Combination of Organic and Inorganic Materials

Silane Coupling Agents

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Users are solely responsible for determining the suitability of products for their intended use.

For detailed information regarding safety, please refer to the Safety Data Sheet (SDS).

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Users must never use the silicone products described herein for the purpose of implantation into the human body and/or injection into humans.

Users are solely responsible for exporting or importing the silicone products described herein, and complying with all applicable laws, regulations, and rules relating to the use of such products. Shin-Etsu recommends checking each pertinent country’s laws, regulations, and rules in advance, when exporting or importing, and before using the products.

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https://www.shinetsusilicone-global.com/guide/

Our diverse array of materials enable users to enhance the quality and functionality of their products, and expand the possibilities for new product development.

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◆What are Silane Coupling Agents?
Silane coupling agents are compounds whose molecules contain functional groups that bond with both organic and inorganic materials. A silane coupling agent acts as a sort of intermediary which bonds organic materials to inorganic materials. It is this characteristic that makes silane coupling agents useful for improving the mechanical strength of composite materials, for improving adhesion, and for resin modification and surface modification.

◆Features of Shin-Etsu Silane Coupling Agents
In addition to general-purpose trimethoxy types, Shin-Etsu offers a wide range of dialkoxy and ethoxy type products. We are also developing products with an emphasis on the following:

1. High Functionality
   - Improved adhesion
   - Hydrophobicity
   - Flexibility
   - Compatibility
   - Anti-rust property

2. Eco-friendly
   - Reduced VOC
   - Low Volatile Content

3. Usability
   - One-component products can be used in place of two-component products
   - Eliminate the step of hydrolysis
   - Excellent storage stability

4. Reactive groups that form chemical bonds with organic materials such as synthetic resins
   - Vinyl groups
   - Epoxy groups
   - Amino groups
   - Methacryloxy groups
   - Mercapto groups, other

5. Reaction mechanism on organic materials
   - Improving wettability
   - Improving compatibility
   - Forming chemical bonds with resins

6. Reactive groups that form chemical bonds with inorganic materials including glass, metals, inorganic fillers
   - Methoxy groups
   - Ethoxy groups, other

7. Features of Hydrolyzable Silyl Groups
   - Methoxy type: Hydrolyzes rapidly. Ethoxy type: Hydrolyzes slowly, and compositions will be highly stable even after addition. This type is more eco-friendly, because the product of hydrolysis is ethanol.
   - Dialkoxy type: Good stability after hydrolysis. Condensation products form straight-chain structures.
   - Trialkoxy type: High reactivity with high crosslinking density. Strong bonding with inorganic materials.
Our diverse array of materials enable users to enhance the quality and functionality of their products, and expand the possibilities for new product development.

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Features of Silane Coupling Agents

Features of Silane Coupling Agents

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  - Vinyl groups
  - Epoxy groups
  - Amino groups
  - Methacryloxy groups
  - Mercapto groups, other
- Reaction mechanism on organic materials
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  - Improving compatibility
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- In addition to general-purpose trimethoxy types, Shin-Etsu offers a wide range of dialkoxy and ethoxy type products. We are also developing products with an emphasis on the following:
  - High functionality
  - Eco-friendly
  - Usability

High Functionality
- Improved adhesion
- Hydrophobicity
- Flexibility
- Compatibility
- Anti-rust property

Eco-friendly
- Reduced VOC
- Low Volatile Content

Usability
- One-component products can be used in place of two-component products
- Eliminate the step of hydrolysis
- Excellent storage stability
4 Types of Silane Coupling Agents Application

**Compound**
- **Model of Unifying Organic Resins and Fillers**
- **Untreated with Silane Coupling Agents**
  - The organic resin and filler do not fully combine, so properties do not improve as expected.
- **Treated with Silane Coupling Agents**
  - Organic resin and filler bond together, resulting in improved heat resistance, weatherability, moisture resistance, etc.

**Resulting Properties**
- Heat resistance
- Weatherability
- Water resistance
- Improved durability of resins

**Application Examples**
- Crosslinked polyethylene (Electrical wire covering)
- Phenolic resins, grinders, and moldings
- Artificial marble wall materials

**Model of Interface**

**Filler**
- **Model of Filler Surface Treatment**
  - **Application Examples**
    - Inorganic pigments
    - Talc
    - Aluminium hydroxide
    - Titanium oxide
    - Silica

  - Treating a filler material with a silane coupling agent allows the filler and resin to bond together.

**Resin Modification**

**Surface Treatment**

**Coating**
- **Model of Improved Adhesion**
  - **Application Examples**
    - Adhesives
    - Films
    - Paints & Inks
    - Resists
    - Hard coatings

**Inorganic Substrate**
- **Model of Surface Treatment of Inorganic Substrate**
  - **Application Examples**
    - Copper foil
    - Steel plate
    - Glass
    - Glass fiber
4 Types of Silane Coupling Agents Application
Silane Coupling Agents Usage

Adding into Compound

- **Integral blending method**
  - In this method, the silane coupling agent is added to the organic materials before the inorganic and organic materials are mixed.

- **Application Example of EMC (Epoxy Molding Compound)**
  - Epoxy & Curing agents
  - Fillers
  - Additives (i.e. wax)
  - Catalysts
  - Pigments
  - Silane coupling agents

  - **Mixing**
  - Kneading
  - Cooling
  - Grinding
  - Making tablet

  - **Resulting Properties**
    - Water resistance
    - Moisture resistance
    - Durability

Adding into Coating

- **Adding into Epoxy Paints** (Improving anticorrosion property)
  - Epoxy resin
  - Pigment
  - Filler
  - Solvent

  - Silane (i.e. KMB-403) adding
  - Stirring
  - Final product

  - **Resulting Property**
    - Anti-corrosion property
    - Improved adhesion with substrate

- **Application Example for Paints**
  - Use of silane coupling agents when producing acrylic resins (copolymerization)
  - Example: Using a silane coupling agent (KMB-503) to modify acrylic resins via radical polymerization. Improves adhesion to the substrate and moisture resistance.

  - **Reaction**
    - Silicone Modified Acrylic Emulsion
    - (Non-volatile content: about 50 wt%)

  - **Solution Type**
    - MMA**-**Styrene**-**acrylic acid

  - **Water Type**
    - KMB-503
    - Water
    - Polymerrization initiator-surfactant
    - 1-5 wt%

  - **Preparation**
    - Silane concentrate or hydrolyzed solution
    - Slan concentrate or hydrolyzed solution

Resulting Properties

- Adhesion
- Weatherability
- High cross-linking

Surface Treatment

- **Preparation Method of Hydrolyzed Liquid**
  - Adjust pH of aqueous solution (alcohol can be used in mix)
  - While stirring, gradually drop in silane coupling agent (0.1-3.0 wt%)
  - Stir until solution is clear (around 30-60 min)
  - Filter with a mesh filter to remove foreign matter if present.

  - **Treating the substrate**
    - Wash the substrate.
    - Treat with the hydrolyzed liquid (brush on, dips, etc).
    - Dry (at room temp. or by heating)

  - **Resulting Property**
    - Adhesion with Resins
    - (Mechanical strength of molding)

- **Glass Cloth Application Example**
  - Production process of glass fiber
  - Heating
  - Drying

  - Hydrolyzed water solution of silane coupling agent
  - Production of glass fiber treated with silane coupling agents was completed.

- **Primer Treatment**
  - **Surface Treatment with Dry Method**
    - Features:
      - Productivity is high.
      - Clumping may occur in some cases.

    - **Features:**
      - Slan concentrate or hydrolyzed solution
      - Slane concentrate or hydrolyzed solution

    - **Typical amounts for treatment**
      - Slane: 0.5-1.0 wt% (vs. filler weight)

  - **Preparation**
    - Mixture
    - Preparation
    - Drying
    - Post mixing

  - **Resulting Properties**
    - Dispersibility
    - Adhesion with Resins
Silane Coupling Agents Usage

Adding into Compound

- **Integral blending method**: In this method, the silane-coupling agent is added to the organic materials before the inorganic and organic materials are mixed.

- **Application Example of EMC (Epoxy Molding Compound)**
  - High density polyethylene
  - Peroxide
  - KBM-1003

- **Application Example of Cross-linked Polyethylene** (Slane Grafted Polyethylene)
  - Heating & Mixing
  - Silane grafted-polyethylene
  - Curing agent masterbatch

- **Resulting Properties**
  - Water resistance
  - Moisture resistance
  - Durability

Adding into Coating

- **Adding into Epoxy Paints** (Improving anticorrosion property)
  - MMA**:WGMA** etc.
  - KBM-503
  - Water
  - Polymerization initiator-surfactant

- **Application Example for Paints**
  - Use of silane coupling agents when producing acrylic resins (copolymerization)

- **Model of Resin Modification**
  - Acrylic resin
  - Substrate

- **Resulting Properties**
  - Adhesion
  - Weatherability
  - High cross-linking

Resin Modification

Surface Treatment

- **Surface Treatment with Wet Method**
  - Features:
    - Enables even treatment
    - Productivity is low.
    - Silane-containing waste fluid must be disposed of.

- **Surface Treatment with Dry Method**
  - Features:
    - Productivity is high.
    - Clumping may occur in some cases.

Primer Treatment

- **Glass Cloth Application Example**
  - Production process of glass fiber
  - Hydrolyzed water solution of silane coupling agent
  - Heating
  - Drying

- **Resulting Property**
  - Adhesion with Resins (Mechanical strength of molding)
Reaction Mechanism of Silane Coupling Agents

- **Reaction Examples of Organic Functional Groups**
  - **Epoxy group**
    - HN-: Epoxide ring-opening reaction
    - HO-: Epoxide ring-opening reaction
    - HDO-: Epoxide ring-opening reaction
  - **Acryloxy group**
    - HN-: Dehydrochlorination reaction
    - HO-: Amidation reaction
    - HDO-: Epoxide ring-opening reaction
  - **Isocyanate group**
    - HN-: Ureidation reaction
    - HO-: Uretanization reaction
    - HDO-: Addition reaction
  - **Mercapto group**
    - DCN-: Thioethenation reaction
    - SH-: Sulfide bond formation

- **Organic Functional Groups and Compatible Resins**
  - **Resins**
    - Thermoplastic resins
    - Thermosetting resins
    - Elastomer-Rubber
  - **Functional groups**
    - Vinyl: ++ ++
    - Epoxy: ++ ++
    - Styrene: ++
    - Methacryloxy: ++ ++
    - Acryloxy: ++ ++
    - Amino: ++ ++
    - Ureide: ++
    - Mercapto: + + + + + +
    - Isocyanate: + + + + + +

- **Hydrolytic Properties of Alkoxy Groups**
  - Generally speaking, methoxy groups (OCMe₃) have higher reactivity than ethoxy groups (OC₂H₅). In acidic conditions, fewer alkoxy groups will mean a faster reaction, which means that dimethoxy types will hydrolyze fastest, followed in order by the trimethoxy, diethoxy and triethoxy types. By contrast, in basic conditions, the order goes from the trimethoxy to the dimethoxy, triethoxy and diethoxy types.

- **Types of Inorganic Materials and Reactivity of Silanol**
  - Alkoxy groups hydrolyze to form silanols, which hydrogen-bond to hydroxyls on the surface of inorganic substrates. Typically, Silane coupling agents react more easily with inorganic materials having larger numbers of active hydroxyl groups on their surfaces.
**Reaction Mechanism of Silane Coupling Agents**

**Reaction Examples of Organic Functional Groups**

<table>
<thead>
<tr>
<th>Functional group</th>
<th>Reacting group</th>
<th>Reaction product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy group</td>
<td>HN=</td>
<td>Epoxide ring-opening reaction</td>
</tr>
<tr>
<td></td>
<td>HO=</td>
<td>Epoxide ring-opening reaction</td>
</tr>
<tr>
<td></td>
<td>HDOCl-</td>
<td>Epoxide ring-opening reaction</td>
</tr>
<tr>
<td>Amino group</td>
<td>Cl-</td>
<td>Dehydrochlorination reaction</td>
</tr>
<tr>
<td></td>
<td>ClOC-</td>
<td>Amination reaction</td>
</tr>
<tr>
<td></td>
<td>ClCN-</td>
<td>Epoxide ring-opening reaction</td>
</tr>
<tr>
<td></td>
<td>HO-</td>
<td>Hydrogen bonding with hydrosil groups</td>
</tr>
<tr>
<td></td>
<td>HN-</td>
<td>Hydrogen bonding with siloxane groups</td>
</tr>
<tr>
<td></td>
<td>HDOCl-</td>
<td>Salt formed with chloride</td>
</tr>
<tr>
<td></td>
<td>HDOOCl-</td>
<td>Salt formed with carboxylic acid</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Epoxy group</th>
<th>Vinyl group</th>
<th>Reaction product</th>
</tr>
</thead>
<tbody>
<tr>
<td>HN=</td>
<td>R1</td>
<td>Grafting reaction</td>
</tr>
<tr>
<td>HO=</td>
<td>R1, R2</td>
<td>Copolymerization</td>
</tr>
<tr>
<td>HDOCl-</td>
<td>R1, R2</td>
<td>Cocondensation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amino group</th>
<th>Isocyanate group</th>
<th>Reaction product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl-</td>
<td>HN=</td>
<td>Ureidation reaction</td>
</tr>
<tr>
<td>HO=</td>
<td>HN=</td>
<td>Urethanation reaction</td>
</tr>
<tr>
<td>HDOCl-</td>
<td>HDOCl-</td>
<td>Addition reaction</td>
</tr>
<tr>
<td>HDOOCl-</td>
<td>DCN-</td>
<td>Thioetheration reaction</td>
</tr>
</tbody>
</table>

**Organic Functional Groups and Compatible Resins**

<table>
<thead>
<tr>
<th>Resin Type</th>
<th>Thermoplastic resins</th>
<th>Thermosetting resins</th>
<th>Elastomer-Rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>++ ++</td>
<td>++ ++</td>
<td>++ ++</td>
</tr>
<tr>
<td>Epoxy</td>
<td>++ ++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
</tr>
<tr>
<td>Styrene</td>
<td>++ ++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
</tr>
<tr>
<td>Methacryloxy</td>
<td>++ ++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
</tr>
<tr>
<td>Acryloxy</td>
<td>++ ++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
</tr>
<tr>
<td>Amino</td>
<td>++ ++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
</tr>
<tr>
<td>Ureide</td>
<td>++ ++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
</tr>
<tr>
<td>Mercapto</td>
<td>++ ++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
</tr>
<tr>
<td>Isocyanate</td>
<td>++ ++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
<td>++ ++ ++ ++ ++ ++ ++</td>
</tr>
</tbody>
</table>

*Very effective + Effective
*not all the functional groups are capable of coupling with the resins in question. This should be taken as a guide.

**Hydrolytic Properties of Alkoxy Groups**

Generally speaking, methoxy groups (OCMe3) have higher reactivity than ethoxy groups (OC2H5). In acidic conditions, fewer alkoxy groups will mean a faster reaction, which means that dimethoxy types will hydrolyze fastest, followed in order by the trimethoxy, diethoxy and triethoxy types. By contrast, in basic conditions, the order goes from the trimethoxy types to the dimethoxy, diethoxy and ethoxy types.

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**Reaction with Inorganic Materials**

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<tr>
<th>Silane number</th>
<th>Under acid condition</th>
<th>Under basic condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methoxy</td>
<td>R = Me or Et</td>
<td>R = Me or Et</td>
</tr>
<tr>
<td>Ethoxy</td>
<td>R = Et</td>
<td>R = Me or Et</td>
</tr>
<tr>
<td>Methylsilane</td>
<td>R = Me</td>
<td>R = Me or Et</td>
</tr>
<tr>
<td>Ethylsilane</td>
<td>R = Et</td>
<td>R = Me or Et</td>
</tr>
</tbody>
</table>

**[Test method]**

- pH adjusted water: 0.05% acetic acid + water room temperature
- Mix ratio: Each sample 10 wt part (Me 40 wt part / n-decane 10 wt part / pH adjusted water 20 wt part)
- pH adjusted water: 1% Ammonia + water room temperature
- Mix ratio: Each sample 10 wt part (Me 40 wt part / n-decane 10 wt part / pH adjusted water 20 wt part)

**Structure of methoxysilane**

- R = Me or Et

**Inorganic material**

- Glass
- Silica
- Alumina
- Talc
- Clay
- Alumina
- Titanium oxide
- Zinc oxide
- Iron oxide
- Graphite
- Carbon black
- Calcium carbonate

**Numbers of Hydroxyl Group on the Surface**

- Large
- Small

**Reactivity**

- High
- Low
## Main Products Lineup

### Product List

<table>
<thead>
<tr>
<th>Functional group</th>
<th>Product name</th>
<th>Chemical name</th>
<th>Structural formula</th>
<th>Flash point °C</th>
<th>Minimum covering area m²/g</th>
<th>Solubility parameter</th>
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</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>KBM-1003</td>
<td>Vinyltrimethoxysilane</td>
<td>(CH₃O)₂SiCH=CH₂</td>
<td>23</td>
<td>526</td>
<td>7.49</td>
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<td>Vinyltrimethoxysilane</td>
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<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>115</td>
<td>335</td>
<td>8.53</td>
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<td>3-Methacryloxypropyltrimethoxysilane</td>
<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>125</td>
<td>314</td>
<td>8.66</td>
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<td></td>
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<td>3-Methacryloxypropylmethyldiethoxysilane</td>
<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>136</td>
<td>300</td>
<td>8.54</td>
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<td>128</td>
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<td>126</td>
<td>333</td>
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<td>KBM-602</td>
<td>N-2-(Aminoethyl)-3-aminopropylmethyldimethoxysilane</td>
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<td>110</td>
<td>378</td>
<td>8.87</td>
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<td></td>
<td>KBM-603</td>
<td>N-2-(Aminoethyl)-3-aminopropyltrimethoxysilane</td>
<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>128</td>
<td>351</td>
<td>9</td>
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<td></td>
<td>KBM-903</td>
<td>3-Aminopropyltrimethoxysilane</td>
<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>88</td>
<td>435</td>
<td>8.56</td>
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<tr>
<td></td>
<td>KBE-903</td>
<td>3-Aminopropyltrimethoxysilane</td>
<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>98</td>
<td>352</td>
<td>8.56</td>
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<tr>
<td></td>
<td>KBE-9103P</td>
<td>3-Triethoxysilyl(1,3-dimethylbutylidene) propylamine</td>
<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>134</td>
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<td>8.41</td>
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<tr>
<td></td>
<td>KBM-573</td>
<td>N-Phenyly-3-aminopropyltrimethoxysilane</td>
<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>165</td>
<td>305</td>
<td>9.15</td>
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<tr>
<td></td>
<td>KBM-575</td>
<td>N-(Vinylbenzyl)-2-aminoethyl-3-aminopropyltrimethoxysilane hydrochloride</td>
<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>11</td>
<td>—</td>
<td>—</td>
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<td>Amino</td>
<td>KBE-585A</td>
<td>3-Ureidoxypropylsiloxysilane</td>
<td>(RO)₂SiCH₂OCH₂CH=CH₂</td>
<td>11</td>
<td>—</td>
<td>10.6               (in condition of R = Et)</td>
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<tr>
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<td>KBE-9007N</td>
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<td>315</td>
<td>9.17</td>
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<tr>
<td></td>
<td>KBM-9659</td>
<td>Tris(trimethoxysilylprop)isocyanurate</td>
<td>(CH₂O)₂Si(CH₃)NCO</td>
<td>186</td>
<td>125</td>
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<td>KBM-803</td>
<td>3-Mercaptopropyltrimethoxysilane</td>
<td>(CH₂O)₂SiCH₂OCH₂CH=CH₂</td>
<td>107</td>
<td>398</td>
<td>8.49</td>
</tr>
</tbody>
</table>

*About Product Name of Shin-Etsu Silane Coupling Agents

- **KBM-1003** ➡️ The last digit indicates the number of hydrolysable groups.
  - M indicates methoxy groups.
  - E indicates ethoxy groups.
  *There are certain exceptions.*

**Solubility in water**
The alkoxysilyl groups in a silane coupling agent react with water to form silanol groups.
These silanol groups are unstable and over time will undergo condensation. This results in formation of siloxane linkages, and ultimately gellation.
Silanol groups are generally unstable in aqueous solutions, but their stability improves if the solution is mildly acidic.
Meanwhile, amino silanes are very stable in aqueous solutions, due to interaction of the amino groups.
Methods for improving a solution’s shelf-life include adjusting the pH of the liquid, combining it with alcohol, and storing it at room temperature or as below.

### Solubility and Stability at Optimum pH

<table>
<thead>
<tr>
<th>Product name</th>
<th>Solubility (pH of aqueous solution)</th>
<th>Shelf-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBM-1003</td>
<td>(+3,9)</td>
<td>Up to 10 days</td>
</tr>
<tr>
<td>KBE-1003</td>
<td>(+3,9)</td>
<td>Up to 10 days</td>
</tr>
<tr>
<td>KBM-303</td>
<td>(+4,0)</td>
<td>Up to 30 days</td>
</tr>
<tr>
<td>KBM-403</td>
<td>(+5,3)</td>
<td>Up to 10 days</td>
</tr>
<tr>
<td>KBE-402</td>
<td>(+4,0)</td>
<td>Up to 10 days</td>
</tr>
<tr>
<td>KBE-403</td>
<td>(+4,0)</td>
<td>Up to 30 days</td>
</tr>
<tr>
<td>KBM-1403</td>
<td>Insoluble</td>
<td>—</td>
</tr>
<tr>
<td>KBM-502</td>
<td>(+4,0)</td>
<td>Up to 1 day</td>
</tr>
<tr>
<td>KBM-503</td>
<td>(+4,2)</td>
<td>Up to 1 day</td>
</tr>
<tr>
<td>KBM-5103</td>
<td>(+4,2)</td>
<td>Up to 3 days</td>
</tr>
<tr>
<td>KBM-602</td>
<td>(+10,0)</td>
<td>Up to 1 day</td>
</tr>
<tr>
<td>KBM-603</td>
<td>(+10,0)</td>
<td>Up to 30 days</td>
</tr>
<tr>
<td>KBM-903</td>
<td>(+10,0)</td>
<td>Up to 30 days</td>
</tr>
<tr>
<td>KBE-903</td>
<td>(+10,0)</td>
<td>Up to 30 days</td>
</tr>
<tr>
<td>KBM-573</td>
<td>(+4,0)</td>
<td>Up to 1 day</td>
</tr>
<tr>
<td>KBM-803</td>
<td>(+4,0)</td>
<td>Up to 1 day</td>
</tr>
</tbody>
</table>

*Solubility:
- **++**: 1% silane-water solution can be prepared without adjusting pH of aqueous solution.
- **+**: 1% silane-water solution can be prepared if pH of aqueous solution is adjusted.
- **Insoluble**: Silane-water solution cannot be prepared.
- **Information on shelf-life should be taken as a guide. Shelf-life will vary depending on usage conditions and intended use.**

*Calculated from energy of evaporation and molar volume as determined by the Fedor's method.*
**Main Products Lineup**

### Product List

<table>
<thead>
<tr>
<th>Functional group</th>
<th>Product name</th>
<th>Chemical name</th>
<th>Structural formula</th>
<th>Flash point</th>
<th>Minimum covering area</th>
<th>Solubility parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>KBM-1003</td>
<td>Vinyltrimethoxysilane</td>
<td>(CH₃O)₂Si(CH₃)₂</td>
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<td>526</td>
<td>7.49</td>
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<td>KBM-1005</td>
<td>Vinyltrimethoxysilane</td>
<td>(CH₃O)₂Si(CH₃)₂</td>
<td>54</td>
<td>410</td>
<td>7.76</td>
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<tr>
<td>Epoxy</td>
<td>KBM-303</td>
<td>2-(3,4 epoxycyclohexyl) ethyltrimethoxysilane</td>
<td>(CH₂O)₂Si(CH₂)CH</td>
<td>163</td>
<td>317</td>
<td>8.59</td>
</tr>
<tr>
<td></td>
<td>KBM-402</td>
<td>3-Glycidoxypropyl methyldimethoxysilane</td>
<td>(CH₂O)₂SiCH₂OCH₂CH₂</td>
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<td>354</td>
<td>8.35</td>
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<tr>
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<td>KBM-403</td>
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<td>(CH₂O)₂SiCH₂OCH₂CH₂</td>
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<td>330</td>
<td>8.49</td>
</tr>
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<td>KBM-404</td>
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<td>(CH₂O)₂SiCH₂CH₂</td>
<td>115</td>
<td>335</td>
<td>8.53</td>
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<td>N-2-(Aminoethyl)-3-aminopropyltrimethoxysilane</td>
<td>(CH₂O)₂SiHNHCH₂</td>
<td>128</td>
<td>351</td>
<td>9</td>
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<td>3-Aminopropyltrimethoxysilane</td>
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<td>352</td>
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<td>KBM-9103</td>
<td>3-Triethoxysilyl(1,3-dimethylbutyldiene) propylsilane</td>
<td>(CH₂O)₂SiHC₄H₉</td>
<td>134</td>
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<td>8.41</td>
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<td>KBM-573</td>
<td>N-Phenylyl-3-aminopropyltrimethoxysilane</td>
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<td>9.15</td>
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<td>N-(Vinylbenzyl)-2-aminoethy-3-aminopropyltrimethoxysilane hydrochloride</td>
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<td>—</td>
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<td>3-Ureidopropyltriethoxysilane</td>
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<td>3-Ureidopropyltrimethoxysilane</td>
<td>(RO)₂SiHNHCH₂</td>
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<td>351</td>
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<td>3-Isocyanoacrylopropyltrimethoxysilane</td>
<td>(CH₂O)₂SiHNH₂</td>
<td>118</td>
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<td>Isocyanate</td>
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<td>Tris(trimethoxysilylpropyl)isocyanurate</td>
<td>(CH₂O)₂Si(CH₂)₃N(CH₂)₂Si(OCH₂)₃</td>
<td>186</td>
<td>125</td>
<td>10.6</td>
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<tr>
<td></td>
<td>KBM-802</td>
<td>3-Mercapto propylmethyldimethoxysilane</td>
<td>(CH₂O)₂SiSH</td>
<td>72</td>
<td>432</td>
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<tr>
<td></td>
<td>KBM-803</td>
<td>3-Mercapto propyltrimethoxysilane</td>
<td>(CH₂O)₂SiSH</td>
<td>107</td>
<td>398</td>
<td>8.49</td>
</tr>
</tbody>
</table>

*About Product Name of Shin-Etsu Silane Coupling Agents*

**KBM-1003**

The last digit indicates the number of hydrolyzable groups.

- **M** indicates methoxy groups.
- **E** indicates ethoxy groups.

*There are certain exceptions.

**Solubility in water**

The alkoxysil y groups in a silane coupling agent react with water to form silanol groups. These silanol groups are unstable and over time will undergo condensation. This results in formation of siloxane linkages and ultimately gelation. Silanol groups are generally unstable in aqueous solutions, but their stability improves if the solution is mildly acidic. Meanwhile, amino silanes are very stable in aqueous solutions, due to interaction of the amino groups. Methods for improving a solution’s shelf-life include adjusting the pH of the liquid, combining it with alcohol, and storing it at room temperature or as below.

**Solubility and Stability at Optimum pH**

<table>
<thead>
<tr>
<th>Product name</th>
<th>Solubility (pH of aqueous solution)</th>
<th>Shelf-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBM-1003</td>
<td>+ (3.9)</td>
<td>Up to 10 days</td>
</tr>
<tr>
<td>KBM-1003</td>
<td>+ (3.9)</td>
<td>Up to 10 days</td>
</tr>
<tr>
<td>KBM-303</td>
<td>++ (4.0)</td>
<td>Up to 30 days</td>
</tr>
<tr>
<td>KBM-403</td>
<td>++ (5.3)</td>
<td>Up to 10 days</td>
</tr>
<tr>
<td>KBM-402</td>
<td>++ (4.0)</td>
<td>Up to 10 days</td>
</tr>
<tr>
<td>KBM-403</td>
<td>++ (4.0)</td>
<td>Up to 10 days</td>
</tr>
<tr>
<td>KBM-1403</td>
<td>Insoluble</td>
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</tr>
<tr>
<td>KBM-502</td>
<td>++ (4.0)</td>
<td>Up to 1 day</td>
</tr>
<tr>
<td>KBM-503</td>
<td>++ (4.2)</td>
<td>Up to 1 day</td>
</tr>
<tr>
<td>KBM-503</td>
<td>++ (4.2)</td>
<td>Up to 1 day</td>
</tr>
<tr>
<td>KBM-5103</td>
<td>++ (4.2)</td>
<td>Up to 3 days</td>
</tr>
<tr>
<td>KBM-602</td>
<td>++ (10.0)</td>
<td>Up to 30 days</td>
</tr>
<tr>
<td>KBM-903</td>
<td>++ (10.0)</td>
<td>Up to 30 days</td>
</tr>
<tr>
<td>KBM-903</td>
<td>++ (10.0)</td>
<td>Up to 30 days</td>
</tr>
<tr>
<td>KBM-803</td>
<td>++ (4.0)</td>
<td>Up to 1 day</td>
</tr>
</tbody>
</table>

*Solubility: + + 1% silane-water solution can be prepared without adjusting pH of aqueous solution. + 1% silane-water solution can be prepared if pH of aqueous solution is adjusted.

Insoluble: Silane-water solution cannot be prepared.*

Information on shelf-life should be taken as a guide. Shelf-life will vary depending on usage conditions and intended use.

*Calculated from energy of evaporation and molar volume as determined by the Fedor’s method.
Development Concept of Shin-Etsu Silane Coupling Agents

Shin-Etsu Chemical is developing a range of new products with many special features. Our offerings include products that not only improve functionality but allow users to achieve greener product design, and are easier to use by virtue of allowing users to eliminate certain processes.

High Functionality

- Polymerizable Type
  - Contains acrylic and styrene groups
  - Improved adhesion between inorganic materials and resins

- Liquid Rubber Modified Type
  - Improving hydrophobicity and flexibility
  - Improved compatibility and adhesion with resins
  - Improved water resistance

- Multi Functional Group Type
  - Low volatility
  - Highly improving adhesion

- VOC Free Type
  - Alcohol released: Reduced by 99% or more
  - Eliminate the step of hydrolysis

- Ethoxy Type
  - Product of hydrolysis is ethanol
  - Hydrolyzes slowly, and compositions will be stable even after addition.

Eco-friendly

- Usability

- Anti-rust Properties Imparting Type
  - Improves rust prevention and adhesion to metals

- Protected Functional Group Type
  - One-component products can be used in place of two-component products
  - Highly improving adhesion

Dialkoxy Silane Type

- Compared to trialkoxy types:
  - Lower crosslinking density for better shelf life
  - Less alcohol is released

Highly Functional Products Lineup

Long-chain Spacer Silane Coupling Agents

Compared to general-purpose silane coupling agents, these have higher hydrophobicity, which means that fillers treated with them will have greater dispersibility. Another advantage is that the cured material will have improved flexibility.

Features and Resulting Properties

- Improving hydrophobicity
- Improving compatibility with resins
- Filler high loading
- Improving alkali resistance
- Maximize freedom of functional groups (improving reactivity)
- Improving adhesion
- Improving flexibility

Model of Chemical Structure

- Conventional grade: (MeO)3Si
- Long-chain Spacer Type: (MeO)2Si
- Organic functional group
- Spacer
- Inorganic part
- Organic part

Product List

<table>
<thead>
<tr>
<th>Organic functional group</th>
<th>Product name</th>
<th>Chemical structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>KBM-1083</td>
<td></td>
</tr>
<tr>
<td>Epoxy</td>
<td>KBM-4803</td>
<td>(MeO)3Si</td>
</tr>
<tr>
<td>Methacryloxy</td>
<td>KBM-5803</td>
<td>(MeO)2Si</td>
</tr>
<tr>
<td>Amino</td>
<td>KBM-6803</td>
<td>(MeO)3Si</td>
</tr>
</tbody>
</table>

Measurements of cured materials

- Epoxy-on-glass adhesion test
- Dispersibility of treated silicas

Model of cure shrinkage

- Cured film of silane coupling agents
- Warping: the degree of cure shrinkage

Dispersibility of treated silicas

- Long-chain spacer silane coupling agents improve the dispersibility of fillers, and compositions will be more transparent.

Formulation: Silane treated silica 10 wt% / Multifunctional epoxy compounds 90 wt%
Development Concept of Shin-Etsu Silane Coupling Agents

Shin-Etsu Chemical is developing a range of new products with many special features. Our offerings include products that not only improve functionality but also allow users to achieve greener product design, and are easier to use by virtue of allowing users to eliminate certain processes.

High Functionality
- Long-chain Spacer Type
  - Improving hydrophobicity and flexibility
- Polymerizable Type
  - Contains acrylic and styrene groups
  - Improved adhesion between inorganic materials and resins
- Liquid Rubber Modified Type
  - Improved compatibility and adhesion with resins
  - Improved water resistance
- Multi Functional Group Type
  - Low volatility
  - Highly improving adhesion
- VOC Free Type
  - Alcohol released: Reduced by 99% or more
  - Eliminate the step of hydrolysates
- Ethoxy Type
  - Product of hydrolysis is ethanol
  - Hydrolyzes slowly, and compositions will be stable even after addition.

Eco-friendly
- Dialkoxyl Silane Coupling Agent
- Compared to trialkoxyl types:
  - Lower crosslinking density for better shelf life
  - Less alcohol is released

Highly Functional Products Lineup

Long-chain Spacer Silane Coupling Agents

Compared to general-purpose silane coupling agents, these have higher hydrophobicity, which means that fillers treated with them will have greater dispersibility. Another advantage is that the cured material will have improved flexibility.

Features and Resulting Properties
- Improving hydrophobicity (lipophilicity)
- Improving compatibility with resins
- Filler high loading
- Improving alkali resistance

Model of Chemical Structure
- Conventional grade
  - (MeO)₂Si
- Long-chain Spacer Type
  - (MeO)₂Si
- Organic functional group

Product List

<table>
<thead>
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<th>Chemical structure</th>
</tr>
</thead>
<tbody>
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<td>KBM-1083</td>
<td>(MeO)₂Si</td>
</tr>
<tr>
<td>Epoxy</td>
<td>KBM-4803</td>
<td>(MeO)₂Si</td>
</tr>
<tr>
<td>Methacryloxy</td>
<td>KBM-5803</td>
<td>(MeO)₂Si</td>
</tr>
<tr>
<td>Amino</td>
<td>KBM-6803</td>
<td>(MeO)₂Si</td>
</tr>
</tbody>
</table>

Measurements of cured materials

- Sample: KBM-4803 (Conventional grade)
- Sample: KBM-5803 (Conventional grade)
- Sample: KBM-5003 (Conventional grade)

Epoxy-on-glass adhesion test

- Roughly 3 times better adhesion than with KBM-4803

Dispersibility of treated silicas

- Long-chain spacer silane coupling agents improve the dispersibility of fillers, and compositions will be more transparent.

Formulation: Silane treated silica 10 wt% / Multifunctional epoxy compounds 90 wt%

Viscosity Pa.s
- Long-chain spacer silane coupling agents help hold viscosity down and enable higher filler loadings.

Formulation: Silane treated silica 10 wt% / Multifunctional epoxy compounds 90 wt%
Multi Functional Silane Coupling Agents

When compared to monomer types, multi functional silane coupling agents have lower volatility and a greater number of sites for reaction with resins, so you can expect improved adhesion to the substrate. And because they have film-forming properties, this type of silane coupling agent can also be used as a primer.

Organic Chain Type : Excellent Compatibility with Resins

- Low volatile content: Can be used in high-temperature conditions. Can be effective even in small amounts.
- Many reaction sites for resins: Improved coupling performance.
- Film forming property: Highly functional primers.
- Containing trialkoxysilyl groups: Improving adhesion.

Product List

<table>
<thead>
<tr>
<th>Organic functional group</th>
<th>Product name</th>
<th>Alkyd group</th>
<th>Numbers of functional group**</th>
<th>Viscosity mm²/s</th>
<th>Reactive functional group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic</td>
<td>X-12-1048</td>
<td>MeO</td>
<td>1</td>
<td>33</td>
<td>300</td>
</tr>
<tr>
<td>X-12-1050</td>
<td>MeO</td>
<td>5</td>
<td>6,000</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Epoxy</td>
<td>X-12-9815</td>
<td>BO</td>
<td>3</td>
<td>1,200</td>
<td>290</td>
</tr>
<tr>
<td>X-12-9845</td>
<td>BO</td>
<td>3</td>
<td>2,000</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td>Mercapto</td>
<td>X-12-1154</td>
<td>MeO</td>
<td>3</td>
<td>1,500</td>
<td>240</td>
</tr>
<tr>
<td>Amino</td>
<td>X-12-9792**</td>
<td>HO</td>
<td>5</td>
<td>8.6</td>
<td>660</td>
</tr>
<tr>
<td>X-12-1159L</td>
<td>HO</td>
<td>2</td>
<td>4,000</td>
<td>360</td>
<td></td>
</tr>
</tbody>
</table>

*15% of ethanolic solution  **Number of organic functional groups to each Si atom

Test method:
① A 1% aqueous solution is applied to a glass substrate.
② A cured material (epoxy resin/triethylenetetramine) is prepared and adhesive strength is tested.

Adhesive strength is calculated against a standard of 100 (untreated glass).

Epoxy-on-glass Adhesion Test

Untrated  KBE-003   X-12-9792  KBE-045  X-12-9845

Non-volatile Content of Silane Coupling Agents

Multi functional silane coupling agents have lower volatility compared to monomer types.

<table>
<thead>
<tr>
<th>Organic functional group</th>
<th>Product name</th>
<th>Non-volatile content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBM-5103 (Acryloyl silane)</td>
<td>X-12-9792</td>
<td>29</td>
</tr>
<tr>
<td>KBM-503 (Methacryloyl silane)</td>
<td>X-12-1048</td>
<td>60</td>
</tr>
<tr>
<td>X-12-9803 (Long chain methacryloyl silane)</td>
<td>X-12-1050</td>
<td>98</td>
</tr>
<tr>
<td>X-12-9792 (Multi functional acryloyl silane)</td>
<td>X-12-9513</td>
<td>97</td>
</tr>
<tr>
<td>X-12-9845 (Multi functional epoxy silane)</td>
<td>X-12-9815</td>
<td>97</td>
</tr>
<tr>
<td>X-12-9845 (Multi functional epoxy silane)</td>
<td>X-12-9845</td>
<td>94</td>
</tr>
<tr>
<td>X-12-9815 (Multi functional epoxy silane)</td>
<td>X-12-9845</td>
<td>94</td>
</tr>
<tr>
<td>KR-516 (Epoxy oligomer)</td>
<td>X-12-9845</td>
<td>93</td>
</tr>
</tbody>
</table>

Polymerizable Type Silane Coupling Agents

X-12-1290, KBM-1403

- Resulting Properties
  - Radial cross-linking is possible due to the inclusion of allyl groups.
  - By adding it to polymerizable resin compositions, it improves the adhesion between inorganic materials such as fillers and resins.

KBM-1403

- Because it contains styrene group, anionic polymerization, catonic polymerization, and radical polymerization are possible.
  - By adding it to polymerizable resin compositions, it improves the adhesion between inorganic materials such as fillers and resins.

- General Properties

Liquid Rubber Modified Type Silane Coupling Agents

Butadiene Polymer Modified Silane Coupling Agent X-12-12678-ES

- Resulting Properties
  - Improved compatibility and adhesion of various resins.
  - Improved water resistance due to high hydrophobicity.

- General Properties

Anti-rust Properties Imparting Type Silane Coupling Agents

Silane Coupling Agent with Benzoziazole Groups X-12-1214A

- Resulting Properties
  - Effective for rust prevention of metals. By adhering the alkyd group to the inorganic base material, it stays on the surface of the metal base material and exhibits an excellent rust prevention effect over a long period of time.

- Features
  - It is effective in preventing rust on metals such as copper, silver, and aluminum.
  - In addition, it can be expected to have the effect of imparting adhesion to metals.

- Applications
  - Die casting, etc.
  - Copper, silver plating, etc.
  - Metal parts for electrical products, etc.

- General Properties

Chemical Structure

Copper Plate Treatment

A silane coupling agent with a benzoziazole group as an organic functional group, which is effective for rust prevention of metals. By adhering the alkyd group to the inorganic base material, it stays on the surface of the metal base material and exhibits an excellent rust prevention effect over a long period of time.

- Features
  - It is effective in preventing rust on metals such as copper, silver, and aluminum.
  - In addition, it can be expected to have the effect of imparting adhesion to metals.

- Applications
  - Die casting, etc.
  - Copper, silver plating, etc.
  - Metal parts for electrical products, etc.

- General Properties

Product name | X-12-1214A
---|---
Appearance | Pale yellow transparent liquid
Active ingredient | %
Viscosity at 25°C | mm²/s
1 | 100
2 | 170
Multi Functional Silane Coupling Agents

Compared to monomer types, multi functional silane coupling agents have lower volatility and a greater number of sites for reaction with resins, so you can expect improved adhesion to the substrate. And because they have film-forming properties, this type of silane coupling agent can also be used as a primer.

**Organic Chain Type: Excellent Compatibility with Resins**

**Features and Resulting Properties**
- Low volatile content: Can be used in high temperature conditions, can be effective even in small amounts.
- Many reaction sites for resins: Improved coupling performance.
- Film forming property: Highly functional primers.
- Containing trialkoxysilyl groups: Improving adhesion.

**Product List**

<table>
<thead>
<tr>
<th>Organic functional group</th>
<th>Product name</th>
<th>Alkylox group</th>
<th>Numbers of functional groups</th>
<th>Viscosity (mm²/s)</th>
<th>Resulting functional group <em>R</em> = Me, Ei</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic</td>
<td>X-12-1048</td>
<td>MeO</td>
<td>1</td>
<td>133</td>
<td>300</td>
</tr>
<tr>
<td>Acrylic</td>
<td>X-12-1050</td>
<td>MeO</td>
<td>5</td>
<td>6,000</td>
<td>150</td>
</tr>
<tr>
<td>Epoxy</td>
<td>X-12-9815</td>
<td>BO</td>
<td>3</td>
<td>1,000</td>
<td>290</td>
</tr>
<tr>
<td>Epoxy</td>
<td>X-12-9845</td>
<td>BO</td>
<td>3</td>
<td>2,000</td>
<td>270</td>
</tr>
<tr>
<td>Mercapto</td>
<td>X-12-1154</td>
<td>MeO</td>
<td>3</td>
<td>1,500</td>
<td>240</td>
</tr>
<tr>
<td>Amino</td>
<td>X-12-9735</td>
<td>MeO</td>
<td>5</td>
<td>8,6</td>
<td>500</td>
</tr>
<tr>
<td>Amino</td>
<td>X-12-1159L</td>
<td>MeO</td>
<td>2</td>
<td>4,000</td>
<td>360</td>
</tr>
</tbody>
</table>

* 15% of alcohol solution
* Number of organic functional groups of each, 1 atom

**Epoxy-on-glass Adhesion Test**

Test method:
1. A 1% aqueous solution is applied to a glass substrate.
2. A cured material (epoxy resin/triethylentetramine) is prepared and adhesive strength is tested.

**Non-volatile Content of Silane Coupling Agents**

Multi functional silane coupling agents have lower volatility compared to monomer types.

**Polymerizable Type Silane Coupling Agents**

**X-12-1290, KBM-1403**

- **Resulting Properties**
  - Radical cross-linking is possible due to the inclusion of allyl groups.
  - By adding it to polymerizable resin compositions, it improves the adhesion between inorganic materials such as fillers and resins.

- **General Properties**
  - Because it contains styrene group, anionic polymerization, cationic polymerization, and radical polymerization are possible.
  - By adding it to polymerizable resin compositions, it improves the adhesion between inorganic materials such as fillers and resins.

**Liquid Rubber Modified Type Silane Coupling Agents**

**X-12-1267B-ES**

- **Resulting Properties**
  - Improved compatibility and adhesion of various resins.
  - Improved water resistance due to high hydrophobicity.

**Butadiene Polymer Modified Silane Coupling Agent X-12-12678-ES**

- **General Properties**
  - Improved compatibility and adhesion of various resins.
  - Improved water resistance due to high hydrophobicity.

**Anti-rust Properties Imparting Type Silane Coupling Agents**

**KMB-1214A**

A silane coupling agent with a benzotriazole group as an organic functional group, which is effective for rust prevention of metals. By adhering the alkylox group to the inorganic base material, it stays on the surface of the metal base material and exhibits an excellent rust prevention effect over a long period of time.

**Features**
- It is effective in preventing rust on metals such as copper, silver, and aluminum.

**Applications**
- Clamping, etc.
- Copper, silver plating, etc.
- Metal parts for electrical products, etc.

**Chemical Structure**

- **Copper Plate Treatment**
  - Wash the copper plate with sulfuric acid and water (2:1) for 10 minutes.
  - Rinse with water to remove dissolved copper, then dry.

**Silane Coupling Agent with Benzotriazole Groups X-12-1214A**

**Product name**

<table>
<thead>
<tr>
<th>Product name</th>
<th>X-12-1214A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Pale yellow transparent liquid.</td>
</tr>
<tr>
<td>Active ingredient</td>
<td>100%</td>
</tr>
<tr>
<td>Viscosity at 25°C (Pa.s)</td>
<td>170</td>
</tr>
</tbody>
</table>

*Post specified value*
**Protected Functional Group** Silane Coupling Agents

The functional groups of these silane coupling agents are protected. This means they can be added at the same time to systems that would otherwise be too reactive, and this enables use of a one-component product where a two-component product would have been necessary.

**Features**
- Can be added to organic materials with which silane coupling agents could not normally be used.

**Product List**

<table>
<thead>
<tr>
<th>Product code</th>
<th>Functional group</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-12-1056ES</td>
<td>Protected mercapto group silane coupling agent</td>
</tr>
<tr>
<td>KBE-9103P</td>
<td>Protected amino group (ketimine type)</td>
</tr>
<tr>
<td>X-12-1172ES</td>
<td>Protected amino group (aldimine type)</td>
</tr>
<tr>
<td>X-12-967C</td>
<td>Acid anhydride type</td>
</tr>
</tbody>
</table>

**Benefit of Protecting Functional Groups**

- Model for Improving Stability in Resin
  - Conventional grade: Reaction starts immediately after product is added to resin.
  - Protected functional group type: Product does not react after addition to resin and stability is high. (One-component product can be used.)

- Stability after addition to various resins
  - Shell life of KBE-9103P in epoxy resin
    - Formulation: Epoxy resin…………50 wt. part Silane coupling agent…………5 wt. part Toluene…………50 wt. part
  - Test Result of Viscosity
    - Product name | Condition | No additive | KBE-9103P | KBE-903 |
    - After 3 days mm/s | 4.2 | 4.4 | 7.8 |
    - After 14 days mm/s | 4.3 | 4.7 | 8.6 |

- Change in viscosity when mixed with isocyanate compound
  - Formulation: Isocyanate compound…………95 wt. part Silane coupling agent…………5 wt. part
  - Test Result of Viscosity
    - Product name | Condition | No additive | KBE-1056ES | X-12-1172ES | KBE-903 |
    - Initial | mPa.s | 222 | 139 | 174 | 119 |
    - After 50°C/1 week | mPa.s | 223 | 176 | 380 | 2,070 |

- Application of Urethane Adhesive
  - Tensile Lap-shear Strength Test Result of Urethane Adhesive

**Model of Chemical Structure**

- Protecting organic functional group

**Model for Improving Adhesion**

- Functional groups are protected and migrate to interface with substrate.
- Because there is no reaction, the resin does not inflame.
- Many reaction sites contribute to adhesion.

**Model of Chemical Structure**

- Organomodified silane coupling agent

---

**VOC Free** Silane Coupling Agents

All the alkoxyisilyl groups are silanol, which means the amount of methanol or ethanol released is reduced by 99% or more. The alcohol normally released when a conventional silane coupling agent undergoes hydrolysis can be minimized.

- **Features**
  - The step of hydrolysis can be eliminated.
  - The amount of alcohol released is reduced by 99% or more.
  - Nonflammable
  - Lower amounts of VOCs released

**Resulting Properties**

- Primer
- Surface treatment
- Binder
- Mixing with water paints

**Product List**

<table>
<thead>
<tr>
<th>Product name</th>
<th>Organic functional groups</th>
<th>Active ingredient wt%</th>
<th>Solvent</th>
<th>pH*</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBE-90</td>
<td>Amine -NH₂</td>
<td>30</td>
<td>Water</td>
<td>10-12</td>
</tr>
<tr>
<td>X-12-1353</td>
<td>Amine, vinyl -NH₂ and -CH=CH₂</td>
<td>20</td>
<td>Water</td>
<td>10-12</td>
</tr>
<tr>
<td>X-12-1353M</td>
<td>Amine, methyl -NH₂ and -CH₂</td>
<td>20</td>
<td>Water</td>
<td>10-12</td>
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<td>KBE-64</td>
<td>Ethylenediamine-h₂ -NH₂+NH₂</td>
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<td>Water</td>
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<td>X-12-954</td>
<td>Ethylenediamine -NH₂+NH₂</td>
<td>30</td>
<td>Water</td>
<td>10-12</td>
</tr>
<tr>
<td>X-12-1135</td>
<td>Carboxylic acid -COOH</td>
<td>30</td>
<td>Water</td>
<td>1-3</td>
</tr>
<tr>
<td>X-12-1139</td>
<td>Quaternary ammonium -NMe₂+NH₂+Cl⁻</td>
<td>30</td>
<td>Water</td>
<td>8-10</td>
</tr>
<tr>
<td>X-12-1126</td>
<td>Quaternary ammonium -NMe₂+Cl⁻</td>
<td>30</td>
<td>Water</td>
<td>8-10</td>
</tr>
</tbody>
</table>

*Not specified value

---

**Diaxoxyl** Silane Coupling Agents

**Ethoxo** Silane Coupling Agents

**Model of Chemical Structure**

- Organic functional group

**Features and Resulting Properties**

- Two-dimensional crosslinking
- Good shelf life after addition
- Lower amount of alcohol released
- Eco-friendly

- Hydrolysis is slower compared to methoxy types.
- Product of hydrolysis is ethanol
- Good shelf life after addition

*For data on ease of hydrolysis, see graph on PB.*
### Protected Functional Group Silane Coupling Agents

The functional groups of these silane coupling agents are protected. This means they can be added at the same time to systems that would otherwise be too reactive, and this enables use of a one-component product where a two-component product would have been necessary.

**Features**
- Can be added to organic materials with which silane coupling agents could not normally be used.

**Product List**

<table>
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<tr>
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<td>KBE-9103P</td>
<td>Protected amino group (ketamine type)</td>
</tr>
<tr>
<td>X-12-1172ES</td>
<td>Protected amino group (aldimine type)</td>
</tr>
<tr>
<td>X-12-967C</td>
<td>Acid anhydride type</td>
</tr>
</tbody>
</table>

**Benefit of Protecting Functional Groups**

- **Model for Improving Stability in Resin**
  - Conventional grade: Reaction starts immediately after product is added to resin.
  - Protected functional group type: Product does not react after addition to resin and stability is high. (One-component product can be used.)

- **Stability after addition to various resins**
  - **Shell life of KBE-9103P in epoxy resin**
    - **Condition**: Epoxy resin — 50 wt. part, Silane coupling agent — 5 wt. part, Toluene — 50 wt. part
  - **Test Result of Viscosity**
    - **Condition**: Product name, No additive, KBE-9103P, KBE-903
      - After 3 days mm/s: 4.2, 4.4, 7.8
      - After 14 days mm/s: 4.3, 4.7, 8.6

- **Change in viscosity when mixed with isocyanate compound**
  - **Condition**: Isocyanate compound — 95 wt. part, Silane coupling agent — 5 wt. part

- **Application of Urethane Adhesive**
  - **Condition**: Urethane polymer containing NCO — 100 wt. part, Plasticizer — 40 wt. part, Filler — 100 wt. part, Catalyst — 0.1 wt. part, Silane coupling agent — 1.0 wt. part, Curing conditions: 23°C/50%RH=3 days
  - **Tensile Lap-shear Strength Test Result of Urethane Adhesive**

---

### VOC Free Silane Coupling Agents

All the alkoxysilyl groups are silanols, which means the amount of methanol or ethanol released is reduced by 99% or more. The alcohol normally released when a conventional silane coupling agent undergoes hydrolysis can be minimized.

**Features**
- The step of hydrolysis can be eliminated.
- The amount of alcohol released is reduced by 99% or more.
- Nonflammable
- Lower amounts of VOCs released

**Resulting Properties**
- Primer
- Surface treatment
- Binder
- Mixing with water paints

**Product List**

<table>
<thead>
<tr>
<th>Product name</th>
<th>Organic functional groups</th>
<th>Active ingredient wt%</th>
<th>Solvent</th>
<th>pH*</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBE-90</td>
<td>Amine — NH$_2$</td>
<td>30</td>
<td>Water</td>
<td>10-12</td>
</tr>
<tr>
<td>X-12-1353</td>
<td>Amine, vinyl — NH$_2$ and CH=CH$_2$</td>
<td>20</td>
<td>Water</td>
<td>10-12</td>
</tr>
<tr>
<td>X-12-1353M</td>
<td>Amine, methyl — NH$_2$ and CH$_3$</td>
<td>20</td>
<td>Water</td>
<td>10-12</td>
</tr>
<tr>
<td>KBE-64</td>
<td>Ethylenediamine — NH$_2$+NH$_2$</td>
<td>30</td>
<td>Water</td>
<td>10-12</td>
</tr>
<tr>
<td>X-12-954</td>
<td>Ethylenediamine — NH$_2$+NH$_2$</td>
<td>30</td>
<td>Water</td>
<td>10-12</td>
</tr>
<tr>
<td>X-12-1135</td>
<td>Carboxylic acid — COOH</td>
<td>30</td>
<td>Water</td>
<td>1-3</td>
</tr>
<tr>
<td>X-12-1139</td>
<td>Quaternary ammonium — NMe$_2$++NH$_2$+Cl</td>
<td>30</td>
<td>Water</td>
<td>8-10</td>
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<tr>
<td>X-12-1126</td>
<td>Quaternary ammonium — NMe$_2$+Cl</td>
<td>30</td>
<td>Water</td>
<td>8-10</td>
</tr>
</tbody>
</table>

*Stability suffers once pH is outside this zone.

---

### Dialkoxysilane Silane Coupling Agents

**Model of Chemical Structure**

**Features and Resulting Properties**
- Good shelf life after addition
- Economic

**Product of hydrolysis**
- Higher price compared to methoxy types.
- Good shelf life after addition

**Ethoxy Silane Coupling Agents**

**Model of Chemical Structure**

**Features and Resulting Properties**
- Good shelf life after addition
- Eco-friendly

*For data on ease of hydrolysis, see graph on FB.
Shin-Etsu’s silane products are a group of organosilicon compounds comprised of alkoxysilanes and silazanes. Silanes have many applications in a wide variety of fields. They are commonly applied to the surface of inorganic substrates to improve water repellency, added to inorganic fillers to improve their dispersibility in organic polymers, and used for surface modification of inorganic materials.

**General Properties**

<table>
<thead>
<tr>
<th>Type</th>
<th>Product name</th>
<th>Chemical name</th>
<th>Structural formula</th>
<th>Molecular weight</th>
<th>Specific gravity at 20°C</th>
<th>Flash point °C</th>
<th>UN hazard classification</th>
<th>CAS No.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Methoxy type</strong></td>
<td>KBM-13</td>
<td>Methyltrimethoxysilane</td>
<td>(CH₃)₃Si(OCH₃)</td>
<td>136.2</td>
<td>0.95</td>
<td>1.369</td>
<td>102</td>
<td>8°</td>
</tr>
<tr>
<td></td>
<td>KBM-22</td>
<td>Dimethyldimethoxysilane</td>
<td>(CH₃)₂Si(OCH₃)₂</td>
<td>120.2</td>
<td>0.86</td>
<td>1.371</td>
<td>82</td>
<td>10°</td>
</tr>
<tr>
<td></td>
<td>KBM-103</td>
<td>Phenyltrimethoxysilane</td>
<td>(C₆H₅)Si(OCH₃)</td>
<td>183.1</td>
<td>1.06</td>
<td>1.473</td>
<td>218</td>
<td>94°</td>
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<td></td>
<td>KBM-2025S</td>
<td>Dimethyldimethoxysilane</td>
<td>(CH₃)₂Si(OCH₃)₂</td>
<td>244.4</td>
<td>1.08</td>
<td>1.541</td>
<td>304</td>
<td>145°</td>
</tr>
<tr>
<td></td>
<td>KBM-3033</td>
<td>n-Propyltrimethoxysilane</td>
<td>(C₃H₇)Si(OCH₃)</td>
<td>164.3</td>
<td>0.93</td>
<td>1.388</td>
<td>142</td>
<td>36°</td>
</tr>
<tr>
<td></td>
<td>KBM-3063</td>
<td>Hexamethyldisiloxane</td>
<td>(CH₃)₆SiO</td>
<td>206.4</td>
<td>0.91</td>
<td>1.426</td>
<td>202</td>
<td>81°</td>
</tr>
<tr>
<td></td>
<td>KBM-3103C</td>
<td>Decymethyldisiloxane</td>
<td>(C₃H₇)₆SiO</td>
<td>262.5</td>
<td>0.90</td>
<td>1.421</td>
<td>12°C</td>
<td>122°</td>
</tr>
<tr>
<td></td>
<td>KBM-3066</td>
<td>1,6-Bis(dimethoxymethyl)hexane</td>
<td>(CH₃)₃SiCH₂CH₂Si(OCH₃)₂</td>
<td>326.5</td>
<td>1.02</td>
<td>1.420</td>
<td>12°C</td>
<td>124°</td>
</tr>
<tr>
<td></td>
<td>KBM-7103</td>
<td>Trifluoropropyltrimethoxysilane</td>
<td>(C₃F₇)Si(OCH₃)₂</td>
<td>287.2</td>
<td>1.14</td>
<td>3.152</td>
<td>144</td>
<td>29°</td>
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<tr>
<td><strong>Ethoxy type</strong></td>
<td>KBE-04</td>
<td>Tetraethoxysilane</td>
<td>(C₂H₅)₄SiO</td>
<td>208.3</td>
<td>0.93</td>
<td>1.381</td>
<td>168</td>
<td>54°</td>
</tr>
<tr>
<td></td>
<td>KBE-13</td>
<td>Triethoxysilane</td>
<td>(C₂H₅)₃SiO</td>
<td>178.3</td>
<td>0.89</td>
<td>1.383</td>
<td>143</td>
<td>40°</td>
</tr>
<tr>
<td></td>
<td>KBE-22</td>
<td>Dibutylidimethoxysilane</td>
<td>(C₄H₉)₂Si(OCH₃)₂</td>
<td>148.3</td>
<td>0.83</td>
<td>1.384</td>
<td>115</td>
<td>55°</td>
</tr>
<tr>
<td></td>
<td>KBE-103</td>
<td>Phenylethoxysilane</td>
<td>(C₆H₅)CH₂SiO</td>
<td>240.9</td>
<td>0.99</td>
<td>1.459</td>
<td>236</td>
<td>111°</td>
</tr>
<tr>
<td></td>
<td>KBE-3033</td>
<td>n-Propylmethoxysilane</td>
<td>(C₃H₇)CH₂SiO</td>
<td>206.4</td>
<td>0.89</td>
<td>1.394</td>
<td>179</td>
<td>57°</td>
</tr>
<tr>
<td></td>
<td>KBE-3063</td>
<td>Hexamethyldisiloxane</td>
<td>(C₃H₇)₆SiO</td>
<td>284.8</td>
<td>0.88</td>
<td>1.408</td>
<td>12°C</td>
<td>97°</td>
</tr>
<tr>
<td></td>
<td>KBE-3083</td>
<td>Octamethyldisiloxane</td>
<td>(C₃H₇)₈SiO</td>
<td>276.5</td>
<td>0.88</td>
<td>1.415</td>
<td>12°C</td>
<td>124°</td>
</tr>
</tbody>
</table>

**Silazane**

- **SZ-31** Hexamethyldisilazane
  - Chemical formula: (C₃H₇)₆Si(NH)₂
  - Molecular weight: 264.1
  - Specific gravity at 20°C: 1.03
  - Flash point: 126°
  - UN hazard classification: 3.1
  - CAS No.: 1.0584

- **KPS-3504** Mixture with hydrolysable groups
  - Chemical formula: (C₃H₇)₆Si(OH)₂
  - Molecular weight: 264.1
  - Specific gravity at 20°C: 1.03
  - Flash point: 126°
  - UN hazard classification: 2.1
  - CAS No.: 999-97-3

**Reaction of SZ-31**

In this reaction, hydrolysis results in formation of ammonia.

\[
\text{SiO}_2 + 2\text{NH}_3 \rightarrow \text{SiO}_2 + 2\text{H}_2\text{O} + 2\text{NH}_3
\]

**Water repellency (surface properties)**

1. **Silane (on glass substrate)**
   - **KBM-13**: 63°
   - **SZ-31**: 66°
   - **KPS-3504**: 84°

2. **Silane**
   - **KBM-13**: 20.6°
   - **KBM-7103**: 12.5°
   - **KBM-3103C**: 40.0°

**Hydrolytic properties**

- **Hydrolysis rates of silanes**
  - Diphényl disiloxane
  - Diphényl disiloxane (N/C)
  - KPS-3103C
  - KPS-3303
  - KPS-3503
  - KPS-3503
  - KPS-3503

<table>
<thead>
<tr>
<th><strong>Hydrolytic properties of long-chain allylic silane (room temp.)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Graph showing hydrolytic properties" /></td>
</tr>
</tbody>
</table>

**Condensation reaction properties**

**Condenstation behavior of methyl and phenyl silanes**

- **Trifunctional type**
  In comparing methyltrimethoxysilane (KBM-13) with phenyltrimethoxysilane (KBM-103), it was found that condensation occurs more slowly for phenyltrimethoxysilane.

  \[
  \text{Me-Si(OH)}_3 + \text{Ph-Si(OH)}_3 \rightarrow \text{Me-Ph-Si(OH)}_2
  \]

- **Difunctional type**
  In comparing dimethyldimethoxysilane (KBM-22) with diphenyldimethoxysilane (KBM-2025S), it was found that condensation proceeds more slowly for diphenyldimethoxysilane.

  \[
  \text{Me-Si(OH)}_2 + \text{Ph-Si(OH)}_2 \rightarrow \text{Me-Ph-Si(OH)}_2
  \]

**Condensation of methyl and phenyl silanes**

1. Silanes and hydrocarbons were mixed.
2. Gas chromatography (GC) was performed on the mixed liquids and the initial residual amounts were determined.
3. 0.05% acetic acid water was added, and the liquids were agitated at room temperature.
4. GC was performed again later and the residual rates were calculated based on the initial residual amounts.
Silane

Silane products are a group of organosilicon compounds comprised of alkoxy silanes and silazanes. Silanes have many applications in a wide variety of fields. They are commonly applied to the surface of inorganic substrates to improve water repellency, to add inorganic fillers to improve their dispersibility in organic polymers, and used for surface modification of inorganic materials.

**General Properties**

<table>
<thead>
<tr>
<th>Type</th>
<th>Product name</th>
<th>Chemical name</th>
<th>Structural formula</th>
<th>Molecular weight</th>
<th>Specific gravity</th>
<th>Inherent viscosity at 25°C</th>
<th>Boiling point</th>
<th>Flash point</th>
<th>Minimum flammability</th>
<th>UN hazard classification</th>
<th>HM# No.</th>
<th>CAS No.</th>
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</thead>
<tbody>
<tr>
<td>KBM-13</td>
<td>Methyltrimethoxysilane</td>
<td>(CH₃)₃O(CH₂)₃Si</td>
<td>136.2</td>
<td>0.95</td>
<td>1.369</td>
<td>102</td>
<td>8°C</td>
<td>573</td>
<td>UNI 9931</td>
<td>2.052</td>
<td>1185.55-3</td>
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</tr>
<tr>
<td>KBM-22</td>
<td>Dimethylmethoxydimethoxysilane</td>
<td>(CH₃)₂O(CH₂)₂SiO(CH₃)₂</td>
<td>120.2</td>
<td>0.86</td>
<td>1.371</td>
<td>82</td>
<td>10°C</td>
<td>649</td>
<td>UNI 9931</td>
<td>2.052</td>
<td>1112.39-6</td>
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<tr>
<td>KBM-103</td>
<td>Phenyldimethoxydimethoxysilane</td>
<td>(CH₃)₂O(C₆H₅)SiO(CH₃)₂</td>
<td>198.3</td>
<td>1.06</td>
<td>1.473</td>
<td>218</td>
<td>94°C</td>
<td>393</td>
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<td>2.063</td>
<td>20496.92-1</td>
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<tr>
<td>KBM-2025S</td>
<td>Dimethylphenoxysilane</td>
<td>(CH₃)₂O(SiO(CH₃)₂)</td>
<td>244.4</td>
<td>1.08</td>
<td>1.541</td>
<td>304</td>
<td>145°C</td>
<td>320</td>
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<tr>
<td>KBM-3033</td>
<td>n-Propylenoxysilane</td>
<td>(CH₃)₂O(SiO(CH₃)₃)</td>
<td>164.3</td>
<td>0.93</td>
<td>1.388</td>
<td>142</td>
<td>36°C</td>
<td>47</td>
<td>UNI 9932</td>
<td>2.052</td>
<td>1067.29-0</td>
<td></td>
</tr>
<tr>
<td>KBM-3063</td>
<td>Hexamethyldisiloxane</td>
<td>(CH₃)₆O</td>
<td>206.4</td>
<td>0.91</td>
<td>1.406</td>
<td>202</td>
<td>81°C</td>
<td>378</td>
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<td>2.052</td>
<td>3669.19-0</td>
<td></td>
</tr>
<tr>
<td>KBM-3103C</td>
<td>Decamethyldisiloxane</td>
<td>(CH₃)₁₀O</td>
<td>262.5</td>
<td>0.90</td>
<td>1.421</td>
<td>12°C</td>
<td>122°C</td>
<td>297</td>
<td>Not applicable</td>
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<td>KBM-3066</td>
<td>1,6-Butylenoxysiloxane</td>
<td>(CH₃)₂O(SiO(CH₃)₂)</td>
<td>326.5</td>
<td>1.02</td>
<td>1.420</td>
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<td>144°C</td>
<td>357</td>
<td>UNI 9933</td>
<td>2.0379</td>
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<tr>
<td>KBM-7103</td>
<td>Trifluoro-1,3,5-trimethoxysiloxane</td>
<td>(CF₃)₃O(SiO(CH₃)₃)</td>
<td>218.2</td>
<td>1.14</td>
<td>1.352</td>
<td>144</td>
<td>35°C</td>
<td>357</td>
<td>UNI 9933</td>
<td>2.0379</td>
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</tr>
<tr>
<td>KBE-04</td>
<td>Tetraethoxysilane</td>
<td>(CH₂O)₄Si</td>
<td>208.3</td>
<td>0.93</td>
<td>1.381</td>
<td>168</td>
<td>54°C</td>
<td>375</td>
<td>UNI 1292</td>
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<td>7810.4-3</td>
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</tr>
<tr>
<td>KBE-13</td>
<td>Triethoxysilane</td>
<td>(CH₂O)₃Si</td>
<td>178.3</td>
<td>0.89</td>
<td>1.383</td>
<td>143</td>
<td>40°C</td>
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<td>7810.4-3</td>
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</tr>
<tr>
<td>KBE-22</td>
<td>Dimethyldiethoxysilane</td>
<td>(CH₃)₂O(SiOCH₂)₂</td>
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<td>0.83</td>
<td>1.384</td>
<td>114</td>
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<td>526</td>
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<tr>
<td>KBE-103</td>
<td>Phenyltrimethoxysilane</td>
<td>(CH₃)₃O(C₆H₅)</td>
<td>240.4</td>
<td>0.99</td>
<td>1.459</td>
<td>236</td>
<td>111°C</td>
<td>324</td>
<td>UNI 2880</td>
<td>2.0348</td>
<td>7810.4-3</td>
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</tr>
<tr>
<td>KBE-3033</td>
<td>n-Propylenoxysilane</td>
<td>(CH₃)₂O(SiO(CH₃)₃)</td>
<td>164.3</td>
<td>0.93</td>
<td>1.388</td>
<td>142</td>
<td>36°C</td>
<td>47</td>
<td>UNI 9932</td>
<td>2.052</td>
<td>1067.29-0</td>
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</tr>
<tr>
<td>KBE-3063</td>
<td>Hexamethyldisiloxane</td>
<td>(CH₃)₆O</td>
<td>206.4</td>
<td>0.91</td>
<td>1.406</td>
<td>202</td>
<td>81°C</td>
<td>378</td>
<td>Not applicable</td>
<td>2.052</td>
<td>3669.19-0</td>
<td></td>
</tr>
<tr>
<td>KBE-3083</td>
<td>Octamethyldisiloxane</td>
<td>(CH₃)₈O</td>
<td>276.5</td>
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<td>161.4</td>
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<td>126°C</td>
<td>282</td>
<td>UNI 2880</td>
<td>2.0348</td>
<td>999.97-3</td>
</tr>
</tbody>
</table>

**Condoneation behavior of methyl and phenyl silanes**

**Trifunctional type**

In comparing methyltrimethoxysilane (KBM-13) with phenyltrimethoxysilane (KBM-103), it was found that condensation proceeds more slowly for phenyltrimethoxysilane.

**Difunctional type**

In comparing dimethylmethoxysilane (KBM-22) with diphenylmethoxysilane (KBM-2025S), it was found that condensation proceeds more slowly for diphenylmethoxysilane.
<table>
<thead>
<tr>
<th>Functional group</th>
<th>Product name</th>
<th>Chemical name</th>
<th>Molecular weight</th>
<th>Specific gravity at 25°C</th>
<th>Refractive index at 25°C</th>
<th>Boiling point °C</th>
<th>Flash point °C</th>
<th>Minimum covering area m²/kg</th>
<th>UN hazard classification</th>
<th>Packaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>KBM-1003</td>
<td>Vinyltrimethoxyslane</td>
<td>148.2</td>
<td>0.97</td>
<td>1.391</td>
<td>123</td>
<td>23</td>
<td>526</td>
<td>UN-1993</td>
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<td>KBE-1003</td>
<td>Vinyltrimethoxyslane</td>
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<td>1.397</td>
<td>161</td>
<td>54</td>
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<td>UN-1993</td>
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<tr>
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<td>KBM-1083</td>
<td>7-Octenylmethoxyslane</td>
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<td>0.92</td>
<td>1.423</td>
<td>100°C/0.93 kPa</td>
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<td>336</td>
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<tr>
<td></td>
<td>X-12-1290</td>
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<td>-</td>
<td>1.17</td>
<td>1.483</td>
<td>190</td>
<td>-</td>
<td>Not applicable</td>
<td></td>
<td>1 kg, 18 kg</td>
</tr>
<tr>
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<td>KBM-303</td>
<td>2-(3,4-epoxycyclohexyl) ethyltrimethoxyslane</td>
<td>246.4</td>
<td>1.06</td>
<td>1.448</td>
<td>310</td>
<td>163</td>
<td>317</td>
<td>Not applicable</td>
<td>1 kg, 16 kg, 200 kg</td>
</tr>
<tr>
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<td>KBM-402</td>
<td>3-Glycidoxypoly(methyl)methoxyslane</td>
<td>220.3</td>
<td>1.02</td>
<td>1.432</td>
<td>112°C/0.67 kPa</td>
<td>134</td>
<td>354</td>
<td>Not applicable</td>
<td>1 kg, 16 kg, 180 kg</td>
</tr>
<tr>
<td></td>
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<td>3-Glycidoxypoly(trimethyl)siloxane</td>
<td>236.3</td>
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<td>1.427</td>
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<td>3-Isocyanatepropylmethoxysilane</td>
<td>247.4</td>
<td>1.00</td>
<td>1.418</td>
<td>250</td>
<td>118</td>
<td>315</td>
<td>UN-2927</td>
<td>1 kg</td>
</tr>
<tr>
<td></td>
<td>X-12-1159L</td>
<td>Organosilane</td>
<td>-</td>
<td>1.17</td>
<td>1.500</td>
<td>-</td>
<td>228</td>
<td>-</td>
<td>Not applicable</td>
<td>1 kg</td>
</tr>
<tr>
<td>Isocyanurate</td>
<td>KBM-9655</td>
<td>Tris-(trimethoxysilylpropyl)isocyanurate</td>
<td>615.8</td>
<td>1.18</td>
<td>1.458</td>
<td>250 &lt;</td>
<td>186</td>
<td>125</td>
<td>Not applicable</td>
<td>1 kg</td>
</tr>
<tr>
<td>Mercapto</td>
<td>KBM-802</td>
<td>3-Mercaptopropylmethoxysilane</td>
<td>180.3</td>
<td>1.00</td>
<td>1.448</td>
<td>204</td>
<td>72</td>
<td>432</td>
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<td>1 kg</td>
</tr>
<tr>
<td></td>
<td>KBM-803</td>
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<td>196.4</td>
<td>1.06</td>
<td>1.440</td>
<td>219</td>
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<td>1 kg</td>
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<td>-</td>
<td>1.26</td>
<td>1.514</td>
<td>-</td>
<td>218</td>
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<td>UN-3082</td>
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</tr>
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<tr>
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<td>1.17</td>
<td>1.446</td>
<td>178 - 182</td>
<td>190</td>
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<td></td>
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<td>-</td>
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<td>-</td>
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</table>

◆ VOC Free Type

<table>
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<tr>
<th>Product name</th>
<th>Features</th>
<th>Appearance</th>
<th>Active ingredients wt%</th>
<th>Solvent</th>
<th>UN hazard classification</th>
<th>Packaging</th>
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<tbody>
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<td>Amine type</td>
<td>Colorless to yellow liquid</td>
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<td>Water</td>
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<tr>
<td>X-12-1353</td>
<td>Amine, vinyl type</td>
<td>Colorless to yellow liquid</td>
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<td>Water</td>
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<tr>
<td>X-12-1353M</td>
<td>Amine, methyl type</td>
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<td>Water</td>
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<td>1 kg</td>
</tr>
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<td>KBP-64</td>
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</tr>
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<tr>
<td>X-12-1135</td>
<td>Carboxylic acid type</td>
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<td>Water</td>
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<tr>
<td>X-12-1139</td>
<td>Quaternary ammonium type</td>
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<tr>
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## Product Features & Packaging Options

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<thead>
<tr>
<th>Functional group</th>
<th>Product name</th>
<th>Chemical name</th>
<th>Molecular weight</th>
<th>Specific gravity at 25°C</th>
<th>Refractive index at 25°C</th>
<th>Boiling point °C</th>
<th>Flash point °C</th>
<th>Minimum covering area m²/kg</th>
<th>UN hazard classification</th>
<th>Packaging 1 L cans</th>
<th>18 L cans</th>
<th>200 L drums</th>
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<tr>
<td>Ureide</td>
<td>KBE-585A</td>
<td>3-Ureidopropyltrialkoxysilane (Active ingredients 50% alcohol solution)</td>
<td>-</td>
<td>0.91</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>-</td>
<td>UN-1992</td>
<td>1 kg</td>
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<td>222.3</td>
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<td>1.461</td>
<td>-</td>
<td>182</td>
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<td>16 kg</td>
<td>180 kg</td>
</tr>
<tr>
<td>Isocyanate</td>
<td>KBE-9007N</td>
<td>3-Isocyanatepropylmethoxysilane</td>
<td>247.4</td>
<td>1.00</td>
<td>1.418</td>
<td>250</td>
<td>118</td>
<td>315</td>
<td>UN-2927</td>
<td>1 kg</td>
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<td>-</td>
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<td>-</td>
<td>228</td>
<td>-</td>
<td>Not applicable</td>
<td>1 kg</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Isocyanurate</td>
<td>KBM-9655</td>
<td>Tris(dimethoxysilylethoxy)isocyanurate</td>
<td>615.8</td>
<td>1.18</td>
<td>1.458</td>
<td>250 &lt;</td>
<td>186</td>
<td>125</td>
<td>Not applicable</td>
<td>1 kg</td>
<td>18 kg</td>
<td>200 kg</td>
</tr>
<tr>
<td>Mercapto</td>
<td>KBM-802</td>
<td>3-Mercaptopropylmethyldimethoxysilane</td>
<td>180.3</td>
<td>1.00</td>
<td>1.448</td>
<td>204</td>
<td>72</td>
<td>432</td>
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<td>3-Mercaptopropyltrimethoxysilane</td>
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<td>219</td>
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<td>18 kg</td>
<td>200 kg</td>
</tr>
<tr>
<td></td>
<td>X-12-1154</td>
<td>Organosilane</td>
<td>-</td>
<td>1.26</td>
<td>1.514</td>
<td>-</td>
<td>218</td>
<td>-</td>
<td>UN-3082</td>
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<td>16 kg</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>X-12-1056E5</td>
<td>Organosilane</td>
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<td>1.435</td>
<td>-</td>
<td>160</td>
<td>-</td>
<td>Not applicable</td>
<td>1 kg</td>
<td>16 kg</td>
<td>-</td>
</tr>
<tr>
<td>Acid anhydride</td>
<td>X-12-867C</td>
<td>3-Trimethoxysilylethylene anhydride</td>
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<td>1.17</td>
<td>1.446</td>
<td>178 - 182</td>
<td>190</td>
<td>298</td>
<td>Not applicable</td>
<td>1 kg</td>
<td>16 kg</td>
<td>-</td>
</tr>
<tr>
<td>Benzoisocoumarol</td>
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<td>1.524</td>
<td>-</td>
<td>168</td>
<td>-</td>
<td>Not applicable</td>
<td>1 kg</td>
<td>18 kg</td>
<td>-</td>
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<tr>
<td>Liquid rubber type</td>
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<td>-</td>
<td>0.94</td>
<td>1.480</td>
<td>-</td>
<td>294</td>
<td>-</td>
<td>Not applicable</td>
<td>1 kg</td>
<td>18 kg</td>
<td>180 kg</td>
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(Not specified values)

### VOC Free Type

<table>
<thead>
<tr>
<th>Product name</th>
<th>Features</th>
<th>Appearance</th>
<th>Active ingredients wt%</th>
<th>Solvent</th>
<th>UN hazard classification</th>
<th>Packaging</th>
</tr>
</thead>
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<tr>
<td>KBP-90</td>
<td>Amine type</td>
<td>Colorless to yellow liquid</td>
<td>30</td>
<td>Water</td>
<td>Not applicable</td>
<td>1 kg</td>
</tr>
<tr>
<td>X-12-1353</td>
<td>Amine, vinyl type</td>
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<td>20</td>
<td>Water</td>
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<td>1 kg</td>
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<tr>
<td>X-12-1353M</td>
<td>Amine, methyl type</td>
<td>Colorless to yellow liquid</td>
<td>20</td>
<td>Water</td>
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<td>Water</td>
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<td>Water</td>
<td>Not applicable</td>
<td>1 kg</td>
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<td>X-12-1135</td>
<td>Carboxylic acid type</td>
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<td>30</td>
<td>Water</td>
<td>Not applicable</td>
<td>1 kg</td>
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<td>X-12-1139</td>
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<td>Water</td>
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<td>1 kg</td>
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<td>Water</td>
<td>Not applicable</td>
<td>1 kg</td>
</tr>
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</table>
Selecting silane coupling agents
- Which to use, methoxysilyl groups or ethoxysilyl groups?
  - Among the alkoxysilyl groups, methoxysilyl groups hydrolyze faster than ethoxysilyl groups. Please refer to P8 for data on the hydrolysis ability of alkoxysilyl groups.
  - Methoxysilyl groups hydrolyze to form methanol, while ethoxysilyl groups hydrolyze to form ethanol. If you are concerned about the release of methanol, you should use ethoxysilyl groups (KBE Series).
- Which to use, trialkoxysilyl groups or dialkoxysilyl groups?
  - Whereas the hydrolytic condensation of trialkoxysilyl groups leads to three-dimensional crosslinking, hydrolytic condensation of dialkoxysilyl groups leads to two-dimensional crosslinking. This means that dialkoxysilyl groups will be more stable when prepared in an aqueous solution. However, because trialkoxysilyl groups will have a higher crosslinking density with the substrate, adhesion will often be higher.
- How do I select the right organofunctional group?
  - Choosing the optimal organofunctional groups will depend on the resin or substrate with which they are used. Please see P9 for a chart of organofunctional groups and applicable resins.
- Which resins will show improved adhesion with Silane coupling agents, and which won’t?
  - For a guide on which types of silanes are effective with which resins, see the chart on P9 (Organic functional groups and applicable resins).

Obtaining samples
- How can I obtain samples?
  - Contact us via the form on our website (https://www.shinetsu-silicone-global.com/showinquiry.do), or talk to a ShinEtsu distributor.

Preparation method
- How do I determine how much silane to use?
  - The optimal amount can be determined based on the specific surface area of the filler and the minimum coverage area of the filler (Product list on P10-11, Product Characteristics & Packaging Options on P20-23) (See Note 1). As a rough guide, try using 0.5-2.0 wt% silane vs. the weight of the filler. The user should also be aware that silane coupling agents will be more effective with some types of fillers than with others.
- Treating the filler in advance vs. the integral blend method. Do the results differ?
  - The typical pretreatment method is to treat the inorganic filler first, then mix it into the organic material. In the integral blend method, the inorganic filler, resin, and silane are all added at once. Both methods work, with the pretreatment involved. With the integral blend method, there may be some evaporation of the silane if the material is heat-treated immediately after mixing. We recommend heating after a suitable curing period (See Note 2).

Using silane coupling agents
- What are some tips regarding treatment methods?
  - For best results, wash the surface of the inorganic material to remove oils, then treat with a primer.
- What are the drying conditions?
  - To evaporate the water and initiate the dehydration condensation reaction, we recommend drying at 80-120°C (See Note 3).

Note 1
- Treatment amount
  - The amount of treatment used for fillers is normally 0.5-2% by weight.

Note 2
- Effects of aging on organic resin blends
  - Application to polyester resin
    - When coupling agents are added via the integral blending method and aged at room temperature, the coupling agent migrates to the interface with the inorganic material. The effect is close to that achieved with pretreated glass-fiber cloth.

Note 3
- Change in performance caused by dehydration condensation reaction
  - Comparison of treatment of polyester laminates
    - When compared to different drying conditions, the effectiveness of treatment. It was found that drying the silane coupling agent for around 5 minutes at 110°C after application achieved the best results.

Note 4
- Vapor pressure curve
  - Most silane coupling agents are compounds that have boiling points, and have vapor pressures which are unique to each compound. The graph below shows the relationship between vapor pressure and temperature for some typical silane coupling agents.
### Q & A

**Category** | **Question** | **Answer**
--- | --- | ---
**Selecting silane coupling agents** | Which to use, methoxysilyl groups or ethoxysilyl groups? | Among the alkoxysilyl groups, methoxysilyl groups hydrolyze faster than ethoxysilyl groups. Please refer to P8 for data on the hydrolysis ability of alkoxysilyl groups. Methoxysilyl groups hydrolyze to form methanol, while ethoxysilyl groups hydrolyze to form ethanol. If you are concerned about the release of methanol, you should use ethoxysilyl groups (KBM Series).

Which to use, trialkoxysilyl groups or dialkoxyalkoxysilyl groups? | Whereas the hydrolytic condensation of trialkoxysilyl groups leads to three-dimensional crosslinking, hydrolytic condensation of dialkoxyalkoxysilyl groups leads to two-dimensional crosslinking. This means that dialkoxyalkoxysilyl groups will be more stable when prepared in an aqueous solution. However, because trialkoxysilyl groups will have a higher crosslinking density with the substrate, adhesion will often be higher.

How do I select the right organic functional group? | Choosing the optimal organic functional groups will depend on the resin or substrate with which they are used. Please see P9 for a chart of organic functional groups and applicable resins.

Which resins will show improved adhesion with Silane coupling agents, and which won’t? | For a guide on which types of silanes are effective with which resins, see the chart on P9 (Organic functional groups and applicable resins).

**Obtaining samples** | How can I obtain samples? | Contact us via the form on our website (https://www.shinetsu-kinosauri.com/showInquiry.do), or talk to a ShinEtsu distributor.

**Preparation method** | How do I determine how much silane to use? | The optimal amount can be determined based on the specific surface area of the filler and the minimal coverage area of the filler (Product list on P10-11, Product Characteristics & Packaging Options on P20-23) (See Note 1). As a rough guide, try using 0.5–2.0 wt% silane vs. the weight of the filler. The user should also be aware that silane coupling agents will be more effective with some types of fillers than with others.

Treating the filler in advance vs. the integral blend method. Do the results differ? | The typical pretreatment method is to treat the inorganic filler first, then mix it into the organic material. In the integral blend method, the inorganic filler, resins and silanes are all added at the same time, with pretreatment involved. With the integral blend method, there may be some evaporation of the silane if the materials are heat-treated immediately after mixing. We recommend heating after a suitable curing period (See Note 2).

Using silane coupling agents | What are some tips regarding treatment methods? | For best results, wash the surface of the inorganic material to remove oils, then treat with a primer.

| What are the drying conditions? | To evaporate the water and initiate the dehydration condensation reaction, we recommend drying at 80–120°C. (See Note 3) |

### Note 1
**Treatment amount**
The amount of treatment used for fillers is normally 0.5–2.0% by weight.

The model equation here can be used as a guide with respect to the amount of silane required to surface-treat fillers to produce a monomolecular film on the filler particles.

**Silane treatment amount (g) = Weight of filler (g) × Specific surface area of filler (m²/g) / Minimum covering area of the silane (m³/g)**

### Note 2
**Effects of aging on organic resin blends**

**Application to polyester resin**

When coupling agents are applied via the integral blending method and aged at room temperature, the coupling agent migrates to the interface with the inorganic material. The effect is close to that achieved with pretreated glass fiber cloth.

<table>
<thead>
<tr>
<th>Material</th>
<th>Initial</th>
<th>After boiling for 24 hours</th>
<th>Treatment silane: KBM-503</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass fiber cloth treated with KBM-503</td>
<td>70</td>
<td>68</td>
<td>70</td>
</tr>
<tr>
<td>Aged 24 hours after blending</td>
<td>60</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td>Aged 12 hours after blending</td>
<td>56</td>
<td>58</td>
<td>60</td>
</tr>
<tr>
<td>Aged 8 hours after blending</td>
<td>55</td>
<td>57</td>
<td>60</td>
</tr>
<tr>
<td>Laminates prepared immediately after blending Unaged</td>
<td>55</td>
<td>57</td>
<td>60</td>
</tr>
</tbody>
</table>

**Change in performance caused by dehydration condensation reaction**

**Comparison of treatment of polyester laminates**

The chart compares the effects of different drying conditions or effectiveness of treatment. It was found that drying the silane coupling agent for around 5 minutes at 110°C after application achieved the best results.

<table>
<thead>
<tr>
<th>Material</th>
<th>Initial</th>
<th>After 5 min drying</th>
<th>After 10 min drying</th>
<th>After 15 min drying</th>
<th>After 20 min drying</th>
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<tr>
<td>Glass fiber cloth treated with KBM-503</td>
<td>70</td>
<td>68</td>
<td>65</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>Aged 24 hours after blending</td>
<td>60</td>
<td>62</td>
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<td>60</td>
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<tr>
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<tr>
<td>Aged 8 hours after blending</td>
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<td>57</td>
<td>60</td>
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<td>60</td>
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<td>55</td>
<td>57</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

**Vapor pressure curve**

Most silane coupling agents are compounds that have boiling points, and have vapor pressures which are unique to each compound. The graph below shows the relationship between vapor pressure and temperature for some typical silane coupling agents.

**Using silane coupling agents**

Can materials be treated with silane coupling agents via vapor deposition? | Yes, See Note 4 for the vapor pressure curves of some commonly used products.

I’m going to polymerize the silane to make a coating agent. Do different silanes have different degrees of heat resistance? | See Note 5 for heat loss data for the hydrolysis products of some commonly used products.

Which types of silane coupling agents will be stable when prepared as an aqueous solution? | Ammonium salts are the most stable, and epoxyxilanes (KBM-403) are also stable. (See Note 6)

**Evaluating performance**

How can I check the silane treatment? | A simple means of evaluating hydrophobically-treated fillers is the methanol solubility test (See Note 7). For more detailed analysis, 2951 NMR is also effective.

What are some precautions when storing silane coupling agents? | As a general rule, silane coupling agents should be stored only in their original containers. Silane coupling agents hydrolyze when exposed to moisture, so they should be used as quickly as possible after opening. If the product is not used up, the container should be purged with nitrogen before storage.

How should hydrolyzed treatment liquids be stored? | The storage method may differ depending on the type and number of alkoxysilyl groups, and the type, concentration and pH of the organic functional groups. (See Note 8). Also, adding alcohol will improve shelf life and wetting of inorganic materials.

How should I store pretreated inorganic materials or resins to which silanes have been added? | The filler surface will be stable after dehydration condensation. Once Silane coupling agents have been added or grafted to resins, moisture control is critical. Be sure to store in a cool, dark place that is as dry as possible.

How can I dispose of leftover liquids and old samples? | Be sure to follow the instructions on the Safety Data Sheet. ShinEtsu does not take back leftover liquids or old samples for disposal.

What are some precautions for cleaning equipment after use? | Clean filters, tanks and lines immediately after use. These can typically be cleaned with solvents or alkaline cleaners. (See Note 9)

What are the laws and regulations concerning export to foreign countries? | There are restrictions on countries that can be exported to and on applications and quantities. These are subject to change. Also, containers may differ, so check with a sales representative for details.
Handling Precautions

- **Product quality, storage and handling**
  1. Store in a cool, dark place (out of direct sunlight) in a place cooler than room temperature where there is no risk of condensation and avoid exposure to humidity.
  2. Products containing silanes that polymerize with heat (KBM-1403, KBM-5103, X-12-1048, X-12-1050) should be kept refrigerated (0-5°C).
  3. Shin-Etsu guarantees the quality of its silane coupling agents when in a sealed, unopened state. When exposed to water or moisture, silane coupling agents undergo hydrolysis and degrade, and in the process will release substances which include methanol and hydrogen chloride. Do not leave product containers open, and always close tightly after use to prevent water and moisture from entering the container. Ideally, when closing containers, the air in the container should be replaced with dry nitrogen.
  4. After opening, products should be used up as quickly as possible, since products stored in bottles may become degraded through exposure to the alkali content of the glass.
  5. Isocyanate silane and protected functional group silanes cannot be used as part of pretreatment methods that involve adding them to water to induce hydrolysis. Isocyanate silanes will release carbon dioxide gas and deteriorate, while protected functional group silanes will lose their protective groups and deteriorate.

- **Safety & hygiene**
  1. Ensure there is proper ventilation when using these products. Avoid breathing of vapors from products or their hydrolys products, and avoid bodily contact.
  2. Wear rubber gloves, safety glasses and other protective gear to prevent contact with the skin and mucous membranes. In case of contact, wash immediately and thoroughly with running water.
  3. In case of eye contact, immediately flush eyes with plenty of running water, and consult a physician if necessary.
  4. If products get on clothing, wash off with running water.
  5. Be sure to wash hands thoroughly after handling products and before eating, drinking or smoking.
  6. In case of spills, wash with plenty of water or soak up the spilled liquid using rags or sand and dispose of it by incineration.
  8. Please read the Safety Data Sheets (SDS) before use. SDS can be obtained from our Sales Department.

- **Additional information**
  1. If you need a special high purity product for use in electronics materials manufacturing or other application, please discuss your needs with a Shin-Etsu sales representative.
  2. Contact the Shin-Etsu Sales Department to discuss issues concerning the export of these products.
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