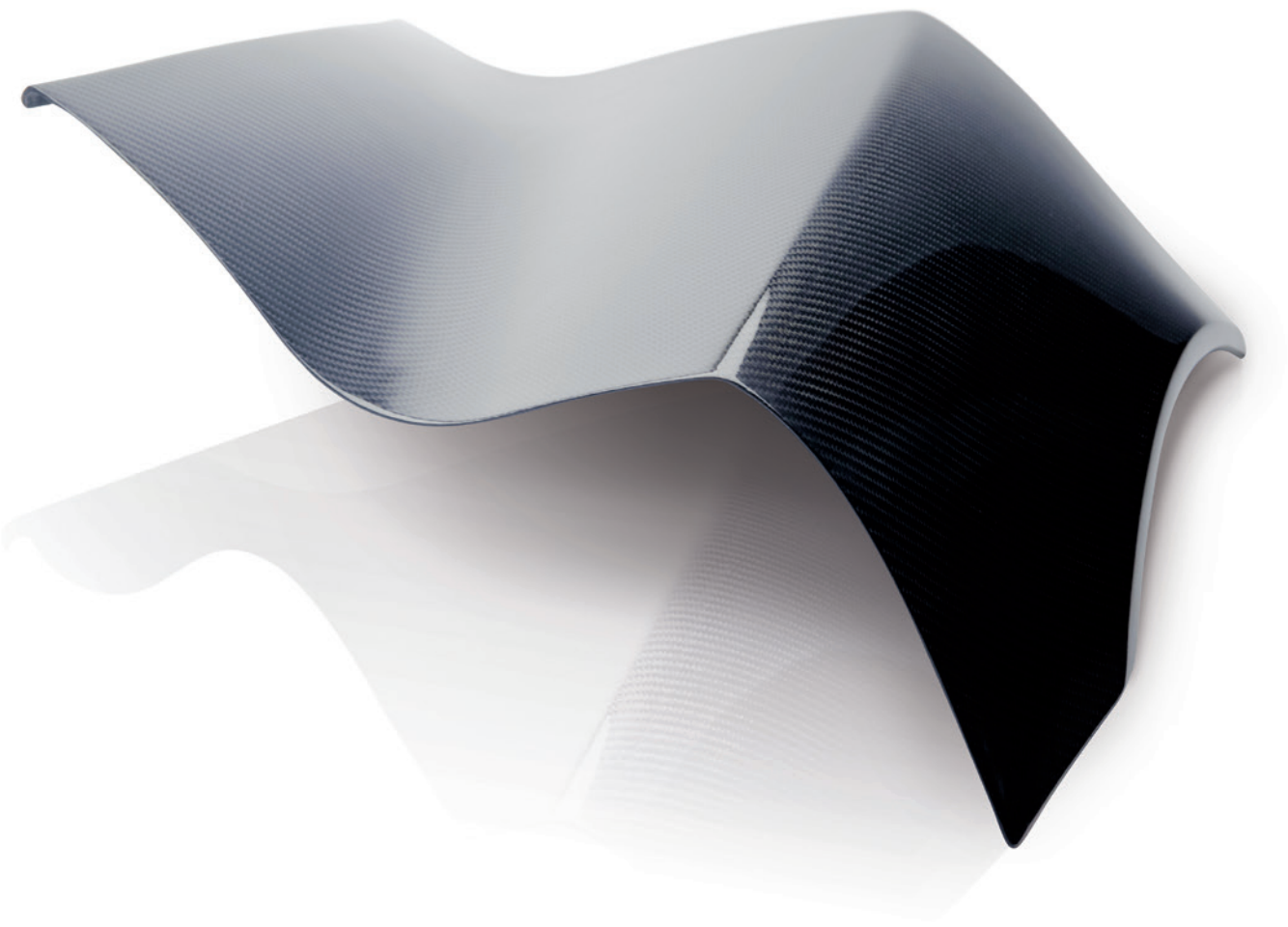
EVONIK FOR COMPOSITES

Products for efficiency
and performance



EVONIK
Leading Beyond Chemistry

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.

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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.

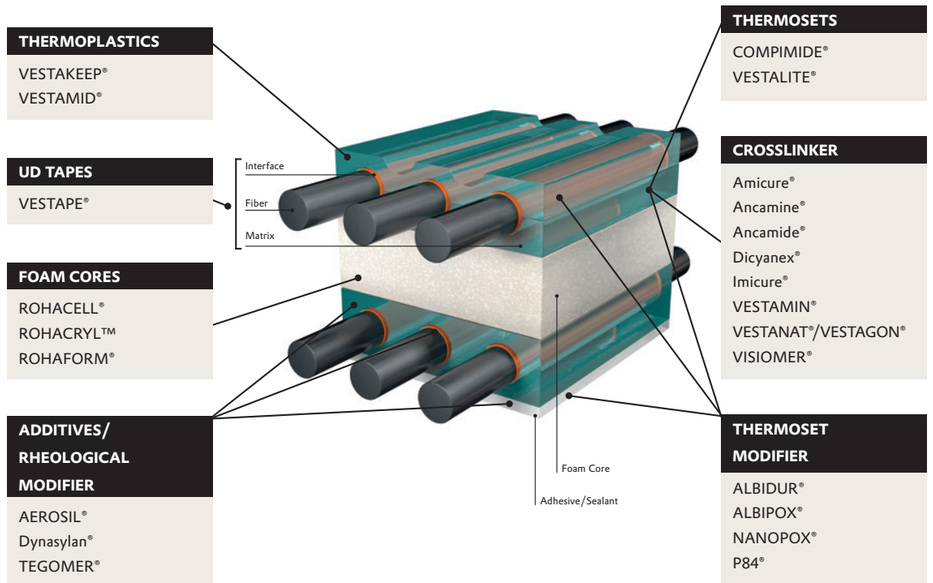
Evonik manufactures a range of products that can be found in almost all components of fiber-reinforced composites. We supply unidirectional tapes, core materials for sandwich construction, thermoplastic and thermosetting resin matrices, as well as the essential components for matrices such as crosslinkers, 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



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.

1 *Automotive*

2 *Aviation*

3 *Construction*

4 *Electronics*

5 *Marine*

6 *Oil & Gas Piping*

7 *Sports*

8 *Wind power*

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.

A thermoplastic matrix has a linear structure that must be heated to be formed, and cooled to be set. That is, the chains lock into place. You can reverse the operation, thereby regenerating the material, and repeat it. The advantage of thermoplastic matrix systems is that they allow faster production rates, are storable at ambient temperatures without any special protection, and are reprocessable.

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.

THERMOSETS

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.

The new VESTAMIN® IPD eCO for reduced CO_2 emissions
Based on renewable raw materials, VESTAMIN® IPD eCO makes your epoxy resin systems more sustainable.

- UV stability
- Chemical resistance
- Mechanical resistance
- Enhanced toughness
- NEW: lower CO_2 profile
- Drop-in solution
- No compromise in performance
- SCC-certified
- Mass balance approach

VESTAMIN® PACM, also a cycloaliphatic diamine, shows a similar behavior to VESTAMIN® IPD in epoxy composites regarding the mechanical properties. An additional advantage is it's 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 it's linear structure. It's high reactivity makes it suitable for ultra fast cured epoxy composites.

The VESTAMIN® product group comprises the following amines

PRODUCT	DELIVERY FORM	CHARACTERISTICS	APPLICATION
VESTAMIN® IPD/ IPD eCO	Liquid, 100%	Isophorone diamine, cycloaliphatic diamine	Hardener component for epoxy resins for rotor blades, pipes, leaf springs, pump cases, high-performance boats, sporting goods
VESTAMIN® PACM	Liquid, 100%	4,4'-Diaminodicyclohexylmethane, cycloaliphatic diamine	Hardener component for epoxy resins for composites
VESTAMIN® TMD	Liquid, 100%	Trimethyl hexamethylene diamine, aliphatic diamine	Fast curing hardener component for epoxy resins for composites

REACTIVE RESIN MODIFIERS

NANOPOX®
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:

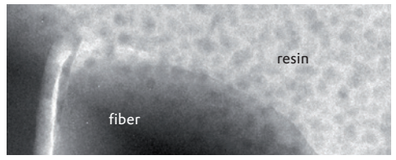
- Significantly improved modulus and flexural strength
- Drastically improved fatigue performance
- Increased toughness
- Improved surface quality (reduced print through)
- Reduced microcrack formation

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.

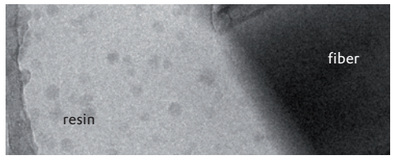
These products are concentrates and, for most composite applications, are diluted with standard epoxy resins. Typical nanosilica levels in, e.g., VARTM resin systems are 10 percent.

The NANOPOX® products are suitable for all hardeners and all manufacturing processes. As the silica nanoparticles do not sediment, even solvent-based prepregging 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.



15 % nanosilica



4 % nanosilica – TEM-Pictures of GFRCs with different levels of SiO_2-nano-particles (based on NANOPOX® F 400)

The standard grades of the NANOPOX® product group

PRODUCT	BASE RESIN	EEW [G/EQUIV]	DYN. VISCOSITY, 25 °C [MPA·S]	CHARACTERIZATION
NANOPOX® F 400	DGEBA	295	60,000	Special for glass, aramide and carbon fibers; 40% SiO_2-nanoparticles
NANOPOX® F 520	DGEBF	275	20,000	Low viscous; 40% SiO_2-nanoparticles
NANOPOX® F 631	EEC	220	5,500	Cycloaliphatic formulations; 40% SiO_2-nanoparticles
NANOPOX® F 700	epoxidized novolac	310	20,000 (at 50 °C)	High-performance novolac, high Tg

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

PRODUCT	BASE RESIN	EEW [G/EQUIV]	DYN. VISCOSITY, 25 °C [MPA·S]	CHARACTERIZATION
ALBIPOX® 1000	DGEBA	330	200,000	Standard type, 40% NBR
ALBIPOX® 3001	DGEBA/DGEBF	215	22,000	Application-ready resin
ALBIPOX® 8001	DGEBA	210	400,000; 4,000 (at 80 °C)	Extremely efficient tackifier (addition level 3–5 %)
ALBIPOX® F 080	DGEBA/DGEBF	330	70,000	Contains NBR*) and nanoparticles
ALBIPOX® F 081	DGEBA/DGEBF	260	35,000	Contains NBR*) and nanoparticles

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.

The standard grades of the ALBIDUR® product group

PRODUCT	BASE RESIN	CORE SHELL CONTENT [WT%]	DYN. VISCOSITY, 25 °C [mPas]
ALBIDUR® EP 2240 A	DGEBA epoxy resin	40	35,000
ALBIDUR® VE 3940	vinyl ester resin/styrene	40	6,000
ALBIDUR® PU 5640	propyleneglycol (triol)	40	2,500

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[1]

PRODUCT NAME	CHEMICAL COMPOSITION	CHARACTERIZATION
TEGOMER® DA 626	Polymeric structure	dispersing agent, defoamer
TEGO® Antifoam D 2340, TEGO® Antifoam D 2345	Polymer solution	defoamer
TEGOPREN® 6875	Alkyl-modified siloxane	dispersing agent, improved scratch resistance
TEGOMER® M-SI 2650	Organo-modified siloxane containing non-reactive aromatic groups	internal release agent, dispersing agent

[1] no specification

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

Internal release agent

RESIN	FIRST RECOMMENDATION	SECOND RECOMMENDATION
Standard epoxy resins	0.1 – 0.2 % TEGOMER® M-Si 2650	
Standard UP resins	0.1 – 0.2 % TEGOMER® M-Si 2650	0.1 – 0.2 % TEGOPREN® 6875

DEFOAMERS

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

Defoamers

RESIN/HARDENER	FIRST RECOMMENDATION	SECOND RECOMMENDATION
Epoxy, anhydride cure	0.2 – 0.8 % TEGOMER® DA 626	0.5 – 1 % TEGO® Antifoam D 2340
Epoxy, amine cure	0.4 – 1 % TEGOMER® DA 626	0.5 – 1 % TEGO® Antifoam D 2340
UP resin, BPO or MEKP cured	0.3 – 0.8 % TEGO® Antifoam D 2345	0.1 – 0.2 % TEGOPREN® 6875

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:

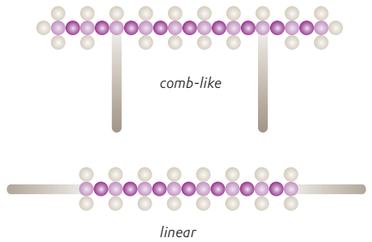
Scratch resistance

CURING AGENT	RECOMMENDATION
Methylethylketone peroxide (MEKP)	TEGOMER® M-Si 2650 TEGOPREN® 6875
Dibenzoyl peroxide (BPO)	TEGOPREN® 6875

[1] no specification

Scratch resistance of cured unsaturated polyester with 0.4 % TEGOMER® M-Si 2650 / without additive

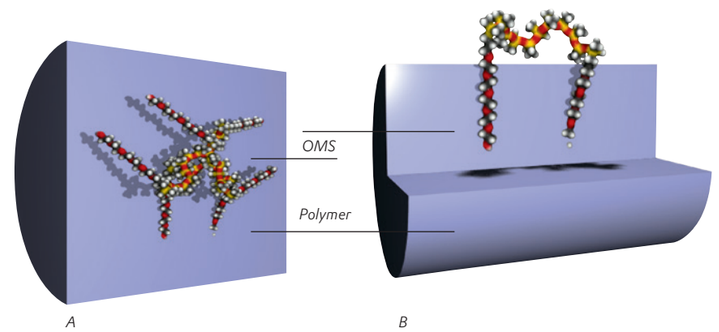
Schematic illustration of the structure of an OMS and its interaction with a polymer



Methylgroup
Silicon
Oxygen

Organic Substituents
- *Alkyl*
- *Epoxide*
- *Hydroxy*
- *Amino*
- *Carboxyl*
- *Acrylate*

HOW IT WORKS Organo-modified siloxanes (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 at the left 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.

EPOXY CURING AGENTS FOR LIGHTWEIGHT SOLUTIONS

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® 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.

VESTALITE® epoxy curing agent for automotive lightweight solutions

	PRODUCT	APPLICATION	BENEFITS
VESTALITE® S	Epoxy Curing Agent	Sheet Molding Compound	Fast curing (< 3 min) High mechanical performance Low VOC

CURING AGENTS FOR EPOXY SHEET MOLDING COMPOUNDS

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 supported by VESTARO to bring next generation composites onto the road with you. VESTARO combines Evonik's chemistry with automotive engineering.

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

Top Recommendations

TECHNOLOGY	Curing Agent	BENEFITS: Low mix viscosity	Long pot life/ Latency @ 25 °C	Low exotherm	Low temp through-cure	Temperature resistance High Tg	Chemical resistance	Mechanical performance ILSS retention	Lap Shear & T-peer	Toughness / Flexibility/ Thermoshock	COMPOSITES PROCESSING ROUTES/ APPLICATIONS: Filament Winding	RTM / Infusion	Casting	Prepreg	Pultrusion	Wet/Hand Lay-up	Pipe Rehabilitation / CIPP	Adhesive Bonding of Composites
Cycloaliphatic	Ancamine® 2167	●	○			●●	●●	●			●	○	○					●
	Ancamine® 2917	●	●●	●●	●●		●	○		●			●	●			●	
Amidoamine	Ancamide® 506	●●	●●	●●	●●	●		●	●	●	●					○		
	Ancamide® 502	●●	●	●●	●●			●		●	●					○		
	Ancamide® 2798	●●	●●	●●	●●					●			●				●	
Polyamide	Ancamide® 350A			●●	●●				●	●								●
	Ancamide® 3030	●	●●						●	●		○		●				●●
	Ancamide® 910			●●	●●				●●	●●								●
Dicyandiamide	Amicure® 1200 series*													●				●
	Amicure® 1400 series*													●				●
	Amicure® UR2T		●●							●				●				●
Imidazoles	Imicure® EMI24					●●								●				●
	Curezol® 2MZ Azine		●●			●●								●				●
Accelerators for heat cure	Ancamine® 2014 AS/FG		●●						●●					●				●●
	Ancamine® K 54		●●		●●	●								●				
	Anchor® 1040		●●			●	●				○				○			

* Benefits depending on formulations

●● excellent
● highly recommended
○ recommended

VISIOMER® SPECIALTY METHARCYLATES FOR VINYL ESTER AND UNSATURATED POLYESTER RESINS

VISIOMER® –
SPECIALTY METHACRYLATES FOR VE AND UP RESINS

Evonik's specialty methacrylate monomers are widely used as reactive diluents in vinyl ester (VE) and unsaturated polyester (UP) resins. The usage of styrene as a reactive diluent for VE and UP resins has recently come under increased environmental and regulatory scrutiny.

Evonik's Specialty Methacrylates product line offers a wide range of low-volatile and low-odor methacrylate monomers (table 1) for full or partial substitution of styrene in composite resins. Crosslinkers such as VISIOMER® 1,4-BDDMA, VISIOMER® EGDMA and VISIOMER® PEG 200 DMA are used as reactive diluents to improve the mechanical properties of low styrene content resins.

Alternatively, these crosslinkers can be used in combination with other methacrylate monomers, such as VISIOMER® BNMA, c-HMA and Terra IBOMA, to create low odor zero-styrene resins. Reactive diluent mixtures of the monomers allow for optimization of desired properties like elongation at break, tensile strength, heat deflection temperature (HDT) and water resistance.

Table 1: Overview VISIOMER® product range for composite applications

	VISIOMER®	APPLICATION AND PROPERTIES
Crosslinkers	EGDMA, TRGDMA, PEG200DMA, 1,3-BDDMA, 1,4-BDDMA, 1,6-HDDMA	Used to enhance mechanical properties of composite resins.
Alkyl/aryl methacrylates	Terra IBOMA, BNMA, c-HMA	Used as reactive diluents for styrene replacement providing low viscosity and good solubility of VE and UP resins.

VISIOMER® TERRA – SUSTAINABLE PERFORMANCE WITHOUT COMPROMISE

Customers and formulators are switching to more sustainable materials, demanding uncompromising products with reduced carbon footprints, improved safety profiles and reliable supply, today and for the sustainable future. VISIOMER® Terra products (table 2) exceed the properties of biobased methacrylates with respect to the following criteria:

- Bio-Carbon content of up to 85 percent
- Bio-Carbon content verified and certified by independent third party according to ASTM D6866 standard
- No severe health or environmental hazards
- Life Cycle Analysis data available

It is our ambition to further expand the portfolio with more VISIOMER® Terra products. This can be done by either using biobased feedstock instead of fossil feedstock for the existing monomers in our portfolio or by developing new structures based on readily available biobased raw materials.

Table 2: VISIOMER® Terra product range

PRODUCT	BIO-CARBON CONTENT
VISIOMER® Terra IBOMA	72%
VISIOMER® Terra C13-MA	76%
VISIOMER® Terra C17,4-MA	81%

VISIOMER® HEMA-P: RESIN STRENGTH PROMOTER FOR GLASS FIBER COMPOSITES

Making composites lighter without compromising strength and durability makes 2-Hydroxyethyl-Methacrylate-Phosphate (HEMA-P) the product of choice in many applications. It can be used to reduce the total composite amount and therefore total material weight. Even the incorporation of relatively small amounts of VISIOMER® HEMA-P can significantly improve the strength-to-weight ratio in glass fiber reinforced VE/UP composites. As a result, wind turbine blades can be made lighter without compromising service life. HEMA-P also increases the durability of composite materials so that ship or yacht hull parts withstand exposure to water for a longer period. HEMA-P (Figure 1) is widely applied as adhesion promoter in applications like adhesives or coating resins, but it can also be used as co-reactive diluent in VE or UP composite resins. Evonik offers VISIOMER® HEMA-P 70M and VISIOMER® HEMA-P 100 (table 3).

Figure 1: Structure of the active ingredient in VISIOMER® HEMA-P

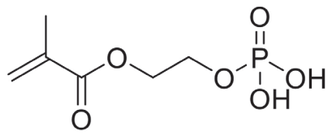


Table 3: Comparison of VISIOMER® HEMA-P 70M and VISIOMER® HEMA-P 100

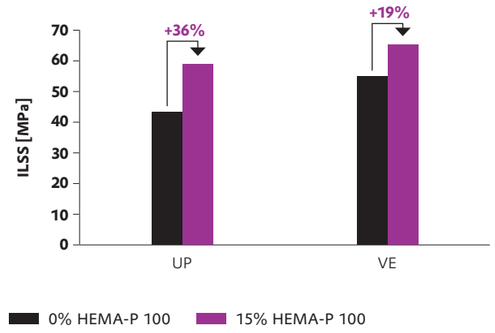
	VISIOMER® HEMA-P 70M	VISIOMER® HEMA-P 100
Supply	in 30% MMA	pure
Viscosity	40–75 mPa*s	3000–7000 mPa*s
P-content	10.6%	15%
Application Areas	• Emulsion Polymerization • Bulk Polymerization • Reactive Resins	• All application areas where MMA is critical due to VOC, odor, flammability or performance

VISIOMER® HEMA-P products demonstrate improved adhesion to glass fibers (GF) and an increase of total resin strength when combined with VE and UP resins. Different mechanical tests confirm the improvement of mechanical properties of glass fiber laminates caused by incorporation of VISIOMER® HEMA-P 100: interlaminar shear strength test (ILSS), the tensile test and the compression test.

Figure 2 shows improvement of the interlaminar shear strength (ILSS) of glass fiber laminates caused by incorporation of VISIOMER® HEMA-P 100. Higher ILSS prolongs the fatigue life of the composite part.

Evonik's specialty methacrylates team looks forward to supporting you in finding the best solution for your next challenge in polymer design.

Figure 2: ILSS improvement of UP/GF and VE/GF laminates by HEMA-P 100



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, platen 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

MONOMERS	CO-MONOMERS	PREFORMULATED RESINS	RESIN SOLUTIONS	RTM RESINS*
COMPIMIDE® MDAB 4,4'-bismaleimidodiphenyl- methane; CAS 13676-54-5	**COMPIMIDE® TM124** o,o'-diallylbisphenol-A; CAS 1745-89-7	**COMPIMIDE® 353 A** Eutectic mixture of bismaleimide monomers	**COMPIMIDE® 1206R55** Formulated resin solution	**COMPIMIDE® 353RTM-ST** Formulated resin blend
COMPIMIDE® TDAB 2,4-bismaleimidotoluene; CAS 6422-83-9	**COMPIMIDE® TM124-Ether** 2,2'-bis[4-allyloxyphenyl] propane; CAS 3739-67-1	**COMPIMIDE® 796** Eutectic mixture of bismaleimide monomers	**COMPIMIDE® 1224 L60** Formulated resin solution	**COMPIMIDE® 353RTM-HT** Formulated resin blend
COMPIMIDE® MXBI m-xylylenebismaleimide; CAS 13676-53-4	**COMPIMIDE® TM123** 4,4'-bis[o-propenylphenoxy]benzophenone; CAS 109423-33-8	**COMPIMIDE® 50LM** Low melting eutectic mixture of bismaleimide monomers		**COMPIMIDE® 50RTM** Formulated resin blend
COMPIMIDE® MAHD 1,6-bismaleimidohexane; CAS 4856-87-5				

* One-pot melt blends for liquid resin processing including RTM, VARTM, resin infusion, etc.

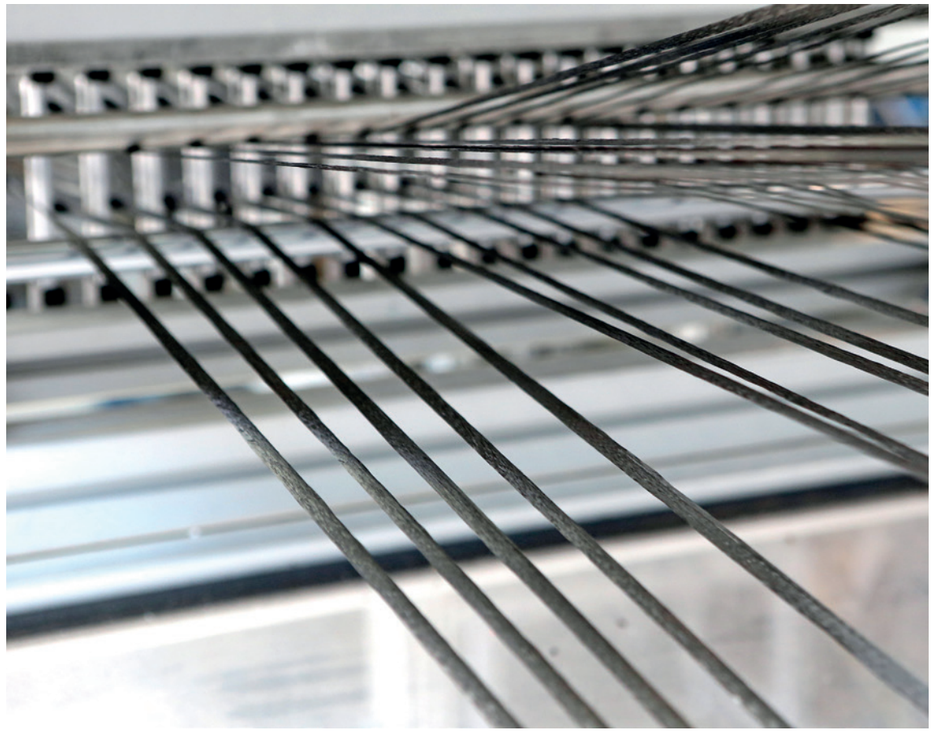
THERMOPLASTICS

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®.



THERMOPLASTIC MATRICES POLYETHERETHERKETONE VESTAKEEP®

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.

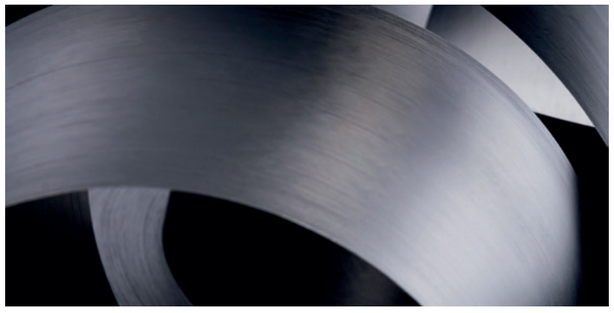
The semi-crystalline polymer features superior, thermal and chemical resistance.

- 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

Our powder grades

VESTAKEEP®	POLYETHERETHERKETONE
2000 P 2000 FP 2000 UFP	Unreinforced, medium viscosity

P	Powder, 500 µm
FP	Fine powder, 55 µm
UFP	Ultra fine powder, 20 µm



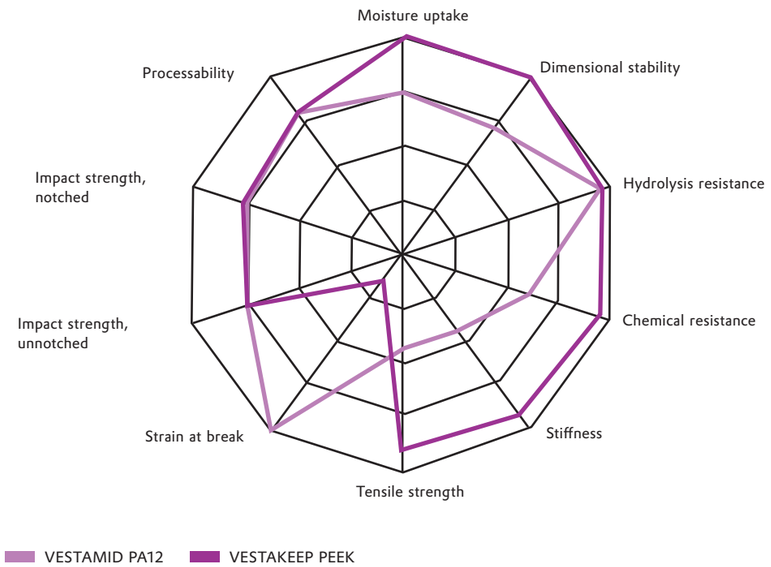
POLYAMIDE VESTAMID® L

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

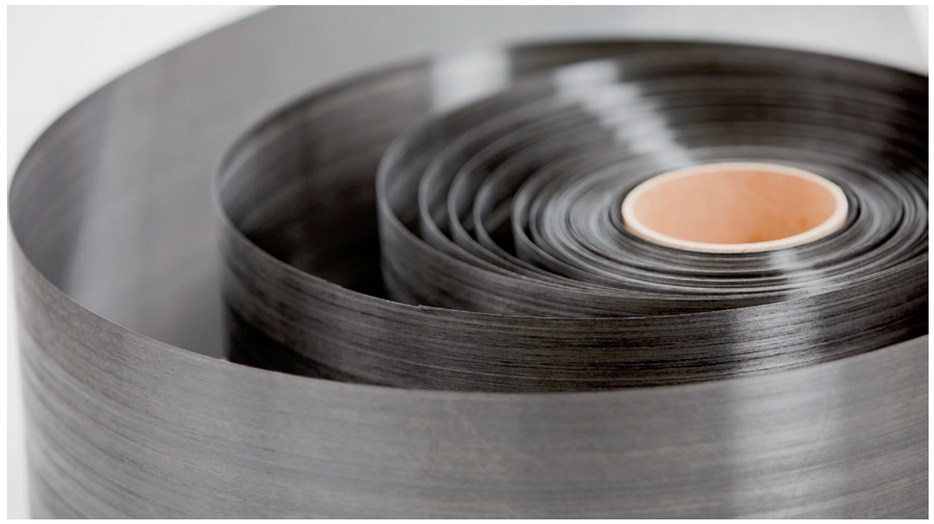
Relative comparison of PA12 and PEEK recommended for composites



Properties of PA12 and PEEK matrix materials for UD tapes

PROPERTIES		UNIT	VESTAMID® PA12	VESTAKEEP® PEEK	TEST METHOD
Polymer		–	Polyamide 12	Polyetherether-ketone	–
Density	23°C	g/cm³	1.01	1.30	ISO 1183
Melting temperature DSC	2nd heating	°C	178	340	ISO 11357
Tensile test					ISO 527-1
Stress at yield		MPa	46	100	ISO 527-2
Strain at yield		%	5	5	ISO 527-2
Strain at break		%	>200	30	ISO 527-2
Tensile Modulus		MPa	1400	3700	ISO 527-1
CHARPY notched impact strength	23 °C	kJ/m²	5C[1]	6C[1]	ISO 179/1eA
CHARPY notched impact strength	-30°C	kJ/m²	4C[1]	6C[1]	ISO 179/1eA

C[1]: complete break



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 handcrafting 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® GH 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.

High-grade materials enhance the functionality of the C-Leg from Otto Bock.

Thermoplastic 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 overmolded 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).

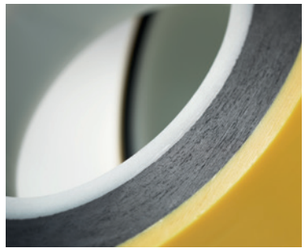
APPLICATIONS

Energy and Oil & Gas industry

VESTAPE® PA12 CF45 is the material of choice for the production of high-end pipe solutions for the oil recovery from deep sea oilfields. Hybrid Flexible Pipes or full TCPs (Thermoplastic Composite Pipes) replace heavy steel solutions and allow for easy to install deployment even in ultra deep water applications. The lightweight construction of the extruded polymer in combination with winded UD tapes offers weight savings up to 60% compared to conventional solutions.

This not only applies for the traditional oil and gas industries, but also more and more for the pipeline infrastructure applications of the energy transition such as transportation of hydrogen and carbon capture, utilitzation and storage (CCUS). VESTAPE® in combination with the TCP technology enables to unlock especially the potential of offshore wind-to-hydrogen, providing a safe and cost-efficient solution.

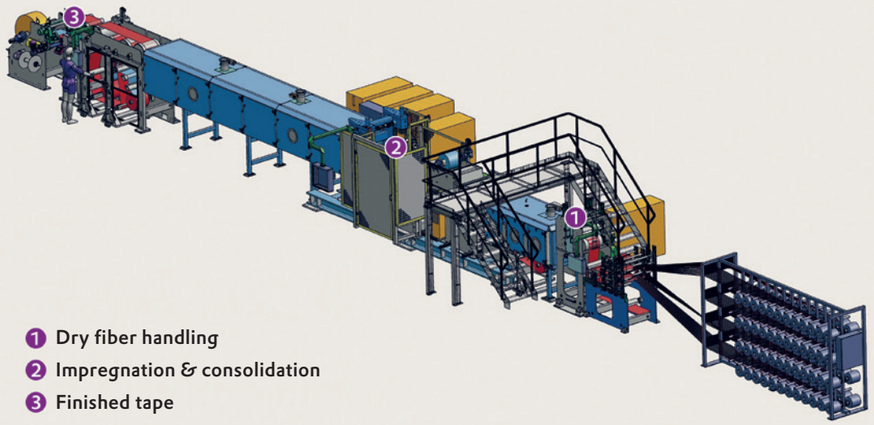
After an extensive and thorough test program the fully generic material qualification of the VESTAPE® PA12 CF45 tape was finalized resulting in the DNV certification acc. to ST-F119 in early 2022.



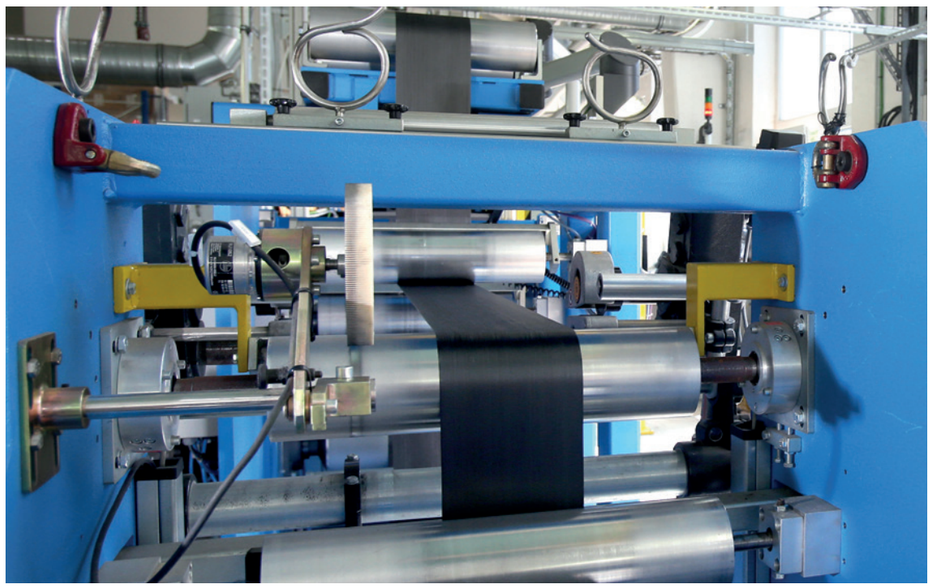
AIRCRAFT

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.

VESTAPE® production line



1 Dry fiber handling
2 Impregnation & consolidation
3 Finished tape



Properties of UD tapes with PA12 and PEEK matrices

	UNIT	VESTAPE® PA12-CF45	VESTAPE® PEEK-CF45	TEST METHOD
TAPE PROPERTIES				
Polymer	–	polyamide 12	PEEK	–
Fiber	–	HT carbon fiber	HT carbon fiber	–
Fiber volume fraction	% by vol.	45	45	EN 2559
Fiber weight fraction	% by weight	59	53	EN 2559
Tape areal weight	g/m^2	343	381	
Tape density	g/cm^3	1.36	1.51	ISO 1183
Tape thickness	mm	0.25	0.25	–
Tape width	mm	150	150	–
LAMINATE PROPERTIES				
Tensile modulus (0°)	GPa	100	100	ISO 527
Tensile strength (0°)	MPa	1750	1750	ISO 527
In plane shear modulus G12	GPa	1.4	3	ISO 14129
In plane shear strength 12M	MPa	30	50	ISO 14129
PROCESSING PROPERTIES				
Melt temperature	°C	approx. 176	approx. 345	ISO 11357
Glass transition temperature	°C	approx. 45	approx. 145	ISO 11357
Typical processing temperature	°C	210–240	370–410	

High Performance Structural Foams

Whether your selection criteria includes density, processing temperature, cell size or a specific mechanical property performance level, Evonik Performance Foams offers a full line of structural foam products to meet whatever your large or small project requires.

FOAMS FOR ALL YOUR APPLICATIONS, VOLUMES, AND PROCESSES

Low density, outstanding material properties, high temperature resistance and boundless design freedom opportunities make our foams ideal for composite sandwich structures in any industry. Our regional experts will guide you in selecting the perfect product for your application's success.

ROHACELL®

ROHACELL® foam has been a core solution in sandwich design composite applications since 1972 and provides impressive mechanical strength, even at very low densities, with a heat distortion temperature and creep compression strength superior to any other rigid foam. For select grades, properties can be even further enhances with heat treatment.

ROHACRYL™

ROHACRYL™ is ideal for high-volume application industries with a clear focus on light weight and sustainability. It's a high-performance foam core solution with a recyclable raw material base. Future-proof your applications for the challenges of a circular economy – without any harmful CFCs!

ROHAFORM®

ROHAFORM® is a state-of-the-art, lightweight particle foam core material for industries with stringent fire, smoke and toxicity level requirements. It exceeds both US and European regulatory FST requirements for commercial aircraft interiors.

ROHACELL® Triple F

With innovative **ROHACELL® Triple F** particle foam, you can design a density specific, highly repeatable, fully integrated part for high volume applications. Complex foam core geometries that were previously only possible with CNC milling, can now be efficiently produced with 100% material utilization.

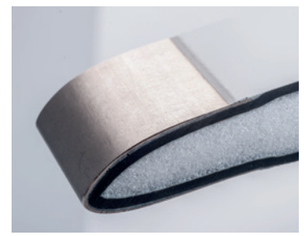
BUILD SANDWICH COMPONENTS THAT ARE LIGHTWEIGHT, YET HIGHLY DURABLE.

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.



Performance foams from Evonik 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.

CORE MATERIAL WITH UNRIVALED HEAT RESISTANCE AND CREEP COMPRESSION STRENGTH

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

ROHACELL® is used as a structural core in component designs. Its natural stiffness can also be useful for braiding, winding, and preforming processing.

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

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.

The right ROHACELL® product for your success

PRODUCT GRADE	APPLICATION INDUSTRY	CELL SIZE	CURING TEMPERATURE	SPECIAL PROPERTIES
A	Aircraft/Space	Coarse	≤130 °C/266 °F	Low temperature curing/ standard aircraft grade
HERO	Aircraft/Space	Medium	≤180 °C/356 °F	High temperature & compressive resistance, highest elongation at break, damage tolerance, grade for structural aerospace parts
RIST*	Aircraft/Space/ Automotive/Industrial	Medium	≤180 °C/356 °F	Designed for resin infusion/small cells
RIMA	Aircraft/Sport/ Space/ Automotive/Industrial	Fine	*≤180 °C/356 °F	Designed for resin infusion/smallest cells
XT	Aircraft/ Space/ Automotive/Industrial	Coarse	*≤190 °C/374 °F	Highest temperature resistance/ usable with BMI resins
WF	Aircraft/Radomes/ Space/Automotive/ Industrial	Coarse	*≤180 °C/356 °F	Most frequently qualified aircraft grade
S	Aircraft/Railway Shipbuilding	Coarse	≤130 °C/266 °F	Good fire behavior for railcars/ships/ small aircraft (no OSU)
EC	Aircraft/Electronics/ Radomes	Medium	*≤180 °C/356 °F	Electrically conductive/designed for UAVs and other stealth applications
HF	Radomes/Medical/ Aircraft/Electronics	Fine	≤130 °C/266 °F	High frequency transparency/designed for radome and medical x-ray table applications
SL	Sport/Automotive/ Industrial	Medium	*≤180 °C/356 °F	Increased elongation at break
IG-F	Automotive/Medical/ Sport/Electronics/ Industrial	Medium	≤130 °C/266 °F	Base grade for various industries

* only with HT version

Some densities of WF are not certified for automotive or industrial applications, speak with a representative

IN-MOLD FOAMED CORES FOR COMPLEX STRUCTURAL PARTS

Using innovative **ROHACELL® Triple F,** geometries that are complex to produce can now be foamed 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-mold foamed
- Complex geometries
- Integrated inserts
- High compression strength and temperature resistance at low density
- Compatible with fast curing processes
- Densities between 70 kg/m^3 and 200 kg/m^3 (4.4 lb/ft^3 and 12.5 lb/ft^3) 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.

THE FST COMPLIANT FOAM FOR COMPOSITES

ROHAFORM®

ROHAFORM® is a lightweight particle foam designed specifically for industries with stringent fire, smoke and toxicity level requirements (FST). It is the only inherently flame retardant foam in the Performance Foams portfolio, impressively exceeding both US and European regulatory FST requirements for commercial aircraft interiors.

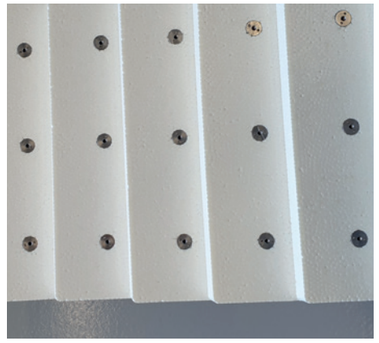
Challenged by a complicated part that is difficult to shape? With ROHAFORM®, no geometry or part elevation variations are too complex. Enjoy full design freedom and let us also integrate any functional inserts required as we mold your foam core. Ready-to-use ROHAFORM® cores are delivered with excellent surface quality, which results in a smooth final part surface with no telegraphing. Plus, the isotropic mechanical properties of the foam ensure consistent core performance across the entire part.

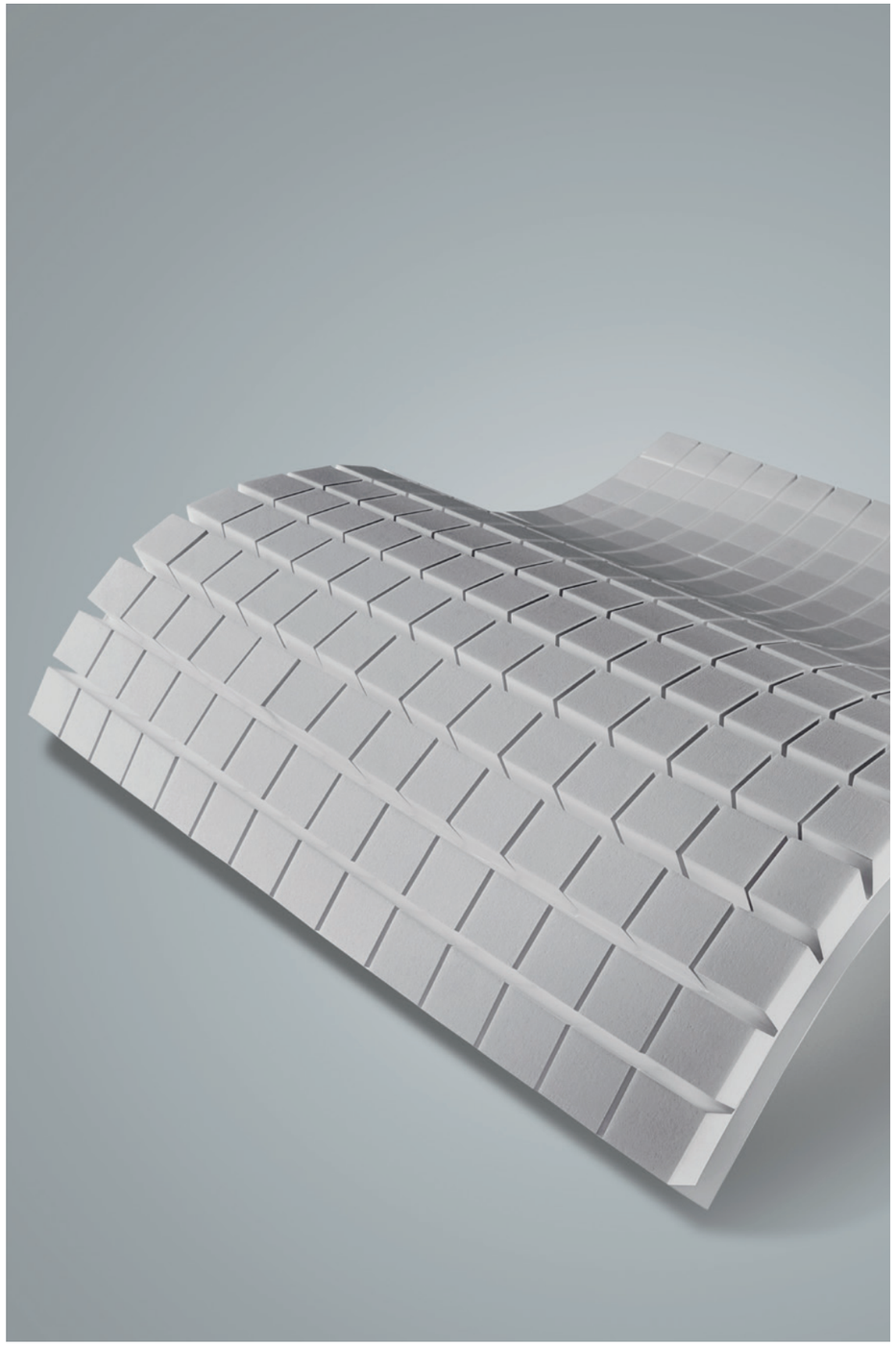
ROHAFORM® cores are ideal for use in automated production as well as state-of-the-art high pressure and extreme temperature processes. Not only do these cores support efficiency in processing and production, they also contribute to sustainability since the foam is fully recyclable.

Fire, smoke and toxicity performance

CHARACTERISTIC	STANDARD	TEST METHOD	ROHAFORM®
Vertical Burn, 60 seconds	FAR/CS 25.853 Appendix F	Part 1 (a) (1) (i)	Pass
Heat Release Peak/Total	FAR/CS 25.853 Appendix F	Part IV	Pass
	Airbus ABD 0031	AITM 2.0006	Pass
	Boeing BSS 7322	ASTM E906	Pass
Smoke Density[1]	FAR/CS 25.853 Appendix F	Part V	Pass
	Airbus ABD 0031	AITM 2.0007	Pass
	Boeing BSS 7238	ASTM E662	Pass
Combustion Toxicity[1]	Airbus ABD 0031	AITM 3.0005	Pass
	Boeing BSS 7239	ASTM E662	Pass

[1] Flaming mode





Mechanical properties of ROHACRYL™

PROPERTIES	TEST METHOD	ROHACRYL™ SW60	ROHACRYL™ SW80	ROHACRYL™ SW100
Density [kg/m³]	ASTM 1622	60	80	100
Compressive Strength [MPa]	ASTM 1621	0.8	1.4	2
Compressive Modulus [MPa]	ASTM 1621	40	70	105
Tensile Strength [MPa]	ASTM D638	1.6	2,2	2.79
Tensile Modulus [MPa]	ASTM D638	70	98	127
Shear Strength [MPa]	ASTM C273	0.75	1.23	1.7
Shear Modulus [MPa]	ASTM C273	25	38	52

THE RECYCLABLE STRUCTURAL FOAM FOR HIGH VOLUME APPLICATIONS

ROHACRYL™ has been developed to meet the requirements of high-volume industries with a clear focus on lightweight and sustainable applications. Its high-performance and contribution to sustainability are a step ahead for products, processes and value chains in the composite industry.

EXCELLENT PROPERTIES

The unique combination of mechanical strength and stiffness at low densities allows you to build your sandwich design leaner and lighter. Highly isotropic cells, tailored for low resin absorption, offer additional weight saving potential. Rethink your design and watch the weight of your products decrease!

SUSTAINABLE

The recyclable raw material base of ROHACRYL™ offers a low carbon footprint and a clean end-of-life solution. Low resin consumption, a leaner design, and short cycle times are additional levers for responsible production in our global environment. Future-proof your applications for the challenges of a circular economy – without any harmful CFCs!

PROCESS BENEFITS

ROHACRYL™ is easy to machine with the ability to cut it quickly and cleanly. The compatibility with automated handling systems due to closed cells and the high processing temperature are a requisite for shorter cycle times. The result is increased production efficiency from start to finish.

ROHACRYL™ is the foam of choice for automated, high-volume production with RTM and infusion processes. It addresses the needs of the whole design and production chain with excellent mechanical properties at low densities, low resin absorption and high process temperatures.

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.

POLYISOCYANATES VESTANAT®

Composite materials exhibit a limited weathering durability, which is attributable to the inherent properties of matrix systems used nowadays, such as epoxy or unsaturated polyesters. It is thus essential to use aliphatic, non-yellowing polyurethanes (PUR), either as a gel coat as coating or as inmold coating, for exterior applications like rotor blades, automotive composite parts, or yachts. With its 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 durabilty and scratch resistance as the M-grades but are based on ethoxysilane technology. The EP-E grades offer full formulation freedom in terms of flexibilty, 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

PRODUCT	CHARACTERISTICS	BENEFITS	APPLICATIONS
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	Branched, high TG crosslinker to impart drying properties and chemical resistance
VESTANAT® E 95	VESTANAT® EP-E grades are high temperature curing adducts, the addition of the catalyst VESTANAT® EP-CAT 21 allows for room temperature curing within less than 60 minutes.	• Do-it-yourself conform • Room temperature curable • Touch dry within one hour • Low viscosity • Easy handling and dosing • Enhanced compatibility to esters	Scratch resistance “booster” for stoving enamels
VESTANAT® EP-MF 203	This crosslinker enables coatings with high reactivity and fast return-to-service times.	• Silane 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.

The epoxysilane Dynasylan® GLYMO and the aminosilanes Dynasylan® AMEO and water-based Dynasylan® HYDROSIL 1153 sized products show superior performance in epoxy resins. A tailormade range of cationic aminosilanes is succesfully applied with polyamide, epoxy and phenolic resins. Aqueous oligomeric silanes guarantee next sustainable silane generation with reduced carbon footprint.

Dynasylan® for glass fiber

PRODUCT	DELIVERY FORM	CHARACTERISTICS	APPLICATIONS
Dynasylan® AMEO	Liquid	Aminosilane	*, PA, PU, EP, Phenolic, Melamine
Dynasylan® GLYMO	Liquid	Epoxysilane	*, PU, EP, Phenolic, Melamine
Dynasylan® 1161 EQ	Liquid	Benzylamino-functional silane in methanol	High temperature resistance in glass fibers and fabrics
VPS 2961	Liquid	Aqueous, oligomeric aminoalkyl- and benzylamino-functional silane hydrolysate based on Dynasylan® 1161 EQ	High temperature resistance in glass fibers and fabrics
Dynasylan® 2201 EQ	Liquid	Ureidosilane 50% in methanol	Aminobased reacivity in moderate pH-range, speciality for PA and Phenolic
Dynasylan® 2101	Liquid	Ureidosilane	Aminobased reacivity in moderate pH-range, speciality for PA and Phenolic
Dynasylan® 4148	Liquid	PEG modified	Speciality for improved fiber processing
Dynasylan® HYDROSIL 1153	Liquid	Aqueous, oligomeric amino silane system	Speciality for PA, PU, EP, Phenolic
VPS 1178	Liquid	Primary, secondary, cationic amino silane with Vinylbenzyl and Si(OCH3)3 functionality	Multifunctional cationic Silane for high temperature resistance in glass fibers and fabrics
VPS 2978	Liquid	Aqueous, oligomeric aminoalkyl- and vinylbenzylamino-functional silane hydrolysate based on VPS 1178	Unique oligomeric multifunctional cationic Silane for high temperature resistance in glass fibers and fabrics
VPS 2975	Liquid	Aqueous, oligomeric aminoalkyl- and ammoniumalkyl-functional silane hydrolysate	Unique oligomeric cationic Silane with antistatic properties

* established standard for sizing formulations
PA = polyamide, PU = polyurethane, EP = epoxy resin, 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, vinylester 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

PRODUCT	DELIVERY FORM	CHARACTERISTICS	APPLICATIONS
AEROSIL® R 208	White powder	Hydrophobic fumed silica	The most efficient thixotrope for bonding pastes. Highly hydrophobic.
AEROSIL® R 202	White powder	Hydrophobic fumed silica	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.
AEROSIL® R 805	White powder	Hydrophobic fumed silica	Special thixotrope for bonding pastes based on EP and PU. Especially recommended to improve the storage stability of special amine hardeners.
AEROSIL® 200	White powder	Hydrophilic fumed silica	Thixotrope for bonding pastes based on polyester and MMA resins, and for relatively non-polar amine hardeners for epoxy systems.
AEROSIL® R 7200 AEROSIL® R 8200 AEROSIL® R 9200	White powder	Structure-modified hydrophobic fumed silica	Reinforcing agent with low thickening properties and excellent mechanical properties.
Dynasylan® AMMO	Liquid	Primary aminosilane	Conventional adhesion promoter – especially suitable for amine hardeners.
Dynasylan® 1124	Liquid	Secondary aminosilane	Adhesion promoter – especially suitable for amine hardeners for bonding pastes. High crosslinking potential.
Dynasylan® 1146	Liquid	Oligomeric aminosilane	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.
Dynasylan® GLYMO	Liquid	Epoxy silane	Adhesion promoter, can be formulated into the resin part of 2K-EP, and can be used in 2K-PU as well.
VPS 4721	Liquid	Oligomeric epoxysilane	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.
VPS SIVO 260	Liquid	Oligomeric aminosilane	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.
VPS SIVO 280	Liquid	Oligomeric aminosilane	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.

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01/2024

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