Shin-Etsu Silicone

Silane Coupling Agents

Combination of Organic and Inorganic Materials

Resins & Oligomers, Silanes Products Selection Guide

Please scan the QR code with your smartphone or tablet, or access https://www.shinetsusilicone-global.com/guide/.
You can search for the most suitable products.

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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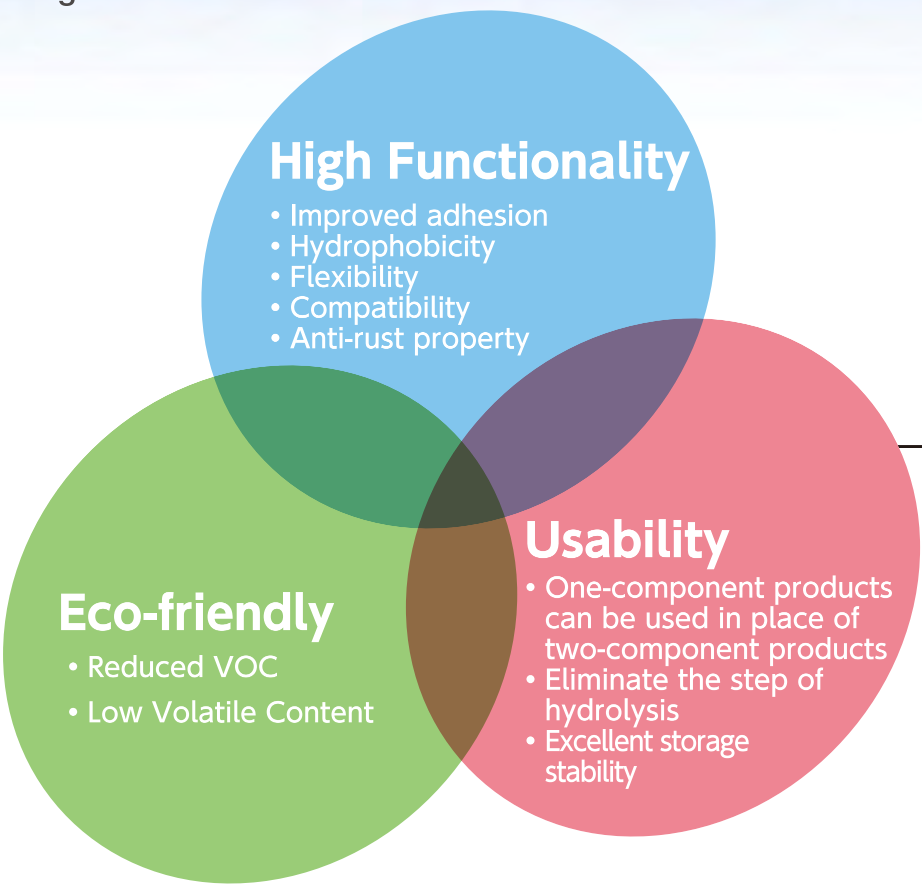


◆What are Silane Coupling Agents?

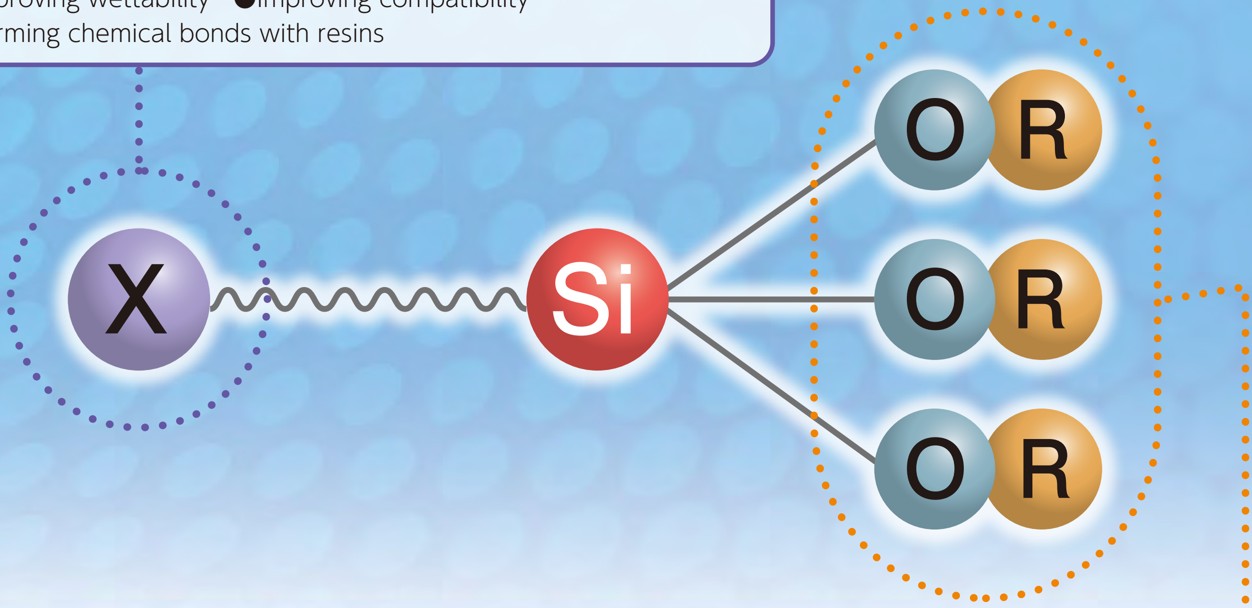
Silane coupling agents are compounds whose molecules contain functional groups that bond with both organic and inorganic materials. A silane coupling agent acts as a sort of intermediary which bonds organic materials to inorganic materials. It is this characteristic that makes silane coupling agents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

X Reactive groups that form chemical bonds with organic materials such as synthetic resins

●Vinyl groups ●Epoxy groups ●Amino groups
●Methacryloxy groups ●Mercapto groups, other

◆Reaction mechanism on organic materials

●Improving wettability ●Improving compatibility
●Forming chemical bonds with resins



OR Reactive groups that form chemical bonds with inorganic materials including glass, metals, inorganic fillers

●Methoxy groups ●Ethoxy groups, other

◆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.

◆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:

❶High Functionality ❷Eco-friendly ❸Usability

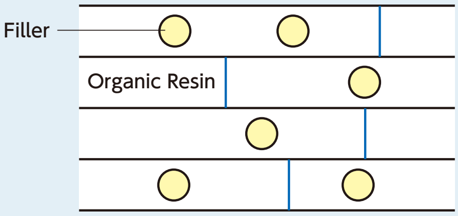
4 Types of Silane Coupling Agents Application

Compound

◆Model of Unifying Organic Resins and Fillers

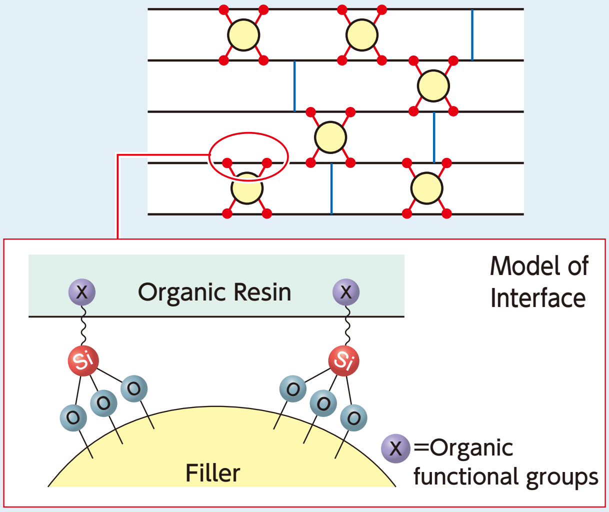
●Untreated with Silane Coupling Agents

The organic resin and filler do not fully combine, so properties do not improve as expected.



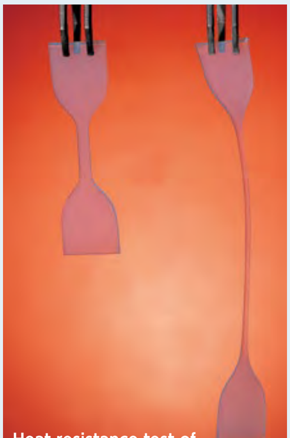
●Treated with Silane Coupling Agents

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



Heat resistance test of crosslinked polyethylene
Left: treated Right: untreated

◆Application Examples

Crosslinked polyethylene (Electrical wire covering)

Phenolic resins (grinders, moldings)

Artificial marble wall materials

SBR (tires), rubbers

Epoxy Resins (EMC)

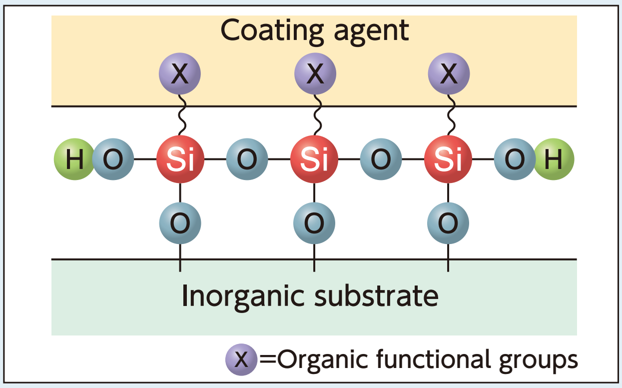
Resin Modification

Coating

Resulting Properties

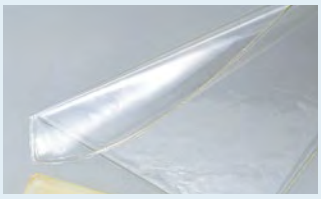
- Adhesion
- Water resistance
- Alkali resistance

◆Model of Improved Adhesion



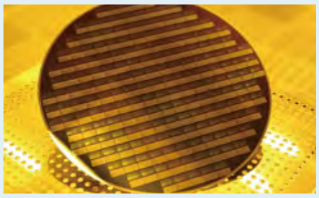
◆Application Examples

Adhesives

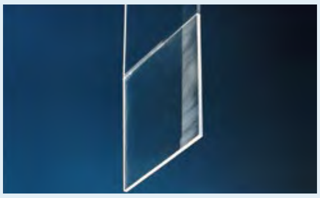


Films

Paints & Inks



Resists



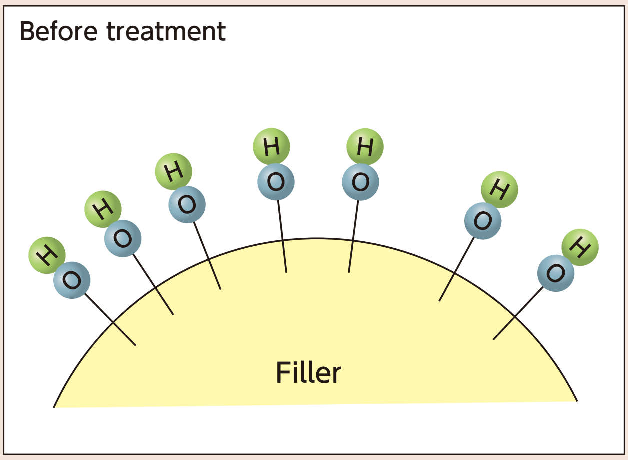
Hard coatings

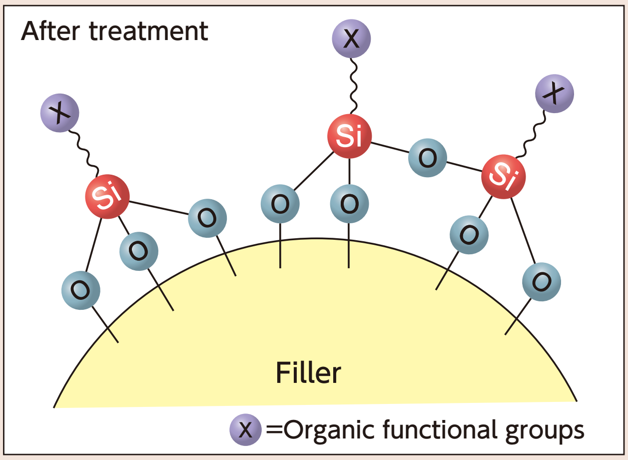
Surface Treatment

Filler

Resulting Properties
• Dispersibility • Hydrophobicity • Flowability • High loading

◆Model of Filler Surface Treatment

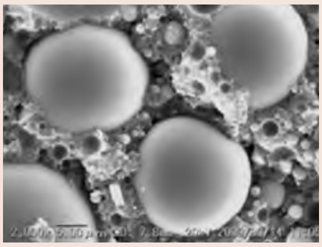


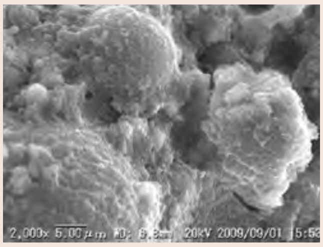


◆Application Examples

- 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.

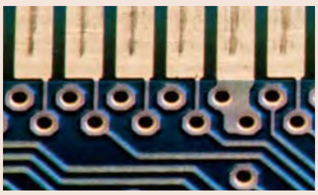

Untreated with silane coupling agents


Treated with silane coupling agents

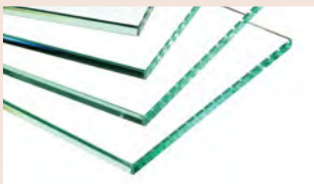
Inorganic Substrate

Resulting Properties
• Anti-rust property • Water resistance • Adhesion

◆Application Examples

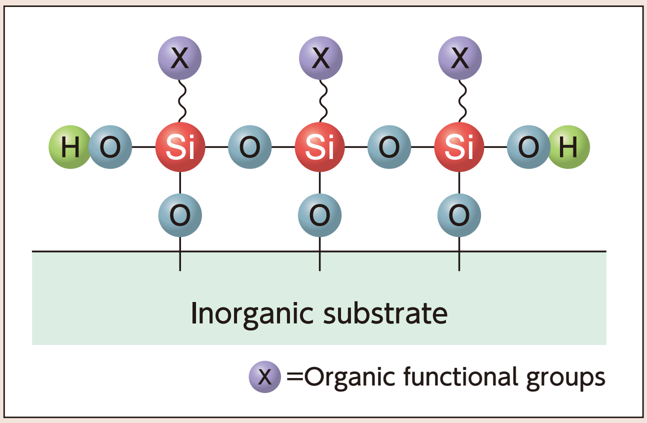

Copper foil


Steel plate


Glass


Glass fiber

◆Model of Surface Treatment of Inorganic Substrate



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.

Kneading

●Application Example of EMC
(Epoxy Molding Compound)

Epoxy & Curing agents | Fillers | Additives (i.e. wax) | Catalysts | Pigments | Silane coupling agents

Mixing
↓
Kneading
70–100℃
↓
Cooling
↓
Grinding
↓
Making tablet

EMC tablet

Resulting Properties
•Water resistance •Moisture resistance
• Durability

●Application Example of Cross-linked Polyethylene
(Silane Grafted Polyethylene)

High density polyethylene | Peroxide | KBM-1003
→ Heating & Mixing
↓
Silane grafted polyethylene

High density polyethylene | Curing agent
→ Mixing
↓
Curing agent masterbatch

Mixing
↓
Molding
↓
Immersion into hot water
100℃×2–3 h
↓
Finish

Cross-linked polyethylene
(Electrical wire covering)

Resulting Property
•Heat resistance

Resin Modification

Adding into Coating

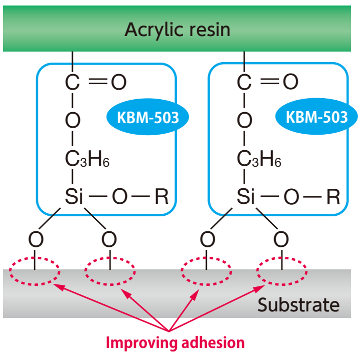
Prepare a coating liquid by adding 0.5–2.0 wt% (vs. resin weight) of a silane coupling agent.

●Adding into Epoxy Paints
(Improving anticorrosion property)

Epoxy resin | Pigment | Filler | Solvent
↓
Silane (i.e. KBM-403) adding → Stirring
↓
Final product

Resulting Property
•Anticorrosion property
(Improved adhesion with substrate)

●Model of Resin Modification



●Application Example for Paints

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

Water Type

MMA*1·BMA*2etc	KBM-503	Water	Polymerization initiator·surfactant
Total about 50 wt%	0.5–2 wt%	50–100 wt%	1–5 wt%

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

Solvent Type

MMA*1·BMA*2etc	KBM-503	Solvent	Polymerization initiator
Total about 50 wt%	0.5–2 wt%	50–100 wt%	1–2 wt%

Reaction
↓
Silicone Modified Acrylic Resin
(Non-volatile content : about 50 wt%)

*1 MMA= Methyl methacrylate
*2 BMA= Butyl Methacrylate

Resulting Properties
•Adhesion •Weatherability •High cross-linking

Surface Treatment

Filler Surface Treatment

◆Surface Treatment with Wet Method

Features :

- Enables even treatment
- Productivity is low.
- Silane-containing waste fluid must be disposed of.


Preparation


Dripping silane

Mixer
↓
Preparation ← Fillers, solvents
↓
Stirring
↓
Dripping (Under room temperature) ← Silane concentrate or Hydrolyzed solution
↓
Stirring (Under room temperature or heating)
↓
Filtering → Liquid waste disposal
↓
Drying 100–150℃
↓
Sifter

●Typical amounts for treatment
Silane: 0.5–1.0 wt% (vs. filler weight)

◆Surface Treatment with Dry Method

Features :

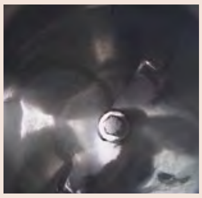
- Productivity is high.
- Clumping may occur in some cases.

Mixing
↓
Preparation ← Fillers, solvents
↓
Stirring
↓
Dripping or spraying ← Silane concentrate or Hydrolyzed solution
↓
Post mixting
↓
Sifter

●Facility
Henschel mixer
V type blender etc.

●Typical amounts for treatment
Silane: 0.5–1.0 wt% (vs. filler weight)


Preparation


Stirring


Dripping silane

Resulting Properties
・Dispersibility ・Adhesion with Resins

Primer Treatment

◆Preparation Method of Hydrolyzed Liquid

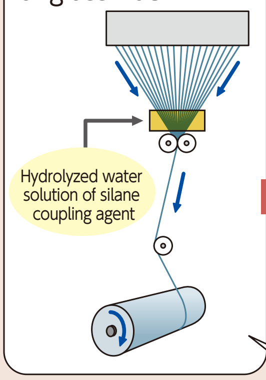
Adjust pH of aqueous solution (alcohol can be used in mix)
↓
While stirring, gradually drop in silane coupling agent (0.1–3.0 wt%).
↓
Stir until solution is clear (around 30–60 min)
↓
Filter with a mesh filter to remove foreign matter if present.

◆Treating the substrate

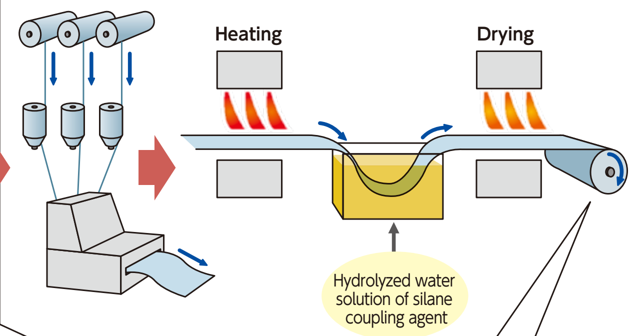
Wash the substrate.
↓
Treat with the hydrolyzed liquid (brush on, dip, etc.).
↓
Dry (at room temp. or by heating)

●Glass Cloth Application Example

Production process of glass fiber



Production process of glass cloth



Production of glass fibers treated with silane coupling agents was completed.

Production of glass clothes treated with silane coupling agents was completed.

Resulting Property
・Adhesion with Resins
(Mechanical strength of molding)

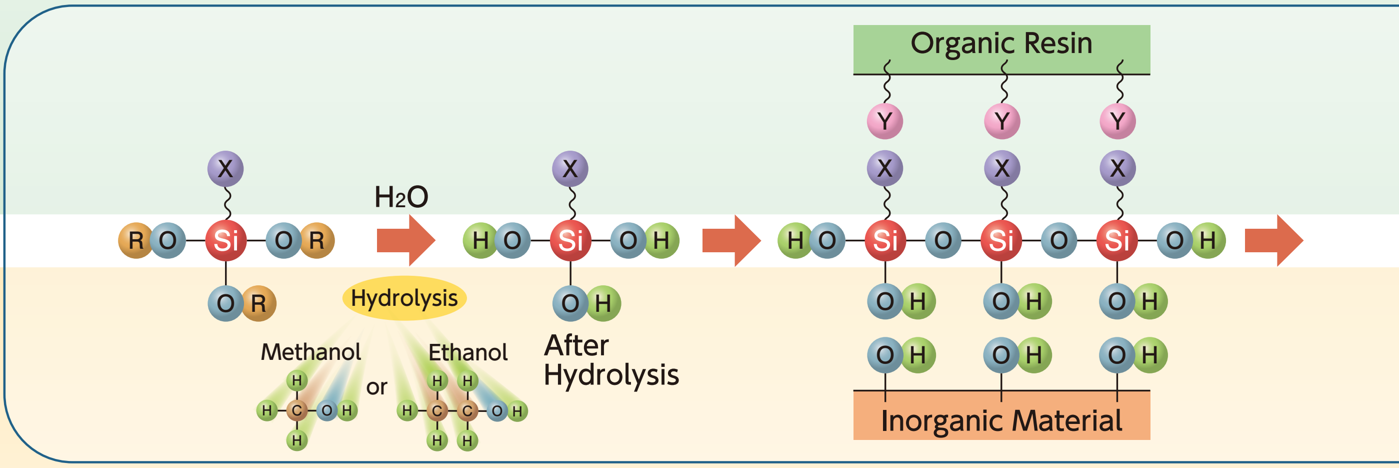
Reaction Mechanism of Silane Coupling Agents

Reaction with Organic Resins

◆Reaction Examples of Organic Functional Groups

Functional group	Reactive group	Reaction product
Epoxy group	H_2N-	Epoxide ring-opening reaction
	$HO-$	Epoxide ring-opening reaction
	$HOOC-$	Epoxide ring-opening reaction
Amino group	$Cl-$	Dehydrochlorination reaction
	$ClOC-$	Amidation reaction
	(epoxide)	Epoxide ring-opening reaction
	$OCN-$	Ureidation reaction
	$HO-$	Hydrogen bonding with hydroxyl groups
	H_2N-	Hydrogen bonding with amino groups
	$HOSO_2-$	Salt formed with sulfonic acid
	$HOOC-$	Salt formed with carboxylic acid

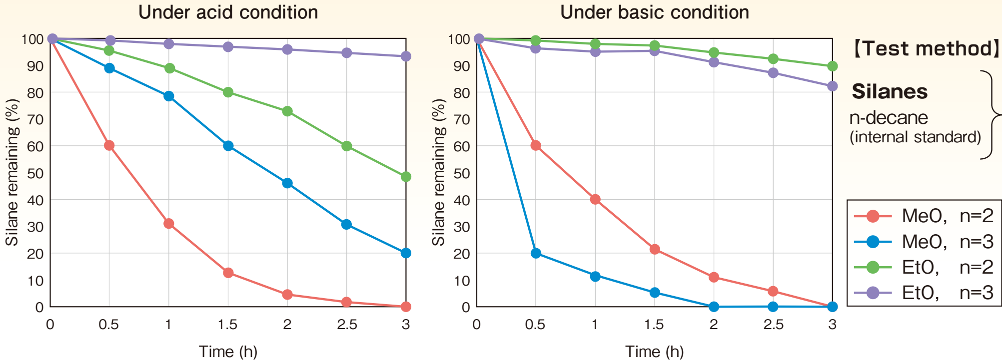
Functional group	Reactive group	Reaction product
Vinyl group		Grafting reaction
(Meth) Acryloxy group	R_1–C=CH_2–COOR	Copolymerization
Isocyanate group $-NCO$	H_2N-	Ureidation reaction
	$HO-$	Urethanation reaction
	$HOOC-$	Addition reaction
Mercapto group $-SH$	$OCN-$	Thiourethanation reaction
		Ene-thiol reaction



Reaction with Inorganic Materials

◆Hydrolytic Properties of Alkoxy Groups

Generally speaking, methoxy groups ($-OCH_3$) have higher reactivity than ethoxy groups ($-OC_2H_5$). 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, triethoxy and diethoxy types.



pH adjusted water : 0.05% acetic acid water room temperature
Mix ratio : Each silane10 wt. part (Total 40 wt. part) / n-decane 10 wt. part / pH adjusted water 20 wt. part

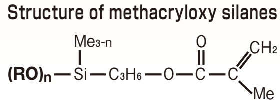
pH adjusted water : 1% Ammonia water room temperature
Mix ratio : Each silane10 wt. part (Total 40 wt. part) / n-decane 10 wt. part / pH adjusted water 20 wt. part

[Test method]

Silanes
n-decane
(internal standard)

Initial GC analysis → GC analysis (pH adjusted water)
Room temperature・Stirring

Structure of methacryloxy silanes



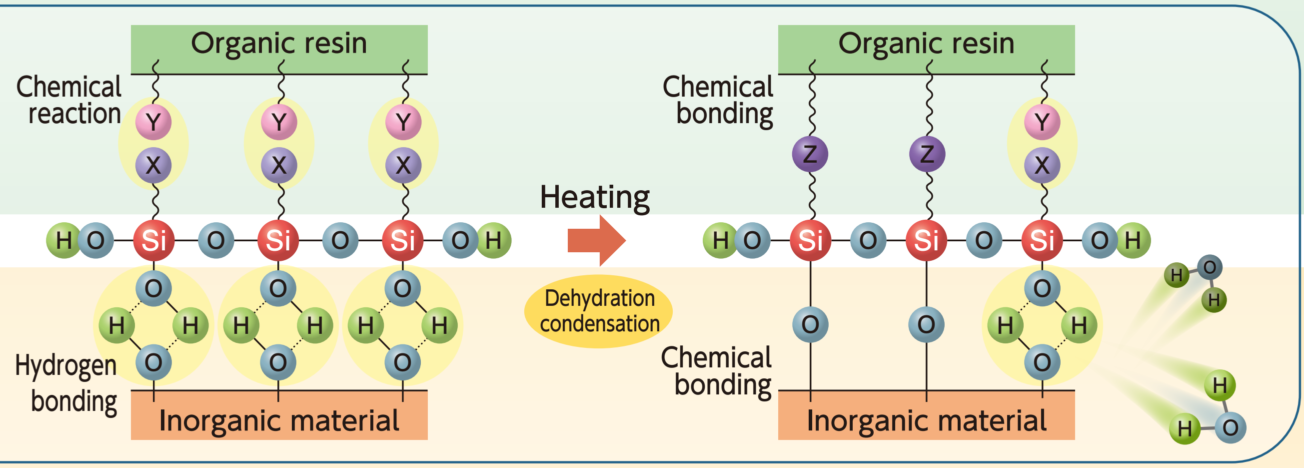
R: Me or Et

◆Organic Functional Groups and Compatible Resins

Functional groups \ Resin	Thermoplastic resins										Thermosetting resins								Elastomer･Rubber										
	Polyethylene	Polypropylene	Polystyrene	Acrylic	PVC	Polycarbonate	Nylon	Urethane	PBT･PET	ABS	Melamine	Phenolic	Epoxy	Urethane	Polyimide	Diallyl phthalate	Unsaturated polyester	Furan	Polybutadiene rubber	Polyisoprene rubber	Sulfur-crosslinked EPDM	Peroxide Crosslinked EPDM	SBR	Nitrile rubber	Epichlorohydrin rubber	Neoprene rubber	Butyl rubber	Polysulfide	Urethane rubber
Vinyl	++	++														+	+				+	+							
Epoxy	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+					+	+	+		+	+	+
Styrene			+	+																									
Methacryloxy	++	++	++	+		+		+		++						+	++				+	++							
Acryloxy	+	+	+	+		+		+		++						+	++				+	++							
Amino	+	+	++	++	++	+	++	+	+	+	+	++	++	+	+			++			+	+		+		+	+	+	+
Ureide							++					+		+	+														
Mercapto	+	+	+		+			+		+		+	+	+					+	+	++	+	+	+	+	+		++	++
Isocyanate						+	+	++	+	+	+	+	+	++	+			+											+

++: Very effective + : Effective

*Not all the functional groups are capable of coupling with the resins in question. This should be taken as a guide.



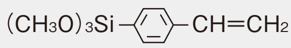
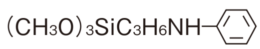
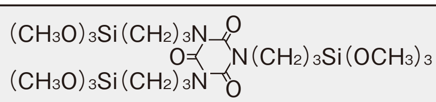
◆Types of Inorganic Materials and Reactivity of Silanol

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.

Numbers of Hydroxyl Group on the Surface	Large			Small
Reactivity	High			Low
Inorganic material	Glass Silica Alumina	Talc Clay Mica Aluminum Iron	Titanium oxide Zinc oxide Iron oxide	Graphite Carbon black Calcium carbonate

Main Products Lineup

◆Product List

Functional group	Product name	Chemical name	Structural formula
Vinyl	KBM-1003	Vinyltrimethoxysilane	$(CH_3O)_3SiCH{=}CH_2$
	KBE-1003	Vinyltriethoxysilane	$(C_2H_5O)_3SiCH{=}CH_2$
Epoxy	KBM-303	2-(3,4 epoxycyclohexyl) ethyltrimethoxysilane	
	KBM-402	3-Glycidoxypropyl methyldimethoxysilane	$(CH_3O)_2\overset{CH_3}{\overset{\vert}{Si}}C_3H_6OCH_2\overset{O}{\widehat{CH-CH_2}}$
	KBM-403	3-Glycidoxypropyl trimethoxysilane	$(CH_3O)_3SiC_3H_6OCH_2\overset{O}{\widehat{CH-CH_2}}$
	KBE-402	3-Glycidoxypropyl methyldiethoxysilane	$(C_2H_5O)_2\overset{CH_3}{\overset{\vert}{Si}}C_3H_6OCH_2\overset{O}{\widehat{CH-CH_2}}$
	KBE-403	3-Glycidoxypropyl triethoxysilane	$(C_2H_5O)_3SiC_3H_6OCH_2\overset{O}{\widehat{CH-CH_2}}$
Styrene	KBM-1403	p-Styryltrimethoxysilane	
Methacryloxy	KBM-502	3-Methacryloxypropyl methyldimethoxysilane	$(CH_3O)_2\overset{CH_3}{\overset{\vert}{Si}}C_3H_6O\underset{O}{\underset{\Vert}{C}}\overset{CH_3}{\overset{\vert}{C}}{=}CH_2$
	KBM-503	3-Methacryloxypropyl trimethoxysilane	$(CH_3O)_3SiC_3H_6O\underset{O}{\underset{\Vert}{C}}\overset{CH_3}{\overset{\vert}{C}}{=}CH_2$
	KBE-502	3-Methacryloxypropyl methyldiethoxysilane	$(C_2H_5O)_2\overset{CH_3}{\overset{\vert}{Si}}C_3H_6O\underset{O}{\underset{\Vert}{C}}\overset{CH_3}{\overset{\vert}{C}}{=}CH_2$
	KBE-503	3-Methacryloxypropyl triethoxysilane	$(C_2H_5O)_3SiC_3H_6O\underset{O}{\underset{\Vert}{C}}\overset{CH_3}{\overset{\vert}{C}}{=}CH_2$
Acryloxy	KBM-5103	3-Acryloxypropyl trimethoxysilane	$(CH_3O)_3SiC_3H_6O\underset{O}{\underset{\Vert}{C}}CH{=}CH_2$
Amino	KBM-602	N-2-(Aminoethyl)-3-aminopropylmethyldimethoxysilane	$(CH_3O)_2\overset{CH_3}{\overset{\vert}{Si}}C_3H_6NHC_2H_4NH_2$
	KBM-603	N-2-(Aminoethyl)-3-aminopropyltrimethoxysilane	$(CH_3O)_3SiC_3H_6NHC_2H_4NH_2$
	KBM-903	3-Aminopropyltrimethoxysilane	$(CH_3O)_3SiC_3H_6NH_2$
	KBE-903	3-Aminopropyltriethoxysilane	$(C_2H_5O)_3SiC_3H_6NH_2$
	KBE-9103P	3-Triethoxysilyl-N-(1,3 dimethyl-butylidene) propylamine	$(C_2H_5O)_3SiC_3H_6N{=}C\begin{matrix}C_4H_9\\CH_3\end{matrix}$
	KBM-573	N-Phenyl-3-aminopropyltrimethoxysilane	
	KBM-575	N-(Vinylbenzyl)-2-aminoethyl-3-aminopropyltrimethoxysilane hydrochloride	Active ingredients: 40%, methanol solution
Ureide	KBE-585A	3-Ureidopropyltrialkoxysilane	$(RO)_3SiC_3H_6NH\underset{O}{\underset{\Vert}{C}}NH_2$ Active ingredients: 50%, alcohol solution
	KBM-585	3-Ureidopropyltrimethoxysilane	$(CH_3O)_3SiC_3H_6NH\underset{O}{\underset{\Vert}{C}}NH_2$
Isocyanate	KBE-9007N	3-Isocyanatepropyltriethoxysilane	$(C_2H_5O)_3SiC_3H_6N{=}C{=}O$
Isocyanurate	KBM-9659	Tris-(trimethoxysilylpropyl)isocyanurate	
Mercapto	KBM-802	3-Mercaptopropylmethyldimethoxysilane	$(CH_3O)_2\overset{CH_3}{\overset{\vert}{Si}}C_3H_6SH$
	KBM-803	3-Mercaptopropyltrimethoxysilane	$(CH_3O)_3SiC_3H_6SH$

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

Flash point ℃	Minimum covering area m²/g	Solubility parameter*
23	526	7.49
54	410	7.76
163	317	8.59
134	354	8.35
149	330	8.49
128	314	8.38
144	280	8.51
136	348	8.88
115	335	8.53
125	314	8.66
136	300	8.54
128	270	8.64
126	333	9.05
110	378	8.87
128	351	9
88	435	8.56
98	352	8.56
134	—	8.41
165	305	9.15
11	—	—
11	—	10.6 (On condition of R = Et)
182	351	11.0
118	315	9.17
186	125	10.6
72	432	8.32
107	398	8.49

◆About Product Name of Shin-Etsu Silane Coupling Agents

KBM-1003 → The last digit indicates the number of hydrolyzable groups.

*There are certain exceptions.

M indicates methoxy groups, E indicates ethoxy groups.

◆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 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.

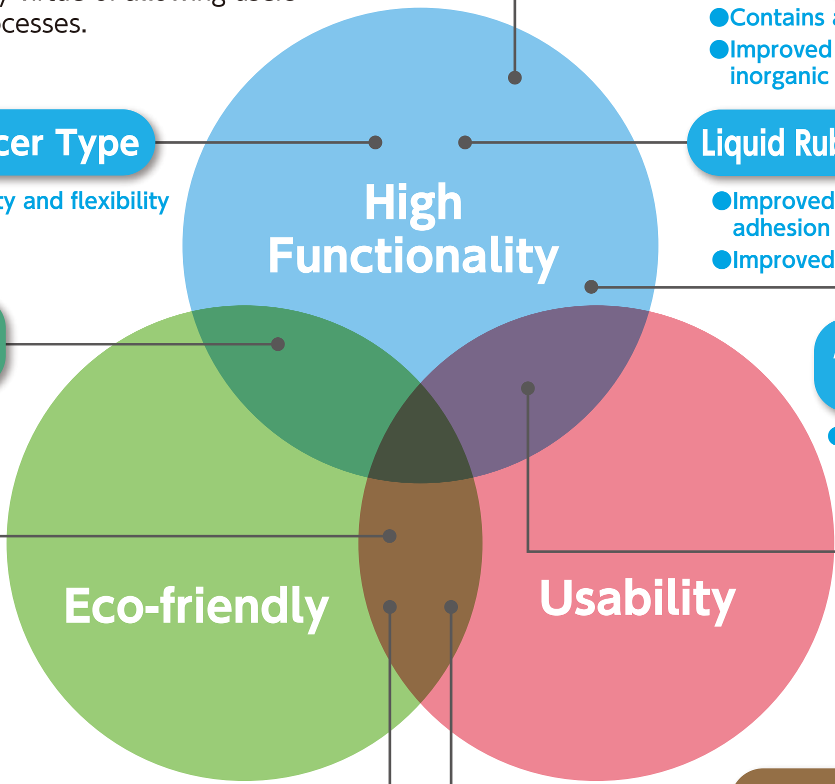
◆Solubility and Stability at Optimum pH

Product name	Solubility (pH of aqueous solution)	Shelf-life
KBM-1003	+(3.9)	Up to 10 days
KBE-1003	+(3.9)	Up to 10 days
KBM-303	+(4.0)	Up to 30 days
KBM-403	++(5.3)	Up to 30 days
KBE-402	+(4.0)	Up to 10 days
KBE-403	+(4.0)	Up to 10 days
KBM-1403	Insoluble	—
KBM-502	+(4.0)	Up to 1 day
KBM-503	+(4.2)	Up to 1 day
KBM-5103	+(4.2)	Up to 3 days
KBM-602	++(10.0)	Up to 30 days
KBM-603	++(10.0)	Up to 30 days
KBM-903	++(10.0)	Up to 30 days
KBE-903	++(10.0)	Up to 30 days
KBM-573	+(4.0)	Up to 1 day
KBM-803	+(4.0)	Up to 1 day

*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.

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.



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

Long-chain Spacer Type
- Improving hydrophobicity and flexibility

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

Multi Functional Group Type
- Low volatility
- Highly improving adhesion

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

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

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

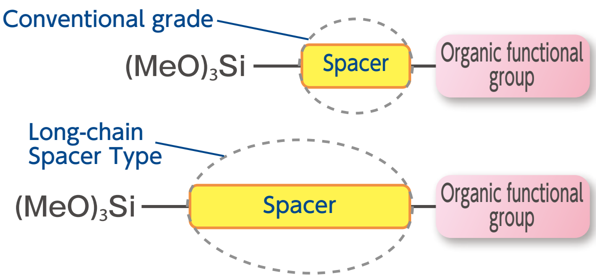
Ethoxy Type
- Product of hydrolysis is ethanol
- Hydrolyzes slowly, and compositions will be stable even after addition.

Dialkoxy Silane Type

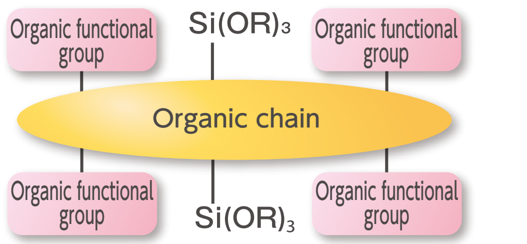
Compared to trialkoxy types:
- Lower crosslinking density for better shelf life
- Less alcohol is released

◆Model of Chemical Structure

Long-chain Spacer Type →P13

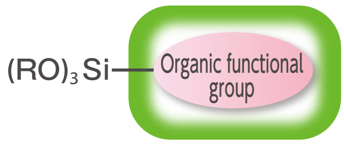


Multi Functional Group Type →P14

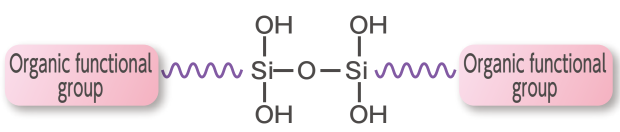


R = Me, Et

Protected Functional Group Type →P16

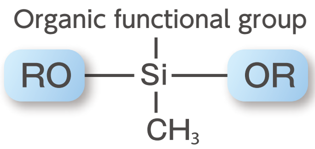


VOC Free Type →P17



Remaining amount of alcohol is up to 1 wt %.

Dialkoxy Silane Type →P17



Ethoxy Type →P17

Highly Functional Products Lineup

Long-chain Spacer Silane Coupling Agents

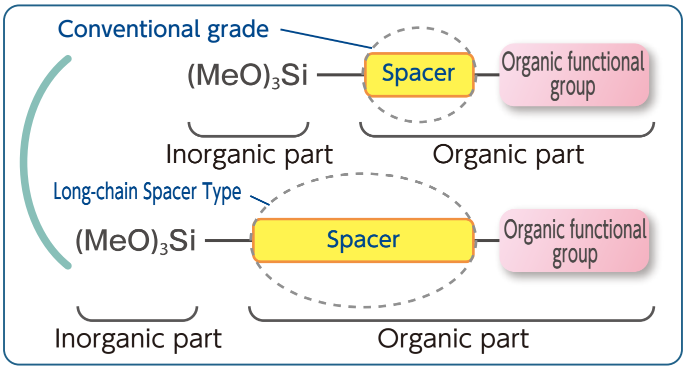
Compared to general-purpose silane coupling agents, these have higher hydrophobicity, which means that fillers treated with them will have greater dispersibility.
Another advantage is that the cured material will have improved flexibility.

◆Features and Resulting Properties

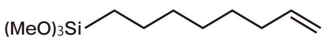
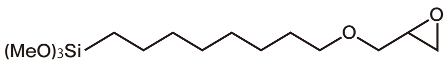
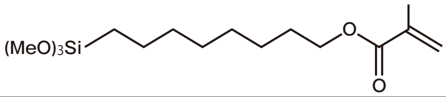
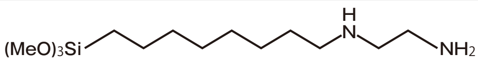
Improving hydrophobicity (lipophilicity) → Improving compatibility with resins / Filler high loading / Improving alkali resistance

Improving flexibility → Maximize freedom of functional groups (Improving reactivity) / Improving adhesion / Improving flexibility of cured materials

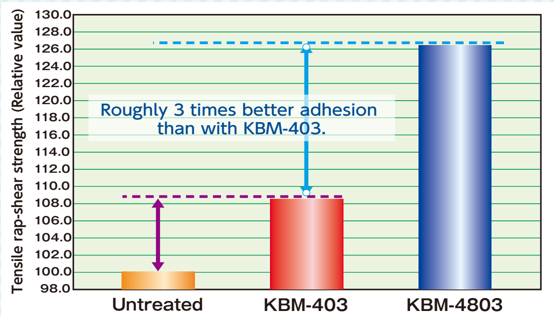
◆Model of Chemical Structure



◆Product List

Organic functional group	Product name	Chemical structure
Vinyl	KBM-1083	
Epoxy	KBM-4803	
Methacryloxy	KBM-5803	
Amino	KBM-6803	

◆Epoxy-on-glass adhesion test



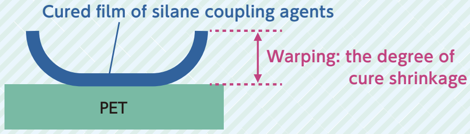
Test method
① A 1% aqueous solution is applied to a glass substrate.
② A cured material (epoxy resin/triethylenetetramine) is prepared and adhesive strength is tested.
*Adhesive strength is calculated against a standard of 100 (untreated glass).
KBM-403: 3-Glycidoxypropyl trimethoxysilane

◆Measurements of cured materials

Sample / Parameter	KBM-4803 condensate	KBM-403 (conventional grade) condensate	KBM-5803 condensate	KBM-503 (conventional grade) condensate
Pencil hardness	3H	5H	B	H
Cure shrinkage*	No	Yes	No	Yes

Cured film thickness : 5μm   Substrate : PET (thickness 0.2mm)   (Not specified values)

***Model of cure shrinkage**



◆Dispersibility of treated silicas

KBM-5803	KBM-503 (Conventional grade)

Sample / Parameter		KBM-4803 treatment	KBM-403 treatment
Viscosity	Pa･s	120	260

Long-chain spacer silane coupling agents help hold viscosity down and enable higher fill factors.
Formulation : Silane treated silica 10 wt% / Multifunctional epoxy compounds 90 wt%

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

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

Multi Functional Silane Coupling Agents

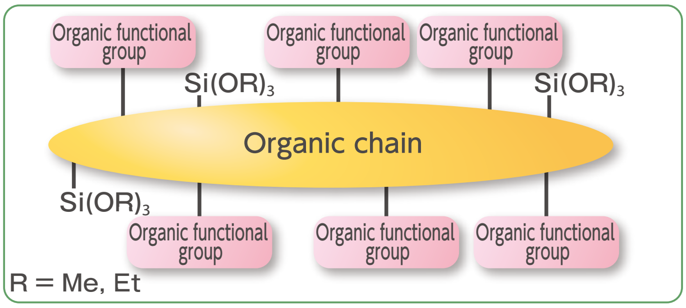
Compared to monomer types, multi functional silane coupling agents have lower volatility and a greater number of sites for reaction with resins, so you can expect improved adhesion to the substrate. And because they have film-forming properties, this type of silane coupling agent can also be used as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

◆Model of Chemical Structure

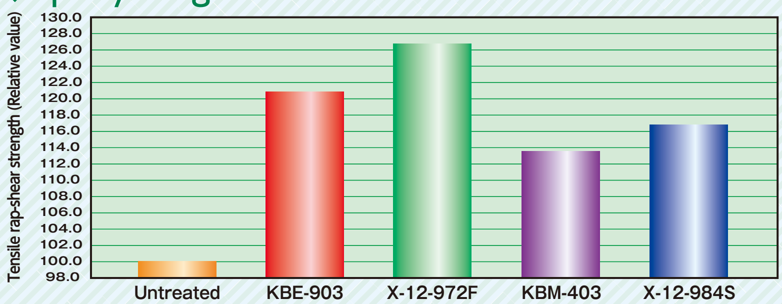


◆Product List

Organic functional group	Product name	Alkoxy group	Numbers of functional groups*2	Viscosity mm²/s	Reactive functional group equivalent g/mol
Acrylic	**X-12-1048**	MeO	1	33	300
	X-12-1050	MeO	5	6,000	150
Epoxy	**X-12-981S**	EtO	3	1,000	290
	X-12-984S	EtO	3	2,000	270
Mercapto	**X-12-1154**	MeO	3	1,500	240
Amino	**X-12-972F*1**	EtO	5	8.6	600
Isocyanate	**X-12-1159L**	MeO	2	4,000	360

*1 15% of ethanol solution *2 Number of organic functional groups to each Si atom (Not specified values)

◆Epoxy-on-glass Adhesion Test



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

*Adhesive strength is calculated against a standard of 100 (untreated glass).
KBE-903 : 3-Aminopropyltriethoxysilane
KBM-403 : 3-Glycidoxypropyl trimethoxysilane

◆Non-volatile Content of Silane Coupling Agents

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

Organic functional group	Product name	Non-volatile content %		
		105℃×3 h	150℃×3 h	180℃×3 h
(Meth)acryloxy	**KBM-5103** (Acryloxy silane)	29	0	-
	KBM-503 (Methacryloxy silane)	60	0	-
	KBM-5803 (Long-chain methacryloxy silane)	98	34	37
	X-12-1048 (Multi functional acryloxy silane)	97	84	79
	X-12-1050 (Multi functional acryloxy silane)	99	97	97
	KR-513 (Acryloxy alkoxy oligomer)	97	94	93
	X-40-9296 (Methacryloxy alkoxy oligomer)	98	95	95
Epoxy	**KBM-403** (Epoxy silane)	66	4	-
	KBM-4803 (Long-chain epoxy silane)	98	68	39
	X-12-981S (Multi functional epoxy silane)	92	87	74
	X-12-984S (Multi functional epoxy silane)	94	90	88
	KR-516 (Epoxy alkoxy oligomer)	93	85	80

*Measurements are performed on 2 g of undiluted silane in a 50 cc beaker. (Not specified values)

Polymerizable Type Silane Coupling Agents

X-12-1290, KBM-1403

◆Resulting Properties

X-12-1290 :

●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.

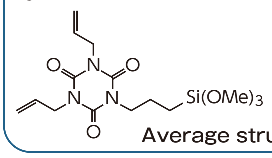
KBM-1403 :

●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.

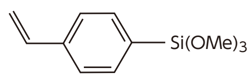
◆Chemical Structure

●X-12-1290



Average structure

●KBM-1403

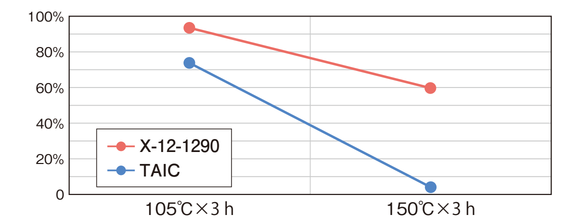


◆General Properties

Organic functional group	Product name	Chemical name	Specific gravity at 25℃	Refractive index at 25℃	Flash point ℃
Vinyl	X-12-1290	Organosilane	1.17	1.483	190
Styrene	KBM-1403*	p-styryltrimethoxysilane	1.06	1.504	136

*This product must be stored below 0℃. (Not specified values)

◆Non-volatile Content Measurement Data



Liquid Rubber Modified Type Silane Coupling Agents

Butadiene Polymer Modified Silane Coupling Agent X-12-1267B-ES

◆Resulting Properties

●Improved compatibility and adhesion of various resins

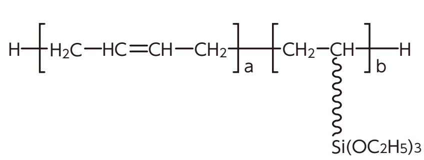
●Improved water resistance due to high hydrophobicity

◆General Properties

Item \ Product name	X-12-1267B-ES
Appearance	Pale yellow slightly cloudy liquid
Viscosity at 25℃ mPa·s	1,100
Non-volatile content 105℃×3 h %	>98
Number average molecular weight*	6,200

*Calculated by styrene conversion (Not specified values)

◆Chemical Structure



Anti-rust Properties Imparting Type Silane Coupling Agents

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

A silane coupling agent with a benzotriazole group as an organic functional group, which is effective for rust prevention of metals. By adhering the alkoxy 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.

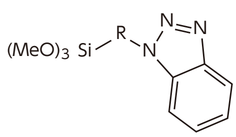
◆Applications

●Piping, etc.

●Copper, silver plating, etc.

●Metal parts for electrical products, etc.

◆Chemical Structure



◆General Properties

Product name	X-12-1214A
Appearance	Pale yellow transparent liquid
Active ingredient %	100
Viscosity at 25℃ mm²/s	170

(Not specified values)

Copper Plate Treatment

①Wash the copper plate with sulfuric acid and water

②Epoxy silane, benzotriazole, X-12-1214A 1 wt% solution immersed for 5 minutes, dried

●Initial

Untreated | KBM-403 Epoxy silane Treatment | Benzotriazole Treatment | X-12-1214A Treatment

●1day after salt water spray

Untreated | KBM-403 Epoxy silane Treatment | Benzotriazole Treatment | X-12-1214A Treatment

Polymerizable, Liquid Rubber Modified, Anti-rust Properties Imparting Type Silane Coupling Agents

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.

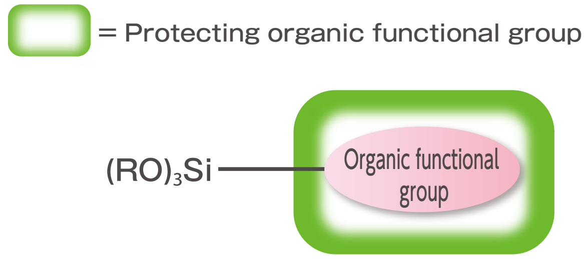
◆Features

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

◆Product List

Product name	Functional group
X-12-1056ES	Protected mercapto group silane coupling agent
KBE-9103P	Protected amino group (ketimine type)
X-12-1172ES	Protected amino group (aldimine type)
X-12-967C	Acid anhydride type

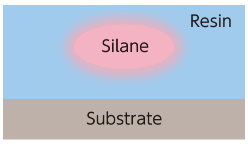
◆Model of Chemical Structure



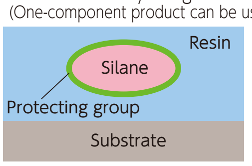
◆Benefit of Protecting Functional Groups

●Model for Improving Stability in Resin

Conventional grade
Reaction starts immediately after product is added to resin.



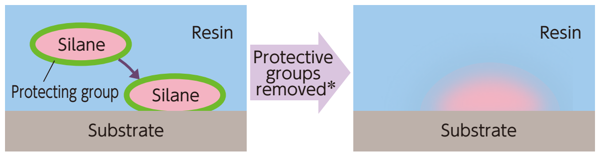
Protected functional group type
Functional groups are protected.
Product does not react after addition to resin and stability is high.
(One-component product can be used.)



●Model for Improving Adhesion

Functional groups are protected and migrate to interface with substrate. Because there is no reaction, the resin does not thicken.

Many reaction sites contribute to adhesion.



*The protective groups are removed by water or moisture, then the reaction begins.

◆Stability after addition to various resins

Shelf 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

Condition \ Product name	No additive	KBE-9103P	KBE-903
After 3 days mm^2/s	4.2	4.4	7.8
After 14 days mm^2/s	4.3	4.7	8.6

(Not specified values)

Adhesion test with KBE-9103P internal addition adhesive

●Formulation

Epoxy resin······50 wt. part　Triethylenetetramine···5 wt. part
Silane coupling agent···5 wt. part

●Tensile Strength Test Result with Aluminum

Condition \ Product name	No additive	KBE-9103P	KBE-903
Initial MPa	3.9	7.6	6.1
Water resistance test 95℃×10 h MPa	3.4	6.4	5.2

(Not specified values)

◆Change in viscosity when mixed with isocyanate compound

●Formulation

Isocyanate compound······95 wt. part
Silane coupling agent·······5 wt. part

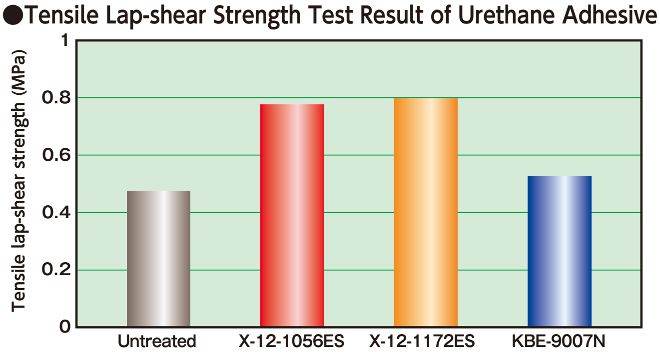
●Test Result of Viscosity　Aromatic isocyanate

Condition \ Product name	No additive	X-12-1056ES	X-12-1172ES	KBM-803
Initial mPa·s	222	139	174	119
After 50℃×1 week mPa·s	223	176	380	2,070

(Not specified values)

◆Application of Urethane Adhesive

●Tensile Lap-shear Strength Test Result of Urethane Adhesive



Formulation :
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℃/50%RH×3 days

Substrate : Glass

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.
(Ex.) When 100 kg of KBE-903 is hydrolyzed, 62 kg of ethanol is released.
Users are looking to eliminate VOCs from their operations.

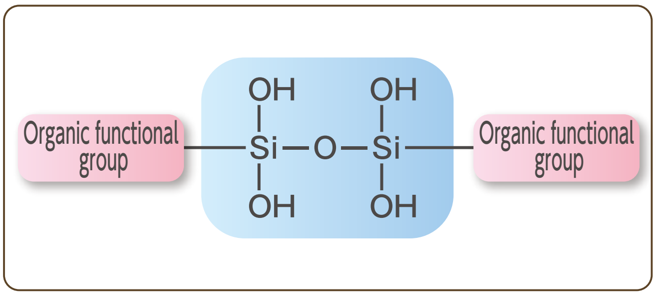
◆Features

- 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

◆Model of Chemical Structure



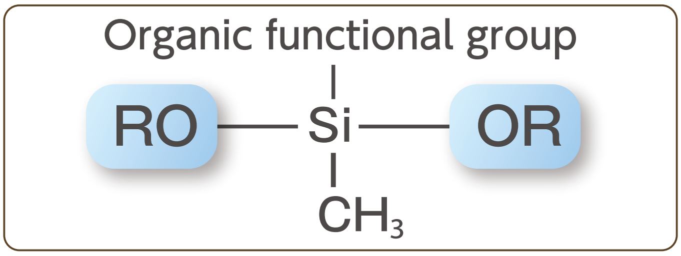
◆Product List

Product name	Organic functional groups	Active ingredient wt%	Solvent	pH*
KBP-90	**Amine** $-NH_2$	30	Water	10–12
X-12-1353	**Amine, vinyl** $-NH_2$ and $-CH{=}CH_2$	20	Water	10–12
X-12-1353M	**Amine, methyl** $-NH_2$ and $-CH_3$	20	Water	10–12
KBP-64	**Ethylenediamine+α** $-NH-C_2H_4-NH_2$	30	Water	10–12
X-12-954	**Ethylenediamine** $-NH-C_2H_4-NH_2$	30	Water	10–12
X-12-1135	**Carboxylic acid** -COOH	30	Water	1–3
X-12-1139	**Quaternary ammonium** $-NMe_2C_{18}H_{37}{}^{+}Cl^{-}$	30	Water	8–10
X-12-1126	**Quaternary ammonium** $-NMe_3{}^{+}Cl^{-}$	30	Water	8–10

*Stability suffers once pH is outside this zone. (Not specified values)

Dialkoxy Silane Coupling Agents

◆Model of Chemical Structure

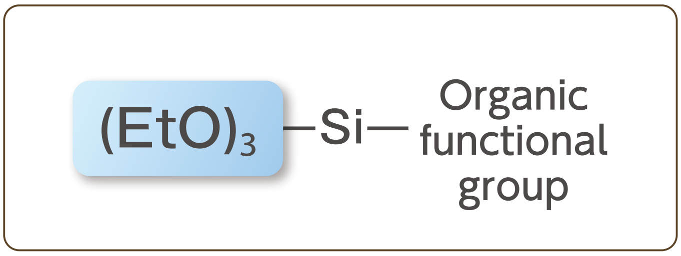


◆Features and Resulting Properties

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

Ethoxy Silane Coupling Agents

◆Model of Chemical Structure



◆Features and Resulting Properties

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

*For data on ease of hydrolysis, see graph on P8.

Silane

Shin-Etsu's 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, added to inorganic fillers to improve their dispersibility in organic polymers, and used for surface modification of inorganic materials.

◆General Properties

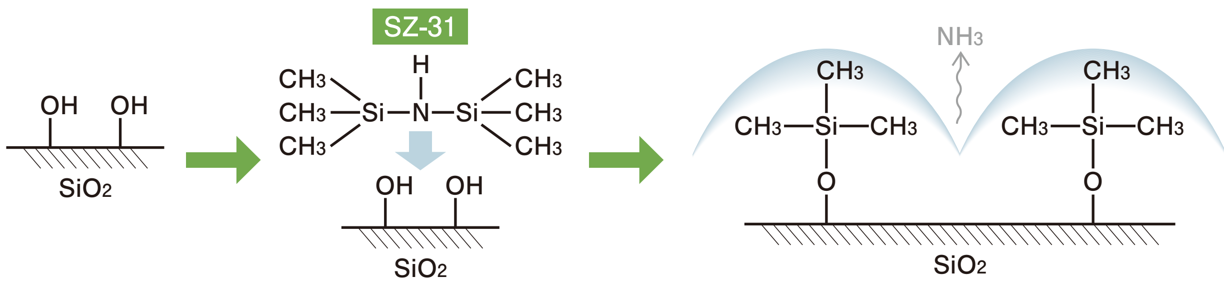
Type	Product name	Chemical name	Structural formula	Molecular weight	Specific gravity at 25℃	Refractive index at 25℃	Boiling point ℃	Flash point ℃	Minimum covering area m²/g	UN hazard classification	METI No.	CAS No.
Methoxy type	KBM-13	Methyltrimethoxysilane	$(CH_3O)_3SiCH_3$	136.2	0.95	1.369	102	8*1	573	UN-1993	2-2052	1185-55-3
	KBM-22	Dimethyldimethoxysilane	$(CH_3O)_2Si(CH_3)_2$	120.2	0.86	1.371	82	-10*1	649	UN-1993	2-2052	1112-39-6
	KBM-103	Phenyltrimethoxysilane	$(CH_3O)_3SiC_6H_5$	198.3	1.06	1.473	218	94*2	393	Not applicable	3-2635	2996-92-1
	KBM-202SS	Diphenyldimethoxysilane	$(CH_3O)_2Si(C_6H_5)_2$	244.4	1.08	1.541	304	145*2	320	UN-3082	3-2635	6843-66-9
	KBM-3033	n-Propyltrimethoxysilane	$(CH_3O)_3Si(CH_2)_2CH_3$	164.3	0.93	1.388	142	36*1	475	UN-1993	2-2052	1067-25-0
	KBM-3063	Hexyltrimethoxysilane	$(CH_3O)_3Si(CH_2)_5CH_3$	206.4	0.91	1.406	202	81*2	378	Not applicable	2-2052	3069-19-0
	KBM-3103C	Decyltrimethoxysilane	$(CH_3O)_3Si(CH_2)_9CH_3$	262.5	0.90	1.421	132℃/ 1.3kPa	122*1	297	Not applicable	2-3512	5575-48-4
	KBM-3066	1,6-Bis(trimethoxysilyl) hexane	$(CH_3O)_3Si(CH_2)_6Si(OCH_3)_3$	326.5	1.02	1.420	161℃/ 0.26kPa	164*2	239	Not applicable	2-3732	87135-01-1
	KBM-7103	Trifluoropropyl-trimethoxysilane	$(CH_3O)_3SiCH_2CH_2CF_3$	218.2	1.14	1.352	144	23*1	357	UN-1993	2-2079	429-60-7
Ethoxy type	KBE-04	Tetraethoxysilane	$(C_2H_5O)_4Si$	208.3	0.93	1.381	168	54*1	375	UN-1292	2-2048	78-10-4
	KBE-13	Methyltriethoxysilane	$(C_2H_5O)_3SiCH_3$	178.3	0.89	1.383	143	40*1	437	UN-1993	2-2052	2031-67-6
	KBE-22	Dimethyldiethoxysilane	$(C_2H_5O)_2Si(CH_3)_2$	148.3	0.83	1.384	114	15*1	526	UN-2380	2-2052	78-62-6
	KBE-103	Phenyltriethoxysilane	$(C_2H_5O)_3SiC_6H_5$	240.4	0.99	1.459	236	111*2	324	Not applicable	3-2635	780-69-8
	KBE-3033	n-Propyltriethoxysilane	$(C_2H_5O)_3Si(CH_2)_2CH_3$	206.4	0.89	1.394	179	57*1	378	UN-1993	2-2052	2550-02-9
	KBE-3063	Hexyltriethoxysilane	$(C_2H_5O)_3Si(CH_2)_5CH_3$	248.4	0.88	1.408	120.6℃/ 2.8kPa	97*1	314	Not applicable	2-2052	18166-37-5
	KBE-3083	Octyltriethoxysilane	$(C_2H_5O)_3Si(CH_2)_7CH_3$	276.5	0.88	1.415	98℃/ 10.27kPa	126*2	282	Not applicable	2-3784	2943-75-1
Silazane	SZ-31	Hexamethyldisilazane	$(CH_3)_3SiNHSi(CH_3)_3$	161.4	0.77	1.408 (20℃)	126	14*1	967	UN-3286	2-2955 or 2-2044	999-97-3
Siloxane	KPN-3504	Siloxane with hydrolyzable groups	Proprietary	—	0.97	1.405	—	190*2	—	Not applicable	Registered	—

*1: Closed cup　*2: Open cup
※1 kPa: 7.5 mmHg

(Not specified values)

◆Reaction of SZ-31

In this reaction, hydrolysis results in formation of ammonia.



◆Water repellency (surface properties)

1. Water repellency (on glass substrate)

Silane	Water contact angle (°)
KBM-13	63
SZ-31	66
KBM-3103C	84

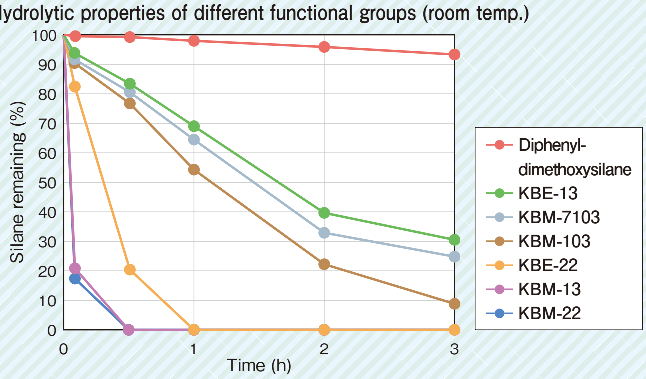
2. Surface energy reduction
Critical surface tension of silane treated surfaces (γ crit)

Silane	γc (mN/m)
KBM-7103	20.6
KBM-13	22.5
KBM-103	40.0

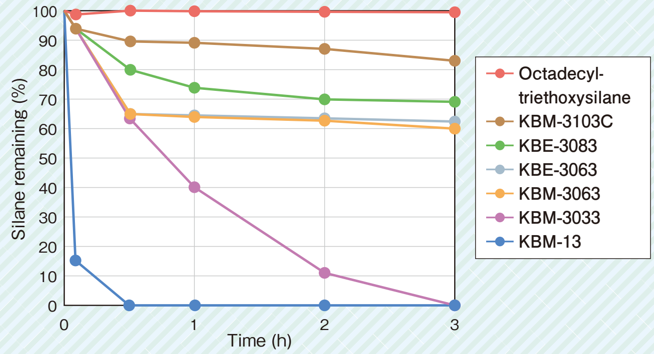
Hydrolytic properties

◆Hydrolysis rates of silanes

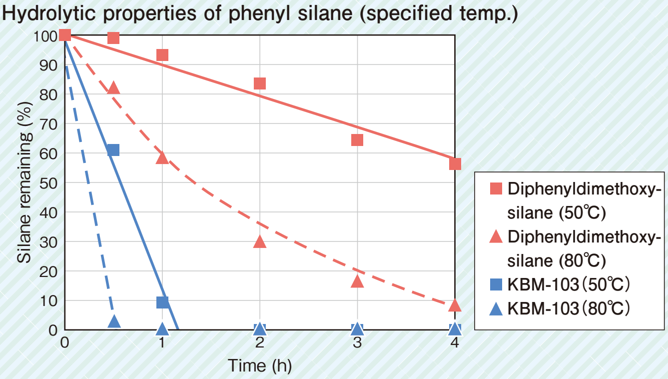
Hydrolytic properties of different functional groups (room temp.)



Hydrolytic properties of long-chain alkyl silanes (room temp.)



Hydrolytic properties of phenyl silane (specified temp.)



[Test method]

Silanes
n-decane
(internal standard)
→ Initial GC analysis → (0.05% acetic acid water; Room temp. or specified temp.) → GC analysis after passage of time

1. Silanes and n-decane 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 residue amounts.

Condensation reaction properties

◆Condensation behavior of methyl and phenyl silanes

●Trifunctional type

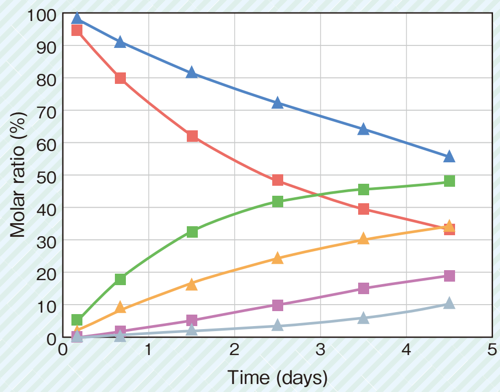
In comparing methyltrimethoxysilane (KBM-13) with phenyltrimethoxysilane (KBM-103), it was found that condensation proceeds more slowly for phenyltrimethoxysilane.

■ $Me-Si(OH)_3$ ▲ $Ph-Si(OH)_3$

■ $Me-Si(OH)_2$ (OSi≡) ▲ $Ph-Si(OH)_2$ (OSi≡)

■ $Me-SiOH$ $(OSi≡)_2$ ▲ $Ph-SiOH$ $(OSi≡)_2$

Conditions: silane 2%, acetic acid 0.3%, ethanol 50%, water 48%, temp. at 28°C



●Difunctional type

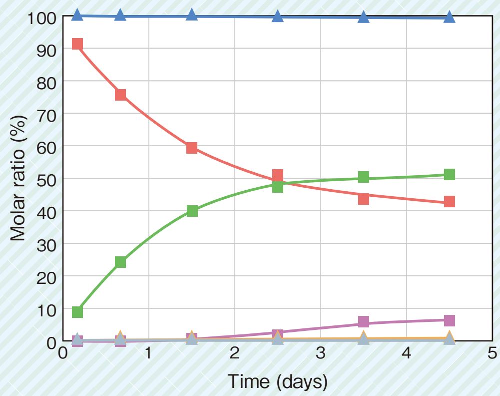
In comparing dimethyldimethoxysilane (KBM-22) with diphenyldimethoxysilane (KBM-202SS), it was found that condensation proceeds more slowly for diphenyldimethoxysilane.

■ Me, $Me-Si(OH)_2$ ▲ Ph, $Ph-Si(OH)_2$

■ Me, $Me-SiOH$, O–Si≡ ▲ Ph, $Ph-SiOH$, O–Si≡

■ Me, $Me-SiOH$, $(O-Si≡)_2$ ▲ Ph, $Ph-Si$, $(O-Si≡)_2$

Conditions: silane 2%, acetic acid 0.3%, ethanol 50%, water 48%, temp. at 28°C



Silane

Product Features & Packaging Options

Functional group	Product name	Chemical name	Molecular weight	Specific gravity at 25℃
Vinyl	KBM-1003	Vinyltrimethoxysilane	148.2	0.97
	KBE-1003	Vinyltriethoxysilane	190.3	0.90
	KBM-1083	7-Octenyltrimethoxysilane	232.4	0.92
	X-12-1290	Organosilane	-	1.17
Epoxy	KBM-303	2-(3,4 epoxycyclohexyl) ethyltrimethoxysilane	246.4	1.06
	KBM-402	3-Glycidoxypropyl methyldimethoxysilane	220.3	1.02
	KBM-403	3-Glycidoxypropyl trimethoxysilane	236.3	1.07
	KBE-402	3-Glycidoxypropyl methyldiethoxysilane	248.4	0.98
	KBE-403	3-Glycidoxypropyl triethoxysilane	278.4	1.00
	KBM-4803	8-Glycidoxyoctyltrimethoxysilane	306.5	1.01
	X-12-981S	Organosilane	-	1.11
	X-12-984S	Organosilane	-	1.16
	KR-516	Siloxane	-	1.15
Styrene	KBM-1403	p-Styryltrimethoxysilane	224.3	1.06
Methacryloxy	KBM-502	3-Methacryloxypropyl methyldimethoxysilane	232.4	1.00
	KBM-503	3-Methacryloxypropyl trimethoxysilane	248.4	1.04
	KBE-502	3-Methacryloxypropyl methyldiethoxysilane	260.4	0.96
	KBE-503	3-Methacryloxypropyl triethoxysilane	290.4	0.99
	KBM-5803	8-Methacryloxyoctyltrimethoxysilane	318.5	0.99
Acryloxy	KBM-5103	3-Acryloxypropyl trimethoxysilane	234.3	1.06
	X-12-1048	Organosilane	-	1.15
	X-12-1050	Organosilane	-	1.19
	KR-513	Siloxane	-	1.15
Amino	KBM-602	N-2-(Aminoethyl)-3-aminopropylmethyldimethoxysilane	206.4	0.97
	KBM-603	N-2-(Aminoethyl)-3-aminopropyltrimethoxysilane	222.4	1.02
	KBM-903	3-Aminopropyltriethoxysilane	179.3	1.01
	KBE-903	3-Aminopropyltriethoxysilane	221.4	0.94
	KBE-9103P	3-Triethoxysilyl-N-(1,3 dimethyl-butylidene) propylamine	-	0.92
	X-12-1172ES	Organosilane	-	1.01
	KBM-573	N-Phenyl-3-aminopropyltrimethoxysilane	255.4	1.07
	KBM-575	N-(Vinylbenzyl)-2-aminoethyl-3-aminopropyltrimethoxysilane hydrochloride (Active ingredients 40% methanol solution)	-	0.91
	KBM-6803	N-2-(aminoethyl)-8-aminooctyltrimethoxysilane	292.5	0.97
	X-12-972F	Organosilane (Active ingredients 15% ethanol solution)	-	0.83

Refractive index at 25℃	Boiling point ℃	Flash point ℃	Minimum covering area m^2/g	UN hazard classification	Packaging		
					1 L cans	18 L cans	200 L drums
1.391	123	23	526	UN-1993	1 kg	18 kg	180 kg
1.397	161	54	410	UN-1993	1 kg	17 kg	180 kg
1.423	100℃/0.93 kPa	122	336	Not applicable	1 kg	16 kg	-
1.483	-	190	-	Not applicable	1 kg	18 kg	-
1.448	310	163	317	Not applicable	1 kg	16 kg	200 kg
1.432	112℃/0.67 kPa	134	354	Not applicable	1 kg	16 kg	180 kg
1.427	290	149	330	Not applicable	1 kg	16 kg	200 kg
1.431	259	128	314	Not applicable	1 kg	16 kg	180 kg
1.425	124℃/0.39 kPa	144	280	Not applicable	1 kg	16 kg	200 kg
1.438	160℃/0.004 kPa	180	254	Not applicable	1 kg	16 kg	-
1.465	-	193	-	Not applicable	1 kg	-	-
1.474	-	193	-	Not applicable	1 kg	-	-
1.441	-	184	-	Not applicable	1 kg	18 kg	-
1.504	115℃/0.001 kPa	136	348	Not applicable	1 kg	16 kg	-
1.433	83℃/0.39 kPa	115	335	Not applicable	1 kg	16 kg	200 kg
1.429	255	125	314	Not applicable	1 kg	16 kg	200 kg
1.432	265	136	300	Not applicable	1 kg	16 kg	200 kg
1.427	129℃/0.67 kPa	128	270	Not applicable	1 kg	16 kg	200 kg
1.439	145℃/0.004 kPa	186	245	Not applicable	1 kg	16 kg	-
1.427	102℃/0.53 kPa	126	333	Not applicable	1 kg	16 kg	200 kg
1.453	-	166	-	Not applicable	1 kg	16 kg	-
1.481	-	194	-	Not applicable	1 kg	16 kg	-
1.450	-	192	-	Not applicable	1 kg	18 kg	-
1.447	234	110	378	Not applicable	1 kg	16 kg	200 kg
1.442	259	128	351	Not applicable	1 kg	16 kg	200 kg
1.422	215	88	435	Not applicable	1 kg	16 kg	200 kg
1.420	217	98	352	UN-3267	1 kg	16 kg	180 kg
1.437	-	134	-	Not applicable	1 kg	16 kg	180 kg
1.491	-	146	-	Not applicable	1 kg	-	-
1.504	312	165	305	Not applicable	1 kg	16 kg	200 kg
-	-	11	-	UN-1992	-	15 kg	160 kg
1.447	180℃/0.9 kPa	164	267	Not applicable	1 kg	16 kg	-
-	-	12	-	UN-2924	1 kg	16 kg	-

(Not specified values)

Product Features & Packaging Options

Functional group	Product name	Chemical name	Molecular weight	Specific gravity at 25℃
Ureide	KBE-585A	3-Ureidopropyltrialkoxysilane (Active ingredients 50% alcohol solution)	-	0.91
	KBM-585	3-Ureidopropyltrimethoxysilane	222.3	1.15
Isocyanate	KBE-9007N	3-Isocyanatepropyltriethoxysilane	247.4	1.00
	X-12-1159L	Organosilane	-	1.17
Isocyanurate	KBM-9659	Tris-(trimethoxysilylpropyl)isocyanurate	615.8	1.18
Mercapto	KBM-802	3-Mercaptopropylmethyldimethoxysilane	180.3	1.00
	KBM-803	3-Mercaptopropyltrimethoxysilane	196.4	1.06
	X-12-1154	Organosilane	-	1.26
	X-12-1056ES	Organosilane	-	1.05
Acid anhydride	X-12-967C	3-(Trimethoxysilyl)propylsuccinic anhydride	262.1	1.17
Benzotriazole	X-12-1214A	Organosilane	-	1.21
Liquid rubber type	X-12-1267B-ES	Organosilane	-	0.94

◆VOC Free Type

Product name	Features	Appearance
KBP-90	Amine type	Colorless to yellow liquid
X-12-1353	Amine, vinyl type	Colorless to yellow liquid
X-12-1353M	Amine, methyl type	Colorless to yellow liquid
KBP-64	Ethylenediamine +α type	Colorless to yellow liquid
X-12-954	Ethylenediamine type	Colorless to yellow liquid
X-12-1135	Carboxylic acid type	Colorless to yellow liquid
X-12-1139	Quaternary ammonium type	Colorless to pale yellow liquid
X-12-1126	Quaternary ammonium type	Colorless to yellow liquid

Refractive index at 25℃	Boiling point ℃	Flash point ℃	Minimum covering area m²/g	UN hazard classification	Packaging		
					1 L cans	18 L cans	200 L drums
-	-	11	-	UN-1992	1 kg	16 kg	180 kg
1.461	-	182	351	Not applicable	1 kg	16 kg	180 kg
1.418	250	118	315	UN-2927	1 kg	15 kg	-
1.500	-	228	-	Not applicable	1 kg	-	-
1.458	250 <	186	125	Not applicable	1 kg	18 kg	200 kg
1.448	204	72	432	UN-3082	1 kg	18 kg	200 kg
1.440	219	107	398	UN-3082	1 kg	18 kg	200 kg
1.514	-	218	-	UN-3082	1 kg	16 kg	-
1.435	-	160	-	Not applicable	1 kg	16 kg	-
1.446	178 - 182	190	298	Not applicable	1 kg	16 kg	-
1.524	-	168	-	Not applicable	1 kg	18 kg	-
1.480	-	294	-	Not applicable	1 kg	18 kg	180 kg

(Not specified values)

Active ingredients wt%	Solvent	UN hazard classification	Packaging	
30	Water	Not applicable	1 kg	16 kg
20	Water	Not applicable	1 kg	16 kg
20	Water	Not applicable	1 kg	-
30	Water	Not applicable	1 kg	18 kg
30	Water	Not applicable	1 kg	16 kg
30	Water	Not applicable	1 kg	16 kg
30	Water	Not applicable	1 kg	-
30	Water	Not applicable	1 kg	16 kg

Q & A

Here are some of the questions we frequently get from customers.
Check here first to see if your own question has been answered.

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 hydrolyzability 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 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.shinetsusilicone-global.com/showInquiry.do), or talk to a Shin-Etsu 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 silane (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.
Using silane coupling agents	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, with no 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)**
	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.
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.

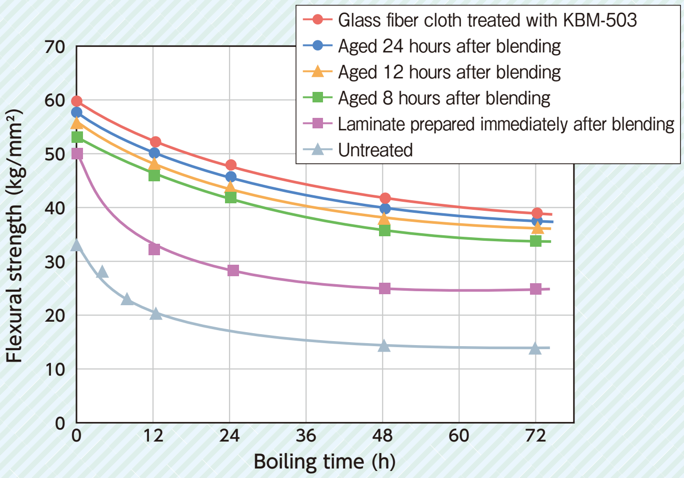
$$\text{Silane treatment amount (g)} = \frac{\text{Weight of filler (g)} \times \text{Specific surface area of filler (m}^2\text{/g)}}{\text{Minimum covering area of the silane (m}^2\text{/g)}}$$

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.



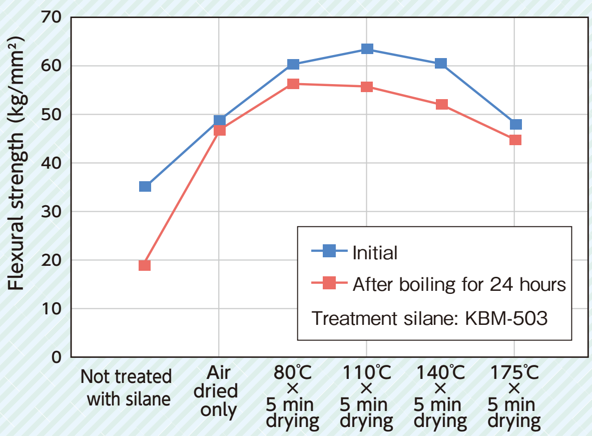
Category	Question	Answer
Using silane coupling agents	Can materials be treated with silane coupling agents via vapor deposition?	Yes. See **Note 4** for the vapor pressure curves of some commonly used products.
	I'm going to polymerize the silane to make a coating agent. Do different silanes have different 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?	Aminosilanes are the most stable, and epoxysilanes (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 wettability test **(See Note 7)**. For more detailed analysis, 29Si NMR is also effective.
Storage	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 alkoxy 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.
Disposal	How can I dispose of leftover liquids and old samples?	Be sure to follow the instructions on the Safety Data Sheet. Shin-Etsu does not take back leftover liquids or old samples for disposal.
Other	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.

Note 3

◆Change in performance caused by dehydration condensation reaction

■Comparison of treatment of polyester laminates

We compared the effects of different drying conditions on 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.



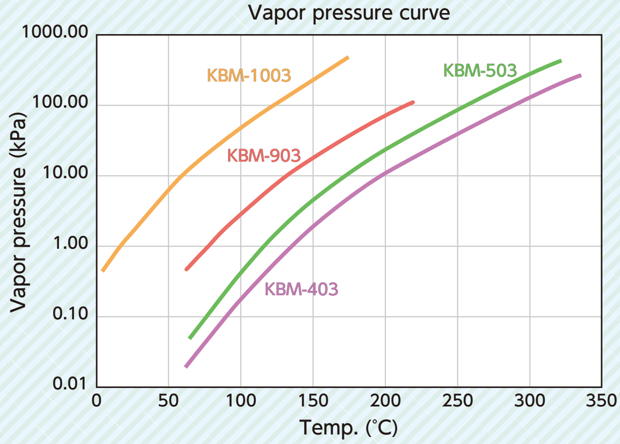
Note 4

◆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.

Vapor pressure curve



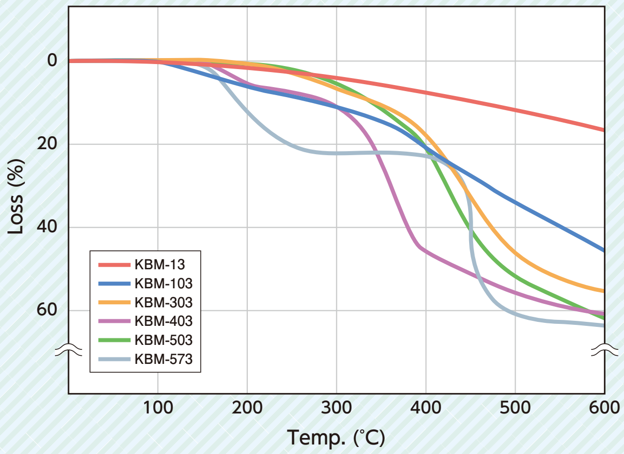
Q & A

Note 5

◆Heating loss of silane hydrolysates

Measured in a heated state.

Heating loss of silane hydrolysates

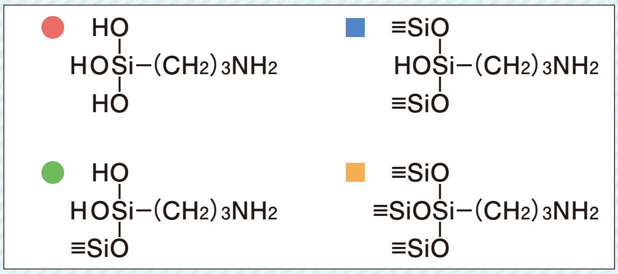


*In air, rate of temperature increase: 7.5°C/min

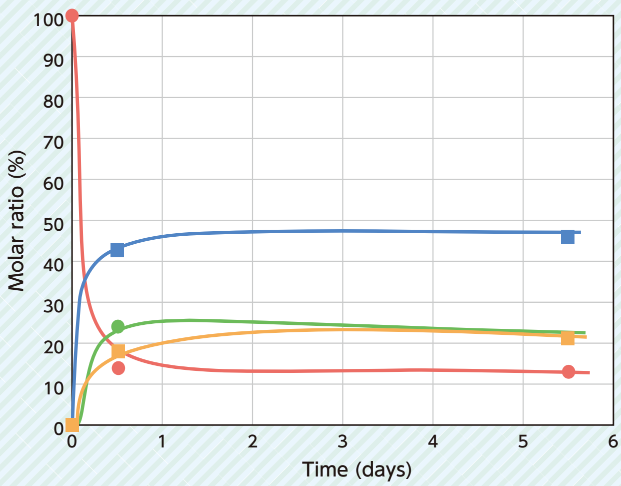
Note 6

◆Condensation behavior of amino silane in aqueous solution

An amino silane (KBE-903) was found to be very stable in aqueous solutions.



KBM-903 5% water solution (pH=11.1)



Note 7

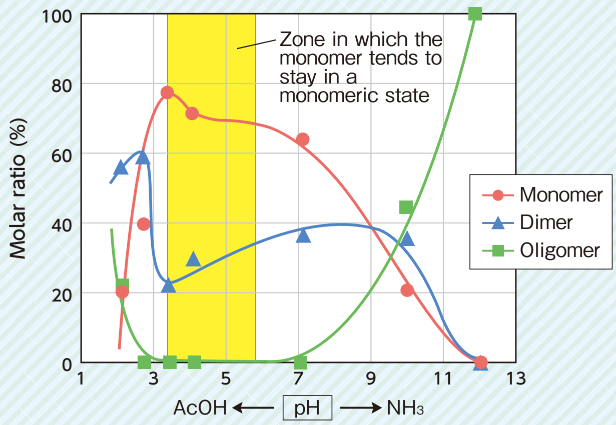
◆Checking the results of hydrophobic treatment

① Weigh out 0.5 g of the sample into a 500 mL erlenmeyer flask.
② Add 50 mL of ion-exchange softened water to ① and agitate with a magnetic stirrer.
③ While continuing agitation, drip in methanol using a burette. When all of the sample is in suspension in the softened water, note the amount of methanol that has been dripped in.
④ Determine hydrophobicity using the following equation.

$$\text{Hydrophobicity} = \frac{\text{Methanol drip amount (mL)} \times 100}{\text{Methanol drip amount (mL)} + \text{Ion-exchange softened water amount (mL)}}$$

Note 8

◆Stability of epoxy silane-water solutions and pH



Conditions: silane 10%, temp. at 30°C, time 4 h

Epoxy silane (KBM-403): $(CH_3O)_3SiC_3H_6OCH_2CH{-}CH_2$ (with O bridging CH and CH_2, epoxide ring)

Note 9

◆Cleaning silane from reactors, containers, pipes, etc.

The following methods are good for cleaning, but keep in mind that results will vary depending on the type of silane (hydrophilic, hydrophobic), the material being cleaned (glass, metal, plastic), whether the silane has simply adhered to or has reacted onto the surface, and how much has built up. Use proper caution when handling solvents and alkalis.

1. Cleaning with solvents

This method involves cleaning off the silane by placing equipment in an organic solvent (alcohol, aromatic solvent, etc.). Agitation and heating will yield better cleaning results. With some physical effort, such as scrubbing with a brush, the results will be even better. Clean the insides of pipes by flushing them with large amounts of solvent.

2. Cleaning with alkalis

If the silane has reacted to the surface or has built up in significant amounts, cleaning with a solvent will not be sufficient. If so, the silane can be removed by placing equipment in an alkaline water solution (e.g. 50% potassium hydroxide-water solution). Again, agitation and heating will yield better cleaning results. When cleaning stainless steel, the solution can be heated to around 80°C without problems. However, glass-lined equipment will be damaged at this temperature, so such equipment should not be soaked more than a few hours at temperatures not higher than around 50°C. After cleaning, be sure to remove the alkaline component by washing thoroughly with water or alcohol.

⚠ 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.
   Products containing silanes that polymerize with heat (KBM-1403, KBM-5103, X-12-1048, X-12-1050) should be kept refrigerated (0–5°C).

2. 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.
   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.

3. 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 hydrolysis 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.
7. Keep out of reach of children.
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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MS CM003
MS CM009

The Development and Manufacture of Shin-Etsu Silicones are based on the following registered international quality and environmental management standards.

Gunma Complex	ISO 9001 (JCQA-0004	ISO 14001 JCQA-E-0002)
Naoetsu Plant	ISO 9001 (JCQA-0018	ISO 14001 JCQA-E-0064)
Takefu Plant	ISO 9001 (JQA-0479	ISO 14001 JQA-EM0298)

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

This is an edited version of the product data released on Oct. 2023.