

Silane Coupling Agents

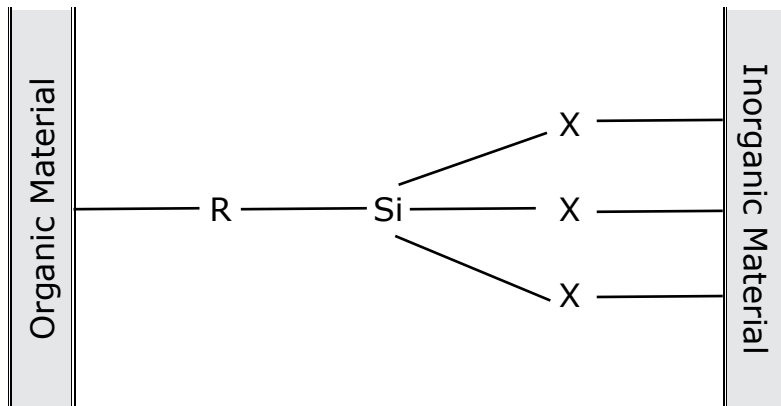
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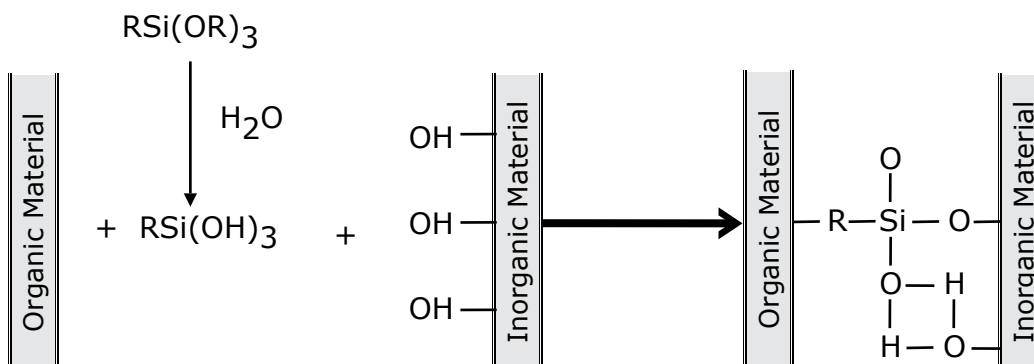
Introduction:

Silane coupling agents are generally illustrated:



Silicon (Si) is the center of the silane molecule which contains an inorganic functional group (R) [ex: vinyl, amino, chloro, epoxy, mercapto, etc.] with a (X) [ex: methoxy, ethoxy, etc.]. The functional group (R) will attach to an organic resin while the functional group (X) attaches to an inorganic material or substrate to achieve a "coupling" effect.

Silane coupling agents are predominantly used as mediators, binding organic materials to inorganic materials. As a result, silanes will improve the electrical and mechanical strength properties of materials in wet or dry conditions.



Silane coupling agents are primarily used in reinforced plastics and electric cables composed of crosslinked polyethylene. Other uses include resins, concrete, sealant primers, paint, adhesives, printing inks and dyeing auxiliaries.

The inorganic group (X) of the silane molecule will react to produce silanol, which forms a metal hydroxide or siloxane bond with the inorganic material. The organic group (R) of the silane molecule will react with the organic material to produce a covalent bond. As a result, the organic material and the inorganic material are tightly bound together after heating.

Treating Process of Aqueous Solutions of Silanes for Glass Fiber:

An aqueous solution of distilled or deionized water (or a mixed solution of water and alcohol) and 0.1% to 0.5% silane coupling agent is prepared. The glass fiber is dipped into the solution and dried at ambient temperature, followed by heating at 110°C to 120°C for 5 to 10 minutes.

Fillers: A filler which contains an excess of hydroxyl groups on the surface is especially effective.

- **Very Effective:** Silica, Alumina, Glass, Quartz or Aluminum silicate
- **Moderately Effective:** Talc, Hydrated Clay, Alumina or Iron Powder
- **Fairly Effective:** Asbestos, Titanium Dioxide or Zinc Oxide

1. Dry Process - the filler is treated by spraying an aqueous solution of silane followed by forced air or nitrogen to dry.
2. Wet Process - an aqueous solution of silane is added to a filler dispersed in water. Following agitation, the filler is allowed to precipitate by separation and drying.
3. Spray Process - an aqueous solution of silane is sprayed on the filler followed by heating. This process is simple and drying after application is unnecessary.

Silane Treating Process for Metal, Ceramic or Glass Substrates:

The substrate is treated with a mixed solution of 0.2% to 2.0% silane coupling agent and 98.0% to 99.8% diluent (water/alcohol mixture or hydrocarbon). The dilution could be applied by spray or immersion procedures, followed by drying at 120°C to 180°C for 2 to 5 minutes. An aqueous solution of silane is the most effective because the silane hydrolyzes to form silanol.

Calculating the Quantity of Silane Required:

The silicone molecule is preferably attached to the surface of the inorganic material as a primer to form a mono-layer. Applying the silane as a primer will product optimum coupling results between the substrate and the resin to be applied. When used as a primer the required amount of silane can be calculated by the following:

$$\text{Amount of silane (g)} = \frac{\text{Amount of filler (g)} \times \text{Surface area (m}^2\text{/g)}}{\text{Minimum coating area of silane coupling agent (m}^2\text{/g)}}$$

The actual values may deviate from the calculated value depending on the surface condition of the filler or the silane treating process. The following values may be used as guidelines when the value is unknown. A dilution of 1% silane to filler may be considered as standard. Generally 0.3% to 0.5% is recommended:

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Surface area of filler (m²/g):

E-glass	0.1 - 0.12
Quartz	1 - 2
Kaolin	7
Clay	7
Talc	7
Aluminum polysilicate	1
Calcium carbonate	5
Calcium silicate	2.6

Reactivity:

The alkoxy groups of the coupling agents react with water to form silanol groups which immediately form covalent bonds by dehydration and condensation:



Silane Characteristics:

Product Name	Minimum Coverage Area (m ² /g)	Specific Gravity (@ 25°C)	Refractive Index (@ 25°C)
AP-Silane-21	515	0.97	1.391
AP-Silane-22	410	0.90	1.397
AP-Silane-30	315	0.94	1.398
AP-Silane-31	380	0.97	1.445
AP-Silane-32	351	1.02	1.445
AP-Silane-33	353	0.94	1.420
AP-Silane-51	330	1.07	1.427
AP-Silane-71	314	1.04	1.429
AP-Silane-81	398	1.06	1.440
AP-Silane-99	345	0.91	1.404

Amino Functional Silane Coupling Agents:

Product Name	Chemical Name	Chemical Structure	Molecular Weight	Flash Point	Compatible Resins
AP-Silane-31	N-β(aminoethyl)-γ-aminopropylmethylmethoxy silane	$\text{H}_2\text{NC}_2\text{H}_4\text{NHC}_3\text{H}_6\text{Si} \begin{array}{l} \diagup \text{CH}_3 \\ \diagdown \text{OCH}_3 \\ \diagdown \text{OCH}_3 \end{array}$	206.4	230°F	Epoxy Phenolic Melamine Furan
AP-Silane-32	N-β(aminoethyl)-γ-aminopropyltrimethoxy silane	$\text{H}_2\text{NC}_2\text{H}_4\text{NHC}_3\text{H}_6\text{Si} \begin{array}{l} \diagup \text{OCH}_3 \\ \diagdown \text{OCH}_3 \\ \diagdown \text{OCH}_3 \end{array}$	222.4	262°F	Epoxy Phenolic Melamine
AP-Silane-33	γ-aminopropyltriethoxy silane	$\text{H}_2\text{NC}_3\text{H}_6\text{Si} \begin{array}{l} \diagup \text{OC}_2\text{H}_5 \\ \diagdown \text{OC}_2\text{H}_5 \\ \diagdown \text{OC}_2\text{H}_5 \end{array}$	221.4	208°F	Nylon Phenolic Epoxy Melamine

Epoxy Functional Silane Coupling Agent:

Product Name	Chemical Name	Chemical Structure	Molecular Weight	Flash Point	Compatible Resins
AP-Silane-51	γ-glycidopropyltrimethoxy silane	$\text{CH}_2 \begin{array}{l} \diagdown \text{O} \\ \diagup \end{array} \text{CHCH}_2\text{OC}_3\text{H}_6\text{Si} \begin{array}{l} \diagup \text{OCH}_3 \\ \diagdown \text{OCH}_3 \\ \diagdown \text{OCH}_3 \end{array}$	236.3	300°F	Epoxy Phenolic Melamine

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Vinyl Functional Silane Coupling Agent:

Product Name	Chemical Name	Chemical Structure	Molecular Weight	Flash Point	Compatible Resins
AP-Silane-21	Vinyltrimethoxy silane	$\text{CH}_2=\text{CHSi} \begin{array}{l} \diagup \text{OCH}_3 \\ \text{---} \text{OCH}_3 \\ \diagdown \text{OCH}_3 \end{array}$	148.2	90°F	Crosslinking Polyethylene
AP-Silane-22	Vinyltriethoxy silane	$\text{CH}_2=\text{CHSi} \begin{array}{l} \diagup \text{OC}_2\text{H}_5 \\ \text{---} \text{OCH}_3 \\ \diagdown \text{OC}_2\text{H}_5 \end{array}$	190.3	138°F	Crosslinking Polyethylene

Additional Silane Coupling Agents:

Product Name	Chemical Name	Chemical Structure	Molecular Weight	Flash Point	Compatible Resins
AP-Silane-30	N-Propyl-trimethoxy silane	$\text{CH}_3\text{CH}_2\text{CH}_2\text{Si} \begin{array}{l} \diagup \text{CH}_3 \\ \text{---} \text{OCH}_3 \\ \diagdown \text{OCH}_3 \end{array}$	164.3	93°F	Fiberglass
AP-Silane-71	γ-Methacryloxy-propyl trimethoxy silane	$\text{CH}_2=\overset{\text{CH}_3}{\underset{\text{O}}{\text{C}}}-\text{C}-\text{O}-\text{C}_3\text{H}_6\text{Si} \begin{array}{l} \diagup \text{OCH}_3 \\ \text{---} \text{OCH}_3 \\ \diagdown \text{OCH}_3 \end{array}$	248.4	257°F	Unsaturated polyester
AP-Silane-81	γ-Mercaptopropyl trimethoxy silane	$\text{HSC}_3\text{H}_6\text{Si} \begin{array}{l} \diagup \text{OCH}_3 \\ \text{---} \text{OCH}_3 \\ \diagdown \text{OCH}_3 \end{array}$	196.4	210°F	Rubber
AP-Silane-99	N-Hexyltrimethoxy silane	$\text{CH}_3(\text{CH}_2)_5\text{Si} \begin{array}{l} \diagup \text{OCH}_3 \\ \text{---} \text{OCH}_3 \\ \diagdown \text{OCH}_3 \end{array}$	206.4	144°F	Concrete

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