELL® enable customers to remove internal risks, lower overall lead time by eliminating dependence on shaping subcontractors, and reduce in-house shaping waste and inventory costs.

Design freedom is unlimited at Evonik’s shaping facilities with a choice of shaping your foam cores using either CNC machining, thermoforming or thermoshaping.
LOSE WEIGHT. ADD VALUE.

ROHACELL® for aeronautics:
- stable and reliable process
- short curing times
- co-curing
- no freeze damage
- more net load

ROHACELL® for automotive:
- high temperature resistance for short curing cycles
- lowest weight
- cataphoretic painting of the finished part
- temperature stable
- fuel consumption savings
- stabilized crash elements

ROHACELL® for antennas and radomes:
- dielectric properties close to that of air
- high mechanical properties, but almost transparent to electromagnetic waves
- tightest dimension tolerances for best antenna performance

ROHACELL® for sports and leisure:
- lightweight professional equipment with extreme durability
- highest specific mechanical properties
- design freedom

ROHACELL® for medical technology:
- stable and reliable process
- lightweight beds for easy handling
- low attenuation ensures high-quality X-rays and CT patient beds with minimal radiation exposure

ROHACELL® for wind power:
- reduced blade mass and lower turbine loads
- shorter cycle times (pre-curing and post-curing)
- enables extended blade lifetime

IN-SITU FOAMED CORES FOR COMPLEX STRUCTURAL PARTS

Using innovative ROHACELL® Triple F, geometries that are complex to produce can now be foamed “in-situ” – directly inside a mold. Even geometries previously impossible with NC machining.

The ROHACELL® Triple F granules are foamed into final shapes, incorporating metal inserts when needed, in one single production step inside the mold.

ROHACELL® Triple F foam core:
- In-situ foamed
- Complex geometries
- Integrated inserts

- High compression strength and temperature resistance at low density
- Compatible with fast curing processes
- Densities between 70 kg/m³ and 200 kg/m³ (4.4 lb/ft³ and 12.5 lb/ft³) can be customized to your needs.

The process conditions for final parts made with ROHACELL® Triple F are optimized for high volume serial production rates between 1,000 and 50,000 or more parts/year.
Coatings & gel coats

IN A VARIETY OF APPLICATIONS, SUCH AS YACHTS, PIPES, OR ROTOR BLADES FOR WIND TURBINES, THE COMPOSITE HAS TO BE PROTECTED AGAINST, FOR EXAMPLE, SUNLIGHT, HUMIDITY, AND ABRASION. IN SUCH CASES, OR FOR SURFACE REFINEMENT, COATINGS OR GEL COATS ARE USED.

VESTANAT® polyisocyanates, Evonik offers whereas IPDI polyisocyanates (VESTANAT® T 1890) to optimize drying and chemical resistance. Special solutions for high-solids formulations are available.

VESTANAT® EP-MF GRADES
The VESTANAT® EP-MF product range transforms the unique hybrid properties of IPMS-based adducts into moisture-curable systems for room temperature applications with drying times of less than one hour.

VESTANAT® EP-E GRADES
VESTANAT® EP-E grades impart the same high performance in terms of durability and scratch resistance as the M-grades but are based on ethoxysilane technology. The EP-E grades offer full formulation freedom in terms of flexibility, durability and reactivity.

DIAMINES VESTAMIN®
For applications where light stability is not required, epoxy resin systems are often used as gel coats. Furthermore they can be used as inmold coatings for automotive composite applications. Our products play an important role as crosslinkers in this regard (see product description on page 9).

VESTANAT® products for composite coatings

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>CHARACTERISTICS</th>
<th>BENEFITS</th>
<th>APPLICATIONS</th>
</tr>
</thead>
</table>
| VESTANAT® T 1890 Cycloaliphatic polyisocyanate | • Durability against environmental impacts  
• High reactivity even at ambient temperature  
• First-class chemical resistance  
• Short curing cycles  
• Excellent compatibility & high reactivity | Branching, high TG crosslinker to impart drying properties and chemical resistance |
| VESTANAT® E 95 | Do-it-yourself conform  
Room temperature curable  
Touch dry within one hour  
Low viscosity  
Easy handling and dosing  
Enhanced compatibility to esters | Scratch resistance "boost-er" for stoving enamels |
| VESTANAT® EP-MF 203 | Slime content and crosslinking density are the highest among the MF-range  
Outstanding scratch and also chemical resistance  
100% solids  
Touch dry within one hour possible | Ready-to-use, self-crosslinking hybrid binder |
Additives

GLASS FIBER REINFORCED COMPOSITES

Glass fiber products, such as endless glass fibers, chopped strands, mats, rovings, yarns and milled glass fibers are used as reinforcing materials in plastics. Natural glass fiber shows poor adhesion to polymers, especially in the presence of moisture. For this reason, the glass surface is made organophilic by a size or finish treatment. Our Dynasylan® products are essential components in sizing or finishing, which positively effect the following:

- Transmission of glass fiber strength to the polymer
- Improvement of adhesion
- Minimization of moisture sensitivity, and mechanical protection of glass fibers

Selecting the right organofunctional group of Dynasylan® silane is decisive for the bond to the polymer. The best results in polyester and vinyl ester resins. In polyester and vinyl ester resins unsaturated silanes like methacryl-functionalised Dynasylan® MEMO and mixed functionalised SIVO 560 are first choice. The epoxysilane Dynasylan® GLYMO and the aminosilanes Dynasylan® AMEO and water-based Dynasylan® HYDROSIL 1153 sized products show superior performance in epoxy resins. A tailor made range of cationic aminosilanes is successfully applied with polyamide, epoxy and phenolic resins.

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DELIVERY FORM</th>
<th>CHARACTERISTICS</th>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynasylan® AMEO</td>
<td>Liquid</td>
<td>Aminosilane</td>
<td>*, PA, PU, EP, Phenolic, Melamine</td>
</tr>
<tr>
<td>Dynasylan® GLYMO</td>
<td>Liquid</td>
<td>Epoxysilane</td>
<td>*, PA, PU, Phenolic, Melamine</td>
</tr>
<tr>
<td>Dynasylan® MEMO</td>
<td>Liquid</td>
<td>Methacrylate</td>
<td>*, UP, Acrylic</td>
</tr>
<tr>
<td>Dynasylan® SIVO 560</td>
<td>Liquid</td>
<td>Mixed functionalised</td>
<td>speciality for UP, Acrylic</td>
</tr>
<tr>
<td>Dynasylan® 2201 EQ</td>
<td>Liquid</td>
<td>Ureidosilane</td>
<td>speciality for PA, Phenolic</td>
</tr>
<tr>
<td>Dynasylan® 4148</td>
<td>Liquid</td>
<td>PEG modified</td>
<td>speciality for PA, Phenolic</td>
</tr>
<tr>
<td>Water based and water free</td>
<td>Liquid</td>
<td>Cationic aminosilane</td>
<td>speciality for PA, EP, Phenolic</td>
</tr>
<tr>
<td>catonic aminosilanes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® HYDROSIL 1153</td>
<td>Liquid</td>
<td>Waterborne silane system</td>
<td>speciality for PA, PU, Phenolic</td>
</tr>
</tbody>
</table>

* = established standard for sizing formulations

PA = polyamide, PU = polyurethane, EP = epoxy resins, UP = unsaturated polyester, PP = polypropylene
ADDITIVES FOR BONDING PASTES

Large quantities of bonding pastes are used in the manufacturing of wind turbine rotor blades. The normal production procedure is to manufacture the upper and lower shell of the rotor blade shell in separate molds and glue them together by the bonding pastes. These bonding pastes must have good thixotropic and specific slump properties. That is why AEROSIL® fumed silica are traditionally used as effective thixotropes in bonding pastes based on epoxy, polyurethane, vinyl ester resins, etc. The hydrophobic fumed silicas AEROSIL® R 208 and AEROSIL® R 202 are high-performance thixotropes used in bonding pastes for the manufacturing of rotor blades. Furthermore, bonding pastes must also possess excellent fatigue properties. Structure-modified fumed silica grades like AEROSIL® R 7200, AEROSIL® R 8200, and AEROSIL® R 9200 can adjust bonding pastes with excellent reinforcing properties. Organofunctional silanes like Dynasylan® GLYMO, VPS 4721, Dynasylan® AMMO, Dynasylan® 1124, and Dynasylan® 1146 act as adhesion promoters in bonding pastes, and they can further improve the crosslinking density of suitable bonding pastes.

### Product range for bonding pastes

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>DELIVERY FORM</th>
<th>CHARACTERISTICS</th>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEROSIL® R 208</td>
<td>White powder</td>
<td>Hydrophobic fumed silica</td>
<td>The most efficient thixotrope for bonding pastes. Highly hydrophobic.</td>
</tr>
<tr>
<td>AEROSIL® R 202</td>
<td>White powder</td>
<td>Hydrophobic fumed silica</td>
<td>The thixotrope of choice for bonding pastes based on EP, PU, as well as VE resins for the bonding of rotor blades. Excellent storage stability.</td>
</tr>
<tr>
<td>AEROSIL® R 805</td>
<td>White powder</td>
<td>Hydrophobic fumed silica</td>
<td>Special thixotrope for bonding pastes based on EP and PU. Especially recommended to improve the storage stability of special amine hardeners.</td>
</tr>
<tr>
<td>AEROSIL® 200</td>
<td>White powder</td>
<td>Hydrophilic fumed silica</td>
<td>Thixotrope for bonding pastes based on polyester and MMA resins, and for relatively non-polar amine hardeners for epoxy systems.</td>
</tr>
<tr>
<td>AEROSIL® R 7200</td>
<td>White powder</td>
<td>Structure-modified hydrophobic fumed silica</td>
<td>Reinforcing agent with low thickening properties and excellent mechanical properties.</td>
</tr>
<tr>
<td>AEROSIL® R 8200</td>
<td>White powder</td>
<td>Structure-modified hydrophobic fumed silica</td>
<td>Reinforcing agent with low thickening properties and excellent mechanical properties.</td>
</tr>
<tr>
<td>AEROSIL® R 9200</td>
<td>White powder</td>
<td>Structure-modified hydrophobic fumed silica</td>
<td>Reinforcing agent with low thickening properties and excellent mechanical properties.</td>
</tr>
<tr>
<td>Dynasylan® AMMO</td>
<td>Liquid</td>
<td>Primary aminosilane</td>
<td>Conventional adhesion promoter – especially suitable for amine hardeners.</td>
</tr>
<tr>
<td>Dynasylan® 1124</td>
<td>Liquid</td>
<td>Secondary aminosilane</td>
<td>Adhesion promoter – especially suitable for amine hardeners for bonding pastes. High crosslinking potential.</td>
</tr>
<tr>
<td>Dynasylan® 1146</td>
<td>Liquid</td>
<td>Oligomeric aminosilane</td>
<td>Adhesion promoter – especially recommended to 2K-PU and 2K-EP chemistries. Can also improve the crosslinking densities of bonding pastes and impart outstanding hydrophobicity. Innovative silane due to reduced VOC.</td>
</tr>
<tr>
<td>Dynasylan® GLYMO</td>
<td>Liquid</td>
<td>Epoxy silane</td>
<td>Adhesion promoter, can be formulated into the resin part of 2K-EP, and can be used in 2K-PU as well.</td>
</tr>
<tr>
<td>VPS 4721</td>
<td>Liquid</td>
<td>Oligomeric epoxy silane</td>
<td>Adhesion promoter – especially recommended to 2K-PU and 2K-EP chemistries. Can also improve the crosslinking densities of bonding pastes. Innovative silane due to reduced VOC.</td>
</tr>
<tr>
<td>VPS SIV0 260</td>
<td>Liquid</td>
<td>Oligomeric aminosilane</td>
<td>Adhesion promoter for critical to adhere substrates – especially suitable for amine hardeners for bonding pastes. Can improve mechanical properties of 2K-EP bonding pastes. Innovative silane due to reduced VOC.</td>
</tr>
<tr>
<td>VPS SIV0 280</td>
<td>Liquid</td>
<td>Oligomeric aminosilane</td>
<td>Adhesion promoter for critical to adhere substrates – especially suitable for amine hardeners for bonding pastes. Can improve mechanical properties of 2K-EP bonding pastes. Innovative silane due to reduced VOC.</td>
</tr>
</tbody>
</table>
Contacts

PICTURE CREDITS

Adobe Stock/davidaguerophoto, Rainer Dittrich, Nico Martinez, Michaela Koch
istock/Dmytro Aksonov Rainer Dittrich
fotolia/peshkova Jeff Haller/Keyhole Photo
ChrisKlugPhotography HanseYachts AG

AEROSIL®
Patrick Becker
Rodenbacher Chaussee 4
63457 Hanau-Wolfgang
Germany
PHONE +49 6181 59-13410
patrick.becker@evonik.com

NANOPOX®, ALBIPOX®, ALBIDUR®
Stephan Sprenger
Charlottenburger Straße 9
21502 Geesthacht
Germany
PHONE +49 4152 8092-36
stephan.sprenger@evonik.com

COMIMIDE®
Sabine Leick
Rodenbacher Chaussee 4
63457 Hanau-Wolfgang
Germany
Phone +49 6181 59-2923
sabine.leick@evonik.com

ROHACELL®
Alexander Roth
Kirschenallee
64293 Darmstadt
Germany
PHONE +49 6151 18-4818
alexander.roth@evonik.com

DEGAPLAST®
Peter Neugebauer
Kirschenallee
64293 Darmstadt
Germany
PHONE +49 6151 18-4261
peter.neugebauer@evonik.com

VESTALITE®
Leif Ickert
Paul-Baumann-Straße 1
45772 Marl
Germany
PHONE +49 2365 49-5981
leif.ickert@evonik.com

Dynasylan®
Jürgen Fritz
Untere Kanalstraße 3
79618 Rheinfelden
Germany
PHONE +49 7623 91-8592
juergen.fritz@evonik.com

VESTAMID®, VESTAPE®
Jochen Weiguny
Paul-Baumann-Straße 1
45772 Marl
Germany
PHONE +49 2365 49-19899
jochen.weiguny@evonik.com

VESTAKEEP®
Steffen Kanzler
Paul-Baumann-Straße 1
45772 Marl
Germany
PHONE +49 2365 49-7579
steffen.kanzler@evonik.com

VESTAMIN®, VESTANAT®, VESTAGON®, Amicure®, Ancamid®, Dicyanex®, Imicure®, Curezol®
Michael Vogel
Paul-Baumann-Straße 1
45772 Marl
Germany
PHONE +49 2365 49-7086
michael.vogel@evonik.com

Curezol® is a registered trademark of Shikoku Chemical Corporation

Curezol® is a registered trademark of Shikoku Chemical Corporation
® is a registered trademark of Evonik Industries AG or one of its subsidiaries if not named otherwise.

This information and all further technical advice is based on our present knowledge and experience. However, it implies no liability or other legal responsibility on our part, including with regard to existing third party intellectual property rights, especially patent rights. In particular, no warranty, whether express or implied, or guarantee of product properties in the legal sense is intended or implied. We reserve the right to make any changes according to technological progress or further developments. The customer is not released from the obligation to conduct careful inspection and testing of incoming goods. Performance of the product described herein should be verified by testing, which should be carried out only by qualified experts in the sole responsibility of a customer. Reference to trade names used by other companies is neither a recommendation, nor does it imply that similar products could not be used.