Information About *Dow Corning*® Z-6040 Silane

Chemical Type
Glycidoxy (epoxy) functional methoxy silane

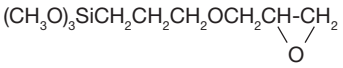
Physical Form
Low-viscosity liquid

Special Properties
Organic and inorganic reactivity; improves adhesion; increases composite strength properties

Primary Use
Coupling agent to improve adhesion of organic resins to inorganic surfaces

DESCRIPTION

Dow Corning® Z-6040 Silane contains reactive glycidoxy and methoxy groups. Chemically, *Dow Corning* Z-6040 Silane has the formula:



It is designated 3-glycidoxypropyltrimethoxysilane.

This glycidoxy functional silane is one of a series of organofunctional silane chemicals from Dow Corning Corporation. Other reactive silanes include amines (*Dow Corning*® Z-6020 and Z-6026 Silanes), styrylamine (*Dow Corning*® Z-6032 Silane), methacrylate (*Dow Corning*® Z-6030 Silane), vinyl (*Dow Corning*® Z-6075 Silane) and chloroalkyl (*Dow Corning*® Z-6076 Silane).

USES

Dow Corning Z-6040 Silane possesses both organic and inorganic reactivity that allows it to react with or "couple" organic polymers and inorganic surfaces. This dual reactivity should be considered when using *Dow Corning* Z-6040 Silane in specific applications.

Dow Corning Z-6040 Silane is particularly recommended as:

- A treatment on glass fiber for use in reinforced plastics
- A treatment on mineral surfaces for use in mineral-filled plastics
- An adhesion promoter to enhance the bonding of a polymer coating or adhesive to glass, metals or other polymer surfaces

For example, *Dow Corning* Z-6040 Silane is used as a finish on woven glass fabric for glass fiber-reinforced epoxy resin composites to improve the physical properties, especially the wet strength, of the composite[1] (see Table I).

Dow Corning Z-6040 Silane is effective in improving the physical properties of a mineral-filled polymer such as silica-filled epoxy resins[2] (see Table II).

Table III shows the effectiveness of *Dow Corning* Z-6040 Silane in glass bead-reinforced polybutylene terephthalate.

Dow Corning Z-6040 Silane is also recommended as an additive to improve the adhesion of acrylic latex caulks[3].

Other polymers that are receptive to *Dow Corning* Z-6040 Silane are urethanes, acrylics, polysulfides and nylon.

A more detailed discussion of chemistry and applications can be found in "A Guide to Dow Corning Silane Coupling Agents," Form No. 23-012, available from Dow Corning Corporation.

[1]E.C. Elliott, K.R. Hoffman, Society of Plastics Industry, 18 Annual Tech. Conf., paper 1-E, 1963.

[2]Malvern Minerals Corporation, Novacite® product bulletin.

[3]Rohm & Haas Company, Product Bulletin No. 2890, December 1970.

TYPICAL PROPERTIES

These values are not intended for use in preparing specifications.

CTM 0176[1]	Appearance	Clear liquid
	Color, APHA	100
CTM 0004	Viscosity, cs.	3
CTM 0001A	Specific Gravity at 25°C (77°F)	1.07
CTM 0002	Refractive Index	1.428
CTM 0021A	Flash Point, closed cup, °C (°F)	>101 (>213)
CTM 0625B	Typical Purity, percent, by gas chromatography	97.5
	Molecular Weight	236

[1]CTMs (Corporate Test Methods) correspond to ASTM standard tests in most instances. Copies of CTMs are available upon request.

Specification Writers: Please obtain a copy of the Dow Corning Sales Specification for this product and use it as a basis for your specifications. It may be obtained from any Dow Corning Sales Office, or from Dow Corning Customer Service in Midland, MI. Call (517) 496-6000.

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LIMITATIONS

Not intended for medical use.

BENEFITS

The improved bonding at the organic/inorganic interface often provides:

- Improved adhesion
- Increased composite wet and dry tensile strength and modulus
- Increased composite wet and dry flexural strength and modulus
- Increased wet and dry compressive strength
- Better appearance

Surface treatment in mineral-filled systems provides these benefits, plus:

- Better filler wet-out and dispersion
- Lower viscosity of filled liquid resins
- Improved processability

HOW TO USE

Dow Corning Z-6040 Silane can be applied in inorganic surfaces as a dilute aqueous solution (0.1 to 0.5 percent silane concentration). Aqueous solutions are easily prepared by first adjusting the pH of the water to 3.5 to 4.5 with about 0.1 percent acetic acid and then adding the silane and stirring. After adding the silane to acidified water, it is usually necessary to stir the mixture for about 15 minutes before it hydrolyzes and forms a clear, homogeneous solution. Higher concentrations of *Dow Corning* Z-6040 Silane in water are not stable indefinitely and after standing several days may deposit an oily phase of condensed polysiloxane. *Dow Corning* Z-6040 Silane can also be applied as a solution in many common organic solvents. Solubility and stability of a specific organic solvent should, however, be verified before use in a commercial process.

In the case of mineral fillers, the mineral can be treated by mixing with the silane at low shear for several minutes with no additional solvent.

After applying the silane, the glass or mineral surface should be dried briefly at 104 to 121°C (220 to 250°F) to effect condensation of silanol groups at the surface and to remove traces of methanol from hydrolysis of the methoxysilane. Optimum application and drying conditions such as time and temperature should be determined for each use in a commercial process.

For use as a primer, 49.5 parts of *Dow Corning* Z-6040 Silane and 0.5 parts of an organic amine such as benzyldimethylamine (Mixture A) are diluted with about 950 parts methanol, isopropanol or ether glycol. Alternatively, a prehydrolyzed primer may be prepared by adding 5 parts water and 1,000 parts of the above primer solution. In both cases, the primer solution is applied to a solid surface such as glass or metal and a polymer is heat pressed or cured on the surface.

Dow Corning Z-6040 Silane can be added directly to a resin system at 0.5 to 2.0 pph to promote unprimed adhesion.

CHEMISTRY

Two types of reactivity must be considered with an organofunctional silane

Table I: Fiberglass-Reinforced Epoxy Laminates[1]

Fiberglass Finish[2]	Flexural Strength, psi Dry	Flexural Strength, psi Wet[3]	Compressive Strength, psi Dry	Compressive Strength, psi Wet[3]
None	88,000	65,000	55,000	23,000
0.2% *Dow Corning* Z-6040 Silane	94,400	85,400	62,000	61,000

[1]14 ply 7781 fabric, 1/8-inch laminate using D.E.R. 330 and m-phenylenediamine.
[2]Aqueous solution concentration on an active silane basis, applied as a fiberglass finish.
[3]Specimen strength retention after 2 hours in boiling water.

Table II: Silica-Reinforced Epoxy Resin[1]

1% Silane Treatment	Flexural Strength, psi Dry	Flexural Strength, psi Wet[2]	Volume Resistivity, ohm-cm Dry	Volume Resistivity, ohm-cm Wet[2]	Dissipation Factor x 10^2 Dry	Dissipation Factor x 10^2 Wet[2]
None	18,800	14,900	2.2×10^{15}	1.9×10^{12}	0.0051	0.053
Dow Corning Z-6040 Silane	22,400	18,500	1.1×10^{15}	6.4×10^{14}	0.0046	0.014

[1]100 parts D.E.R. 331 epoxy resin, 18 parts curing agent Z, 50 parts Malvern Minerals, Novacite® 1250 (naturally occurring silica).
[2]After 4 hours immersion in boiling water.

Table III: Glass Bead[1]-Reinforced Polybutylene Terephthalate

Strength Properties	Unfilled Resin	35% (w/w) Glass Bead Reinforcement Untreated	35% (w/w) Glass Bead Reinforcement 0.25% *Dow Corning* Z-6040 Silane
Flexural Strength, psi			
Dry	12,900	10,800	14,900
Wet[2]	13,000	10,100	14,400
Flexural Modulus, 10^5 psi			
Dry	3.14	5.83	6.07
Wet[2]	3.00	4.04	5.38
Tensile Strength, psi			
Dry	7,300	5,600	8,000
Wet[2]	7,300	4,800	7,900

[1]Potters 3000 glass beads from Potters Industries, Inc.
[2]Strengths after 16 hours at 50 C (122 F) in water.

such as *Dow Corning* Z-6040 Silane: the epoxy group and the trimethoxysilyl group.

Epoxy Reactivity
The epoxy group in *Dow Corning* Z-6040 Silane has a reactivity similar to that of organic epoxides; that is, it will undergo ring-opening reactions with acids, amines, alcohols, thiols and other epoxides. The presence of acid or basic catalysis facilitates this reactivity.

Trimethoxysilyl Reactivity
The trimethoxysilyl portion of *Dow Corning* Z-6040 Silane undergoes the typical chemistry of alkoxysilanes. The methoxysilyl group is subject to hydrolysis in water or water/alcohol solutions.

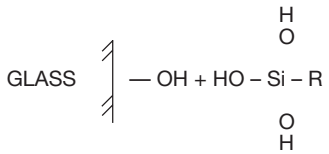
The initial product of hydrolysis is a silanetriol:

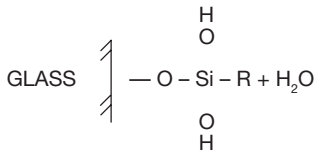
$$RSi(OCH_3)_3 + 3\ H_2O$$

$$RSi(OH)_3 + 3\ CH_3OH$$

Silanetriols are moderately stable at dilute concentrations in polar solvents such as water and alcohols. Dispersions of *Dow Corning* Z-6040 Silane are more stable and have more favorable orientation on siliceous surfaces if they are applied from a slightly acid solution.

Silanol groups are capable of condensing with hydroxyl groups at the surface of glass and siliceous minerals as shown below:





After condensing with the mineral surface, the remaining silanol groups are capable of hydrogen bonding or condensing with adjacent silanol groups. By this combination of covalent and hydrogen bonding, the coupling agent is bonded to the inorganic surface and modifies it so that it is organoreactive.

SHIPPING LIMITATIONS
None.

STORAGE AND SHELF LIFE
When stored in original, unopened containers at or below 25°C (77°F), *Dow Corning* Z-6040 Silane has a shelf life of 36 months from date of manufacture. After opening, *Dow Corning* Z-6040 Silane should be protected from atmospheric moisture to prevent gelation.

PACKAGING
Dow Corning Z-6040 Silane is available in 4-oz (100-g) samples and 40- and 441-lb (18.1- and 200-kg) containers, net weight.

SAFE HANDLING INFORMATION
Dow Corning Z-6040 Silane may irritate skin and may cause discomfort to eyes. If contamination occurs, flush with large amounts of water.

Dow Corning Z-6040 Silane hydrolyzes when exposed to moisture, generating methanol. Appropriate measures should be taken to prevent the accumulation of hazardous concentrations of methanol fumes in the working environment. Overexposure to methanol vapors can cause serious systemic injury. If swallowed, methanol may case blindness or death.

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Printed in USA AGP3348-6040 Form No. 25-308C-98

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