Dynasylan®
in Filled Plastic Compounds
Today, most plastics are filled systems in which a mineral filler has been incorporated into the polymer matrix. The inclusion of such mineral fillers offers a number of advantages for the functionality of the final product.

For instance, flame retardants reduce flammability and smoke in fires. Furthermore, mechanical properties can be enhanced. In addition, using Dynasylan® treated fillers improves processing, for example, rheology, and reduces the cost of the final product.

Such improvements in properties can be achieved only when the filler and the polymer have excellent compatibility and adhesion. This is not an easy task, as organic and inorganic substances do not allow for optimal adhesion under normal circumstances.

Dynasylan® silanes are an ideal additive for producing filled plastic compounds. They are available for nearly any kind of polymer.
Typical fillers in plastics

- Aluminum trihydroxide
- Magnesium dihydroxide
- China clay
- Glass fibers
- Glass beads
- Quartz flour, silica, sand
- Cristobalite
- Wollastonite
- Mica
- Corundum
- Talc
- Iron oxides
- Titanium oxides

Applications

- HFFR cable insulation
- Rubber cables
- Glass fiber-reinforced composites
- Artificial stone
- Polymer concrete
- Foundry resins
Dynasylan® significantly reduces water uptake

Silanes improve the hydrophobicity of filled plastics. Through the use of silanes, the absorption of water by the polymer is significantly reduced. Positive effects are, for example, an improvement of the electrical properties of rubber power cables. The following diagram shows the positive effect of Multifunctional Silane Systems™ on the dissipation factor of filled rubber cables, especially after exposure to water.

**Silanes significantly reduce the water uptake in filled plastic**

![Diagram showing untreated and hydrophobized samples](image)

- Polymer matrix
- Inorganic filler
- Water molecules
- Silane

**Electrical properties improve significantly with Dynasylan® 6598**

![Graph comparing electrical properties](image)

- Dissipation factor (tan delta 10^{-3})
- Competing product
- Dynasylan® 6498
- Dynasylan® 6598

- Silane
- 16 h, 23°C (73°F), 60 % rel. humidity
The dispersion of fillers in polymers is a significant technological challenge. Reason behind is the different polarity between the inorganic fillers and the organic polymer matrices. Silanes can act as excellent compatibilizers because of their dual character – the combination of organic and inorganic groups within one molecule. Some significantly improved characteristics:

- Reduced viscosity
- Improved processing
- Increased output
- Reduced agglomeration
- Higher filler loading
- Reduced total cost

### Melt-flow ratio depends on the type of silane used

<table>
<thead>
<tr>
<th>Melt-flow ratio [g/10 min]</th>
<th>w/o silane</th>
<th>Dynasylan® SIVO 214</th>
<th>Dynasylan® 1189</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

### Silanes improve dispersion of fillers in polymer matrices

- **Untreated**
- **Treated**

- Polymer matrix
- Inorganic filler
- Silane

Silanes improve dispersion of fillers in polymer matrices.
Mechanical properties can be improved by chemically coupling the polymer to the filler

An important characteristic of silanes is that they allow the coupling of inorganic mineral fillers and organic polymers through a chemical bond. As a consequence of the coupling, the mechanical properties of the filled compounds are significantly improved. Examples include the use of silane-treated glass fibers in polypropylene, quartz in unsaturated polyester, and aluminum trihydroxide in ethyl vinyl acetate.

**Dynasylan® couples fillers and polymers**

**Dynasylan® binds the resin to the filler**

Scanning electron microscope (SEM) images of the broken edge of a quartz-filled unsaturated polyester. Silane coupling improves the adhesion of the filler to the polymer. The gap between the filler and the polymer is eliminated.

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

The mechanical properties of magnesium hydroxide-filled polypropylene (PP) compound, with additional maleic anhydride as a coupling agent.
The organofunctional Y-group of the silane links with the polymer. This group must be chosen to ensure maximum compatibility with the resin. A first possibility is to choose a silane that is compatible with the polymer. This ensures improved dispersion. For improved mechanical properties, a reaction needs to take place between the Y-group of the silane and the polymer.

The silane must also react with the filler. There are two steps to this reaction: first, hydrolysis of the alkoxy group, and then reaction of the resulting silanol with the surface hydroxyl groups of the inorganic filler.

**How does it work?**

Coupling mechanism between filler and polymer

**Polymer**
- EVA
- EVA-polyolefin blends
- EPDM rubber
- EP rubber
- Polyolefins

**Interaction**
Interaction with polymer matrix by:
- Chemical reaction
- Hydrogen bonding
- Electrostatic attraction

**Filler**
- AlM (aluminum trihydroxide)
- MDH (magnesium dihydroxide)
- Calcined clay
- Calcined talc
- Ammonium polyphosphate
- Other char formers

Formation of chemical bonds
Bonding to the filler through:
- Hydrolysis
- Condensation
- Formation of chemical bonds
Halogen-free flame retardant cable compounds

The use of silanes in filled polypropylene HFFR compounds affords the same advantages as in other HFFR compounds:

- Increased loading levels
- Effective flame retardation
- Significantly reduced water uptake into the polymer
- Much improved electrical properties
- Improved processability of the highly filled polymers
- Increased throughput during cable production
- Improved mechanical properties

Special Multifunctional Silane Systems™ such as Dynasylan® SILFIN 70 and SILFIN 71 achieve a simultaneous crosslinking of the polyethylene and coupling between the filler and the resin.

### Positive impact of Dynasylan® on Melt-Flow Ratio (MFR)

**Melt-Flow Ratio (MFR)** is increased by a factor of at least four through use of silanes.

<table>
<thead>
<tr>
<th>Dynasylan®</th>
<th>Melt-flow ratio [g/10min] (21.6 kg @ 230°C/446°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>w/o Dynasylan®</td>
<td>25</td>
</tr>
<tr>
<td>1% Dynasylan® SIVO 214</td>
<td>20</td>
</tr>
<tr>
<td>1% Dynasylan® 1189</td>
<td>15</td>
</tr>
</tbody>
</table>

### Dynasylan® – Significant reduction of water-uptake

Water uptake is reduced by a factor of four through use of silanes.

<table>
<thead>
<tr>
<th>Dynasylan®</th>
<th>Water uptake [mg/cm²] (144h @ 70°C/158°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>w/o Dynasylan®</td>
<td>0.5</td>
</tr>
<tr>
<td>1% Dynasylan® SIVO 214</td>
<td>0.4</td>
</tr>
<tr>
<td>1% Dynasylan® 1189</td>
<td>0.2</td>
</tr>
</tbody>
</table>
For safety reasons, the use of low-flame and low-smoke cables is becoming more and more important. These cables are usually based on polymers, such as polyethylene and EVA, and are filled with mineral fillers that release water upon exposure to elevated temperatures. The result is a cable that, in the case of a fire, produces significantly less smoke, chars instead of melts, and thus dramatically reduces fire propagation. Common fillers are aluminum trihydroxide and magnesium dihydroxide. Which is the right silane to choose depends on the polymer matrix.

How to find a suitable Dynasylan® grade

The choice of Dynasylan® depends on the ratio of EVA to polyethylene in the polymer mix

<table>
<thead>
<tr>
<th>Vinyl acetate content in %</th>
<th>Dynasylan® 6490</th>
<th>Dynasylan® 6498</th>
<th>Dynasylan® SIVO 214</th>
<th>Dynasylan® SIVO 210</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vinyl acetate content in %
## Product Overview

<table>
<thead>
<tr>
<th>Product name</th>
<th>Description and use</th>
<th>Applications</th>
<th>Crosslinking</th>
<th>Coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Multifunctional Silane Systems™</strong></td>
<td></td>
<td>Cables</td>
<td>Pipes</td>
<td>Filled plastics compounds</td>
</tr>
<tr>
<td>Dynasylan® SILFIN 06</td>
<td>Standard product for cables</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 13</td>
<td>Standard product for cables</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 22</td>
<td>Standard product for cables</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 25</td>
<td>Multifunctional Silane System™, enables higher throughput</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 50</td>
<td>Multifunctional Silane System™ for pipes</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 53</td>
<td>Multifunctional Silane System™ for cables, LLDPE</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 63</td>
<td>Multifunctional Silane System™ for cables, ambient curing</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 70</td>
<td>High-performance Multifunctional Silane System™ for crosslinking of HFFR cables</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 71</td>
<td>High-performance Multifunctional Silane System™ for crosslinking of HFFR cables</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 75</td>
<td>High-performance Multifunctional Silane System™ for crosslinking of cables</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 80</td>
<td>All-in-one Multifunctional Silane System™ for cables</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SILFIN 100</td>
<td>DBTDL-free alternative to Dynasylan® SILFIN 06</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VPS SILFIN 201</td>
<td>Tin-free Multifunctional Silane System™ for crosslinking of cables</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VPS SILFIN 202</td>
<td>Tin-free Multifunctional Silane System™ for crosslinking of cables</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Aminosilanes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® AMEO</td>
<td>Coupling agent for polar compounds</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SIVO 214</td>
<td>High-performance Multifunctional Silane System™ for polar compounds</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® SIVO 210</td>
<td>High-performance Multifunctional Silane System™ for polar compounds</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® 1189</td>
<td>High-performance silane for polar compounds</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® HYDROSIL 1151</td>
<td>Waterborne, VOC-free high-performance Multifunctional Silane System™ for polar compounds</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® HYDROSIL 2775</td>
<td>Waterborne, VOC-free high-performance Multifunctional Silane System™ for polar compounds</td>
<td>•</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Product Overview

<table>
<thead>
<tr>
<th>Product name</th>
<th>Description and use</th>
<th>Applications</th>
<th>Crosslinking</th>
<th>Coupling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vinylsilanes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® VTMO</td>
<td>Vinysilane</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® VTEO</td>
<td>Vinysilane</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® HYDROSIL 2907</td>
<td>Waterborne, VOC-free high-performance Multi-functional Silane System™ for polar compounds</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® VTMSEO</td>
<td>Vinysilane</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® 6490</td>
<td>High-performance Multifunctional Silane System™ for non-polar compounds</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® 6498</td>
<td>High-performance Multifunctional Silane System™ for non-polar compounds</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® 6598</td>
<td>High-performance Multifunctional Silane System™ for non-polar compounds</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Alkylsilanes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® 9896</td>
<td>Hydrophobation agent</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® OCTEO</td>
<td>Hydrophobation agent</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® IBTEO</td>
<td>Hydrophobation agent</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® HYDROSIL 2776</td>
<td>Waterborne, VOC-free hydrophobation agent</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® HYDROSIL 2909</td>
<td>Waterborne, VOC-free hydrophobation agent</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phenylsilanes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® 9165</td>
<td>High-performance silane for high temperature polymers</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® 9265</td>
<td>High-performance silane for high temperature polymers</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fluorosilanes</strong></td>
<td></td>
<td></td>
<td>● ● ● ●</td>
<td></td>
</tr>
<tr>
<td>Dynasylan® F 8261</td>
<td>High-performance silane for fluorinated polymers</td>
<td>●</td>
<td>● ● ● ●</td>
<td></td>
</tr>
<tr>
<td>Dynasylan® HYDROSIL F8815</td>
<td>Waterborne, VOC-free hydrophobation agent</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other functional silanes</strong></td>
<td></td>
<td></td>
<td>● ● ● ●</td>
<td></td>
</tr>
<tr>
<td>Dynasylan® MEMO</td>
<td>Coupling agent for unsaturated compounds</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® GLYMO</td>
<td>Coupling agent for polar compounds</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® 4144</td>
<td>High-performance silane for hydrophilic applications</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® 4148</td>
<td>High-performance silane for hydrophilic applications</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynasylan® HYDROSIL 2926</td>
<td>Waterborne, VOC-free high-performance Multi-functional Silane System™ for hydrophobation and oleophobation</td>
<td>● ● ● ●</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This information and any recommendations, technical or otherwise, are presented in good faith and believed to be correct as of the date prepared. Recipients of this information and recommendations must make their own determination as to its suitability for their purposes. In no event shall Evonik assume liability for damages or losses of any kind or nature that result from the use of or reliance upon this information and recommendations. EVONIK EXPRESSLY DISCLAIMS ANY REPRESENTATIONS AND WARRANTIES OF ANY KIND, WHETHER EXPRESS OR IMPLIED, AS TO THE ACCURACY, COMPLETENESS, NON-INFRINGEMENT, MERCHANTABILITY AND/OR FITNESS FOR A PARTICULAR PURPOSE (EVEN IF EVONIK IS AWARE OF SUCH PURPOSE) WITH RESPECT TO ANY INFORMATION AND RECOMMENDATIONS PROVIDED. Reference to any trade names used by other companies is neither a recommendation nor an endorsement of the corresponding product, and does not imply that similar products could not be used. Evonik reserves the right to make any changes to the information and/or recommendations at any time, without prior or subsequent notice.

Dynasylan® and SIVO® are registered trademarks of Evonik Industries or one of its subsidiaries.