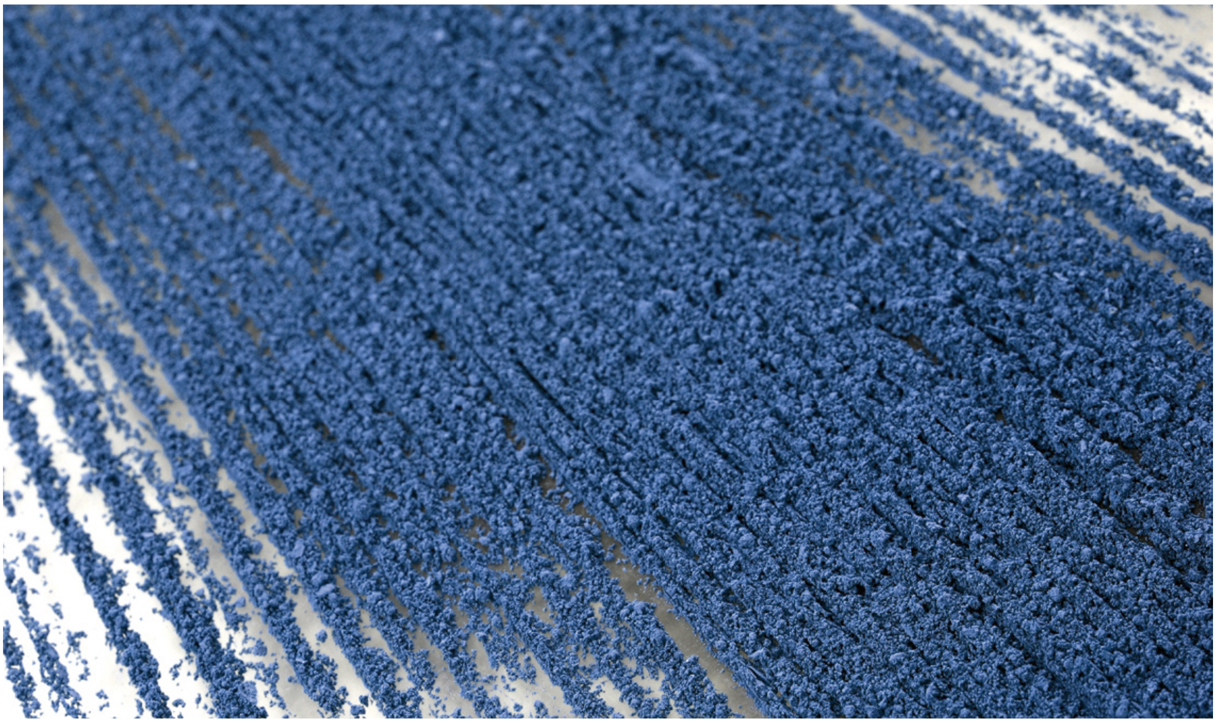
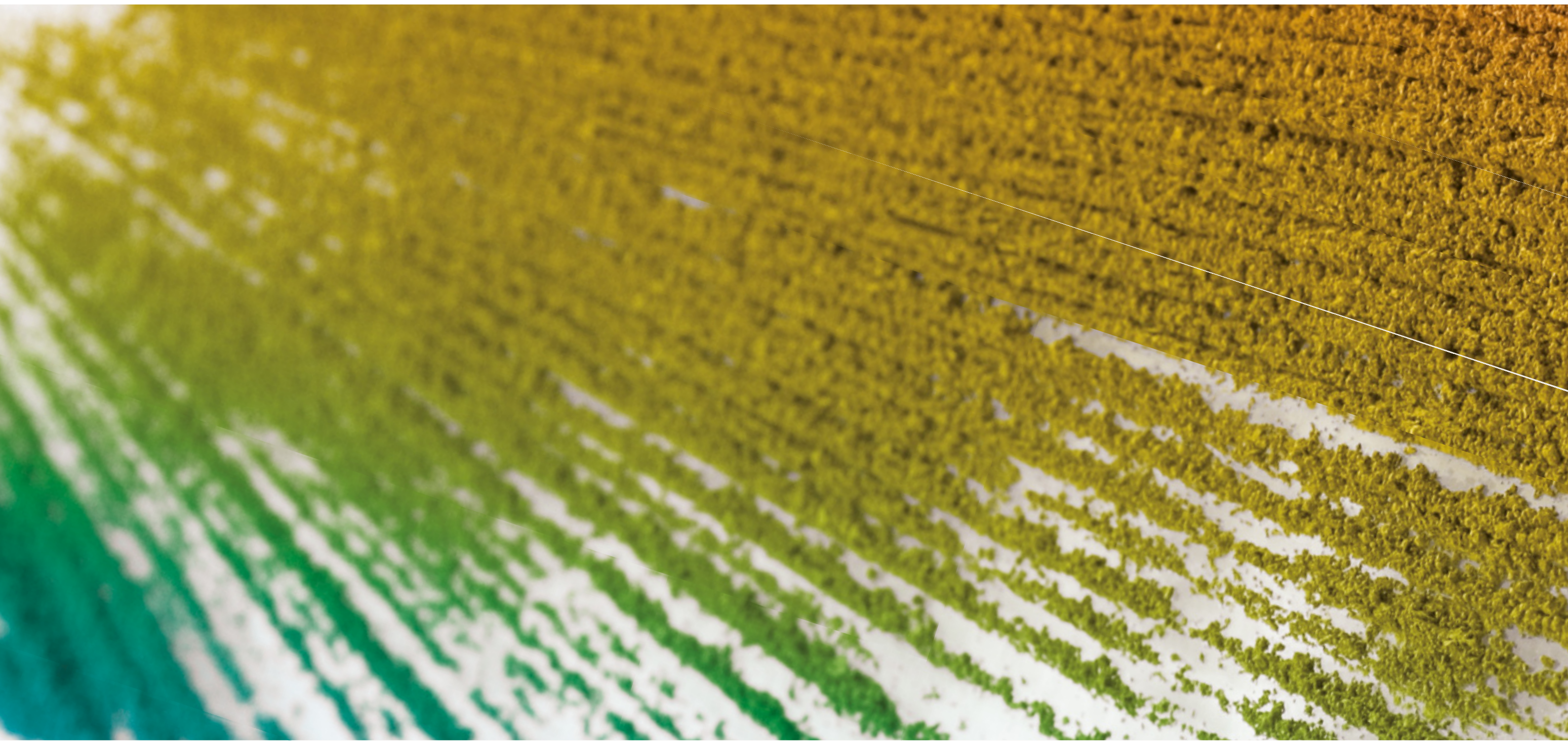
Dynasylan®
for Mineral Fillers and Pigments



Dynasylan®

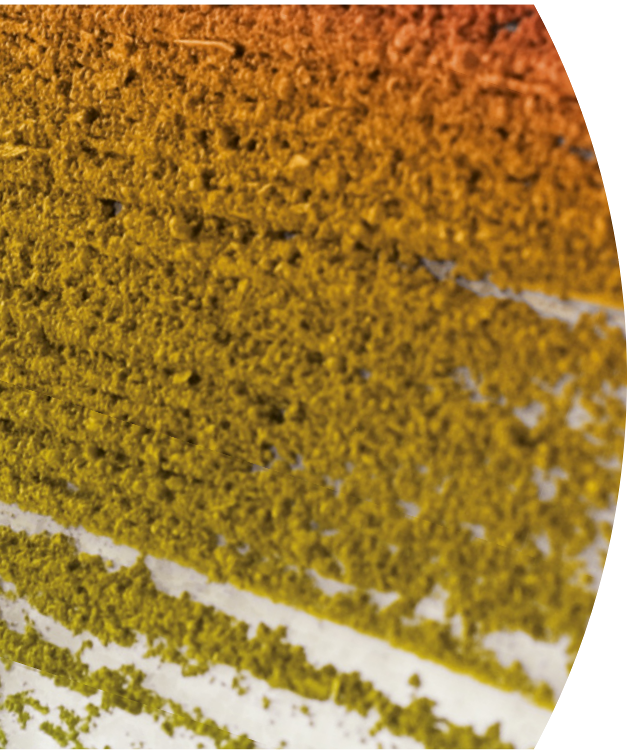
EVONIK
Leading Beyond Chemistry



The Compatibilizer: Silanes in Filled Plastics

More than 30 percent of all thermoplastics, thermosets, and elastomers worldwide are compounded and reinforced with fillers and fibers.

Since their development more than 50 years ago, organosilanes have been used to provide a variety of performance and process benefits to mineral-filled compounds. Organosilanes provide better adhesion at the polymer-filler interface, as well as improved filler dispersibility and composite durability.



A hybrid between inorganic and organic constituents, the organosilane, works as a molecular bridge between inorganic and organic materials. Based on the concept of “bridging the gap”, silanes form permanent chemical bonds which do not only improve, but also create new exceptional functionalities.

While there are many other materials called “adhesion promoters” or “coupling agents”, silanes have a unique dual reactivity that distinguishes them from all other surface treatments. By forming chemical bonds, silanes work on the interface between inorganic and organic materials and do not migrate to the surface of the composite.

Content

Mastering the Challenge

Dynasylan® imparts unique, high-end properties to finished products. Reduced water up-take through hydrophobization and an improved melt flow ratio through better dispersion of the mineral in the polymer matrix can be achieved. Chemical coupling between the inorganic and the organic parts of a composite is the key and basis for improved dimensional stability, improved wet-out between the resin and the filler, and reduced viscosity through improved dispersion.

Dynasylan® keeps costs down by maximizing the throughput of high-value products.

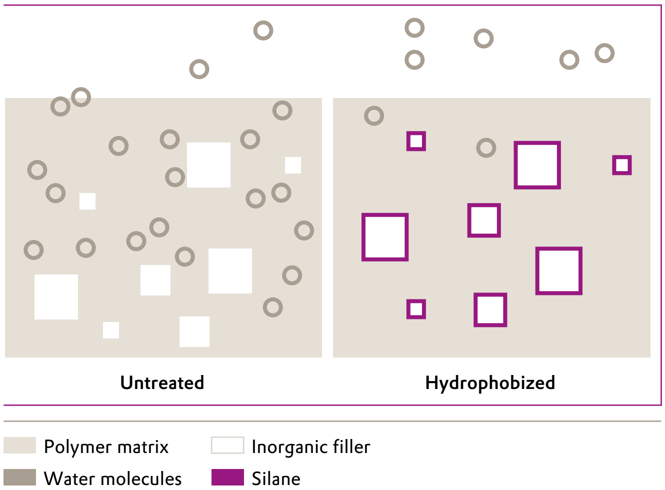
Dynasylan® silanes are used in many research and high-tech projects. For example, the MAGLEV traction technology employed in the Transrapid uses cables manufactured with Dynasylan® silanes to meet stringent requirements.

- Lower viscosity
- Improved processing
- Increased output
- Improved dispersion
- Higher filler-loading
- Improved cost-efficiency

Dynasylan® In – Water Out

Silanes further enhance the hydrophobicity of filled plastics. When silanes are used, the absorption of water by the polymer is significantly reduced.

Reduction of water up-take by incorporating silane

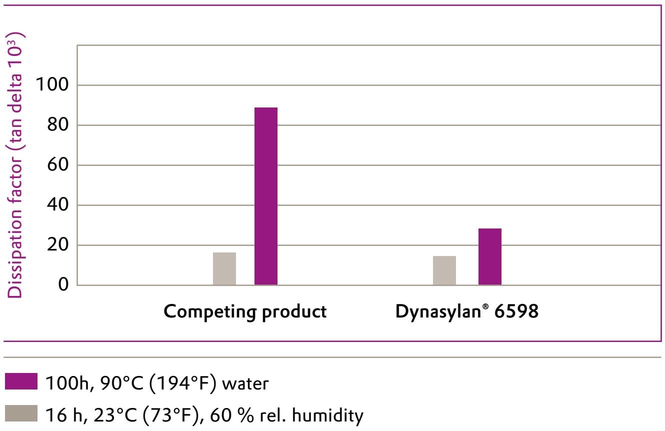


Dynasylan® 6598 significantly improves electrical properties

The diagram to the right illustrates the positive effect of Multifunctional Silane Systems™ on the dissipation factor of calcined clay-filled EPDM rubber cables after exposure to water. Positive effects include, for example, an improvement of wet-electrical properties in rubber power cables.

The performance of Dynasylan® treatment versus other surface treatments in a filled-rubber formulation: The dissipation factor is significantly improved as a result of the significantly reduced water up-take.

Dynasylan® 6598 significantly improves electrical properties

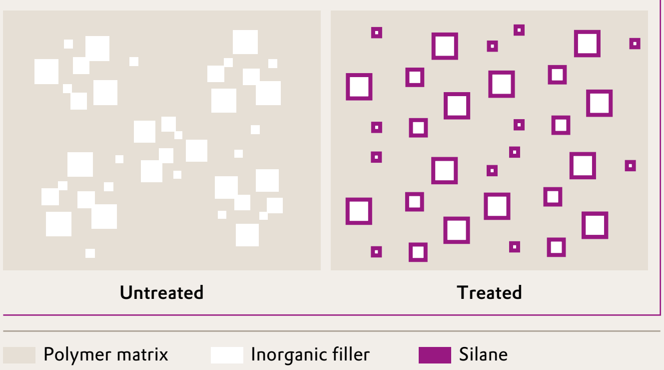


Easier Processing with Dynasylan®

The dispersion of fillers in polymers is a demanding technological challenge, as inorganic fillers and the organic polymer matrices have different polarities.

Properly chosen silanes can serve as excellent compatibilizers because of their dual role: combining organic and inorganic groups within one molecule.

Silanes improve dispersion of fillers in polymer matrices

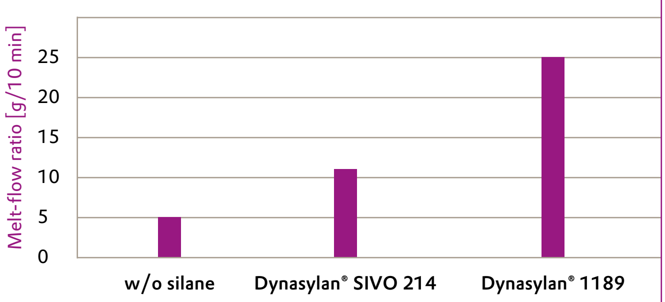


Melt flow ratio of magnesium hydroxide (MDH) – filled polypropylene compounds

Reduced agglomeration is a consequence of improved dispersion of the inorganic in the organic matrix. Also the melt flow ratio of the compound is significantly increased.

The better the choice of silane, the better the compatibilizing effect in the final compound (see diagram).

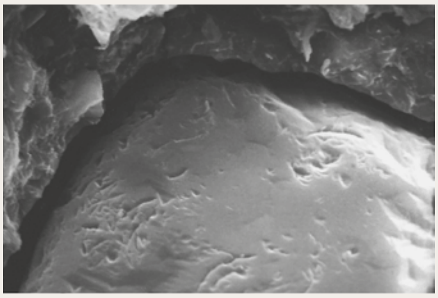
Melt flow ratio of a MDH/PP/PP-MAH compound with different silanes



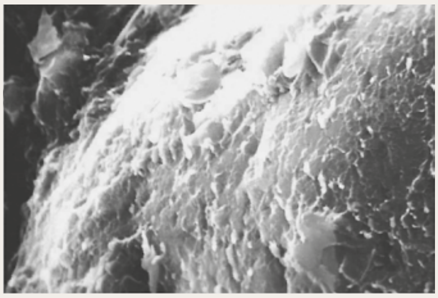
Dynasylan® Couples Fillers and Polymers

What makes silanes so important is that they can couple inorganic and mineral fillers with organic polymers through a chemical bond. As a consequence of the coupling, the mechanical properties of the filled compounds are significantly improved. Examples are the use of silane-treated glass fibers in polypropylene, quartz in unsaturated polyester, and aluminum hydroxide in ethylene vinyl acetate.

Dynasylan® binds the resin to the filler



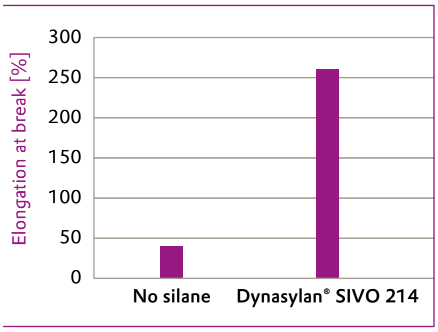
Untreated

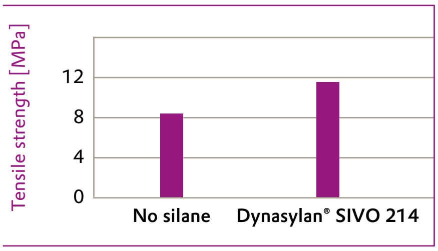


Treated with 1 % Dynasylan® MEMO

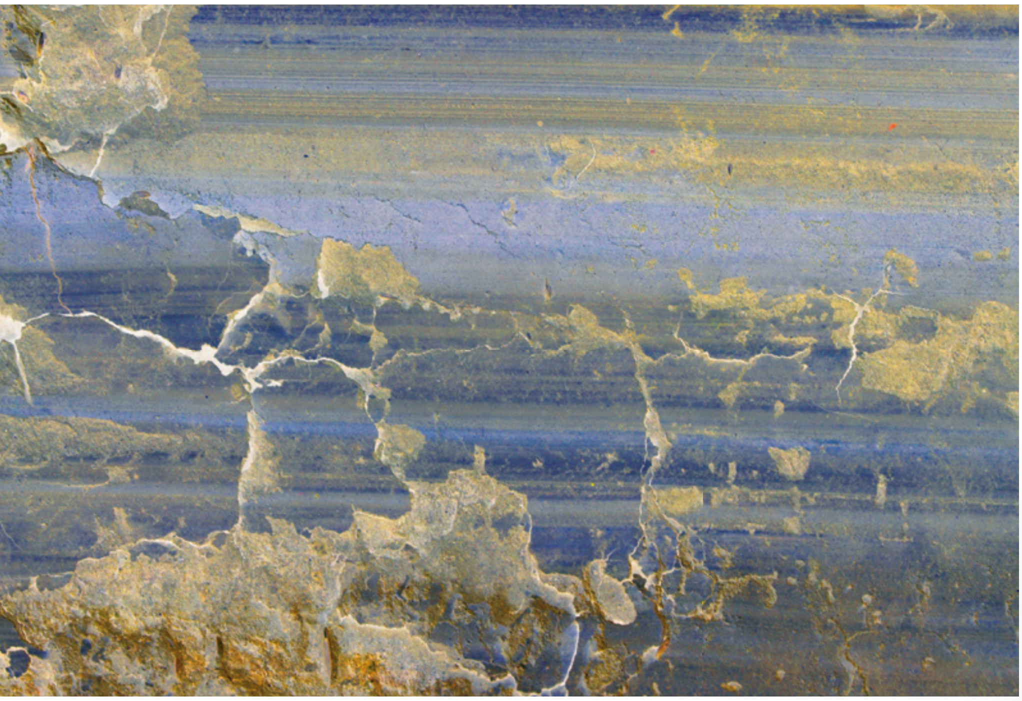
Mechanical properties can be improved by chemically coupling the polymer to the filler

The chemical bond between the inorganic and the organic part of the compound is crucial to achieve improved mechanical properties. The elongation at break of magnesium hydroxide-filled PP based cable compound, for instance, improves significantly, without any adverse effects onto the tensile strength.





The elongation at break of a magnesium hydroxide-filled polypropylene (PP) compound with additional maleic anhydride as coupling agent.



Chemistry

Silanes are adhesion promoters that unite the different phases present in a composite material. These phases are typically organic resins (e. g., ethylene/vinyl-acetate copolymer, EVA) and inorganic fillers (e. g., ATH) or fibrous reinforcements. Silanes form molecular bridges to create strong, stable, water-resistant and chemical-resistant bonds between two otherwise weakly bonding or even incompatible surfaces.

The properties and effects of silanes are defined by their molecular structure. The silicon at the center is combined with the organofunctional group, Y, and the silicon-functional alkoxy groups, OR.

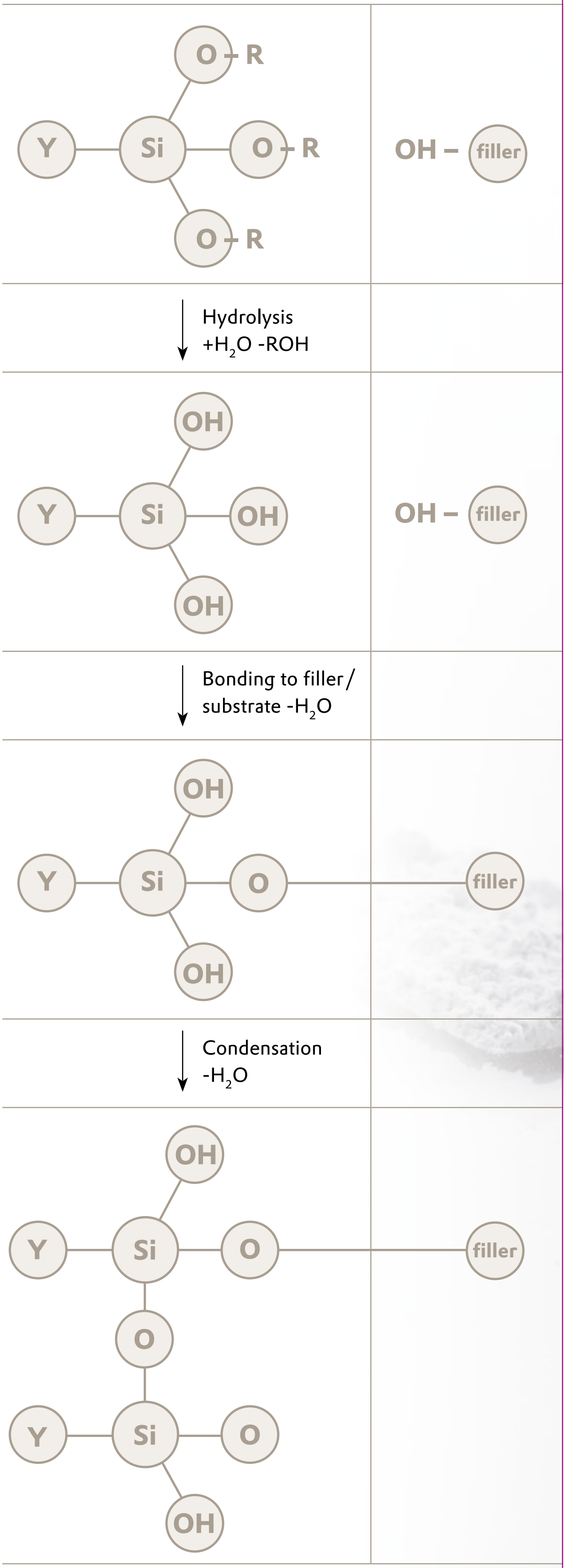
The silicon-functional groups, OR, are hydrolyzed in the first stage of application, liberating the corresponding alcohol (see diagram page 9).

The organofunctional group, Y, binds to the polymer by:

- Chemical reactions such as grafting, addition, and substitution
- Physico-chemical interactions such as hydrogen bonding, acid-base interaction, entanglement, or electrostatic attraction.

The fixation of the silanol on the filler surface is accomplished in a first step through hydrogen bonding with the surface OH group. Therefore, mineral substrates that provide a high OH group density exhibit better reactivity towards silanes than others. Until the water molecule is split off and eliminated from the reaction site, this reaction is reversible. As long as there is only hydrogen bonding, the silane can still migrate on the filler surface. The covalent [silane-O-filler] bond finally fixes the silane on the filler surface. In theory, the silane forms a monolayer on the filler surface. In reality, alkoxysilanes, react not only with the filler surface, but they can also condense with themselves to produce three-dimensional networks, the result being on the filler surface.

The chemical mechanism of silane reactivity



Exemplary filler

- ATH (aluminum hydroxide)
- MDH (magnesium hydroxide)
- Calcined clay
- Calcined talc
- AlO(OH)
- Ammonium polyphosphate
- Other char formers

Practice

There are different ways to introduce the silane onto the filler or into the final compound.

Pre-treatment method

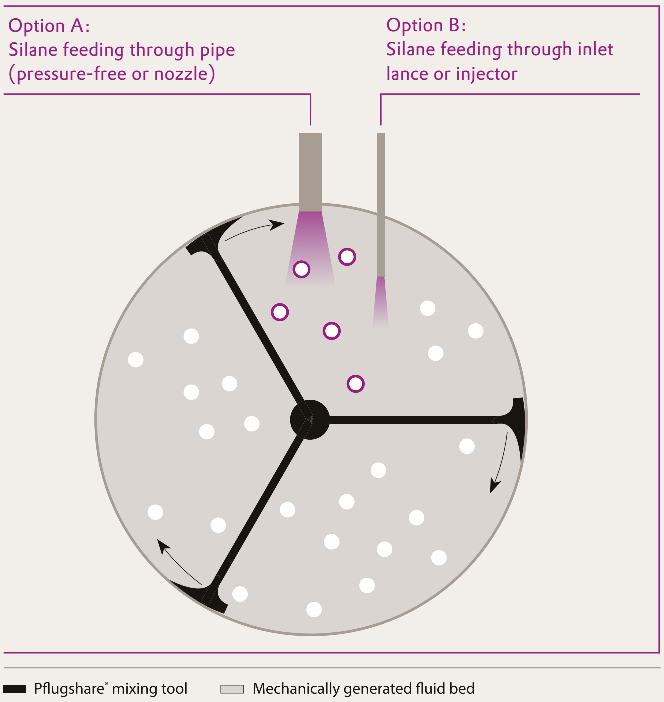
a) Pure silane on filler
In this process, the silane is sprayed onto a well-agitated filler. For maximum efficiency, uniform silane dispersion is essential, and this is made possible by the high shear rates provided by the mixing equipment.

Examples of manufacturers of processing equipment include Loedige, Littleford Day, Hosokawa Alpine, and Thyssen Henschel. The most important commercial silane-coating processes are continuous and have high through-put rates. Control of silane addition, dwell time, and exact temperature control within the system are essential. An elevated temperature is required for a complete reaction to occur between the silane and the filler; however, an excessively high temperature may lead to a loss of silane through evaporation.

b) Slurry process
The slurry procedure of filler treatment is limited to quickly water-soluble silanes and waterborne silane systems. In rare cases, silanes in emulsion form can also be applied. Fillers that react with water obviously cannot be treated by this method. The slurry procedure should be considered for commercial treatment when the filler is handled as a slurry during manufacturing.

Treating solutions may be aqueous, mixtures of alcohol and water, or a variety of polar and non-polar solvents. Typically, low concentrations of the silane (up to 5 %) are dissolved by hydrolysis. The silane solution or emulsion is applied by spraying. Removal of water, solvents, and reaction by-products requires additional steps such as dehydration and drying.

Schematic view of a horizontal Pflugshare® mixer



In-situ method

The neat silane can also be added during compounding and should migrate to the filler surface. The in-situ treatment procedure makes it possible to coat freshly formed filler surfaces, for example, during silica/rubber compounding.

The undiluted silane is added directly to the polymer before or together with the filler. It is essential that the resin or other additives do not react with the silane prematurely, as otherwise the coupling efficiency will be reduced. Typical compounding equipment includes internal mixers, kneaders, Banbury mixers, two-roll mills, co-rotating twin screw extruders, and Buss kneaders.

Dry silane method

The silane can also be added as a dry concentrate, for example, as a wax dispersion, dry liquid, or masterbatch. Here, the silane is adsorbed at very high levels onto suitable carriers and then blended with the polymer and the filler during compounding. The use of "solid" silanes leads to highly effective dispersions, even with simple production equipment. In addition, an easy and safer handling method is assured. Silane loadings are comparable to those in the in-situ method.

General Considerations

Silanes need a certain time to react with the filler surface. Dwell times of 2–3 minutes are common. Generally, silane loadings are between 0.7 to 2 wt. % relative to the filler, and depend on filler surface and final application.

Typical set-up

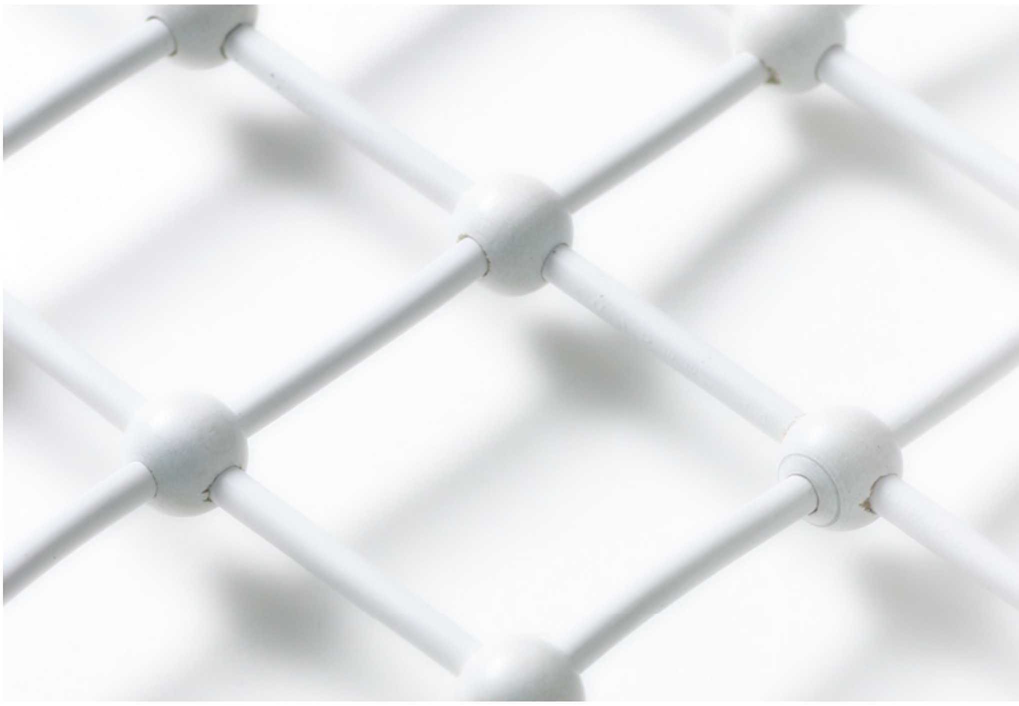
The mineral should be agitated in a high shear mixing device at either room or elevated temperature (40 °C). The silane should be distributed evenly through a nozzle or inlet lance while the mineral is moving. The main covalent reaction is completed after about 15–30 minutes. To assure fixation of the silane on the mineral surface, allow 30 additional minutes at elevated temperatures (60–80 °C). In some cases, a catalyst can help to activate a slowly reacting silane or mineral combination. In general, the treated filler is heated after the silane is added to remove reaction by-products, solvents, and water, and to bond the silane completely and permanently to the filler surface. Important in this step is controlling by-products such as alcohols.

Concentration of the released alcohol relative to the explosion limits should be considered, and special collection systems can be installed to reduce the risk of explosion and to minimize the release of by-products into the environment.

All process parameters need to be optimized, depending on the type of silane employed, on the mineral used, as well as on the type and the technical details of the equipment used.

A check list for operation:

- Take sufficient health and safety precautions (MSDS, exposure limits, explosion limits, toxicity of by-products). Watch off-gases.
- Check the surface area of your mineral. Minerals with surface areas higher than 70 m^2/g need a dosage higher than 1 % of silane.
- Check the correct combination of the chosen silane and resin to which the mineral should be applied.
- Make sure that the mineral surface provides enough moisture.
- Avoid additional dispersing aids.
- Use high shear mixers.
- Silane should be distributed evenly on the filler surface; best results through spraying.
- Allow the mineral filler to blend properly.
- Heat up to remove generated alcohol and water.
- Keep mixing to avoid agglomerates and hard particles.
- Check for proper treatment level and formed chemical bonds through extraction and physico-chemical analysis.



A Successful Combination

The mineral part of the equation

Organosilanes rely on the reaction with surface hydroxyl groups to produce a stable covalent bond and a stable layer on the filler surface. They are, thus, most effective on fillers with high concentrations of reactive hydroxyl groups and a sufficient amount of residual surface water. Silica, silicates (including glass), oxides, and hydroxides are most reactive towards silanes. Silanes are generally not as effective on materials such as sulfates and carbonates. These can be encapsulated with silica and further modified with Dynasylan®. Such layers are highly complex and depend on the nature of the coating conditions, the type of mineral surface, and the chemistry of the reactive functionalities present.

Reactivity of selected fillers and pigments with hydrolyzed silanes

Excellent	Good	Poor
• Aluminium hydroxide (ATH) • Cristobalite • Fumed silica • Glass fiber • Kaolin (clay) • Precipitated silica • Quartz • Wollastonite • Aluminium pigments • Glass spheres	• Inorganic oxides • Magnesium hydroxide (MDH) • Mica • Other silicate fillers • Talc • Titanium dioxide • Iron oxide	• Barium sulfate • Calcium carbonate • Carbon black
HO – HO – HO – HO –	HO – HO – HO –	HO –

Comparison of silane-filler reactivities with schematic visualization of the surface activity of different fillers

The silane part of the equation

Not only the inorganic material provides reactive groups for the successful combination of inorganic and organic materials, but also the silane must be chosen according to the resin and the curing system.

The following chart provides a brief overview of polymers in the final application and the respective recommended product. The surface reactivity of many fillers generally precludes strong bonding with a polymer matrix and, in some cases, leads to poor compatibility and dispersion. These filler surfaces can be made polymer-reactive provided full consideration is given to the choice of the silane.

Polymer	Recommended Product
Polypropylene (PP) – maleated	Dynasylan® 1189 Dynasylan® SIVO 214 Dynasylan® HYDROSIL 1151* Dynasylan® HYDROSIL 2909*
EVA/PE	Dynasylan® AMEO Dynasylan® SIVO 214 Dynasylan® SIVO 210 Dynasylan® 1189 Dynasylan® 6498 Dynasylan® 6598 Dynasylan® HYDROSIL 1151* Dynasylan® HYDROSIL 2907* Dynasylan® HYDROSIL 2909*
Polyamide	Dynasylan® SIVO 214 Dynasylan® AMEO Dynasylan® HYDROSIL 1151* Dynasylan® HYDROSIL 2909*
Rubber, peroxide-cured	Dynasylan® 6498 Dynasylan® 6598 Dynasylan® VTMOEO Dynasylan® HYDROSIL 2907*
Unsaturated Polyester Resin (UP)	Dynasylan® MEMO Dynasylan® VTMOEO Dynasylan® HYDROSIL 2907*
Epoxy Resin (EP)	Dynasylan® GLYMO Dynasylan® AMEO Dynasylan® GLYEO Dynasylan® HYDROSIL 1151* Dynasylan® HYDROSIL 2926*

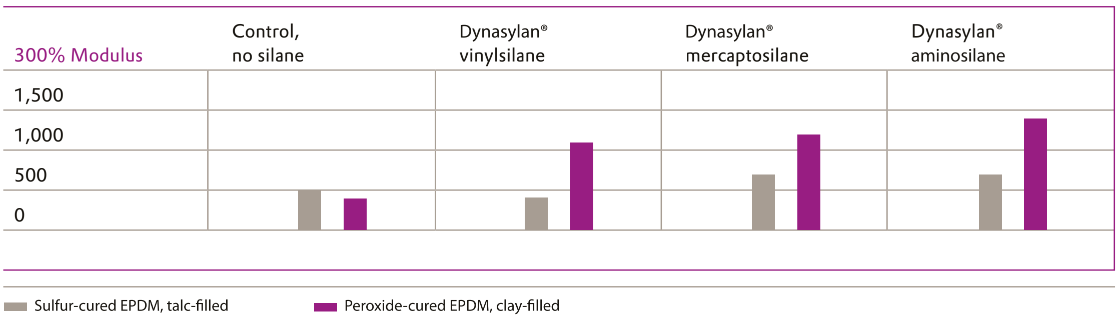
* Dynasylan® HYDROSIL products for fillers/pigments treatment (prior adding to the polymer)

An Illustration: Vulcanized EPDM Systems

The importance of selecting the right coupling agent with an organo-functionality complementary to the curing or polymer system is illustrated below. Comparative modulus values are shown for two filled EPDM (ethylene propylene diene monomer rubber) systems cured with sulfur and peroxide, respectively. In the formulation, one part per hundred parts of resin (phr) of each silane indicated was introduced during compounding of 100 phr filler in a two-roll mill, and the composite properties were determined by standard (DIN 53504) methods.

As for the sulfur-cured system, the primary amino-functional silane and the mercapto-functional silane are able to participate in the cure mechanism to a far greater extent than the vinylsilane, as shown by the higher modulus values. In the peroxide-cured system, all silanes provide significant improvements in modulus, but to different degrees – depending on their relative reactivity.

Modulus of sulfur-and peroxide-cured EPDM filled compounds with different silanes



Surface Modification in Detail

The major disadvantage of ATH is the high loading required for flame retardancy. Such high levels result in severely compromised melt processability and poor physical properties. Silane-bound surface treatments surmount these problems by increasing the filler-matrix adhesion and reducing the surface energy of the filler.

Reducing high levels of by-product, measured as VOC (Volatile Organic Compound), is a key challenge for future development.

At the same time, no mechanical or other properties may be compromised. Multifunctional Silane SystemsTM with vinyl-functionality of the Dynasylan® brand make it possible to reduce VOC without losing other properties and without changing the formulation.

Viscosity reduction is always a big issue, no matter whether we talk about highly filled composite systems or hard-to-disperse inorganic systems. With Dynasylan® 4148, it is even possible to achieve self-dispersing systems.

A typical formulation for thermoplastic HFFR cables (Halogen-Free Flame Retardant)

Base polymer (PE, EVA or a blend thereof)	100	phr
ATH (aluminum hydroxide) or MDH (magnesium hydroxide)	150–200	phr
Dynasylan® (amino- or vinylsilane)	1.5–2.5	phr
Stabilizers	1.0	phr
In the case of vinyl-based silanes: peroxide	0.01–0.05	phr

The basic formulation contained 160 phr of ATH, 1 phr stabilizer, and variable amounts of monomeric and oligomeric silanes, and peroxide. A co-rotating twin screw extruder was used to produce sheets for the tests. Silane content is based on filler, the silane was pre-blended with EVA, dicumyl peroxide (DCP), and phenolic stabilizers were used. A comparison to a formulation without silane is not included since it leads to scorch.

Flame-Retardant Cable Formulation

Hydrated fillers such as ATH achieve their flame retardancy by decomposing endothermically, with the release of water close to the temperature at which the polymers themselves decompose. They do not have the smoke and corrosive gas problems associated with other types of flame retardants. For a high-performing HFFR compound with very high ATH loadings of 60 to 65 wt. %, the ATH particle size and shape have to be carefully controlled. Experience suggests that large and thick particles of ATH with a low surface area are required for effective flame retardancy. When Multifunctional Silane SystemsTM with vinyl-functionality are used in HFFR materials, a small amount of peroxide is required to obtain good coupling.

Lower VOC

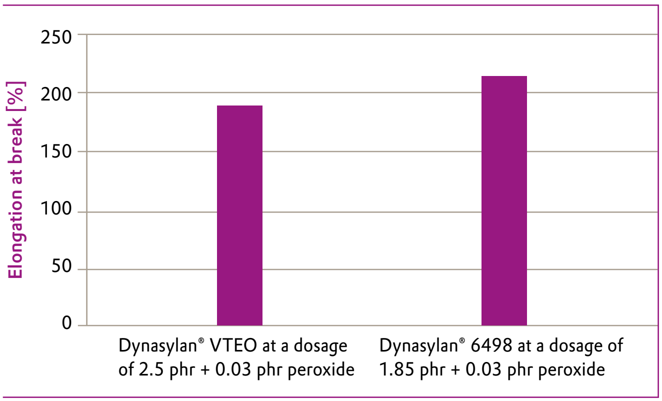
Oligomeric vinyl silanes will release a significantly reduced quantity of alcohol (and hence lower VOC emissions) upon reaction with moisture. Correct use of Dynasylan® oligomeric vinyl silanes may also reduce the compound viscosity and produce a smooth, defect-free surface.

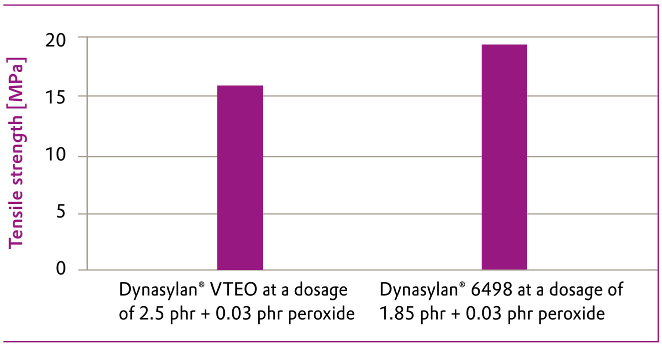
Mechanical properties

For oligomeric vinyl silanes, the absence of peroxide results in poor tensile strength. In the presence of peroxide, however, the overall picture changes dramatically. As the ATH couples to the EVA, tensile strength increases and water pick-up is reduced, both through increasing the crosslink density and also by rendering the compound hydrophobic. Elongation at break is not significantly affected by the presence of peroxide. Oligomeric vinylsilanes perform better than monomeric vinyl silanes, even at a lower concentration of 1.6 phr.

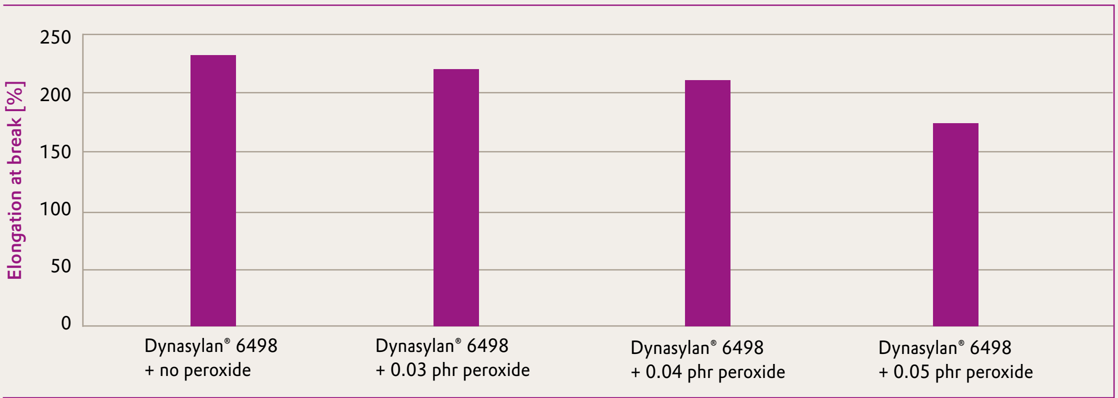
At these low silane levels, the vinyl silane or peroxide ratio has to be monitored carefully. At a silane concentration of 1.6 phr, the peroxide concentration should not exceed 0.04 phr because of the risk of scorching.

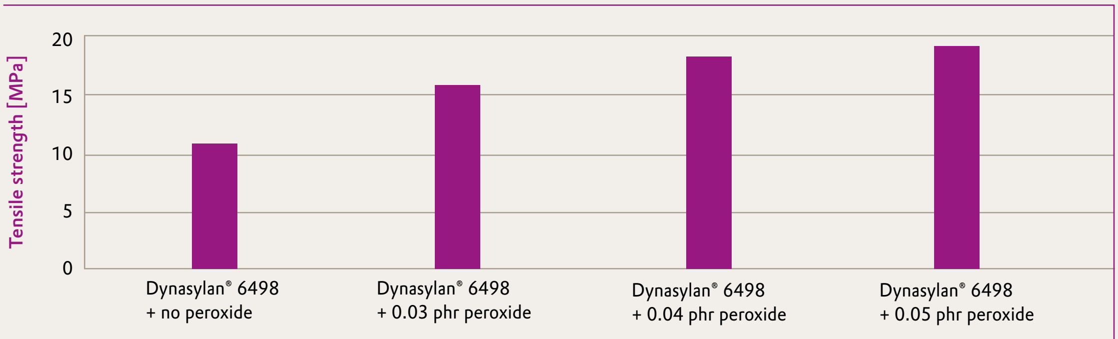
Oligomers outperform monomers in mechanical properties





Mechanical properties – Influence of peroxide dosage





Dynasylan® 9896 Improves Compatibility

The largest market for mineral fillers is the mineral-filled plastics market. For this type of application, the virgin, untreated mineral has to be surface-modified in order to be compatible with the polymer matrix.

For some applications, surface modifiers are used that do not bond to the mineral surface and therefore exhibit disadvantages in the final application. For example, silicone-oil-modified minerals in a plastic compound do not allow the finished good, for example, a plastic bag, to be printed on. Dynasylan® silanes are thus used in high-end and standard applications to improve process conditions and product properties.

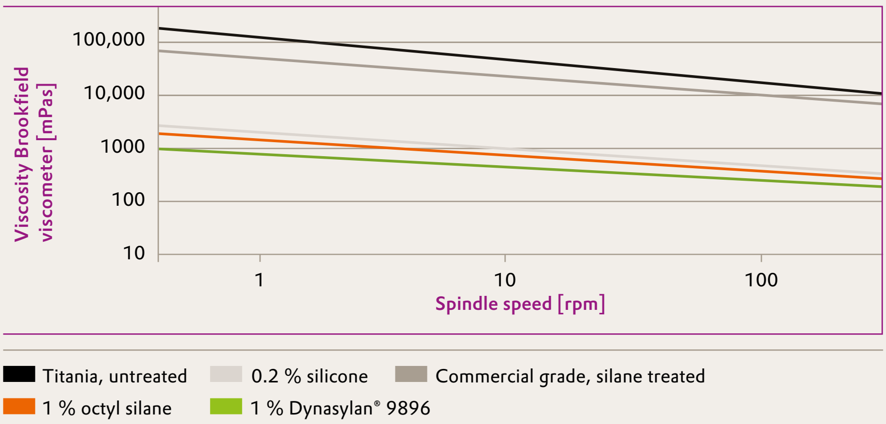
Equally as important as performance is an in-depth understanding of their environmental impact. Our Dynasylan® 9896 provides the ideal combination of low VOC and hydrophobic treatment of minerals for unpolar plastic applications, for example, PVC and polyolefins.

To prove the concept, we examined the viscosity of paraffin oil dispersions with untreated and treated titania. Treatment with 1 % Dynasylan® 9896 reduces viscosity best.

The relevance of this test system towards practical conditions is:

- Higher filler loadings
- Improved processability
- Less VOC, VOC < 100g/l

Viscosity of paraffin oil filled with 27 wt.-% of treated and untreated titania respectively



Multifunctional Silane Systems™ – the Next Generation Coupling Agents

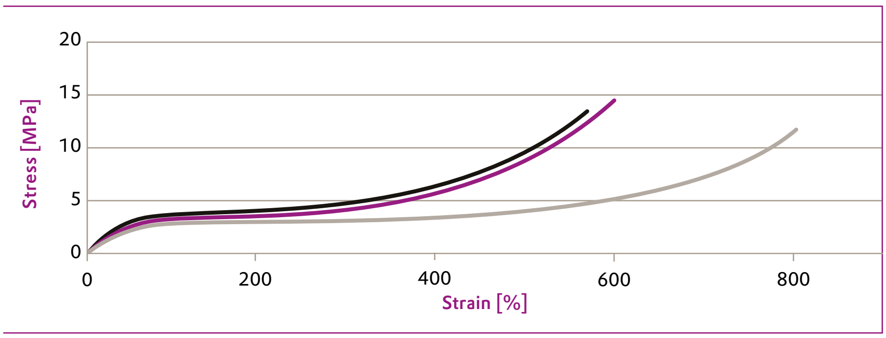
Besides strong reinforcement capabilities, the requirements on advanced silane coupling agents also cover environmental aspects and cost/performance issues. The focus for new vinyl silanes has to be on the silicon functional part responsible for the undesired emission of VOCs.

Through oligomerization, a reduction of 57% of the potential emission of VOCs is obtained with Dynasylan® 6498, compared to Dynasylan® VTEO, the respective monomeric vinyl silane.

Fewer ethoxy groups per vinyl unit in Dynasylan® 6498 also result in a reduced molecular weight per vinyl unit. Thus, for reaching the same level of reinforcement, a lower amount of Dynasylan® 6498 is necessary, compared to monomeric vinyl silanes like Dynasylan® VTEO or Dynasylan® VTMOEO.

The graph shows the resulting stress-strain curves for EPM compounds with an equimolar amount of Dynasylan® 6498 (1.34 phr) and Dynasylan® VTMOEO (2.94 phr) (equimolar related to vinyl units). As a reference, a stress-strain curve of a compound without any silane is also given. The calculation for the silane dosage is based on the differences in molecular weight.

Stress-strain curves of different vinyl silanes in an EPM-formulation



2.94 phr Dynasylan® VTMOEO · 1.34 phr Dynasylan® 6498 · No silane

An EPM compound containing 1 phr Dynasylan® VTEO was the basis for similar compounds containing equimolar amounts of vinyl units Dynasylan® 6498 and Dynasylan® VTMOEO.

Mechanical properties of EPM compounds filled with 50 phr silica

	Units	No Silane	Dynasylan® 6498	Dynasylan® VTMOEO
Dosage	phr	–	0.67	1.17
M.Scorch t5	min	22.88	16.91	16.88
ML (1+4) at 100 °C –	ME	120	111	113
Shore A hardness	SH	63	65	64
Tear resistance	N/mm	40	36	33
DIN Abrasion	mm^3	127	84	84
Comp. set 22 h at 70 °C	%	29.9	21.5	20.7
Comp. set 22 h at 100 °C	%	42.7	24.6	24.7
Tensile strength	MPa	12.7	14.1	13.5
Modulus 100 %	MPa	1.2	1.6	1.6
Modulus 200 %	MPa	1.8	2.7	2.7
Modulus 300 %	MPa	2.6	4.3	4.5
Elongation at break	%	795	605	570

Dynasylan® 6498 shows the same excellent properties as Dynasylan® VTMOEO. Using Dynasylan® 6498 even allows lower dosage, but nevertheless achieves the same level of reinforcement. If we compare Dynasylan® 6498 with Dynasylan® VTMOEO, a silane weight reduction of 54 % is possible without compromising properties.

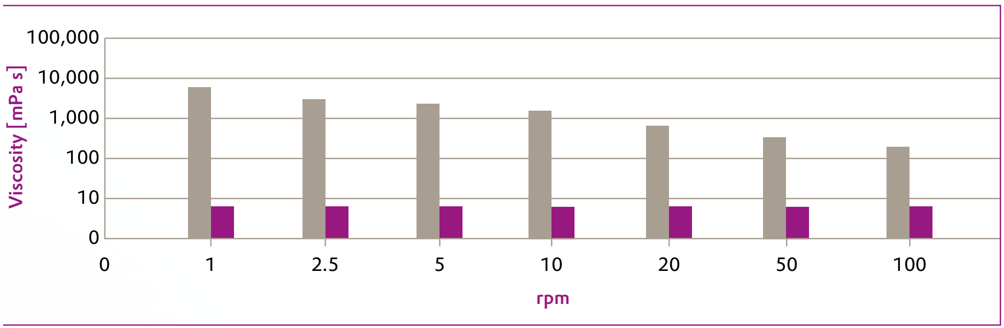
Furthermore, hazardous methoxyethanol emissions from Dynasylan® VTMOEO can be avoided. Compared to triethoxy silanes like Dynasylan® VTEO, ethanol emissions can be reduced with Dynasylan® 6498 by approx. 60 %. Thus, the vinylsilane Dynasylan® 6498 is an economical and ecological solution that fulfills the requirements of advanced silane coupling agents.

Dynasylan® 4148: A Hydrophilic Dispersion Aid Agent

When composites are produced at a high volume, it is critical that viscosity is reduced for easier processing. Highly filled composite systems are possible only when adhesion promoters are used. Combined properties of adhesion promotion, chemical bonding to the inorganic substrate, and viscosity reduction that can be achieved by using Dynasylan® 4148 in highly filled systems.

By using this polar, non-reactive, and neutral silane, which does not provide chemical reactivity, mineral surfaces can be modified without losing their hydrophilic nature. Excellent wetting properties are achieved, and consequently customized surface energy can be introduced to inorganic substrate surfaces. Particle dispersibility is improved, which leads to optimized mechanical performance of composites.

Dynamic viscosity of 72.2 wt% TiO_2 in water



Treated with 1% Dynasylan® 4148
Untreated

Untreated TiO_2 compared to TiO_2 treated with 1% Dynasylan® 4148: the dynamic viscosity drops significantly in the case of the silane.

As Dynasylan® 4148 does not provide chemical reactivity beyond the silicon functional group, this product can be used in combination with all other products of the Dynasylan® product range. Even self-dispersability can be achieved, as shown in the picture on the next page.

Creating Self-Dispersing Pigments

Red iron oxide treated with Dynasylan® 4148 (left) and untreated (right) after 10 s in water

Self-dispersed red iron oxide treated with Dynasylan® 4148 (left) and untreated (right) after 60 s in water

Self-dispersed red iron oxide treated with Dynasylan® 4148 (left) and untreated (right) after 20 s in water

Product Overview

Product name	Discription and use	Coupling/Compatibilizing/Crosslinking								Properties		
		PE	EVA/PE	PP	Rubber	Acrylics	Epoxy	Unsaturated polyester	Others*	Flash point, degrees	% residual moisture required for hydrolysis at 1 wt. % silane loading based on filler	Evolved VOC (alcohol) per kg of fully hydrolyzed silane
Aminosilanes												
Dynasylan® AMEO	Coupling agent for polar compounds		●	●						93 °C (199 °F)	0.25	624 g ethanol/kg
Dynasylan® SIVO 210	High-performance Multifunctional Silane Systems™ for polar compounds		●	●						> 100 °C (> 212 °F)	0.25	630 g ethanol/kg
Dynasylan® HYDROSIL 1151	Waterborne, VOC-free high-performance Multifunctional Silane System™ for polar compounds		●	●					●	80 °C (176 °F)	0	No VOC release only water
Dynasylan® HYDROSIL 2775	Waterborne, VOC-free high-performance Multifunctional Silane System™ for polar compounds		●	●					●	> 93 °C (> 199 °F)	0	No VOC release only water
Dynasylan® SIVO 214	High-performance Multifunctional Silane Systems™ for polar compounds		●	●						> 90 °C (194 °F)	0.25	630 g ethanol/kg
Dynasylan® 1189	High-performance silane for polar compounds		●	●						110 °C (230 °F)	0.20	408 g methanol/kg
Vinylsilanes												
Dynasylan® VTMO	Crosslinking agent	●	●							25 °C (77 °F)	0.37	649 g methanol/kg
Dynasylan® VTEO	Crosslinking agent	●	●							38 °C (100 °F)	0.28	726 g ethanol/kg
Dynasylan® HYDROSIL 2907	Waterborne, VOC-free high-performance Multifunctional Silane System™ for polar compounds	●	●		●				●	> 80 °C (> 176 °F)	0	No VOC release only water
Dynasylan® VTMOEO	Coupling agent	●	●		●					115 °C (239 °F)	0.20	814 g 2-methoxy-ethanol/kg
Dynasylan® 6598	High-performance Multifunctional Silane Systems™ for non-polar compounds	●	●		●					≥ 70 °C (≥ 158 °F)	0.18	465 g ethanol/kg
Dynasylan® 6498	High-performance Multifunctional Silane Systems™ for non-polar compounds	●	●		●					≥ 75 °C (≥ 167 °F)	0.16	480 g ethanol/kg
Dynasylan® 6490	High-performance Multifunctional Silane Systems™ for non-polar compounds	●	●		●					87° C (188 °F)	0.23	400 g methanol/kg

Others* = Fillers/pigments treatment for Dynasylan® HYDROSIL 1151, 2775, 2907

Product Overview

Product name	Discription and Use	Coupling/Compatibilizing /Dispersing: PE	EVA/PE	PP	Rubber	Acrylics	Epoxy	Unsaturated polyester	Others	Properties: Flash point, degrees	% residual moisture required for hydrolysis at 1 wt. % silane loading based on filler	Evolved VOC (alcohol) per kg of fully hydrolyzed silane
Alkylsilanes												
Dynasylan® 9896	Hydrophobizing agent							●	●	> 63 °C (> 145 °F)	0.07	ca. 100 g ethanol/kg
Dynasylan® OCTEO	Hydrophobizing agent								●	> 93 °C (> 199 °F)	0.20	500 g ethanol/kg
Dynasylan® IBTEO	Hydrophobizing agent								●	63 °C (145 °F)	0.25	627 g ethanol/kg
Aminoalkylsilanes												
Dynasylan® HYDROSIL 2776	Waterborne, VOC-free Coupling and compatibilizing agent							●	●*	> 100 °C (> 212 °F)	0	No VOC release only water
Dynasylan® HYDROSIL 2909	Waterborne, VOC-free Coupling and compatibilizing agent							●	●*	> 95 °C (> 203 °F)	0	No VOC release only water
Phenylsilanes												
Dynasylan® 9165	High-performance silane for high temperature polymers								●	29 °C (84 °F)	0.27	485 g ethanol/kg
Dynasylan® 9265	High-performance silane for high temperature polymers								●	121 °C (250 °F)	0.23	575 g ethanol/kg
Fluoroalkylsilanes												
Dynasylan® F 8261	High-performance silane for fluorinated polymers								●	85 °C (185 °F)	0.11	270 g ethanol/kg
Dynasylan® HYDROSIL F8815	Waterborne, VOC-free hydrophobation/oleophobation agent								●*	> 90 °C (> 194 °F)	0	No VOC release only water release
Other Functional Silanes												
Dynasylan® MEMO	Coupling agent for unsaturated compounds				●	●	●	●	●	110 °C (230 °F)	0.22	387 g methanol/kg
Dynasylan® 4148	High-performance silane for hydrophilic applications				●	●		●	●	> 95 °C (> 203 °F)	0.10	185 g methanol/kg
Dynasylan® HYDROSIL 2926	Waterborne, VOC-free high-performance Multifunctional Silane System™ for coupling								●*	> 98 °C (> 208 °F)	0	No VOC release only water release
Dynasylan® GLYMO	Coupling agent for polar compounds				●	●	●	●		122 °C (252 °F)	0.23	407 g methanol/kg

* The Dynasylan® HYDROSIL products for fillers/pigments treatment

Dynasylan® on the Internet

Information, addresses, and contacts

The website **www.dynasylan.com** offers a well-structured platform with information on products, methods, and chemical processes. A solution-finder provides informative brochures and presentations for downloading, in addition to product information and safety data sheets.

The database containing details of Evonik contacts and dealers worldwide gives convenient access to important contact data at any time.

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