EVONIK INDUSTRIES

Evonik for composites

Products for efficiency and performance

Evonik. Power to create.

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–the "matrix", as it is called–plays a pivotal role in composites. Examples of composites include laminates that consist of fiber-matrix combinations, or 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 instead makes the components that go into them. Evonik's broad product portfolio includes different types of matrices or matrix-related products, such as hardeners, additives, and special foams for sandwich constructions. 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.

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, and
- 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 crosslink to harden permanently when heated. 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 antifreeze, 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, 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).

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, 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 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	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:

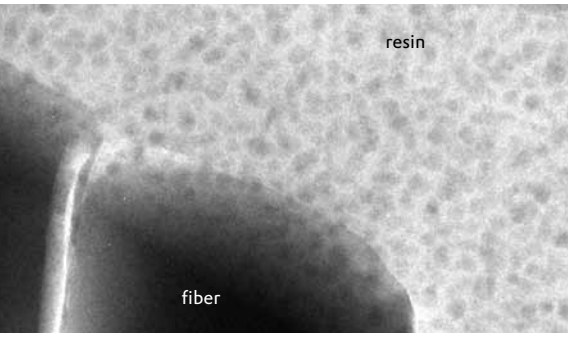
- significantly improved modulus and flexural strength
- drastically improved fatigue performance
- increased toughness
- improved surface quality (reduced print through)
- reduced microcrack formation

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.

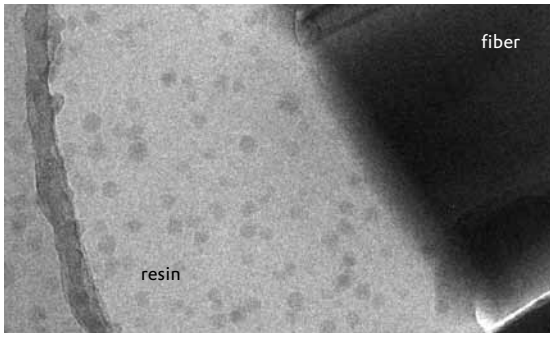
These products are concentrates and, for most composite applications, are diluted with standard epoxy resins. Typical nanosilica levels in e.g. VARTM resin systems are 10 percent.

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 440	DGEBA/ DGEBF	290	45,000	Crystallization-free; 40% SiO_2-nanoparticles
NANOPOX® F 520	DGEBF	275	20,000	Low viscous; 40% SiO_2-nanoparticles
NANOPOX® F 630	EEC	220	5,500	Cycloaliphatic formulations; 40% SiO_2-nanoparticles
NANOPOX® F 640	HDDGE	245	200	For systems with reactive diluents; 40% SiO_2-nanoparticles

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.

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® 1005	TMP-TGDE	320	65,000	Low viscosity; 50% NBR contains diluents
ALBIPOX® 3001	DGEBA/ DGEBF	215	22,000	Application-ready resin
ALBIPOX® F 080	DGEBA/ DGEBF	330	70,000	Contains NBR*) and nanoparticles
ALBIPOX® F 081	DGEBA/ DGEBF	260	35,000	Contains NBR*) and nanoparticles
ALBIPOX® F 091	DGEBA/ DGEBF	220	15,000	Contains NBR*) and nanoparticles

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.

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 toughners, 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.

ALBIDUR® for epoxy resins

Product	Base resin	EEW [g/equiv]	Dyn. viscosity, 25 °C [mPa·s]
ALBIDUR® EP 2240 A	40	300	35,000


HH BA 740

Specialty anhydrides for composite materials

Specialty anhydrides are key components of several materials used in high-performance composites. The anhydrides function as monomers for polymer synthesis and as intermediates for resins used in demanding environments. Specialty anhydrides are important raw materials for polyimides, poly(amide-imides), epoxies, and hybrid resin systems. These materials can be made into a range of articles with direct composite applications, including films, foams, fibers, adhesives, and molded parts. The resulting products have advantages over conventional materials in terms of thermal oxidative stability, chemical resistance, mechanical properties, electrical resistance, weight reduction, and wear resistance. Evonik produces specialty anhydrides for use in high-tech composites and electronic components. BTDA, BPDA, and PMDA are used to improve the properties and the performance of materials for the automotive, aerospace, and consumer electronics markets.

- Optimize properties of polyimide films, foams and resins.
- Reduce delamination defects and improve thermal stability of FCCLs.
- Improve the chemical resistance, mechanical properties and electrical insulation of epoxy resins.
- Increase the functional density of circuits.
- Enhance performance of encapsulants, potting compounds, hybrid resins and coatings.
- Improve the properties of saturated and unsaturated polyesters for a range of applications.

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 30 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 in hot and wet conditions and,
- superior flame and radiation resistance, low smoke and toxicant emissions

Typical processing techniques include prepregging (from the melt, solution, or suspension), resin transfer molding (RTM), filament winding, compression molding, powder coating and pultrusion. The COMPIMIDE® bismaleimide product group comprise COMPIMIDE® Bismaleimide Monomers, Toughening Modifiers and Formulated Bismaleimide Resins.

COMPIMIDE® bismaleimide monomers as main ingredients in various bismaleimide resins:

Product	IUPAC name	CAS No.	EINECS No	TSCA	ENCS No.
COMPIMIDE® MDAB	4,4′-bismaleimidodi-phenylmethane	13676-54-5	237-163-4	Yes	5-3377
COMPIMIDE® TDAB	2,4-bismaleimidoto-luene	6422-83-9	229-175-3	Yes	5-3373

COMPIMIDE® toughening modifiers are designed to be used with COMPIMIDE® bismaleimide monomers, primarily to improve the processing and the toughness of cured composites.

Product	IUPAC name	CAS No.	EINECS No	TSCA	ENCS No.
COMPIMIDE® TM123	4,4′-bis(o-propenylphenoxy)-benzophenone	109423-33-8	n/a	Yes	n/a
COMPIMIDE® TM124	2,2′-bis(3-allyl-4-hydroxyphenyl) -propane	1745-89-7	217-121-1	Yes	4-1587

COMPIMIDE® formulated bismaleimide Resins: The proprietary COMPIMIDE® formulated bismaleimide systems have been customized for the use in several different processing techniques. Evonik's pooled monomer, toughening modifier, and preparation expertise ensures the unique performance of the final composite. COMPIMIDE® formulated bismaleimide systems are available as resolidified melts, powders, or solutions.

COMPIMIDE® types

Product	Type
COMPIMIDE® 353A	Eutectic mixture of BMI building blocks supplied as a resolidified melt
COMPIMIDE® 796	Advanced bismaleimide resin supplied as a resolidified melt
COMPIMIDE® P500	Low-melting toughened bismaleimide powder resin
COMPIMIDE® 200	Heat-curable bismaleimide resin supplied as a powder
COMPIMIDE® 1206R55	Formulated resin solution for manufacturing printed circuit boards
COMPIMIDE® 1224L60	Toughened formulated resin supplied as solution for the manufacturing printed circuit boards
COMPIMIDE® 1251RH60	Formulated resin solution (BMI/epoxy-blend) for manufacturing printed circuit boards
COMPIMIDE® 353RTM	Designed for the Resin Transfer Moulding (RTM) process

For further information, please refer to the COMPIMIDE® brochure or to the technical data sheets, which are obtainable upon request.

Custom–made and optimized bismaleimides: Evonik Degussa has extensive experience in custom products. If you need a monomer designed according to your specifications or a special resin, our knowledgeable technical staff would be happy to work with you to find the solution you are looking for.

Polyetheramide resins CALIDUR®

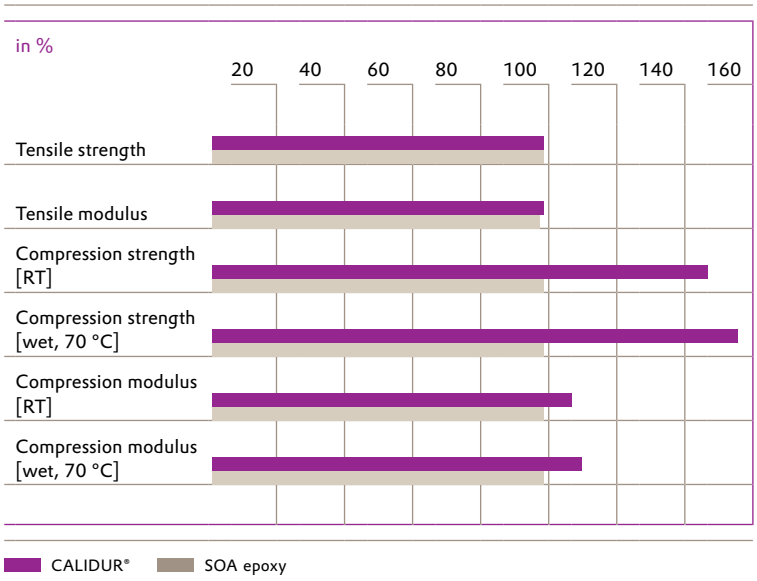
CALIDUR®, a next generation polyaryl ether amide matrix resin
CALIDUR® represents a new class of thermoset matrix resins with a polyaryl ether amide backbone. This technology enables a high degree of crosslinking as is made possible by an intrinsically flexibile chemical network.

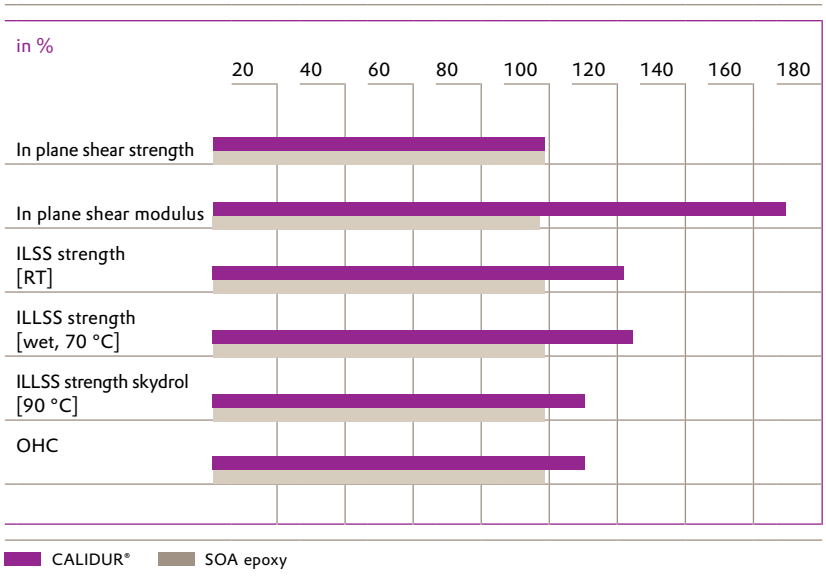
CALIDUR® is a shelf-life stable, one-component system particularly suitable for aerospace and other high-performance, lightweight applications. Improved fiber adhesion translates into extraordinary compressive and shear strengths for structural components.

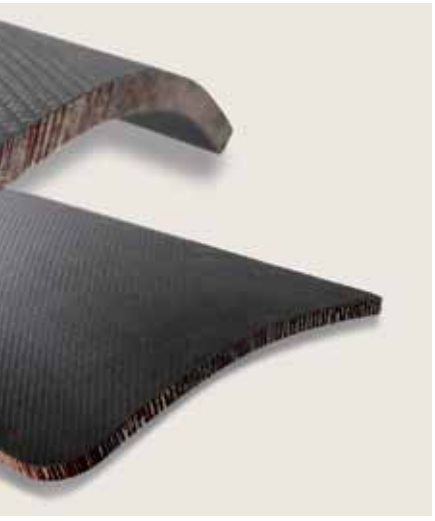
CALIDUR® features a glass transition temperature of 200 °C and a high thermal oxidative stability. The cured resin is characterized by chemical resistance against organic solvents and fluids for example, jet fuels and hydraulic fluids.

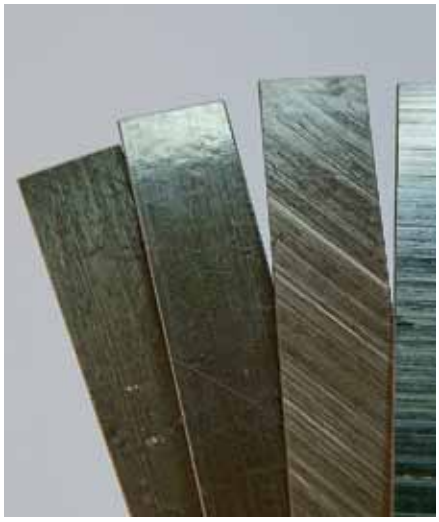
As a result, CALIDUR® makes it possible to manufacture carbon-fiber and glass-fiber composites that excel in mechanical performance and high durability. Low exothermic and minimal shrinkage during curing make it possible to fabricate thicker parts.

CALIDUR® laminates feature greater flame resistance than those based on epoxy resins, thus opening the door to formaldehyde-free interior components.









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), VESTAMID® HT*plus* (PPA), VESTAMID® L (PA12), and TROGAMID® CX (transparent PA), 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.

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

Polyetheretherketone VESTAKEEP®

VESTAKEEP®, the PEEK from Evonik as a matrix for thermoplastic composites
Evonik, which has been producing high performance polymers for more than 40 years, is known for its powder technology expertise in development, production, application, and customer service. Following many years of success on the market, Evonik has extended its product range to include high temperature-resistant polymers. With its PEEK molding compounds and VESTAKEEP® powders, Evonik has once again reaffirmed its technological leadership in the area of high-performance polymers. 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 now established as the ideal polymer for this application.

Properties for laminates out of unidirectional tapes made from VESTAKEEP® 2000 and TENAX HTS

Property	Test method	Unit	Value
Density	ISO 1133	g/cm³	1.61
Matrix content		%	34+/-2
Volatile content		%	<1
Crystallinity		%	35+/-3
Tensile test			
Tensile strength	EN2561	MPa	2480
Tensile modulus	EN2561	GPa	145
Compression strength	EN2850	MPa	1370
Compression modulus	EN2850	GPa	127
Heat release	FAR25.853(c)		Fulfilled
Toxicity	AITM3.0005		Fulfilled
Smoke emission	FAR25.853(c)/ AITM2.0007		Fulfilled
Flammability (60s/12s)	FAR25.853(a)		Fulfilled
Flammability acc. UL94, 0.5 mm	IEC 60695		V-0

By courtesy of TT Group | development@tohotenax-eu.com

Polyphthalamide VESTAMID® HT*plus*

VESTAMID® HT*plus* is a PA10T-based copolyamide that has a number of benefits over other PA6T-based PPAs:

- produced up to 50 percent from renewable sources
- lower water absorption
- better dimensional stability
- higher hydrolysis resistance
- improved processing window

For composite applications Evonik has developed a VESTAMID® HT*plus* PPA grade with very low viscosity, providing for good fiber impregnation. With a glass transition temperature of 125 °C and a processing window of about 300 °C, this is a high-temperature matrix for aircraft and automotive applications when combined with carbon, glass, or aramid fibers.

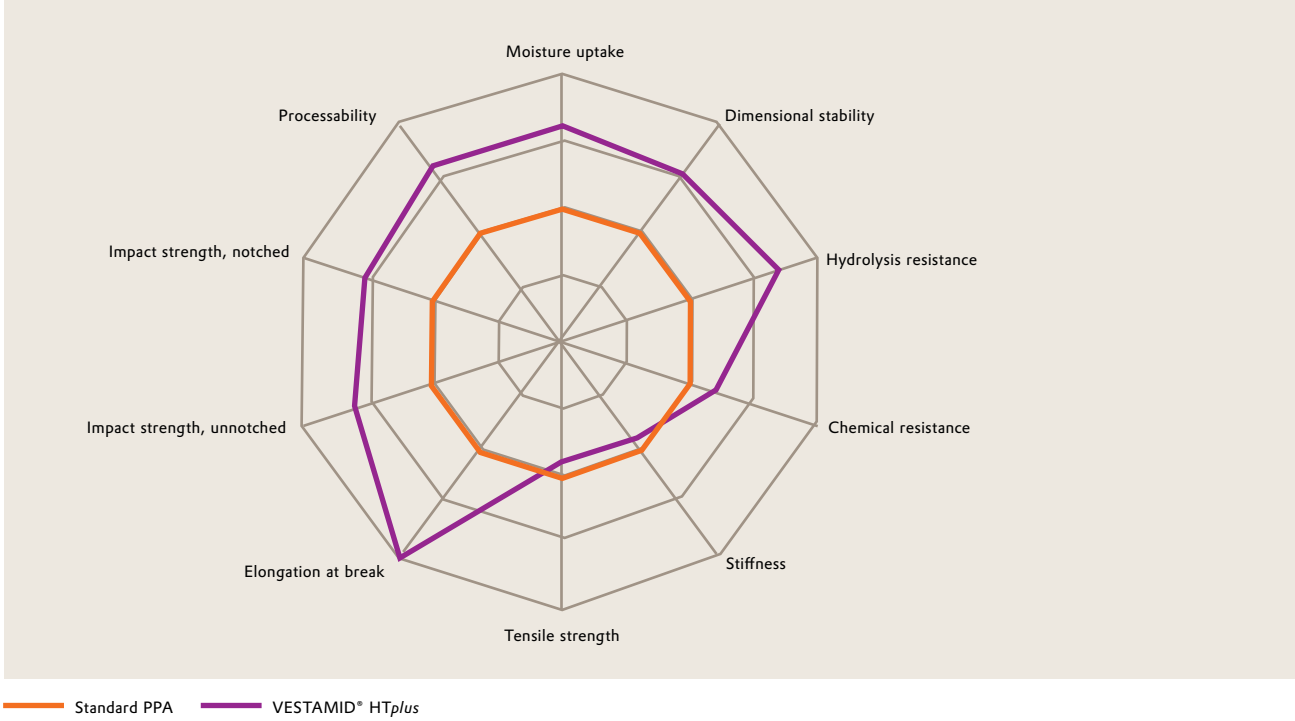
The VESTAMID® HT*plus* composite grade is available as granules and a powder with a particle size of 60 µm. Both melt and powder products attest to this matrix polymer's excellent impregnation behavior. If you will be using a film stacking process for manufacturing composite parts or sheets, we can provide a suitable film of the requisite thickness.

Properties of the VESTAMID® HT*plus* composite grade

Property		Test method	Unit	VESTAMID® HT*plus*
Density	23 °C	ISO 1183	g/cm³	1.11
Tensile test Stress at break Strain at break		ISO 527-1/-2	 MPa %	 62 >100
Tensile modulus		ISO 527-1/-2	MPa	2100
CHARPY Impact strength	23 °C -40 °C	ISO 179/1eU	kJ/m² kJ/m²	N >100
CHARPY notched Impact strength	23 °C -40 °C	ISO 179/1eA	kJ/m² kJ/m²	18 C 15 C
Temperature of deflection under load Method A Method B	 1.8 MPa 0.45 MPa	ISO 75-1/-2	 °C °C	 124 130
Melting point DSC	 2nd heating	ISO 11357	 °C	 Approx. 265
Particle size distribution d_{10} d_{50} d_{90}		Malvern mastersizer	 µm µm µm	 Approx. 20 Approx. 50 Approx. 80

N= No break
C= Complete break

Comparison of a standard PPA with the special grade recommended for composite laminates.



Polyamide VESTAMID® L

VESTAMID® L (PA12) has been used as a matrix for many years in composites with glass fiber fabrics. So far, it has been used in automotive, sports, and orthopedic applications. Composites with VESTAMID® L as the matrix are processable at a lower temperature. Compared to high temperature-resistant matrices such as PEEK and PPA, this presents an advantage, thus significantly shortening cycle times for mass-production.

Further general properties:

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

Properties of the VESTAMID® L composite grade

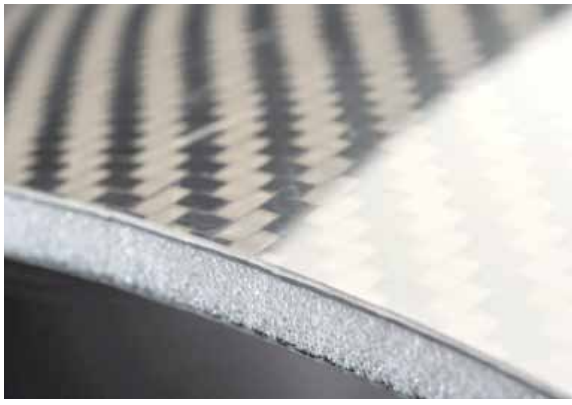
Properties [1]		Test method	Unit	VESTAMID® L
Density	23 °C	ISO 1183	g/cm³	1.02
Tensile test Tensile strength Strain at break Tensile modulus	50 mm/min	ISO 527-1/-2	 MPa % MPa	 40 300 1400
Flexural modulus			MPa	1800
Impact strength	23 °C	ISO 180/1C	kJ/m²	N
Notched impact strength	23 °C	ISO 180/1A	kJ/m²	6C
Temperature of deflection under load Method A Method B	 1.8 MPa 0.45 MPa	ISO 75	 °C °C	 50 130
Melting temperature		ISO 1218	°C	178
Thermal conductivity	23 °C		W m⁻¹ K⁻¹	0.24
Water absorption	23 °C	ISO 62	%	1.5
Abrasion resistance		Taber Abraser	mg/100 rev.	5-13

[1] Representative average values, no warranted minimum or maximum values.

Transparent polyamide TROGAMID® CX

TROGAMID® CX is a microcrystalline, transparent PA12 that is used as a thermoplastic matrix material in composite parts where attractive appearance is an important criterion. Furthermore, it can be used in combination with glass or carbon fibers and is the material of choice in design applications targeted at end consumers. TROGAMID® reveals its brilliance by working with the structure of the fibers used. Typical applications are, for example, cell phone- or laptop covers. Reduced cycle times are the key benefit, besides the following general properties:

- Excellent light transparency
- Low water absorption
- Low weight
- Processable at low temperature
- Zero tension cracking



Properties of the TROGAMID® CX7323 composite grade

Properties [1]		Test method	Unit	Value
Density	23 °C	ISO 1183	g/cm³	1.02
Tensile test Stress at yield Strain at yield Nominal strain at break	50 mm/min	ISO 527-1/-2	 MPa % %	 60 8 >50
Tensile modulus		ISO 527-1/2	MPa	1400
CHARPY impact Strength	23 °C -30 °C	ISO 179/1eU	kJ/m² kJ/m²	N N
CHARPY notched impact strength	23 °C -30 °C	ISO 179/1eA	kJ/m² kJ/m²	14C 11C
Temperature of deflection under load Method A Method B	 1.8 MPa 0.45 MPa	ISO 75-1/2	 °C °C	 108 122
Melting temperature		ISO 1218	°C	250
Thermal conductivity	23 °C		W m⁻¹ K⁻¹	0.22
Water absorption	23 °C	ISO 62	%	3.5
Abrasion resistance		DIN 53754	mg/100 rev.	18

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

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

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

DEGAPLAST® Casting Resins 103 P 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® Laminating Resins 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, different kinds of canvas DEGAPLAST® Resins as well as. Producing inlays by a casting process it can be adjusted with 20 percent (m/m) DEGAPLAST® Casting Resins 103 P 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® Laminating Resins C is a specially developed reactive resin for laminating carbon-fibers.

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

Foams

Sandwich composites in lightweight, yet highly durable components are one way to save weight and costs.

A lightweight core of polymeric foam, to cite one example, can be sandwiched between two skins of fiber composite, sheet metal, or film. The core lends the skins their shape, spacing them apart from each other evenly.

Because of the space between the skins, the core significantly increases the rigidity of the composite: The greater the space, 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. That is, 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.

ROHACELL®, Polymethacrylimide

ROHACELL®, a polymethacrylimide based structural foam, has been used in the composites industry for about 40 years.

Unique performance:

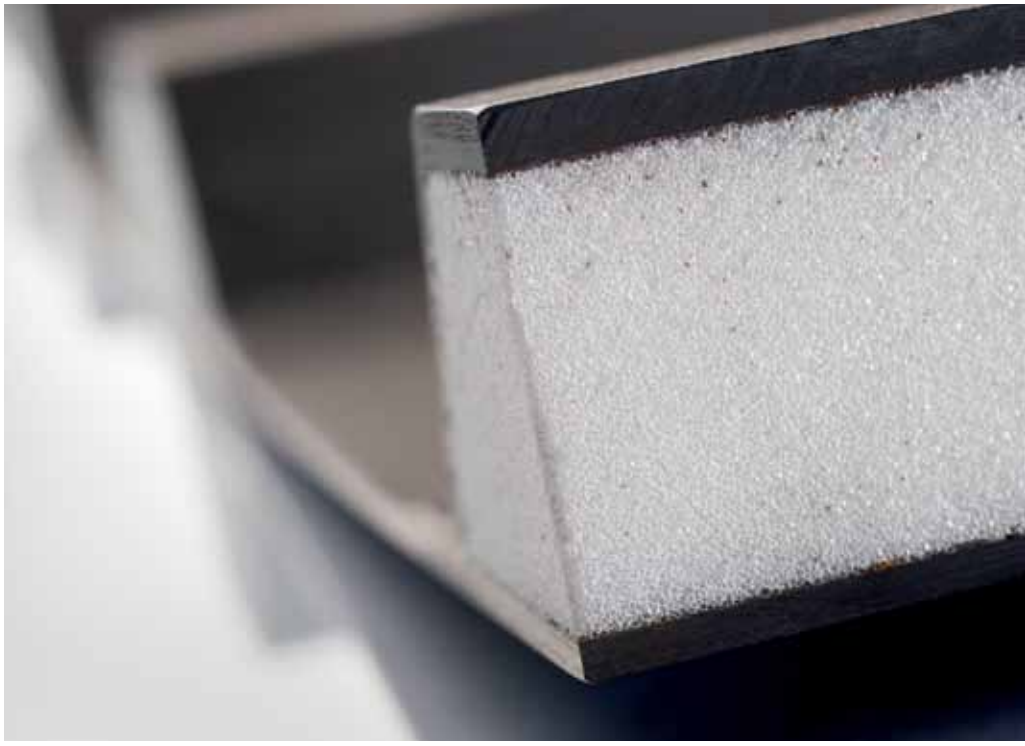
- low weight
- Excellent mechanical properties and stability over a wide temperature range, even at low densities
- High temperature resistance up to 220 °C
- Unique compressive creep behavior for processing up to 190 °C and 0.7 MPa
- Excellent dynamic strength
- Cell sizes customizable to each processing method
- Featuring entirely closed cells, ROHACELL® is manufactured without CFC or heavy metals.

ROHACELL® is used as a structural core in component designs (see figure below). Its natural stiffness can also be useful for braiding, winding, and preforming processing. To realize a complex integral sandwich design, producers can use ROHACELL® as a means of ensuring an efficient and stable process.

Sandwich design

Construction concept	Sketch	Rigidity	Weight	Layup cost	Jointing cost
Full sandwich design		++	+	++	++
Skin sandwich		+	++	+	0
Profile reinforcement		+	+	0	+

■ ROHACELL®
■ Cover layer, e.g. CFRP
++ Very good
+ Good
0 Satisfactory



Improve your efficiency

Preparation and long production cycles have become key cost drivers in composite technology. ROHACELL® can be shaped easily on common CNC-machines or thermoformed within minutes without special outgassing or surface preparation. Because of its high thermal and creep resistance, it 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® reduces production time and costs.

Added value with ROHACELL®

ROHACELL® in aeronautical applications:
- stable and reliable process
- short curing times
- co-curing
- no water damage
- more net load

ROHACELL® in the automotive industry:
- high temperature resistance for short curing cycles
- lowest weight
- cataphoretic painting temperature stable
- save fuel consumption
- stabilize crash elements

ROHACELL® for railcars:
- FST (with skins)
- lightweight structure
- weight saving for high acceleration

ROHACELL® for antennas and radomes:
- dielectric properties close to that of air
- high specific properties but almost transparent
- tidiest dimension tolerances for best antenna performance

ROHACELL® for medical technology:
- stable and reliable process
- low weight beds for easy handling
- lowest dielectric properties ensure high-quality X-ray and CT patient beds with minimal radiation exposure.

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

With its ROHACELL® product range, Evonik offers, for process temperatures up to 190°C, a whole line of different grades customizable to a large number of applications. Customers can choose from products with various cell sizes and densities—from 32 to 200 kg/m^2—thus making it possible for various mechanical and weight targets to be met.

The right product for your success

ROHACELL® grade	
IG/IG-F	Sporting goods, medical, automotive
A*	Aircraft applications, curing up to 125 °C/0.35 MPa
WF*	Aircraft applications, curing up to 180 °C/0.7 MPa
RIST*	Designed for **R**esin **I**nfusion, **ST**ructural application
RIMA*	Designed for **R**esin **I**nfusion, **M**inimized **R**esin **A**bsorption
XT*	E**XT**ended temperature, curing up to 190 °C/0.7 MPa - BMI
HP*	Highest creep resistance, for example, 32 kg/m^3 180 °C/vacuum
S	Good fire behavior, railcars/ ship/ smaller aircraft
HF	Antennas, radomes, medical
WIND/WIND-F	Wind energy blades for advanced curing temperatures

*Used mainly in aircraft

Added value of our solution centers

To support our customers the best possible way, we offer them a number of options for incorporating ROHACELL® even more efficiently in their design work.

- At our Sandwich Technology Center (STC), we can arrange prototype construction and small production runs and conduct all kinds of sandwich core testing.
- We're able to demonstrate the use of ROHACELL® in common curing techniques such as liquid composite molding and autoclaving.
- In addition, we provide samples to our customers and offer them training in handling and thermoforming ROHACELL®.

Our SHAPES department creates added value

Everything from one source. That's the mission of our SHAPES department. Every application needs its own shaping process to ensure that you will meet cost and quality targets. Innovative and suitable equipment for machining ROHACELL® ensures high-quality core solutions.

Buy ROHACELL® ready-to-use, and enjoy your "TIM WOOD targets"

- Transportation reduction
- Inventory reduction
- Motion reduction in house
- Waiting time reduction
- Over production reduction
- Over processing management and reduction
- Defect / rework reduction
- Niques such as liquid composite molding and autoclaving

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. The epoxy-based gel coats perform unsatisfactorily outdoors, too. It is thus essential to use aliphatic, non-yellowing polyurethanes (PUR), either as a gel coat or as a coating, for exterior applications like rotor blades or yachts. With its VESTANAT® polyisocyanates, Evonik offers a full range of crosslinkers for light-stable PUR coatings: HDI-polyisocyanates (VESTANAT® HB, HT) as standard crosslinker, whereas the IPDI trimer (VESTANAT® T 1890) is used to optimize drying and chemical resistance. Special solutions for high-solids formulations are available.

VESTANAT® products for composite coatings

Product	Delivery form	Characteristics	Applications
VESTANAT® HB 2640	Solvent-free, various solution grades	Aliphatic polyisocyanate based on HDI-biuret	Light-stable 2K PUR coatings
VESTANAT® HT 2500	Solvent-free, various solution grades	Aliphatic polyisocyanate based on HDI-isocyanurate	Lower in viscosity, lower monomer content compared to HDI-biuret
VESTANAT® T 1890	Various solution grades	Cycloaliphatic polyisocyanate	High TG crosslinker to impart drying properties and chemical resistance

Diamines VESTAMIN®

For applications where light stability is not required, epoxy resin systems are often used as gel coats. Our ® products play an important role as crosslinkers in this regard (see product description on page 5).

Additives

Glass fiber reinforced composites

Glass fiber products, such as endless glass fibers, chopped strands, mats, rovings, yarns and milled glass fiber 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 are obtained with methacryl-functionalized Dynasylan® MEMO in polyester and vinyl ester resins. The epoxysilane Dynasylan® GLYMO and the aminosilanes Dynasylan® AMEO and water-based Dynasylan® HYDROSIL 1151 show superior performance in epoxy resins.

Dynasylan® for glass fiber

Products	Delivery form	Characteristics	Applications
Dynasylan® AMEO	Liquid	Aminosilane	*, ** PA, PU, EP, Phenolic, Melamine
Dynasylan® GLYMO	Liquid	Epoxysilane	*, ** EP, PU, Phenolic, Melamine
Dynasylan® MEMO	Liquid	Methacrylsilane	*, ** UP, Acrylic,
Dynasylan® VTMOEO	Liquid	Vinylsilane	*, ** UP
Dynasylan® 2201 EQ	Liquid	Ureidosilane	PA, Phenolic
Dynasylan® 1189	Liquid	Sec. Aminosilane	PP, PA
Dynasylan® SIVO 214	Liquid	Proprietary aminosilane composition	PP, PA, Phenolic
Dynasylan® 1175	Liquid	Cationic aminosilane	PA, EP, Phenolic
Dynasylan® HYDROSIL 1151	Liquid	VOC free water borne silane system	PA, PU, EP, Phenolic

* Important component in glass fiber sizes
** adhesion promoter for (selection): PA = polyamide, PU = polyurethane, EP = epoxyresin, UP = unsaturated polyester, PP = polypropylene

Additives for bonding pastes (Windmill applications)

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 moulds 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 used as standard thixotropes in bonding pastes based on epoxy, polyurethane and vinylester resins .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, 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.

Please do not hesitate and contact us directly, if you would like to learn or discuss more about new, tailor made and innovative AEROSIL® and Dynasylan® products for windmill bonding pastes not described in this version of the brochure.

Product	Delivery form	Characteristics	Applications
AEROSIL® R 208	White powder	Hydrophobic fumed silica	The most efficient thixotrope for bonding pastes. Highly hydrophobic behaviour.
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® 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 dedicated 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.

Contacts

VESTAMIN®, VESTANAT®

Michael Vogel
Paul-Baumann-Straße 1
45772 Marl
Germany

PHONE +49 2365 49 -7086
FAX +49 2365 49 80-7086
michael.vogel@evonik.com

DEGAPLAST®

Dr. Peter Neugebauer
Kirschenallee
64293 Darmstadt
Germany

PHONE +49 6181 59-5108
FAX +49 6181 59-4919
matthias.safadi-mueller@evonik.com

NANOPOX®, ALBIPOX®, ALBIDUR®

Dr. Stephan Sprenger
Charlottenburger Str. 9
21502 Geesthacht
Germany

PHONE +49 4152 8092-36
stephan.sprenger@evonik.com

VESTAMID®, VESTAKEEP®

Martin Risthaus
Paul-Baumann-Straße 1
45772 Marl
Germany

PHONE +49 2365 49-4356
FAX +49 2365 49-80-4356
martin.risthaus@evonik.com

Specialty Anhydrides

Dr. Jeffrey H. Dimmit
PO Box 247
8545 SE Jayhawk Drive
Galena, KS 66739, USA

PHONE +1 620 783-1321
FAX +1 620 783-3107
jeff.dimmit@evonik.com

ROHACELL®

Uwe Lang
Kirschenallee
64293 Darmstadt
Germany

PHONE +49 6151 18-3570
uwe.lang@evonik.com
www.rohacell.com

CALIDUR®

Dr. Franz-Albert von Itter
Paul-Baumann-Straße 1
45772 Marl
Germany

PHONE +49 2365 49-2259
FAX +49 2365 49-7585
albert.itter@evonik.com

AEROSIL®, Dynasylan®

Reiner Wartusch
Rodenbacher Chaussee 4
63457 Hanau-Wolfgang
Germany

PHONE +49 6181 59-13476
FAX +49 6181 59-713476
reiner.wartusch@evonik.com

COMPIMIDE®

Dr. Tim Pohlmann
Rodenbacher Chaussee 4
63457 Hanau-Wolfgang
Germany

PHONE +49 6181 59-8755
FAX +49 6181 59-78755
tim.pohlmann@evonik.com

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EVONIK
INDUSTRIES

Evonik Industries AG
Paul-Baumann-Straße 1
45764 Marl
Germany

PHONE +49 2365 49-7628
FAX +49 2365 49-5030
composites@evonik.com
www.evonik.com

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