BRB

A Subsidiary of PETRONAS Chemicals Group

Silanes for Coatings and Adhesives

© 2021 BRB International B.V.
All rights reserved. No part of this document may be reproduced in any form possible, stored in a retrieval system, transmitted and/or disseminated in any form or by any means (digital, mechanical, hard copy, recording or otherwise) without the permission of the copyright owner.

Topics :

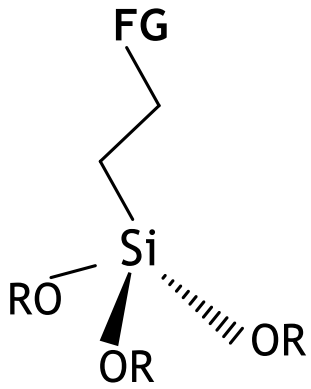
- Chemistry of Silanes
- Silanes for Coatings
  - > Primer
  - > Polymerization
  - > Post Addition
- Silanes for Adhesives and Sealants
- Factors of Silane Reaction

BRB
A Subsidiary of PETRONAS Chemicals Group

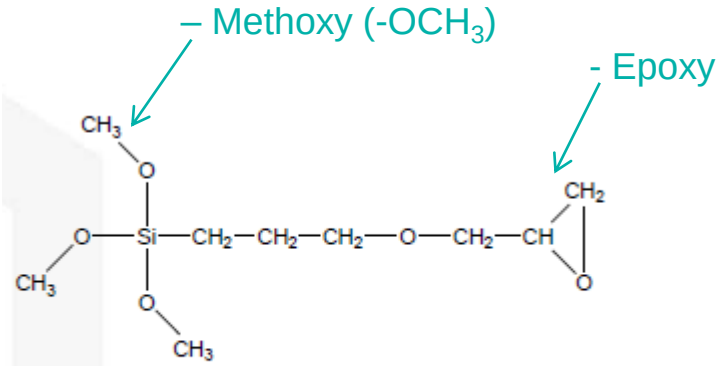
© 2021 BRB International B.V.

Silane Structure

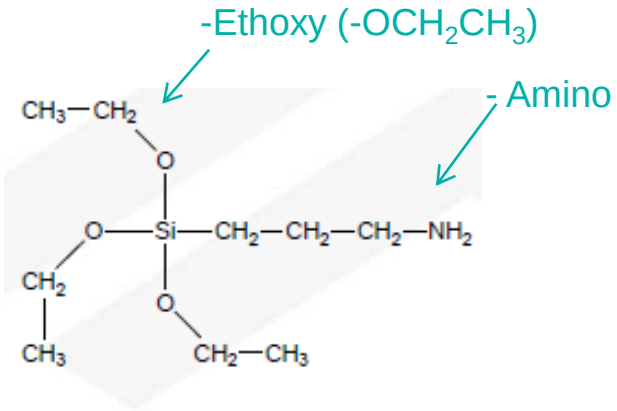
FG = Functional Group (Oragno Type)
e.g. –Vinyl, -Glycidoxy (Epoxy),
-Amino, -Methacryloxy, -Akyl ,etc.



e.g.



Silani® 258



Silanil® 919

OR = Alkoxy, Acetoxy, Oxime
e.g. – Methoxy (-OCH_3) ,
-Ethoxy (-OCH_2CH_3) ,etc.

BRB
A Subsidiary of PETRONAS Chemicals Group

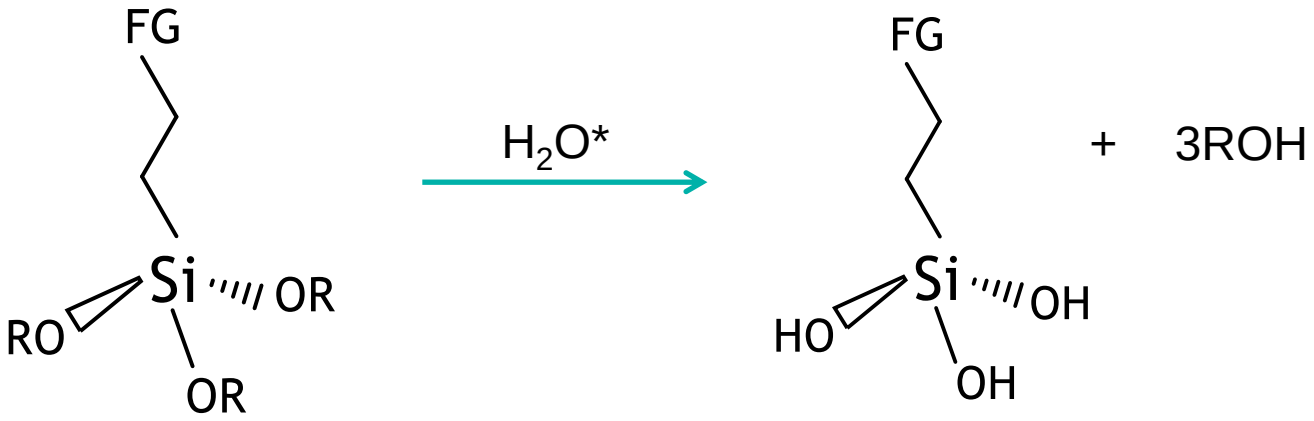
© 2021 BRB International B.V.

How Silanes work

Silanes are 2 step Reaction Chemical which most of them are monomer. When store under inert gas (N_2), Silanes will be non-reactive monomer in form of FG-Si-OR which -R or Akyl is non-reactive group .

However, **Silanes can be hydrolyzed by moisture** which -Si–OR will be changed to -Si- OH called **"Silanol"** group and be ready to react or bond to the substrates or the fillers **.**

The change of –Si-OR to -Si-OH is called "Hydrolysis" which is the 1st step of silane reaction .



1st Step Reaction-Hydrolysis

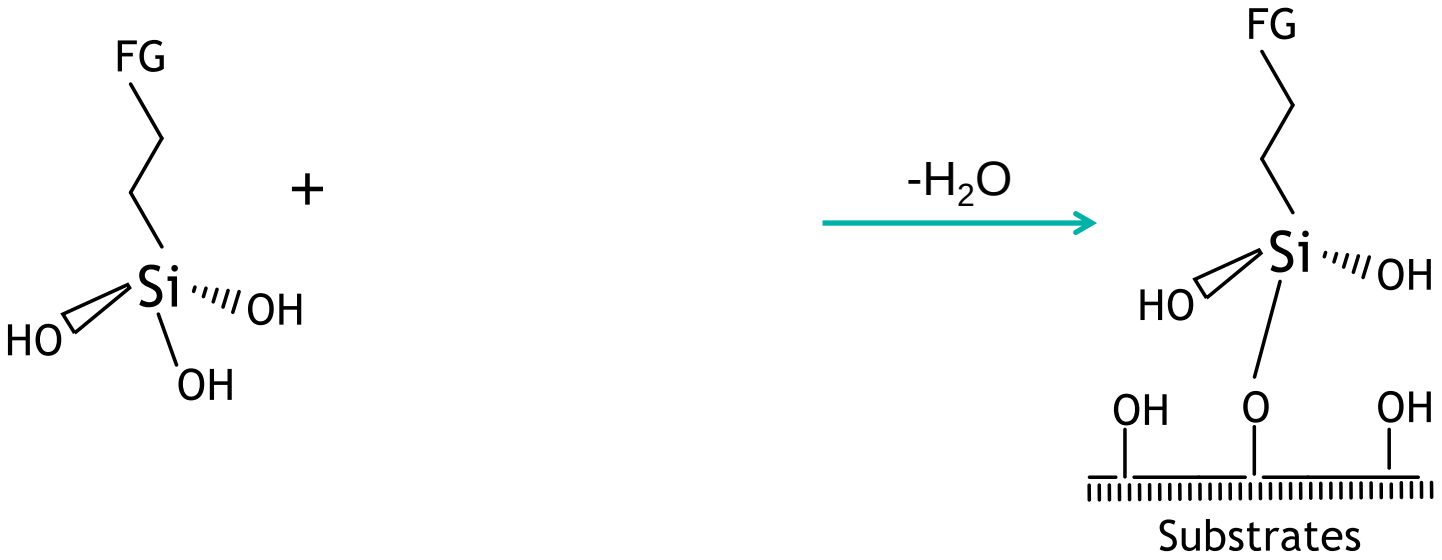
* H_2O can come from atmosphere/air.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

How Silanes work

2nd step of the reaction is **"Condensation"**. After Hydrolysis , Silane contains "Silanol" group or Si-OH which is very reactive and ready to bond to substrates or fillers.
This bonding step is called **"Condensation"** which is function of adhesion promoter to the substrates or coupling/dispersing agent to the fillers



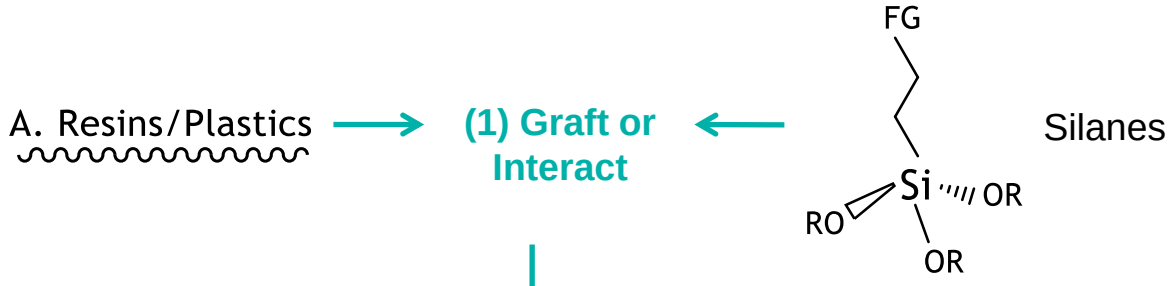
2nd Step Reaction-Condensation

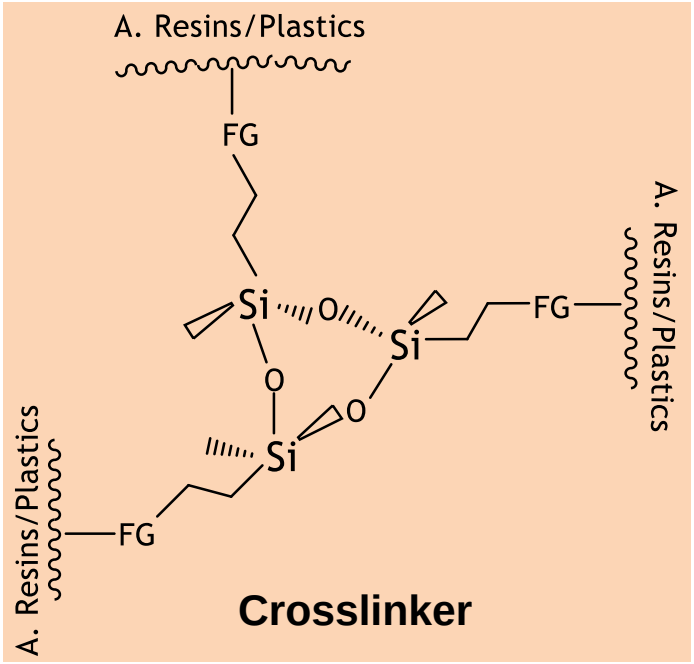
* e.g. Application of Glass Fiber Surface Treatment

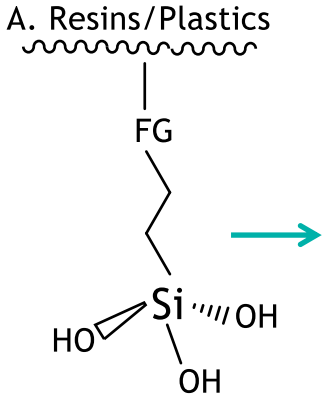
BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

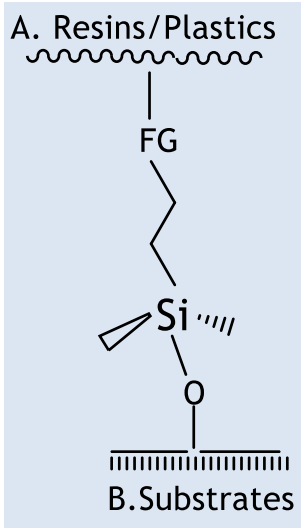
Benefits of Silanes in each function



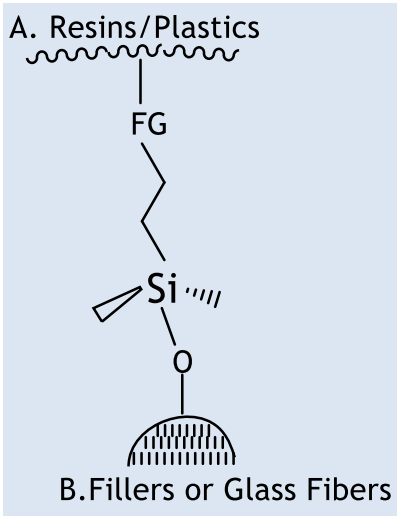




(2) Hydrolysis + Condensation



Adhesion Promoter

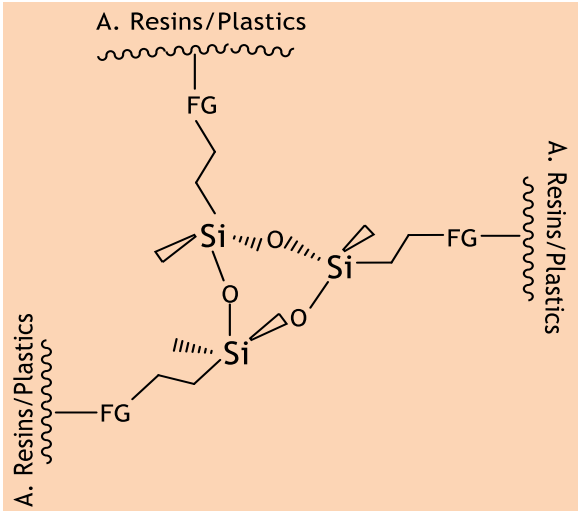


Coupling/Dispersing Agent

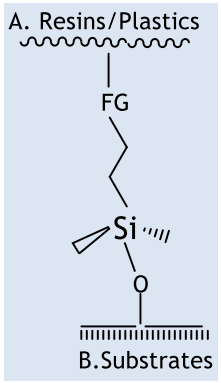
BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Benefits of Silanes in each function

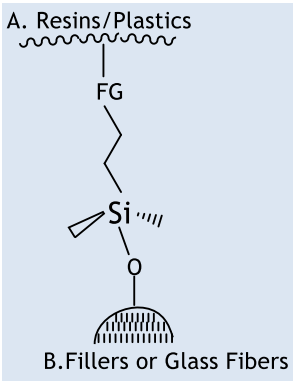


- Create net work structure in Polymer
- Increase strength and hardness
- Longer service life of product
- Higher temperature resistance
- Higher scrub/scratch resistance



Adhesion Promoter

- Enhance adhesion performance btw resins and substrates
- Improve corrosion resistance and prevent corrosion's spreading from crack line .



Coupling/Dispersing Agent

- Link btw resins and fillers, stay together as one system
- Optimize strength of composites
- Able to add higher filler loading
- Improve filler's dispersion in resins

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Silanes for Coatings

BRB

A Subsidiary of PETRONAS Chemicals Group

Benefits of Silanes in Paint and Coatings

- Increase Adhesion Performance to Substrate
- Increase Crosslinking Density of Resin which affected to
  - > Increase hardness
  - > Increase mar resistance*
  - > Improve solvent, acid, alkaline resistance
  - > Improve water resistance
  - > Increase abrasion resistance or scrub resistance
- Change Resin Properties
  - > Thermoplastics to near Thermosets
- Disperse Pigments/Fillers
  - > Improve consistency of viscosity and able to have lower viscosity
  - > Benefit to lower loading of pigments in the formulation
- Bind Pigments/Fillers
  - > Act as coupling agent to pigments/fillers to improve scrub ability

* The mar resistance is surface coating's ability to withstand scratching and scuffing actions which tend to mar (change) the surface appearance of coating .

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Typical Ingredients of Organic Coating

- **Resins** - Be also called binder, usually major non-volatile component, made up of a polymer
- **Solvents** - Dissolve the resin, soften the coating, allow good flow, viscosity control, drying behavior, and reduce cost
- **Surfactants** – Stabilize resin particles in WB coatings
- **Pigments/Fillers** – Provide color, opacity, special effect and cheapen coating
- **Thickeners** – Control and adjust viscosity
- **Stabilizers -** Provide longer service term e.g. Hindered Amine Light Stabilizers (HALS)
- **Neutralizers** - Adjust pH e.g. volatile amines
- **Additives** – **Silane is one of coating additives for adhesion promoter, crosslinker, and coupling agent.**
  Other additives e.g. Flow, Slip, Anti-Foam ,etc.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Application in Paint and Coatings

Primer

2-5% Silani® 919
+
4-5% DI Water
Solvent (Alcohol/Toluene)

↓ Cold Blend

Silane as Adhesion Promoter

Polymerization

Monomers to produce Resin
+
Silanes
e.g. Silanil® 276,250
(0.5-2% in WB,
Up to 10% in SB)

↓ Polymerization

Silane as Crosslinker

Post Addition

Resin+ Silane (e.g.Silanil® 919,258 at 0.2-2% wt.of Resin Solid)

↓ Induction time at least overnight

Other Additives/
Fillers added
+ Mill–base added

↓

Paint

Silane as Crosslinker, Coupling Agent, Adhesion Promoter

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Application: Primer

BRB

A Subsidiary of PETRONAS Chemicals Group

Typical Formulation of Primer

Components

Amino silanes 2-6%

+

Mixed Solution :

Alcohol e.g. IPA

Distilled water

Toluene

n-Butanol

Butyl Cellosolve

- Dissolve 2-6 % wt. silane in a compatible volatile solvent (or mixture of solvents) .
- Amino silanes e.g. Silanil® 919, 138 and 176 are recommended.
- Alcohols are most commonly used, for water compatibility.
- Water at equal part of silane may be added to pre-hydrolyze silane if water is compatible with the solvent.
- Apply to grease-free surface by wiping, spraying, brushing, or dipping.
- Film thickness < 0.1 mil .
- Leave the surface dry to remove solvent around 15- 30 mins. Apply the top coat within 24 hrs to protect surface from contamination .

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Application: Polymerization

BRB

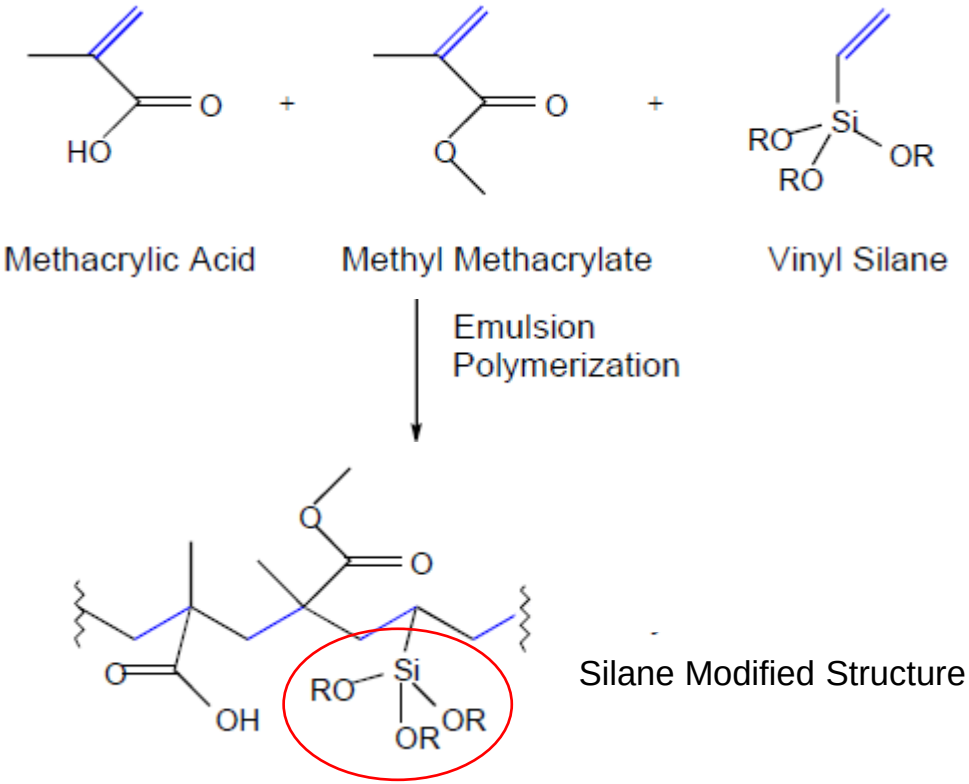
A Subsidiary of PETRONAS Chemicals Group

Silanes for Polymer Modification

Silanil® 276, 780 and 250 are widely used to modify polymer structure especially in surface coating resin for both of WB and SB such as Acrylic Latex which is commonly added in polymerization step.

Silane as Crosslinker in Emulsion Polymerization :

Typical Monomers for Acrylic Latex



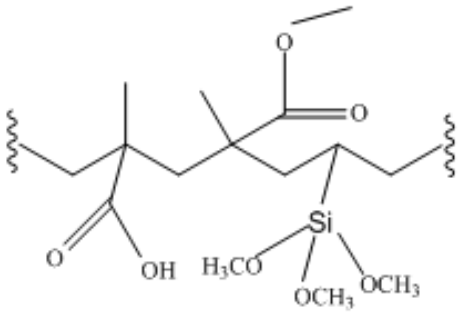
Silane Modified Structure e.g. R is –CH3

BRB
A Subsidiary of PETRONAS Chemicals Group

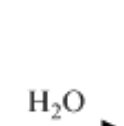
© 2021 BRB International B.V.

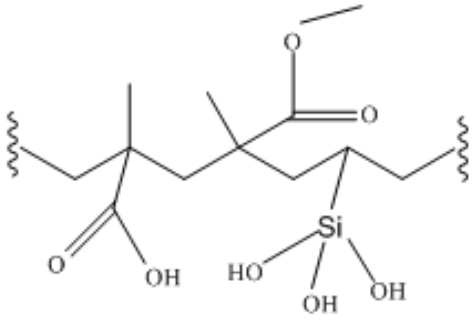
Silanes for Polymer Modification

Silane as Crosslinker in Emulsion Polymerization :

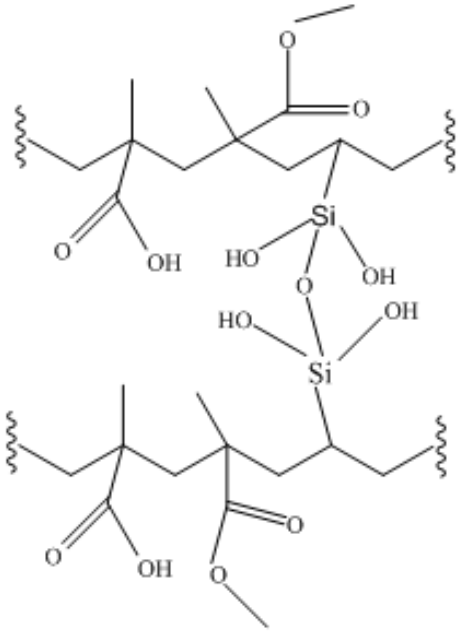


Silane Modified Structure





Silane Modified Structure
after Hydrolysis



Silane as Crosslinker
or called “Silylated Acrylic”

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Silane Dosage in Polymerization

In Soventborne Resin : recommended silane dosage at 0.4-10.0% on total monomer wt.

In Waterborne Resin : recommended silane dosage at 0.1-2.0% on total monomer wt.
pH is recommended close to neutral or
< = 8.5 pH for stability purpose.

For emulsion polymerization, it is recommended to add silane in the pre-emulsion stage.

In case of **none pre-emulsion stage**, it is recommended to add silane into the monomixture at the remaining of 10-15% monomers feeding time .

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Typical Formula of Silylated Acrylic

Monomers :

- BA 20-30 Mole %
- MMA 65-75 Mole %
- MAA 2-3 Mole %
- Silane 1-3 Mole%

Typical Emulsion Recipe

Water 40-50 %

Monomers 40-50 %

Surfactants 2-5 %

Initiator 0.3-0.5 %

Others Additives

General Specification of Emulsion

Tg 40-80

Acid Value 10-50

Solids 40-50%

BRB

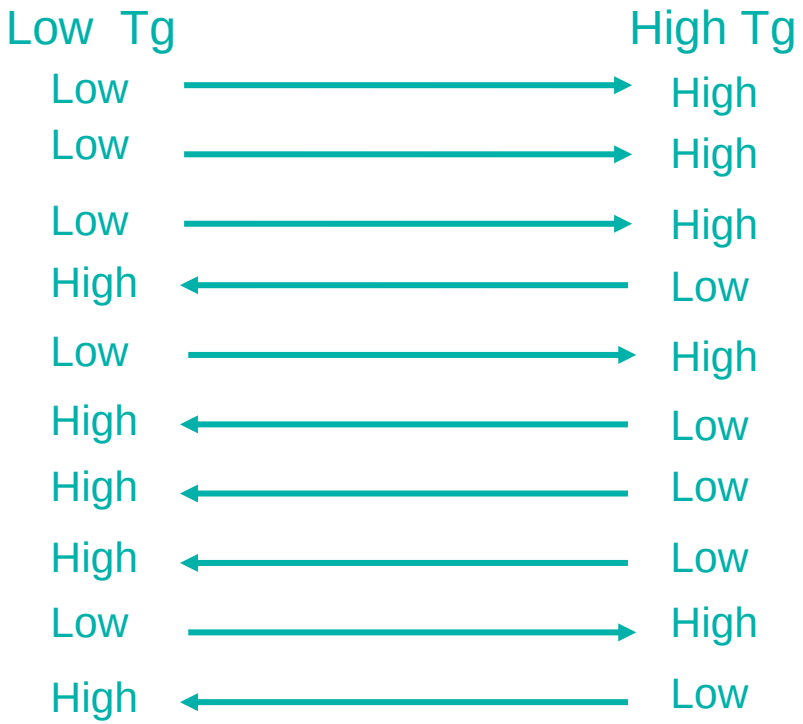
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Effect of Glass Transition (Tg) on Latex Properties

Latex properties

- Drying speed
- Gloss
- Heat resistance
- Resolubility
- Solvent tolerance
- Adhesion
- Film formation
- Flexibility
- Water resistance
- Pigment dispersion



*** Silanes could increase the Tg value in Acrylic Latex .**

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

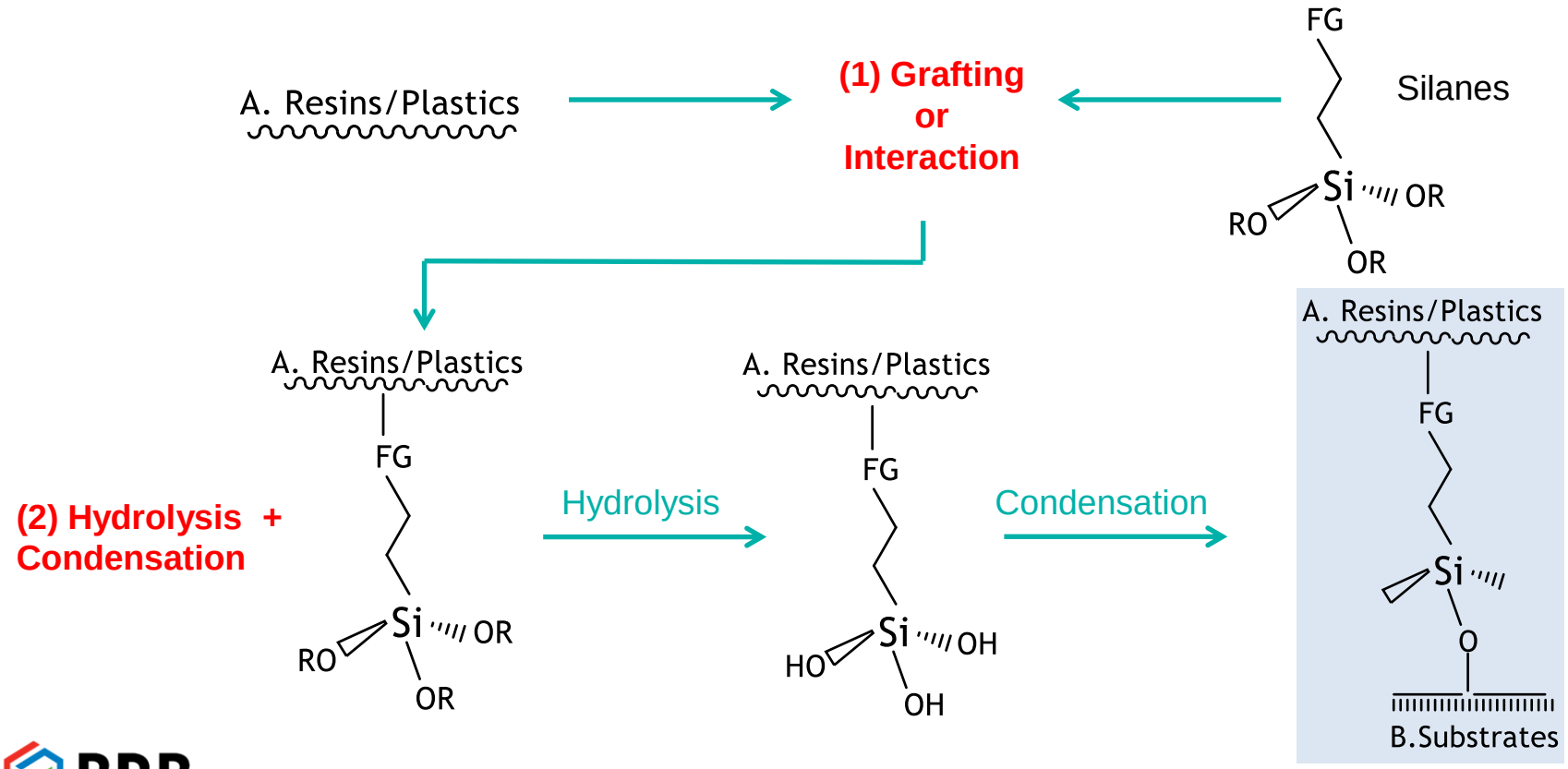
Application: Post Addition

BRB

A Subsidiary of PETRONAS Chemicals Group

Silanes for Post Addition

Post addition is the process to add chemicals or additives into polymer (resin) after the polymer is formed or after polymerization. Silanes in Post addition show 2 mechanisms 1) Grafting in part of functional group of silanes and 2) Hydrolysis and condensation in part of -OR which is changed to –ROH (Silanol Group) .



BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Manufacturing Process of Paint

Part 1 – Accurate measurement of ingredient

Part 2 – Mill-base preparation and pigment dispersion

Part 3 – Let-down
In a separate, larger, vat the rest of the paint (resin, solvent, additives and also “Silanes”) is combined and mixed. This is called the let-down. When the let-down and the mill-base are completed, the mill-base is added with stirring to the let-down. At this stage, if required by the formulation, any final additions are made and added in.

Part 4 – Finished product and in process laboratory testing

Part 5 – Canning

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Application Guideline for Post Addition

First step

Silane + Resin

→

Second step

Addition of Solvent or Water + Other Additives
e.g. Matting Agent, Wetting Agent, Wax,
Pigments , Ammonia ,etc .

Guide Line for Post Addition : Silane Grafting on Resin

- Blend silane directly into resin . (without other additives or pigments)
- Prefer pH near to neutral or pH of resin should be < 8.5 before adding silane. (for water-based resin)
- Induction time is needed after adding silane into resin. pH may be increased during induction time comparing to resin without silane. Proper induction time is able to study by pH evolution curve VS time.
- The induction time is at the onset point which pH is started to increase dramatically. Typical induction time is 5-48 hrs.
  High shear agitation is able to accelerate the induction time
- It is recommended to add additives and fillers after the induction period.
- If pH adjustment is required for final coating , it is recommended to adjust pH after the induction period.
- Aging test at high temperature (for product stability study) have to be done after induction period .

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Silane Dosage in Post Addition

Epoxy and amino silanes e.g. Silanil® 258, Silanil® 289, Silanil® 919, and Silanil® 176 are popular to be used for “Post Addition” .

The effective silane dosage is varied up to type of polymers,
“ It is recommended at 0.2-2 %wt of silane based on resin solid content.”

However, ladder test is recommended with various silane dosages to study the optimum point which may show different results in each polymer.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Recommendation in Paint and Coatings

By Functional Group Matching

Acrylic	PU 1K	PU 2K	Epoxy	Alkyd	Polyamide	Phenolic	PBT	Polyester	PUD	Silicone	Melamine
Silanil 250	Silanil 258	Silanil 258	Silanil 258	Silanil 176	Silanil 176	Silanil 258	Silanil 258	Silanil 250	Silanil 258	Silanil 176	Silanil 176
Silanil 258	Silanil 260	Silanil 919	Silanil 919	Silanil 919	Silanil 919	Silanil 919	Silanil 919	Silanil 780	Silanil 289	Silanil 919	Silanil 919
Silanil 289		Silanil 176	Silanil 250		Silanil 1479	Silanil 307	Silanil 176	Silanil 276	Silanil 260	Silanil 1479	Silanil 260
Silanil 919		Silanil 138	Silanil 289			Silanil 176			Silanil 919		Silanil 258
Silanil 276		Silanil 1479									
Silanil 780											

By Functions

Crosslinker		Adhesion Promoter	Coupling Agent	Primer
Process: Polymerization	Process: Post Addition*	Process: Post Addition	Process: Post Addition	Process: Cold Blend
Silanil 250	Silanil258	Silanil 919	Silanil 919	Silanil 919
Silanil 276	Silanil289	Silanil 176	Silanil 176	Silanil 138
Silanil 780		Silanil 138	Silanil 138	Silanil 176
		Silanil 1479	Silanil 258	
		Silanil 258	Silanil 289	
		Silanil 289		

*** Sequence of silane addition into formulation is affected to the function of silane .**

Remark: Recommendation based on testing and historical experience data.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Silanes for Adhesives and Sealants

BRB

A Subsidiary of PETRONAS Chemicals Group

Application in Adhesives and Sealants

Applications are in the same direction
as coatings :

- Primer > as adhesion promoter
- Polymerization > as crosslinker
- Post addition > as adhesion promoter, coupling agent, or crosslinker

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Typical Ingredients of Sealants

Typical Ingredients :

- Resins
- UV stabilizers
- Plasticizers
- ***Moisture scavengers*** > Silanil® 276
- Fillers ($CaCO_3$,etc.)
- Thixotropic agents
  (Fumed silica or additives)
- Pigments/Colorants
- ***Adhesion promoters**** > Silanil® 176, 138, 919, 1479, etc.
- Catalysts > BRB DBTDL, BRB DBTDA , etc.
- Other additives
- May be solvents
- Also ***curing agents for silicone sealants***
  > Silanil® MOS, VOS, MTAS, ETAS, PTAS, etc.

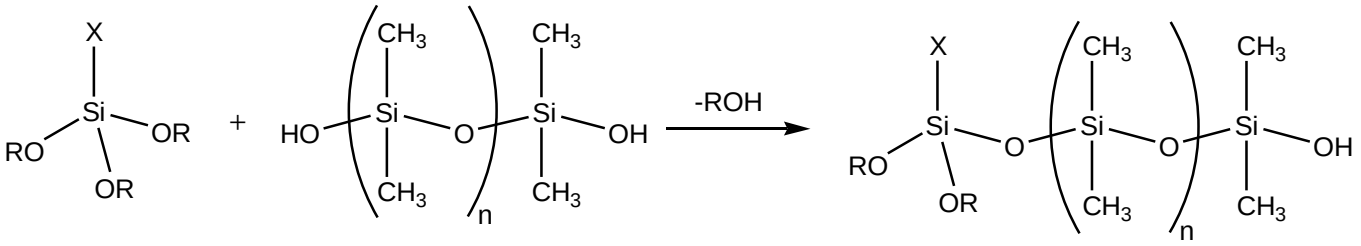
Planetary Mixer for High Viscosity

* Dosage of silanes in range of 0.2-2% on resin solid wt.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Curing (Crosslinking) Type of RTV-1



Curing Type	By product	Features
Oxime	Methylethylketoxime	✓ Good adhesion on plastics
		✓ Neutral cure, no acidic ador
		✓ Low corrosive to metallic substrates
		✓ Longer tack free time and cure time than acetoxy type
Acetoxy	Acetic acid	✓ Fast cure and short tack free time
		✓ Good adhesion on any substrates
		✓ Good stability up to 300°C
		✓ Vinegar odor from by product
		✓ Corrosive to metallic substrates
Alkoxy	Alcohols i.e. Methanol or Ethanol	✓ Neutral cure, non-acidic odor
		✓ Non-corrosive to metallic substrates
		✓ Good adhesion (< acetoxy type)
		✓ Longer tack free time and cure time than acetoxy type
		✓ Stability up to 220°C

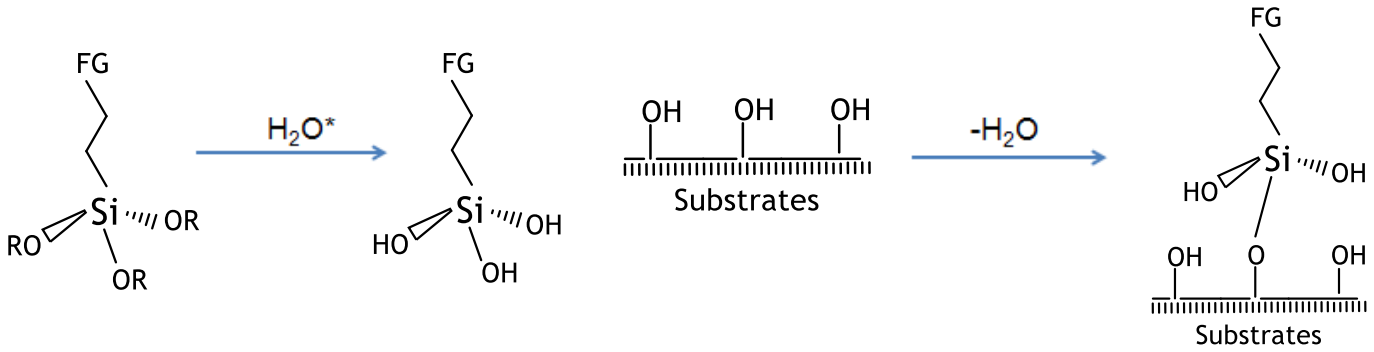
Silanes as RTV-1 Crosslinkers

Curing Type	BRB Silane	Chemical Name	CAS no.
Oxime	Silanil MOS	Methyltris(methylethylketoxime)silane	22984-54-9
	Silanil VOS	Vinyltris(methylethylketoxime)silane	2224-33-1
	Silanil POS	Phenyltris(methylethylketoxime)silane	34036-80-1
Acetoxy	Silanil MTAS	Methyl(triacetoxy)silane	4253-34-3
	Silanil ETAS	Ethyl(triacetoxy)silane	17689-77-9
	Silanil PTAS	Propyl(triacetoxy)silane	17865-07-5
	Silanil MTAS/ ETAS Blend	Methyl(triacetoxy)silane/ Ethyl(triacetoxy)silane	4253-34-3/ 17689-77-9
	Silanil MTAS/ PTAS Blend	Methyl(triacetoxy)silane/ Propyl(triacetoxy)silane	4253-34-3/ 17689-77-5
Alkoxy	Silanil 118	Methyltrimethoxysilane	1185-55-3
	Silanil 203	Methyltriethoxysilane	2031-67-6

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Silanes as RTV-1 Adhesion Promotors



Functional Group	BRB Silane	Chemical Name	CAS no.
Amino	Silanil 919	3-aminopropyltriethoxysilane	919-30-2
	Silanil 138	3-aminopropyltrimethoxysilane	13822-56-5
	Silanil 176	N-(2-aminoethyl)-3-aminopropyl-trimethoxysilane	1760-24-3
New product	Silanil 1479	Diamino alkyl silane co-oligomer	-
Epoxy	Silanil 258	3-glycidoxypropyltrimethoxysilane	2530-83-8
	Silanil 289	3-glycidoxypropylmethyldiethoxysilane	2897-60-1
	Silanil 260	3-glycidoxypropyltriethoxysilane	2602-34-8
Methacryloxy	Silanil 250	3-methacryloxypropyltrimethoxysilane	2530-85-0

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Adhesion Promoter: Silanil® 1479

Diamino Akyl Silane Co-oligomer

The benefits over regular amino silanes:

Lower VOC, less by products, resulting in lower odor during application

Less yellowing to resins

Higher hydrophobicity than diamino silane monomer, resulting in good wet adhesion

High elasticity with lower modulus of cured adhesives

Good adhesion performance between organic resins and inorganic substrates.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Product Package for RTV-1 Sealants

1. Acetoxy sealants

2. Alkoxy Sealants

3. Oxime Sealants

4. MS Polymer Sealants

© 2021 BRB International B.V.

1. Acetoxy sealants

A: 100% Silicone Sealant General Purpose

- BRB OH Fluid 80,000 cSt ➔ 60-80%
- BRB Silicone Oil 1,000 cSt ➔ 10 – 20%
- BRB Silanil® MTAS ➔ 5 – 10%
- BRB DBTDL ➔ 0.2 -1%
- Third party fumed Silica ➔ 10%

*Optional adhesion promoters: BRB Silanil® 176, Silanil® 919, Silanil® 138, Silanil® 1479, etc.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

1. Acetoxy sealants

B: Extended Silicone Sealant General Purpose

- BRB OH Fluid 80,000 cSt ➔ 40-60%
- Third party solvent plasticizer ➔ 20 – 40%
- BRB Silanil® MTAS ➔ 5 – 10%
- BRB DBTDL ➔ 0.2 -1%
- Third party fumed Silica ➔ 10%

*Optional adhesion promoters: BRB Silanil® 176, Silanil® 919, Silanil® 138, Silanil® 1479, etc.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Catalyst for Fast Cure: DBTDA

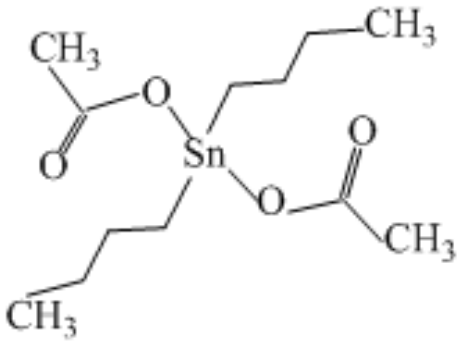
New product

Dibutyltin diacetate (Diacetoxybutyltin)

Faster speed of catalysis performance – faster gelation, tack-free time, and cure time – than DBTDL.

Suitable for acetoxy sealants. (The mixture of DBTDA : DBTDL can be used to design cure time such as ratio of 1.9 : 2.8.)

Soluble in the common solvents i.e. toluene, xylene, benzene, acetone, ethanol, ethyl acetate, chloroform, and other petroleum ethers.



CAS# **1067-33-0**

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

2. Alkoxy sealants

- BRB OH Fluid 20,000 cSt and 80,000 cSt
- BRB Silicone Oil 500 cSt
- Third party coated calcium carbonate
- BRB Silanil® 118

*Optional adhesion promoters: BRB Silanil® 176, Silanil® 919, Silanil® 138, Silanil® 1479, etc.

© 2021 BRB International B.V.

3. Oxime Sealants

Neutral Cure All Weather Purpose

- BRB OH Fluid 80,000 cSt ➔ 30 -40%
- BRB Silicone Oil 100 cSt ➔ 5-10%
- Third party coated calcium carbonate ➔40-50%
- BRB Silanil® MOS and VOS ➔ 3-4%
- BRB DBTDL ➔ 0.2 – 1.0%

*Optional adhesion promoters: BRB Silanil® 176, Silanil® 919, Silanil® 138, Silanil® 1479, etc.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

4. MS-Polymer

Crosslinker and adhesion promoter for MS-Polymer

- BRB Silanil® 118

*Optional adhesion promoters: BRB Silanil® 176, Silanil® 919, Silanil® 138, Silanil® 1479, etc.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

What BRB offers

1. Full range of siloxane, silanes, and tin catalyst products

2. Formulation help

3. Only raw material supplier, not competing with sealants in the market

4. Flexible supply from regional warehouse

5. Competitive prices for continuous sustainable growth

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Recommendation in Adhesives and Sealants

By Functional Group Matching

Acrylic	Polyurethane 1K	Poyurethane 2K	Epoxy	Silicone	Polysulfide	MS Polymers
Silanil 250	Silanil 258	Silanil 258	Silanil 258	Silanil 176	Silanil 258	Silanil 176
Silanil 258	Silanil 260	Silanil 919	Silanil 919	Silanil 919	Silanil 442	Silanil 919
Silanil 289		Silanil 176	Silanil 176	Silanil 780	Silanil 919	Silanil 1479
Silanil 919		Silanil 138	Silanil 289	Silanil 1479		Silanil 118
Silanil 276		Silanil 1479				
Silanil 780						

By Functions

Adhesion Promoter	Coupling Agent	Moisture Scavenger	Primer	Curing Agent for RTV
Silanil 919	Silanil 919	Silanil 276	Silanil 919	Silanil MOS (Oxime)
Silanil 176	Silanil 176		Silanil 138	Silanil VOS (Oxime)
Silanil 138	Silanil 138		Silanil 176	Silanil MTAS (Acetoxy)
Silanil 307	Silanil 307			Silanil ETAS (Acetoxy)
Silanil 258	Silanil 258			Silanil 118 (Alkoxy)
Silanil 289	Silanil 289			Silanil 203 (Alkoxy)
Silanil 442	Silanil 442			Silanil MES (Ester)
Silanil 1479				Silanil VES (Ester)

*** Sequence of silane addition into formulation is affected to the function of silane .**

Remark: Recommendation based on testing and historical experience data.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Factors of Silane Reaction

Factors affecting performance of Silanes

The performance of Silane is influenced by many parameters including:

- Silane Structure
- Dosage of Silane
  : Too high dosage may affect poorer property e.g. too rigid, poor stability.
- pH of Resin or Coating
  : pH can catalyze rate of Hydrolysis and Condensation per next page .
- Unknown Chemicals may catalzse Silane
  : Mineral Acids, Alkoxide Salts, Tin Compound, Titanate Ester, Zirconium Salts, Phosphorous Compound, and Amines are catalysts for Silanes.
- Temperature of System
  : Molecule can be moved faster and met each other at higher temperature.

FG - R- SiX_3

> FG (functional group) matches to the resin chemistry to let silane graft well on the resin chains.

> X group affects to reactivity rate .

> Bulkier group gives slower reactivity .

Methoxy is faster than Ethoxy .

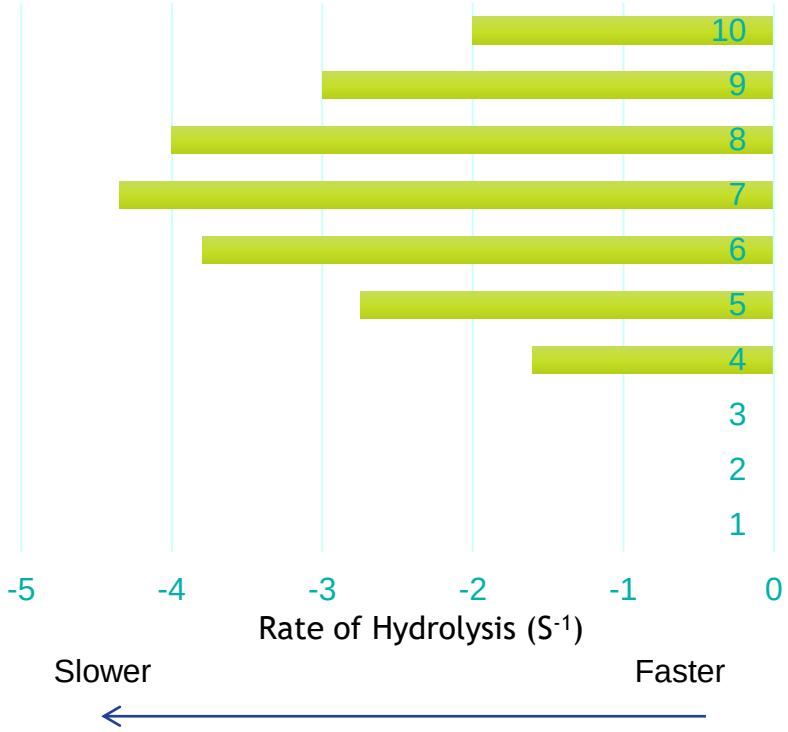
BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

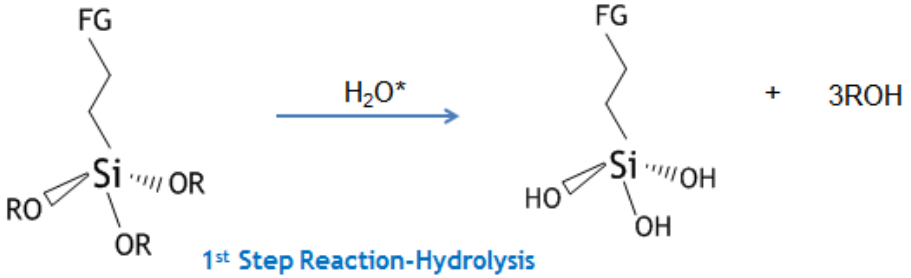
Hydrolysis Rate of Silanes

Time for hydrolysis is dependent on solution's pH.

Rate of Hydrolysis*



* Study of Epoxy Silane Hydrolysis



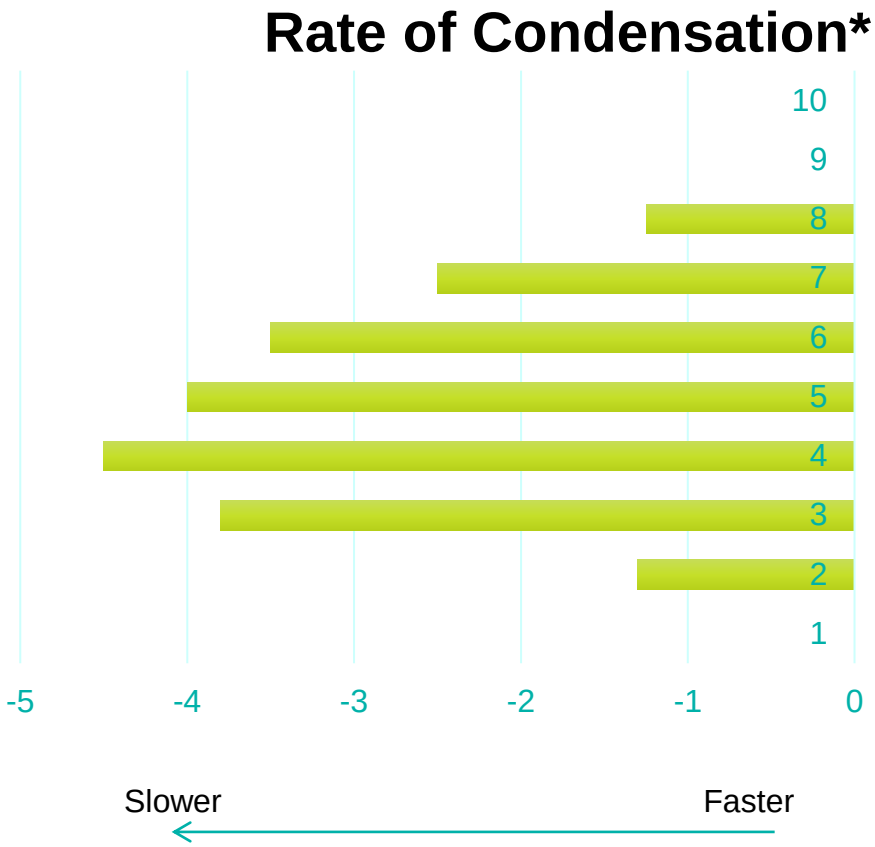
- Prefer pH near to neutral (pH 7) for storage stability purpose in adhesion promoter function .
- For WB, pH is not recommended at > 8.5 which may affect to shelf life of Paints&Coatings .
- -Si-OH (silanol groups) can also react each other or so-called self-crosslink which is not required.

Ref: Pohl, E.R. and F.D. Osterholtz. 1985. Kinetics and mechanism of aqueous hydrolysis and condensation of alkyltrialkoxysilanes. *Polym. Sci. Technol. 27:157-170.*

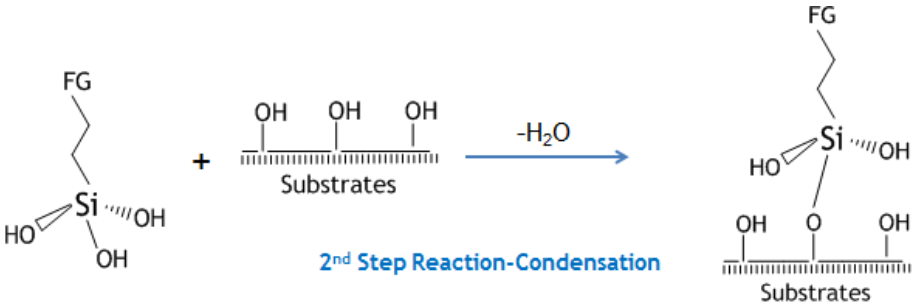
BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Condensation Rate of Silanes (After Hydrolysis)



*Study of Epoxy Silane Condensation



- At pH 7 , condensation rate is medium in which condensation is the reaction happening after hydrolysis of silane.
- During application, the environment which is contained moisture in the air and unstable pH, hydrolysis and condensation can happen and let silane react to substrate.

Ref: Pohl, E.R. and F.D. Osterholtz. 1985. Kinetics and mechanism of aqueous hydrolysis and condensation of alkyltrialkoxysilanes. *Polym. Sci. Technol. 27:157-170.*

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Hydrolysis Tips for WB and SB

Waterborne (WB)

- Hydrolysis is slowest around pH 7, this is good for storage purpose.
- Acid pH and alkaline pH can catalyze rate of hydrolysis.
- Bigger substituents (hydrocarbon) on silicon retard hydrolysis
  e.g. Ethoxy is slower hydrolysis rate than methoxy.

Solventborne (SB)

- Hydrolysis of the first alkoxy group is slow.
- Alcohols can retard hydrolysis rate.
- Silanetriol species are unstable and able to condense in SB.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

Signs of Unexpected Hydrolysis + Condensation of Silane

Trouble signs in Resins or Coatings

- Gel formation
- Seeding
- Viscosity buildup
- White precipitate
- Loss of performance over time

e.g. The first test shows good adhesion performance but after a few weeks, the second test shows poor adhesion on the same sample.

These signs mean silanes may self-crosslink.
The worst case is entire gel.

BRB
A Subsidiary of PETRONAS Chemicals Group

© 2021 BRB International B.V.

BRB

Passionate about Progress