Organomodified Siloxanes for High Filled HFFR Cable Compounds
What are Organomodified Siloxanes (OMS)?

- Organomodified siloxanes (OMS) are performance additives to improve surface and bulk properties.

- They overcome the disadvantages of silicone oil by introduction of organic groups on the silicone backbone.

- They generate a permanent functionalization of thermoplastic polymers.

- Depending on the modification, OMS can orientate to the surface (also internal surfaces) and/or to the bulk phase of the polymer.

- OMS enhances processing, surface and material properties.
Different Flame Retardants in Thermoplastics and Mode of Action

<table>
<thead>
<tr>
<th>Flame Retardant</th>
<th>Mode of Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony trioxide + brominated substances</td>
<td>Formation of radicals which block the flame reaction</td>
</tr>
<tr>
<td>Organic or inorganic phosphorous substances</td>
<td>Flame reaction is stopped by formation of polyphosphoric acid</td>
</tr>
<tr>
<td>Metal hydroxides or carbonates</td>
<td>Formation of not flammable gas ➞ water or carbon dioxide</td>
</tr>
<tr>
<td>Nitrogen containing substances</td>
<td>Formation of not flammable gas ➞ nitrogen oxides</td>
</tr>
<tr>
<td>Plastics with inherent flame retardant characteristics</td>
<td>Polysulfone. Polyether sulfones. Polyaryl ether ketones</td>
</tr>
</tbody>
</table>
Mechanism of HFFR Fillers
Thermal Dekomposition of MDH or ATH

Due to thermal decomposition MDH and ATH will form inorganic oxides and water. The higher decomposition temperature of MDH eases the processing.

Source: Functional Fillers for Plastics. Marino Xanthos
Recommended Products for HFFR Compounds

**TEGOMER® V-Si 4042**
- Liquid. solvent free organomodified siloxane
- Reactive OMS therefore suitable for peroxide curing systems
- Designed for high filled thermoplastic HFFR cable compounds based on polyolefin. EVA. x-PP. x-PE as well as for EPDM
- Recommended Dosage: 0.5 % - 2.0 % on compound

**TEGOMER® FR 100**
- Solid organomodified siloxane compound
- Especially developed for HFFR Cable Compounder. which prefer using non liquid additives
- Suitable for polyolefin. EVA. x-PP. x-PE and EPDM
- Recommended Dosage: 1.0 % - 3.0 % on compound
**TEGOPREN® 5885**

- Liquid. solvent free organomodified siloxane
- Designed for high filled thermoplastic HFFR cable compounds
- Also recommended for nano clay containing compounds

![Diagram: Clay + OMS → OMS coated clay + Polymer → Exfoliated primary clay particles in polymer]

- Suitable for polyolefin. EVA. x-PP. x-PE and EPDM
- Recommended Dosage: 0.5 % - 2.0 % on compound

**TEGOPREN® 6875**

- Liquid organomodified siloxane
- Used as post treatment for fillers to create easy to disperse grades of HFFR fillers
- Used as an universal drawing oil for wire drawing and to reduce “peel off” forces in cable insulating materials. e.g. CPE. Rubber. PVC....
## Which Additive Meets which Type of Customer

<table>
<thead>
<tr>
<th><strong>HFFR Producer</strong></th>
<th><strong>HFFR Compounder</strong></th>
<th><strong>HFFR Cable Manufacture</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of inorganic Fillers for flame retardant application like ATH. AMH. MDH. nano Clays. Carbonates….</td>
<td>Production and development of compounds</td>
<td>Processing of cable extrusion and or wire drawing</td>
</tr>
<tr>
<td><strong>TEGOPREN® 6875</strong></td>
<td><strong>TEGOMER® V-Si 4042</strong></td>
<td><strong>TEGOPREN® 6875</strong></td>
</tr>
<tr>
<td><strong>TEGOPREN® 6875-45</strong></td>
<td><strong>TEGOMER® FR 100</strong></td>
<td><strong>TEGOMER® V-Si 4042</strong></td>
</tr>
<tr>
<td><strong>TEGOMER® 5885</strong></td>
<td><strong>TEGOMER® 5885</strong></td>
<td><strong>TEGOMER® FR 100</strong></td>
</tr>
</tbody>
</table>

- Used for the surface treatment
- Dispersing of filler with high loadings. Improvement of mechanical, surface and FR properties
- Processing aid and dispersant. Lubricant for wire drawing
Additive Technologies used in HFFR Cable Application

Silanes or maleinic acid anhydride grafted polymers are used to interact with hydroxy functional flame retardants.

Silicone oil is an external lubricant only.

OMS can interact with Polymers and FR. adjusted functionalisation is possible.
How to Use TEGOMER® in the Processing

I. During compounding with kneader or double screw extruders

1. **Fast Wetting**
   - Allows higher processing speed
   - Allows higher loadings

2. **Enhanced Grinding**
   - Perfect distribution of HFFR fillers results in enhanced FR classifications and mechanical properties

3. **Excellent Lubrification**
   - Results in excellent smooth surfaces
   - No die drol

II. During cable extrusion

Depending on the chosen TEGOMER® additive, they can easily charged into the main feeder or by direct injected into the kneader
Improvement of Processing Enables Higher Out Put

Example: EVA Compound with 65 % Mg(OH)₂

Extrusion head pressure [bar]

Torsional moment [A%]

1.0 % Additiv
2.0% Additiv

TEGOMER grades for HFFR compounds lower the amperage use and the extruder head pressure. They work as internal lubricant. give less abrasion and therefore reduced maintenance costs.
Influence of TEGOMER® on the MFI in HFFR/EVA Compounds

Example: EVA Compound with 65 % Mg(OH)₂

<table>
<thead>
<tr>
<th>MFI 190°C/10 kg [g/10 min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
</tr>
</tbody>
</table>

TEGOMER® works as a highly efficient dispersing aid and internal lubricant. Not only as an external lubricant as silicon oil. Therefore, it enhances the MFI of high filled HFFR compounds and optimizes the melt flow to receive excellent cable surfaces.
TEGOMER® V-Si 4042 for HFFR Compounds
Treated and Untreated Mg(OH)₂ in EVA

2% TEGOMER® V-Si 4042

TEGOMER® V-Si 4042 improves machine parameters such as extrusion head pressure and torsional moment significantly for a) untreated fillers and

b) even for silane treated grades
Influence of OMS Additives on the Melt Viscosity of HFFR/EVA Compounds

TEGOMER® grades allow significant lowering of the Mooney viscosity. TEGOMER® grades enable to use cheaper untreated filler grades. TEGOPREN® 5885 can be used as well and might create a higher gloss on the final cable surface.
Standard Measurement Devices for Flame Resistance

UL 94V

CC (Cone Calorimeter)
Source: Nabaltec/Germany

LOI (Lowes Oxygen Index)
Char Formation
65% MDH in EVA

Char Formation depends on the selection of the right organomodified siloxane
- TEGOMER® V-Si 4042 is preferred for compounding
- TEGOPREN® 5885 is very efficient for surface treatment
Cone Calorimetry
EVA 19, 65 wt.-% MDH

Without Additive
LOI: 38

+ 2% TEGOPREN®
5885 comp.
LOI: 45

+ 2 % TEGMER®
V-Si 4042 comp.
LOI 43

+ 1 % TEGOPREN®
5885 treat.
LOI: 42
Heat Release Rate
EVA 19, 65 wt.-%
Heat Release Rate
EVA 19, 65 wt.-%

HRR [kW/qm]

Time [s]

ATH without Additive
ATH + 2% TEGOMER® V-Si 4042 comp.
ATH + 2% TEGOPREN® 5885 comp.
Rate of Smoke Released
EVA 19, 65 wt.-%

- MDH without Additive
- MDH + 2% TEGOMER® V-Si 4042 comp.
- MDH + 2% TEGOPREN® 5885 comp.

RSR [m²/s m²]

Time [s]
Rate of Smoke Released
EVA 19, 65 wt.-%
Highest Flame Retardant Classification Due to Efficient Filler Dispersion

Compounds created by using 2% of TEGOMER® Grades result in better flame resistance and LOI.

<table>
<thead>
<tr>
<th>Material Classification according UL 94 V (Vertical Burning Test)</th>
<th>V-0</th>
<th>V-1</th>
<th>V-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion time for each specimen. 1. treatment</td>
<td>≤10s</td>
<td>≤30s</td>
<td>≤30s</td>
</tr>
<tr>
<td>Flaming and glowing combustion for each specimen (1. + 2. treatment)</td>
<td>≤30s</td>
<td>≤60s</td>
<td>≤60s</td>
</tr>
<tr>
<td>Total flaming combustion for all 5 specimens of any set</td>
<td>≤50s</td>
<td>≤250s</td>
<td>≤250s</td>
</tr>
<tr>
<td>Cotton ignited by flaming drips</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>
### Flame Retardancy UL94
#### EVA 19, 59-65 wt.-% ATH

<table>
<thead>
<tr>
<th>ATH content</th>
<th>without additive</th>
<th>2% V-Si 4042 compounding</th>
<th>1% V-Si 4042 treatment</th>
<th>2% TP 6875 compounding</th>
<th>1% TP 6875 treatment</th>
<th>2% TP 5885 compounding</th>
<th>1% TP 5885 treatment</th>
<th>0.5% TP 5885 compounding</th>
</tr>
</thead>
<tbody>
<tr>
<td>59%</td>
<td>failed</td>
<td>failed</td>
<td>failed</td>
<td>V-1</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>61%</td>
<td>failed</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
</tr>
<tr>
<td>63%</td>
<td>V-1</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
</tr>
<tr>
<td>65%</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
</tr>
</tbody>
</table>

A loading of 65% ATH is needed to receive the V0 classification. By using organomodified Siloxanes as processing and dispersing additives, the loading could be reduced down to 61%.

? = not carried out so far
Influence of OMS Additives on the Dispersion of FR

The higher the loading with inorganic FR the more easy is insufficient dispersion of the FR even visible at the exterior roughness of the extruded material.

The dispersion of FR in the inner bulk phase is influencing mechanical properties.

E-Modulus has to be balanced with elongation and an average tensile strength is considered as minimum requirement.

- **TEGOMER® V-Si 4042** can be used in the compounding with up to 2% addition for MDH and ATH whereas **TEGOPREN® 5885** needs lower addition levels.

- **TEGOPREN® 5885** as well as **TEGOPREN® 6875** are suitable substances for surface treatment of MDH and ATH whereas **TEGOMER® V-Si 4042** is not suitable.
Benefits of Organomodified Siloxanes in HFFR Compounds

- They act as internal lubricants and dispersant to reduce abrasion and avoiding die drool
- Higher output by optimized melt rheology
- Less pressure built-up and amperage draw during extrusion
- Less maintenance costs
- Better dispersion of fillers resulting in very good flame resistant classification
- Smooth cable surfaces with excellent printability
Organomodified Siloxanes - Outstanding Properties in Performance

<table>
<thead>
<tr>
<th></th>
<th>TEGOMER®</th>
<th>TEGOPREN®</th>
<th>Silicone oil masterbatches</th>
<th>Silanes</th>
<th>MAA grafted compatibilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cable Compounding</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throughput / Lubrification</td>
<td>+</td>
<td>+</td>
<td>O</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Melt flow / MFI</td>
<td>+</td>
<td>+</td>
<td>O</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Filler distribution</td>
<td>+</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Filler loading</td>
<td>+</td>
<td>+</td>
<td>O</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Cable Extrusion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flame retardancy classification</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Surface smoothness</td>
<td>+</td>
<td>+</td>
<td>O</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Migration</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Printability</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Low Oxygen Index (LOI)</td>
<td>+</td>
<td>O</td>
<td>+</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>Die drol</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Gloss</td>
<td>+</td>
<td>O</td>
<td>O</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Mech. properties</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

+ = good, O = moderate, - = bad