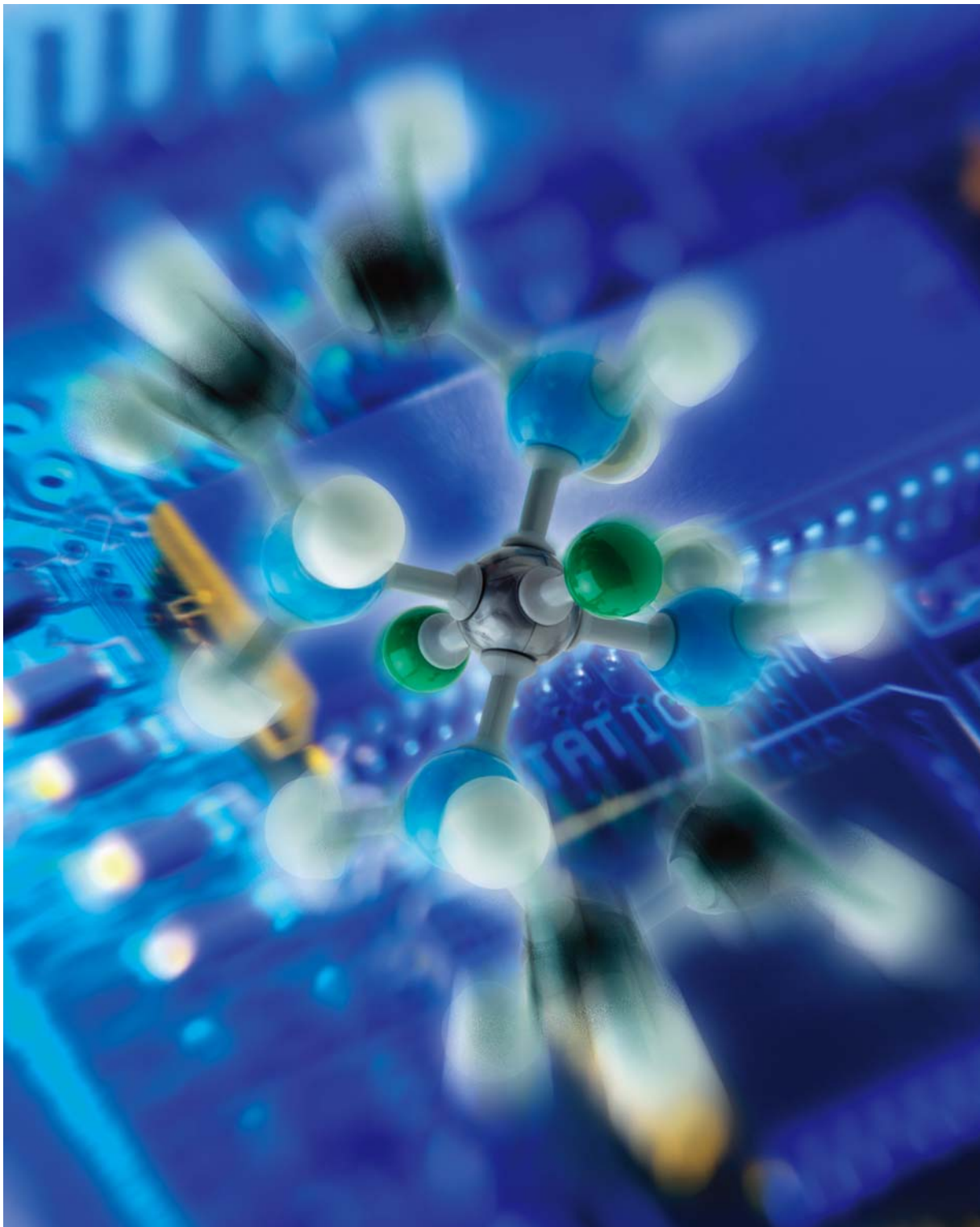
Shin-Etsu

Shin-Etsu Silicone

Silane Coupling Agents



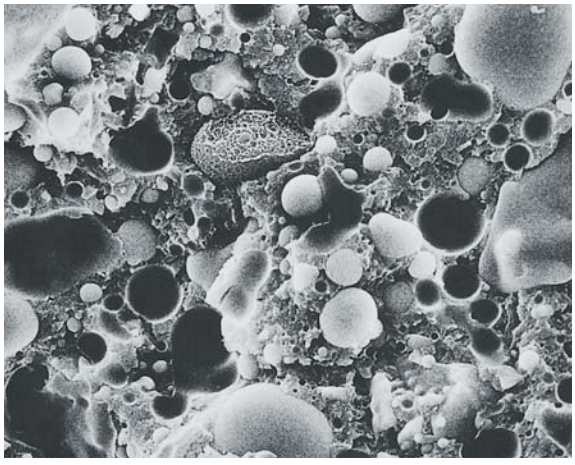
Shin-Etsu's silane coupling agents improve the functionality and quality of materials and make it possible to develop many new products.

Silane coupling agents are organosilicon compounds that have two different functional groups, including one that reacts with organic materials and one that reacts with inorganic materials. This unique characteristic enables them to bond organic materials to inorganic materials.

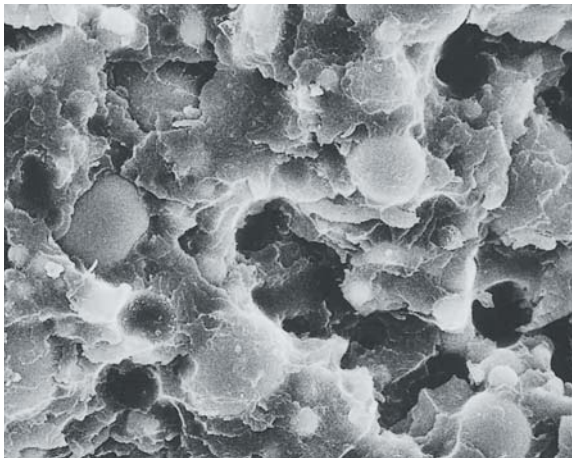
Shin-Etsu's extensive product line includes silane coupling agents with a wide variety of organic functional groups and chemical reactivities. The organic functional groups include epoxy, amino, ketimino, vinyl, methacryloxy, acryloxy, mercapto, polysulfido, isocyanato, styryl, as well as other organic groups. There are also different hydrolyzable groups available, including chloro, methoxy, and ethoxy. In addition, oligomeric organic functional coupling agents with hydrolyzable alkoxy groups are offered that provide other advantages for materials modifications.

Shin-Etsu's silane coupling agents can boost the mechanical strength of compound materials, improve moisture resistance and adhesion, and provide resin modification and surface modification to improve the functionality and quality of a wide range of materials.

Electron micrographs of cross-sections of spherical silica with unsaturated polyester resin filler.



Without silane coupling agent treatment of filler

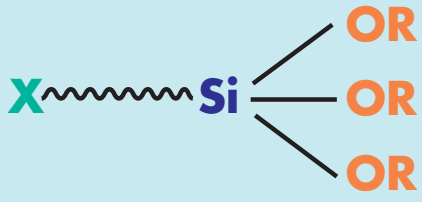


With silane coupling agent treatment of filler

Structure and Functions

■ Structure

Silane coupling agents have two different types of functional groups in each molecule.



X represents the functional organic group that reacts with organic materials such as synthetic resins.

- vinyl
- epoxy
- amino
- methacryl
- mercapto
- etc.

OR represents the hydrolyzable functional group that reacts with inorganic materials such as glass, metals, and silica.

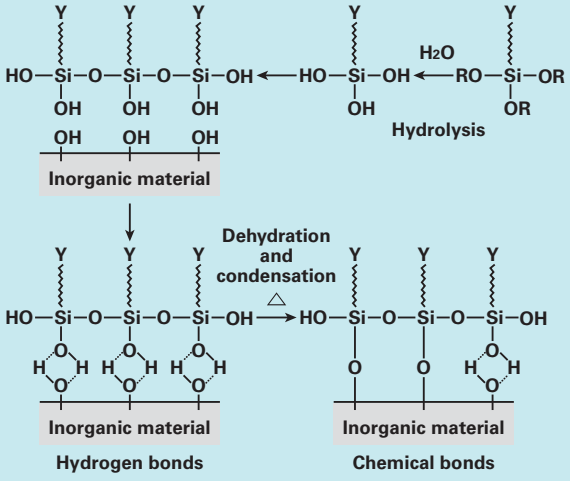
- methoxy
- ethoxy
- etc.

■ Functions

1. Interaction with Inorganic Materials and Metals

In the presence of moisture, silane coupling agents undergo hydrolysis to form reactive silanols. These silanols can condense to form oligomeric structures while simultaneously forming hydrogen bonds to the surfaces of inorganic materials and metals. Additional condensation reactions can then take place between the silanols of the coupling agents and surface hydroxyls, which are generally abundant on most inorganic materials and metals. Drying the silane treated materials leads to further condensation and dehydration reactions, thereby producing inorganic materials and metals with organic functional groups that are attached to the surface through multiple strong chemical bonds.

Source: B. Arkles, Chem. Tech., December, 765 (1977)



2. Interaction with Organic Materials

The improved adhesion between the surfaces of organic resins and inorganic materials treated with silane coupling agents is the result of the following:

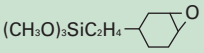
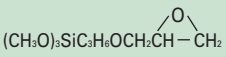
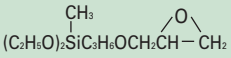
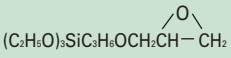
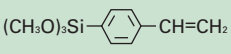
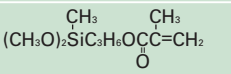
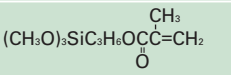
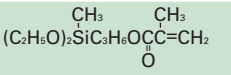
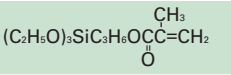
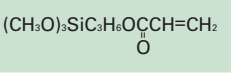
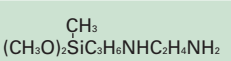
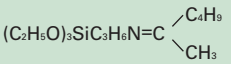
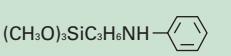
(1) Improved wetting of the treated organic surface by the resin
(2) Improved compatibility between the treated inorganic surface and the resin
(3) Chemical bonding between the treated inorganic surface and the resin
(4) Multiple hydrogen bonds between the treated inorganic surface and the resin

• Thermoplastic resins
Silane coupling agents are more effective with thermoplastic resins that have relatively high polarity.

• Thermosetting resins
Silane coupling agents increase the strength of thermosetting composites if the coupling agents have organic functional groups that match the functional reactivity of the thermosetting resins.

Product List

■ General Properties of Silane Coupling Agents

Functional Group	Grade	Chemical Name	Structural Formula	Molecular Weight	Specific Gravity (25°C)	Refractive Index (25°C)	Flash Point °C	Boiling Point °C	Minimum Covering Area, m^2/g	UN Hazardous Classification	Existing Substances No.	CAS No.
Vinyl	KBM-1003	Vinyltrimethoxysilane	$(CH_3O)_3SiCH=CH_2$	148.2	0.97	1.391	23	123	515	UN-1993	2-2066	2768-02-7
	KBE-1003	Vinyltriethoxysilane	$(C_2H_5O)_3SiCH=CH_2$	190.3	0.90	1.397	54	161	410	UN-1993	2-2066	78-08-0
Epoxy	KBM-303	2-(3,4 epoxycyclohexyl)-ethyltrimethoxysilane		246.4	1.06	1.448	163	310	317	Not applicable	3-2647	3388-04-3
	KBM-403	3-glycidoxypropyl trimethoxysilane		236.3	1.07	1.427	149	290	330	Not applicable	2-2071	2530-83-8
	KBE-402	3-glycidoxypropyl methyldiethoxysilane		248.4	0.98	1.431	128	259	314	Not applicable	2-2072	2897-60-1
	KBE-403	3-glycidoxypropyl triethoxysilane		278.4	1.00	1.425	144	124/3 mmHg	280	Not applicable	2-2071	2602-34-8
Styryl	KBM-1403	p-Styryltrimethoxysilane		224.3	1.06	1.504	136	115/0.009 mmHg	348	Not applicable	Registered	18001-13-3
Methacryloxy	KBM-502	3-methacryloxypropyl methyldimethoxysilane		232.4	1.00	1.433	115	83/3 mmHg	335	Not applicable	2-2075	14513-34-9
	KBM-503	3-methacryloxypropyl trimethoxysilane		248.4	1.04	1.429	125	255	314	Not applicable	2-2076	2530-85-0
	KBE-502	3-methacryloxypropyl methyldiethoxysilane		260.4	0.96	1.432	136	265	300	Not applicable	2-2075	65100-04-1
	KBE-503	3-methacryloxypropyl triethoxysilane		290.4	0.99	1.427	128	129/5 mmHg	270	Not applicable	2-2076	21142-29-0
Acryloxy	KBM-5103	3-acryloxypropyl trimethoxysilane		234.3	1.06	1.427	115	102/4 mmHg	333	Not applicable	Registered	4369-14-6
Amino	KBM-602	N-2(aminoethyl) 3-amino propylmethyldimethoxysilane		206.4	0.97	1.447	110	234	380	Not applicable	2-2084	3069-29-2
	KBM-603	N-2(aminoethyl) 3-amino propyltrimethoxysilane	$(CH_3O)_3SiC_3H_6NHC_2H_4NH_2$	222.4	1.02	1.442	128	259	351	Not applicable	2-2083	1760-24-3
	KBE-603	N-2(aminoethyl) 3-amino propyltriethoxysilane	$(C_2H_5O)_3SiC_3H_6NHC_2H_4NH_2$	264.5	0.97	1.438	123	135/5 mmHg	295	Not applicable	2-2059	5089-72-5
	KBM-903	3-aminopropyl trimethoxysilane	$(CH_3O)_3SiC_3H_6NH_2$	179.3	1.01	1.422	88	215	436	Not applicable	2-2061	13822-56-5
	KBE-903	3-aminopropyl triethoxysilane	$(C_2H_5O)_3SiC_3H_6NH_2$	221.4	0.94	1.420	98	217	353	Not applicable	2-2061	919-30-2
	KBE-9103	3-triethoxysilyl-N-(1,3 dimethyl-butyliden) propylamine		—	0.924	1.437	134	—	—	Not applicable	Registered	—
	KBM-573	N-phenyl-3-aminopropyl trimethoxysilane		255.4	1.07	1.504	165	312	307	Not applicable	3-2644	3068-76-6
	KBM-575	N-(vinylbenzyl)-2--aminoethyl-3-aminopropyl trimethoxysilane hydrochloride	Methanol solution. Active ingredients : 40%	—	0.91	—	11	—	—	UN-1992	3-3378	34937-00-3
	KBM-6123	Proprietary aminosilane	Methanol solution Active ingredients: 50%	—	0.94	—	11	—	—	UN-1992	Registered	Proprietary

(Not specified values)

Functional Group	Grade	Chemical Name	Structural Formula	Molecular Weight	Specific Gravity (25°C)	Refractive Index (25°C)	Flash Point °C	Boiling Point °C	Minimum Covering Area m^2/g	UN Hazardous Classification	Existing Substances No.	CAS No.
Chloro propyl	KBM-703	3-chloropropyl trimethoxysilane	$(CH_3O)_3SiC_3H_6Cl$	198.7	1.08	1.418	83	196	393	Not applicable	2-2079	2530-87-2
Mercapto	KBM-802	3-mercaptopropyl methyldimethoxysilane	$(CH_3O)_2\overset{CH_3}{\underset{\vert}{Si}}C_3H_6SH$	180.3	1.00	1.448	72	204	432	Not applicable	2-3498	31001-77-1
	KBM-803	3-mercaptopropyl trimethoxysilane	$(CH_3O)_3SiC_3H_6SH$	196.4	1.06	1.440	107	219	398	Not applicable	2-2045	4420-74-0
Sulfido	KBE-846	Bis(triethoxysilylpropyl) tetrasulfide	$(C_2H_5O)_3SiC_3H_6S_4C_3H_6Si(OC_2H_5)_3$	—	1.08	1.486	212	—	—	Not applicable	2-3124	40372-72-3
Isocyanato	KBE-9007	3-isocyanatopropyl triethoxysilane	$(C_2H_5O)_3SiC_3H_6N=C=O$	247.4	1.00	1.418	118	250	315	UN-1760	Registered	24801-88-5

(Not specified values)

■ Primers

These primers are silane coupling agents diluted in solvents. Depending upon the substrate and the application, a single silane or a combination of silanes is diluted with one or more solvents to between 1 and 20 % concentration. Silane coupling agents are soluble in most common organic solvents, including toluene, xylene, ethyl acetate, methyl ethyl ketone, acetone, alcohols, and alcohol-water mixtures. Many of the most common applications are in the construction industry where primers are used to improve the adhesion of coatings, adhesives, and sealants.

Main Primers

Grade	Appearance	Features	Active Content	Typical Diluents	UN Hazardous Classification
KBP-40	Clear to light yellow transparent liquid	Amino functional Excellent moisture resistance	7 %	Ethanol	UN-1133
KBP-41	Clear to light yellow transparent liquid	Amino functional Excellent moisture resistance	12 %	Toluene, Ethyl acetate	UN-1133
KBP-43	Clear to light yellow transparent liquid	Amino functional Excellent moisture and weather resistance	21 %	Toluene, Xylene, Ethyl acetate	UN-1133
KBP-44	Clear to light yellow transparent liquid	Isocyanate functional	14 %	Toluene, Ethyl acetate	UN-1133
KBP-90	Clear to yellow	Amino functional Aqueous solution	32 %	Water	Not applicable

(Not specified values)

Related Products

Shin-Etsu offers a wide range of products that are used to improve interfacial interactions between materials. For example, Shin-Etsu Silicones also offers low molecular weight alkoxy oligomers that contain organic substituents and hydrolyzable alkoxy groups in the same molecule. These alkoxy oligomers consist entirely of active ingredients, and they can be used as modification feedstocks and reaction diluents. Since they contain almost no silanol groups, they also have very good storage stability. This class of Shin-Etsu products also includes products that impart water and oil repellency to the surface of inorganic substances.

■ Alkoxy Oligomers

Grade	Organic Substituents	Viscosity mm^2/s	Features	UN Hazardous Classification
KC-89S	Methyl	5	Low molecular weight	UN-1993
KR-500	Methyl	25	Medium molecular weight	Not applicable
X-40-9225	Methyl	80	High molecular weight	Not applicable
KR-213	Methyl/ phenyl	3	Contains high phenyl content	Not applicable
KR-510	Methyl/ phenyl	100	High hardness, economical grade	Not applicable
X-40-9227	Methyl/ phenyl	15	Adds flexibility	Not applicable

Grade	Organic Substituents	Viscosity mm^2/s	Features	UN Hazardous Classification
X-40-9247	Methyl/ phenyl	100	High hardness, low volatile content	Not applicable
X-41-1053	Epoxy	16	Contains epoxy group	Not applicable
X-41-1056	Methyl/ epoxy	50	Contains epoxy group	Not applicable
X-41-1805	Mercapto	30	Contains mercapto group	Not applicable
X-41-1810	Methyl/ mercapto	5	Contains mercapto group	Not applicable
X-40-2308	—	4	No orgnic substiuents	Not applicable

(Not specified values)

■ Main Surface Treating Agents

Grade	Chemical Name	Structural Formula	Molecular Weight	Specific Gravity (25°C)	Refractive Index (25°C)	Flash Point °C	Boiling Point °C	UN Hazardous Classification	Existing Substances No.	CAS No.
KBE-04	Tetraethoxysilane	$(C_2H_5O)_4Si$	208.3	0.93	1.381	54	168	UN-1292	2-2048	78-10-4
KBM-13	Methyltrimethoxysilane	$(CH_3O)_3SiCH_3$	136.2	0.95	1.369	8	102	UN-1993	2-2052	1185-55-3
KBE-13	Methyltriethoxysilane	$(C_2H_5O)_3SiCH_3$	178.3	0.89	1.383	40	143	UN-1993	2-2052	2031-67-6
KBM-22	Dimethyldimethoxysilane	$(CH_3O)_2Si(CH_3)_2$	120.2	0.86	1.371	-10	82	UN-1993	2-2052	1112-39-6
KBM-103	Phenyltrimethoxysilane	$(CH_3O)_3Si$ 	198.3	1.06	1.473	94	218	Not applicable	3-2635	2996-92-1
HMDS-3	Hexamethyldisilazane	$(CH_3)_3SiNHSi(CH_3)_3$	161.4	0.77 (20°C)	1.408 (20°C)	12	126	UN-2924	2-2955	999-97-3
KBM-3063	Hexyltrimethoxysilane	$(CH_3O)_3SiC_6H_{13}$	206.4	0.91	1.406	81	202	Not applicable	2-2052	3069-19-0
KBE-3063	Hexyltriethoxysilane	$(C_2H_5O)_3SiC_6H_{13}$	248.4	0.88	1.408	95	121	Not applicable	2-2052	18166-37-5
KBM-3103C	Decyltrimethoxysilane	$(CH_3O)_3SiC_{10}H_{21}$	262.5	0.90	1.421	79	132/10 mmHg	Not applicable	2-3512	5575-48-4
KPN-3504	Siloxane with hydrolyzable group	—	Viscosity $70mm^2/s$	0.97	1.405	108	—	Not applicable	Registered	—
F-9W-9	Methylhydrogensiloxane	—	Viscosity $20mm^2/s$	1.00	1.396	185	—	Not applicable	7-477	63148-57-2
Polon MF-50	Quaternary amino trialkoxysilane	Methanol solution. Active ingredients: 40%	496.3	0.86	—	11 (methanol)	—	UN-1992	Registered	—

(Not specified values)

Applicable Resins

Functional Group	Grade	Thermoplastic Resins										Thermosetting Resins								Elastomer Rubber									
		Polyethylene	Polypropylene	Polystyrene	Acryl	Polyvinyl chloride	Polycarbonate	Nylon	Urethane	PBT, PET	ABS	Melamine	Phenol	Epoxy	Urethane	Polyimide	Diallylphthalate	Unsaturated polyester	Furan	Polybutadiene rubber	Polyisoprene rubber	Sulfer-crosslinked EPM	Peroxide crosslinked EPDM	SBR	Nitrile rubber	Epichlorohydrin rubber	Neoprene rubber	Butyl rubber	Polysulfide	Urethane rubber
Vinyl	KBM-1003	E	E														P	P				P	P							
	KBE-1003	P	P														P	P				P	P							
Epoxy	KBM-303	P	P	P	P	P	P	P	P	P	P	P	P	E	P	P	P	P	P							P		P	P	P
	KBM-403	P	P	P	E	P	P	P	E	E	E	E	P	E	P	P	P	P	E					P	P	P		P	P	E
	KBE-402	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P					P	P	P		P	P	P
	KBE-403	P	P	P	E	P	P	P	E	E	E	E	P	E	P	P	P	P	E					P	P	P		P	P	E
Styryl	KBM-1403			P	P																									
Methacryloxy	KBM-502	E	E	E	P		P		P		E						P	E				P	E							
	KBM-503	E	E	E	P		P		P		E						P	E				P	E							
	KBE-502	E	E	E	P		P		P		E						P	E				P	E							
	KBE-503	E	E	E	P		P		P		E						P	E				P	E							
Acryloxy	KBM-5103	P	P	P	P		P		P		E						P	E				P	E							
Amino	KBM-602	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			E			P			P		P	P	P	P
	KBM-603	P	P	E	E	E	P	E	P	P	P	E	E	E	P	P			E			P			P		P	P	P	P
	KBE-603	P	P	E	E	E	P	E	P	P	P	E	E	E	P	P			E			P			P		P	P	P	P
	KBM-6123											P	P	E	P															
	KBM-903	P	P	E	E	E	E	E	P	P	P	E	E	E	P	P			E			P			P		P	P	P	P
	KBE-903	P	P	E	E	E	E	E	P	P	P	E	E	E	P	P			E			P			P		P	P	P	P
	KBE-9103			P	E	P	P	P	P	P	P	P	E	E	E	P															
	KBM-573									P		P	P	P		E														
	KBM-575											P	P	E	P	P		P												
Chloropropyl	KBM-703										P			P																
Mercapto	KBM-802	P	P	P		P			P		P		P	P	P					P	P	E	P	P	P	P	P		E	E
	KBM-803	P	P	P		P			P		P		P	P	P					P	P	E	P	P	P	P	P		E	E
Sulfide	KBE-846																					E		P	P	P	P		P	P
Isocyanate	KBE-9007						P	P	E	P	P	P	P	P	E	P			P												P

E : Most effective or most common
P : Effective/ Popular

■ Effectiveness of Silane Coupling Agents with Inorganic Materials

Degree of Effectiveness	Inorganic Material
Extremely effective	Glass, silica, alumina
Very effective	Talc, clay, aluminum, aluminum hydroxide, iron, mica
Somewhat effective	Asbestos, titanium oxide, zinc white, iron oxide
Almost no effect	Graphite, carbon black, calcium carbonate

● Silane coupling agents usually work when their alkoxy groups undergo hydrolysis to form silanol and react with inorganic materials. With metal, however, mercapto, sulfide, or other functional groups may be effective as well.

How to Prepare Solutions

Silane coupling agents are usually diluted with water to a concentration of approximately 0.1 to 2.0%.
With silane coupling agents that have low solubility in water, a combination of 0.1 to 2.0%
of acetic acid in water or water-alcohol (acetic acid, water, and alcohol together) is recommended.
Acetic acid is used to increase the hydrolysis rate and improve the stability of the silanols.
Depending on the resin or on the filler treatment method,
silane coupling agents are sometimes not prepared as solutions.

Preparation Method

1. Prepare water solution containing 0.1 to 2.0% acetic acid.

The concentration of the acetic acid can be reduced if the silane coupling agent has good solubility with water. There is no need to add acetic acid in the case of aminosilanes (except KBM-573 and KBM-575).

2. Mix the acetic acid solution thoroughly while dropping the silane coupling agent.

The usual concentration of silane coupling agent is between 0.1 and 2.0 %. The mixing should be done as fast as possible without splashing. If the coupling agent is dropped too quickly, it will not disperse adequately in the solution and larger amounts of gel will form.

3. After the coupling agent has been added, continue stirring for 30 to 60 minutes.

The hydrolysis of the silane is complete when the solution has become nearly transparent.

4. Filter the solution if necessary.

Filtration is recommended if there are noticeable insoluble materials or suspended solids in the solution. If the silane solution is to be used continuously, then circulating filtration by using a cartridge with a pore size of at most 0.5 μm is recommended.

Solubility with Water

When the alkoxysilyl group in silane coupling agents dissolves in water, it forms a silanol group that is not stable and will condense over time to form a gel-like siloxane structure.
A silanol group is usually unstable in the presence of water, but it is more stable in weakly acidic solutions. Aminosilanes are an exception because the amino group helps to stabilize the silane in water solutions.
The storage stability of the solution can be improved by adjusting the pH to between 4 and 5, by adding alcohol, and by storing the solution below room temperature.

■ Solubility and Stability at Optimal pH

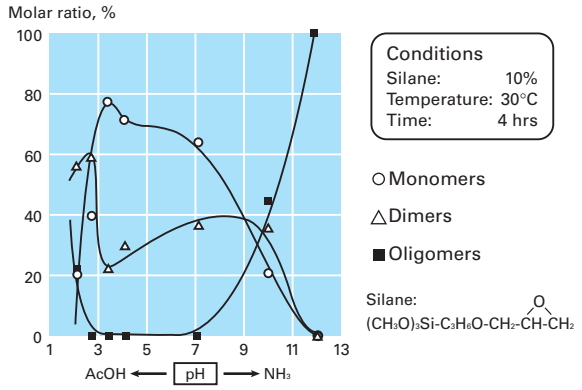
Grade	Solubility (pH of water solution)	Stability (max. storage time)
KBM-1003	M (3.9)	10 days
KBE-1003	M (3.9)	10 days
KBM-303	M (4.0)	30 days
KBM-403	V (5.3)	30 days
KBE-402	M (4.0)	10 days
KBE-403	M (4.0)	10 days
KBM-1403	Insoluble	—
KBM-502	M (4.0)	1 day
KBM-503	M (4.2)	1 day
KBM-5103	M (4.2)	3 days
KBM-602	V (10.0)	30 days
KBM-603	V (10.0)	30 days
KBE-603	V (10.0)	30 days
KBM-903	V (10.0)	30 days
KBE-903	V (10.0)	30 days
KBM-573	M (4.0)	1 day
KBM-703	M (3.9)	10 days
KBM-803	M (4.0)	1 day
KBE-846	Insoluble	—

V: Very soluble. 1% silane solution is obtained without adjusting pH of solution.
M: Moderately soluble. 1% silane solution is obtained by adjusting pH of solution.
This information is provided for comparison only and does not represent product specifications.

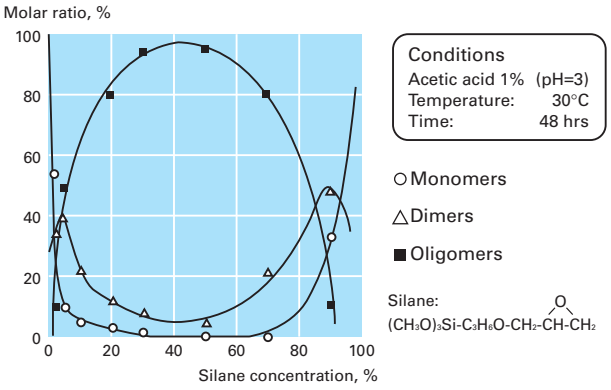
■ Stability of Silane Solutions

The stability of a silane solution varies greatly depending on the solution's pH and the concentration of the silane. The figures below show how the stability of an epoxysilane solution (KBM-403) is affected by changes in the pH and concentration.

Stability of Epoxysilane Solution vs. pH



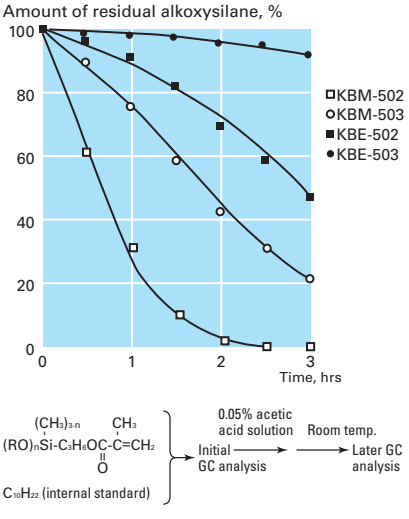
Stability of Epoxysilane Solution vs. Concentration



■ Hydrolysis and Condensation Behavior

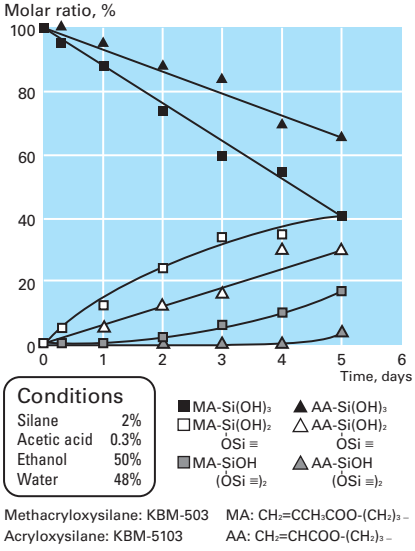
Hydrolysis Rate of Methacrylsilane

The figure below shows data on the hydrolysis rates of methacryloxysilanes as a function of the type (methoxy or ethoxy) and number of hydrolyzable groups.
When the pH was adjusted with an acetic acid solution, KBM-502 had the fastest hydrolysis rate, followed by KBM-503, KBE-502, and KBE-503.



Storage Stability of Methacrylsilane and Acrylsilane

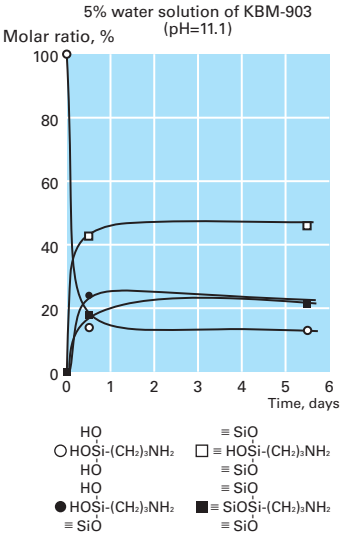
Acryloxysilane (KBM-5103) was found to condense more slowly than the corresponding methacryloxysilane (KBM-503).



Methacryloxysilane: KBM-503 MA: $CH_2=CCH_3COO-(CH_2)_3-$
Acryloxysilane: KBM-5103 AA: $CH_2=CHCOO-(CH_2)_3-$

Condensation Behavior of Aminosilanes in Water Solutions

Aminopropyltrimethoxysilane (KBM-903) is extremely stable in a water solution.



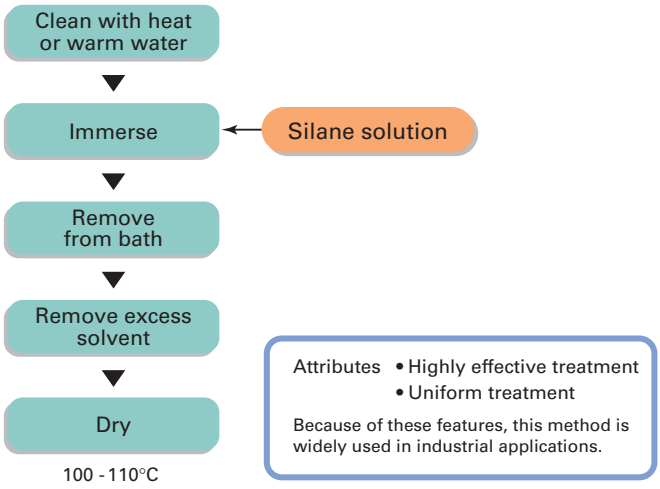
■ Organic Solvents

Silane coupling agents dissolve in most common organic solvents. Caution is required with alcohol solutions. For example, exchange reactions can occur when ethanol is used with methoxysilanes or when methanol is used with ethoxysilanes.

Treatment of Inorganic Materials

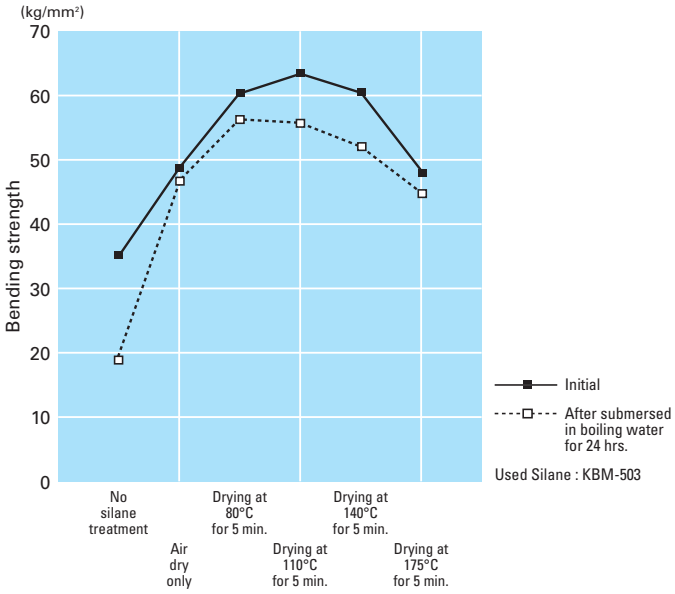
■ Surface Treatment of Inorganic Fibers and Metal Foil

Before treating inorganic fibers that will be used in textiles, clean the fibers with heat or warm water.
For metal foil, choose a solvent that will provide sufficient wetting.



■ Change in Performance by Treatment Conditions (Polyester Laminate)

The figure below shows how the performance of treated materials varied by the drying conditions.
The best results were obtained when the drying was carried out for approximately 5 minutes at 110°C.

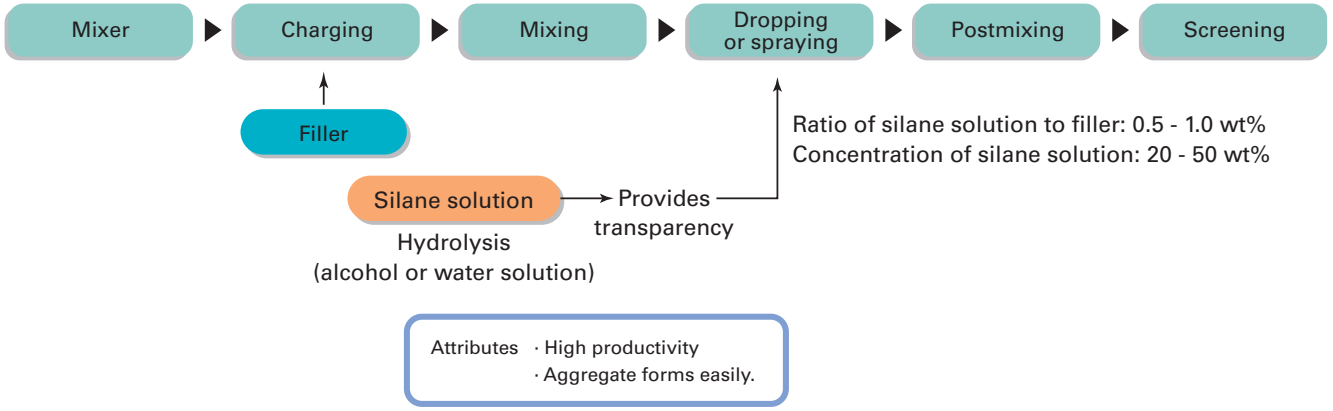


■ Methods for Treating Powders

These methods are used to treat the surfaces of inorganic materials with silane coupling agents before use with organic resins.

Dry Method

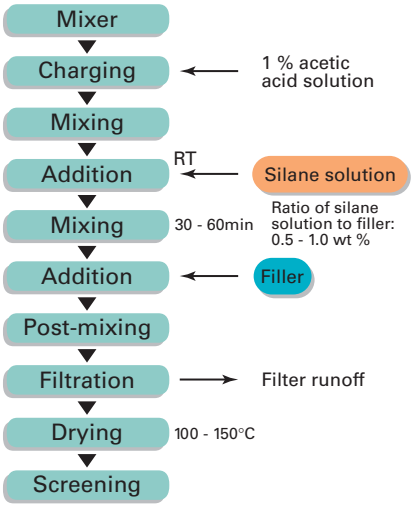
A high speed mixer is used to disperse the silane coupling agent into the inorganic material.
The silane is applied either neat or as a concentrated solution.
Although uniform treatment is more difficult with this method, it is widely used in industry because it enables the treatment of a large amount of filler in a relatively short time.



Wet Method

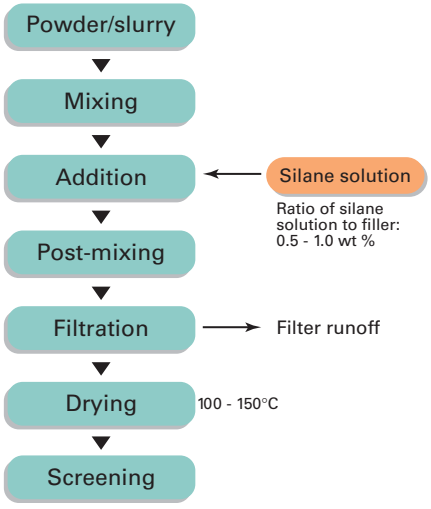
The surface of the material can be treated very uniformly and precisely by mixing a slurry of the inorganic material in a dilute solution of the silane coupling agent or by immersing the material directly into the solution.

■ Treatment Example 1



Attributes
- Uniform treatment is possible.
- Low productivity. (A large amount of heat is needed to remove the moisture.)
- The silane-containing waste fluid must be treated.

■ Treatment Example 2



Attributes
- Uniform treatment is possible.
- This method is appropriate for large volume filler manufacturers.
- The silane/organic mixed-waste effluent must be treated.

Treatment Volume

The amount of silane coupling agent is typically 0.5 to 2.0 wt % relative to the inorganic filter.
The following sample formulation gives a guideline for the amount of silane coupling agent needed to coat the surface of an inorganic filler with a silane monolayer film.

Amount of silane coupling agent (g) =

$$\frac{\text{Weight of filler (g) x Surface/volume ratio of filler } (m^2/g)}{\text{Minimum surface area covered by silane coupling agent } (m^2/g)}$$

Addition to Organic Materials

Compared to the methods previously described for treating the surface of inorganic materials, adding a silane to organic materials is somewhat less effective. Because of its excellent process efficiency, however, this method is used widely in industry.

Integral Blending

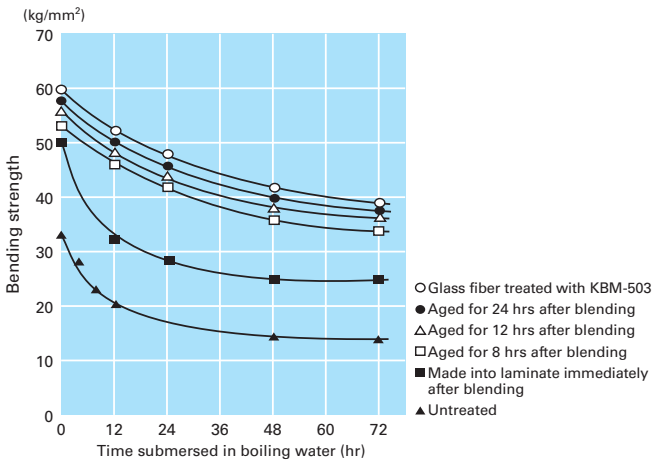
This method involves the simple blending of the silane coupling agents into the composite formula while the inorganic and organic materials are mixed together.
When aminosilanes (such as KBM-602, KBM-603, KBE-603, KBM-903, KBE-903, and KBM-573) are added to resins such as epoxy or phenol, the viscosity may increase or gelation may occur. So the pot life must be considered.

Master Batch

With this method, the silane coupling agent is first added to a small amount of the organic resin to form what is referred to as a "master batch," from which the composite is made.

■ Effect of Aging on Resin Blends (Polyester Resin)

In many cases, when a coupling agent is added by integral blending, room temperature aging can allow the coupling agent to migrate to the surface of the inorganic material. As a result, the bending strength may approach that of pretreated glass fiber.



Applications

■ Applications to Resin Composites

Silane coupling agents can greatly improve filler dispersion in resins, as well as increase the strength, moisture and heat resistance, transparency, and adhesion of the resulting composites. They are especially effective for improving the chemical bonding and polymer compatibility with thermosetting resins. They can also be effective for improving the compatibility and wetting with thermoplastic resins.

Glass Fiber Reinforced Epoxy Resins

One of the most thoroughly studied applications for silane coupling agents is epoxy resin laminated plate. These composites require outstanding electrical properties and resistance to the heat of soldering. In such cases, the glass fibers are first pretreated in an aqueous silane solution and then dipped in a resin varnish.

Encapsulating Semiconductors

The most common use for coupling agents in epoxy molding compounds is as a semiconductor sealing agent, improving the moisture resistance and electrical characteristics of the resulting composites. The coupling agent forms an interfacial bond between the resins and the filler that is stronger and more hydrolytically stable, thereby yielding a more moisture-resistant interface. When an epoxysilane coupling compound is used, the volume resistivity and bending strength are also greatly improved.

Coated Sand

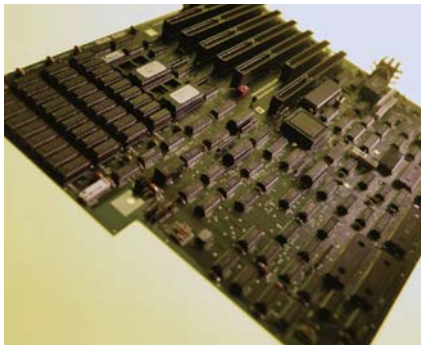
Casting molds are made from fire-resistant sand aggregates and adhesives. The quality of the casting is determined by the strength of the adhesives coated on the surfaces of the sand particles. For shell molding, which uses thermosetting resin binders, silane coupling agents can play an important role in boosting strength and reducing the fragility that is caused by moisture absorption. In most cases, the coupling agents are pre-added directly to the resin.

Paints, Adhesives, and Sealants

Silane coupling agents are used to improve the adhesion and durability of a wide range of paints and adhesives as well as to improve the dispersion of pigments and fillers.

Elastomer Tires

Silane coupling agents are also used in elastomers that are made with silica. A common application is for automobile tires. The coupling agents improve the dispersion of silica and boost the strength of the resulting SBR or other rubber.

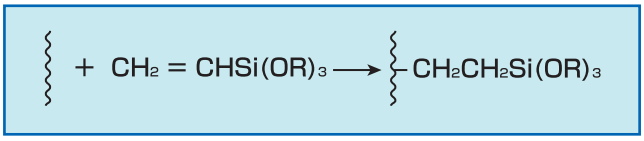


■ Resin Modification

The uses of silane coupling agents are not limited to the interfaces of composite materials. Resin modification with silanes can create high performance resins with unique and superior characteristics. Typically, resins modified with silanes display improved adhesion to inorganic materials and moisture curable properties at low temperature, as well as superior resistance to weathering, acid, heat, and solvents. Applications include polyolefins for electrical wire coatings, acrylic resins for paints, and modified sealants. The following reactions are possible for resin modification with silane coupling agents.

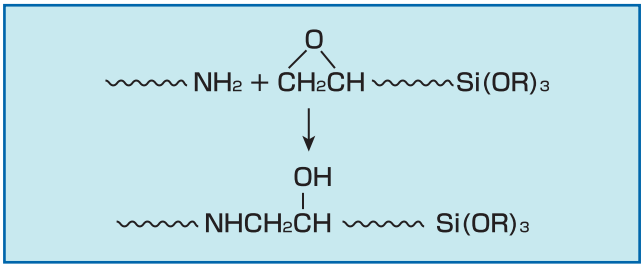
Grafting

Grafting is widely used to produce polyolefin-based materials for sealing electrical wires. Polyolefins that incorporate an unsaturated silane coupling agent (e.g., vinyltrimethoxysilane, 3-methacryloxypropyltrimethoxysilane, etc.) have a silyltrimethoxy group grafted to the polyolefin backbone that enables moisture crosslinkable resins. Moisture crosslinkable polyolefins are greatly preferred for electrical wire applications because of their reasonable cost, excellent electrical insulation, good dielectric and mechanical stability, and good resistance to chemicals. In these applications, tin-based and titanium-based catalysts are used as the silanol condensation catalysts. Dicumyl peroxide is used as a grafting reaction catalyst.



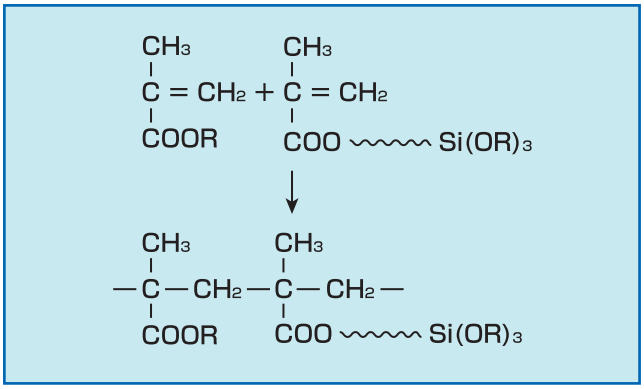
Chemical Reactions

Given the variety of silane coupling agents that are available bearing different organic functional groups as well as the many different types of organic resins produced, a large number of chemical reactions can be developed. Examples of applications for this type of silane modified resins include modified sealants, where polyoxyalkylene resins bearing a terminal aryl group react with a hydrosilane in the presence of platinum catalyst, and moisture curable urethane resins, where a thermoplastic urethane resin has been modified by an amino silane coupling agent. These and other methods for resin modification are expected to continue to produce many new resins in the future.



Copolymerization

Copolymerization of an unsaturated silane monomer along with one or more organic monomers is widely used to modify acrylic resins for paints. This method often uses a silane coupling agent bearing a methacrylic functional group and compatible co-monomers.



Containers

Container / Net weight / Grade	500-cc glass bottles	1-liter plastic bottles	1-liter rectangular cans	18-liter rectangular pails			20-liter cylinders
	500g	1kg	1kg	15kg	16kg	18kg	20kg
KBM-1003			●		●		
KBE-1003			●	●			
KBM-303			●		●		
KBM-403			●		●		
KBE-402			●		●		
KBE-403			●		●		
KBM-1403			●		●		
KBM-502			●		●		
KBM-503			●		●		
KBE-502			●		●		
KBE-503			●		●		
KBM-5103			●		●		
KBM-602			●		●		
KBM-603			●		●		
KBE-603			●		●		
KBM-903			●		●		
KBE-903			●		●		
KBE-9103			●		●		
KBM-573	●				●		
KBM-575		●(1)		●(2)			
KBM-6123			●	●			
KBM-703		●			●		
KBM-802			●		●		
KBM-803			●			●	
KBE-846			●		●		
KBE-9007			●	●			

(1) 2-liter plastic bottles.

(2) 20-liter pails.

● These products are also available in drums. Please contact a sales representative for further information.

Handling Precautions

■ Quality, Storage, and Handling

1. The products described in this catalog should be kept in a dark, dry location that is cooler than room temperature and is not exposed to direct sunlight.
2. Silane coupling agents may deteriorate when in contact with water or moisture, producing byproducts such as hydrogen chloride or methanol. These products should be handled with special care when kept in the open air. After opening, they should be tightly sealed to limit exposure to water or moisture. It is recommended that dry nitrogen be used to replace the air in opened containers.
3. Please contact our Sales Department if you need products with especially high purity for use in electronic materials or other applications.
4. Please read the Material Safety Data Sheet (MSDS) before use. MSDS can be obtained from our Sales Department.

■ Safety

1. These products should be handled with adequate ventilation to avoid inhalation or contact with their vapor or the vapor of their hydrolytic byproducts.
2. To avoid contact with skin or membranes, wear rubber gloves, goggles, and other protective gear. If contact occurs, flush the affected area immediately with large amounts of water.
3. If eye contact occurs, flush the eyes immediately with large amounts of water and consult a doctor if necessary. Special and prompt care is required in the case of aminosilanes.
4. If contact with clothes occurs, flush the exposed clothing with water and then wash the clothes immediately.
5. After using silanes, wash your hands very thoroughly before eating, drinking, or smoking.
6. If silane fluids are spilled, either flush the exposed area with large amounts of water or clean it with rags or sand, which should be promptly disposed of by burning.

■ Other Information

1. Information on Shin-Etsu silanes is available on our Web site. You may obtain information about our products, inquire about purchasing them, request samples, and download catalogs.
2. Catalogs of Shin-Etsu's silanes, silylating agents, silane compounds for organic synthesis, and other products are also available. Please contact our Sales Department.

Shin-Etsu

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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)

CM009

http://www.silicone.jp/