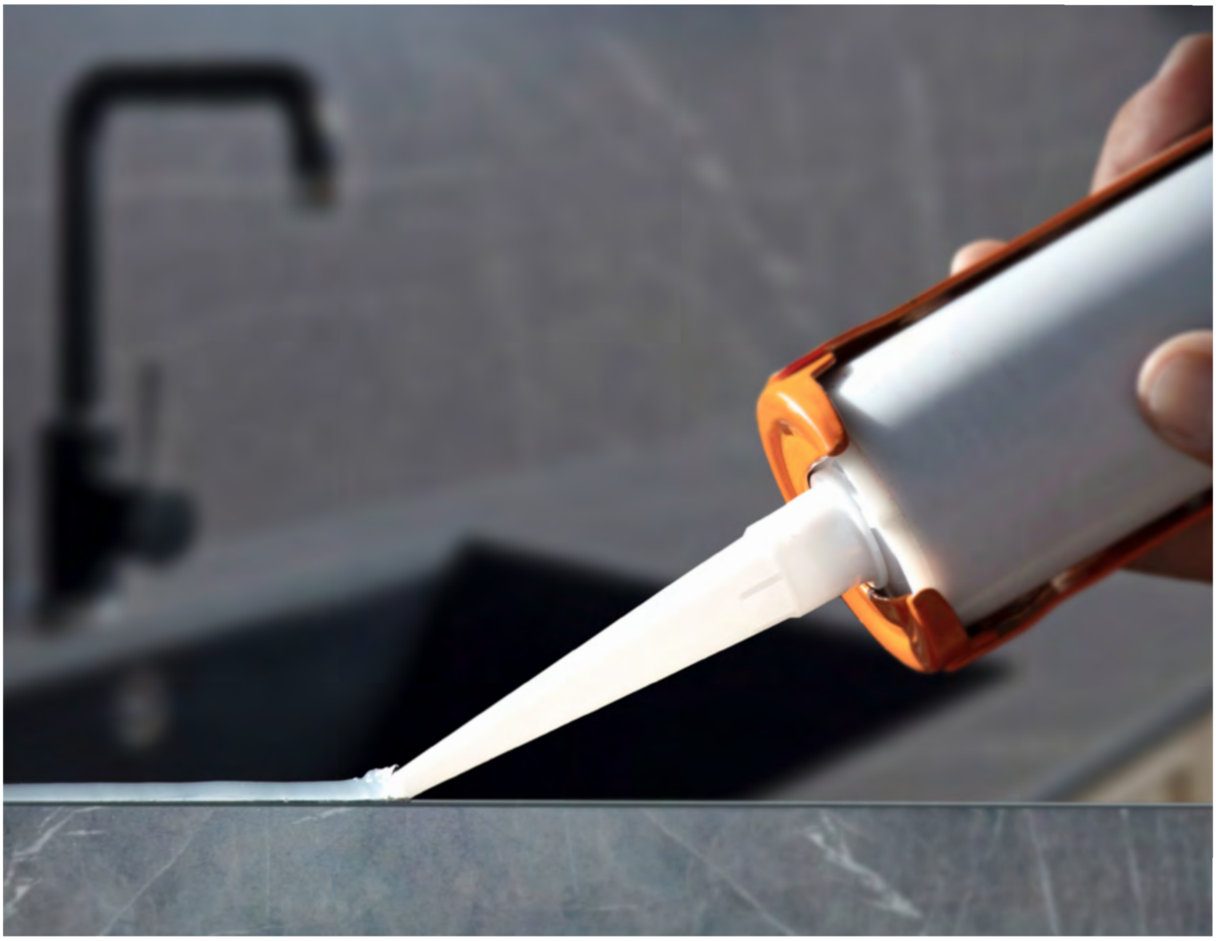
TECHNICAL INFORMATION 1374

PRODUCTS FOR
RTV-1 SILICONE SEALANTS



Leading Beyond Chemistry

CONTENT

1. INTRODUCTION

Silicone sealants have been an important and integral part of the sealants market for more than 60 years. To remain competitive in this large market in the future, producers of RTV-1 Silicone Sealants must develop innovative systems and solutions with an exceptionally wide range of products and services.

It is well known that AEROSIL® fumed silica can improve many properties of these silicone sealant compounds. Evonik Industries developed the AEROSIL® process more than 80 years ago and has been one of the leading companies in the development and production of fumed silica and fumed oxides.

AEROSIL® fumed silica can impart the required rheological and mechanical properties in RTV-1 Silicone Sealants. In addition to fumed silica, the use of AEROXIDE® fumed oxides and Dynasylan silanes can provide unique properties in RTV-1 Silicone Sealants. **Table 1** shows an overview of Evonik products developed

Table 1: Evonik products and their application options in RTV-1 Silicone Sealants

Effect	Product	Starting concentration (wt.%)
Reinforcement	AEROSIL® 150	5 – 15
Thickening	AEROSIL® 150	5 – 15
Improvement of storage stability	AEROSIL® R 972	5 – 15
Increase in transparency	AEROSIL® R 974 AEROSIL® R 106	5 – 15
Adhesion promotion	Dynasylan® product series	1.0 – 3.0
Mechanics (crosslinking)	Dynasylan® product series	2.0 – 5.0

In the following sections, the technical details of these Evonik products developed for **RTV-1 Silicone Sealants** will be discussed.

2 **TECHNICAL FUNDAMENTALS** FOR THE USE OF **AEROSIL®** IN RTV-1 SILICONE SEALANTS

AEROSIL® fumed silica is an ultra-pure amorphous silicon dioxide with extremely small primary particles. These fine particles of high-purity white powder are produced by hydrolysis of chlorosilanes in an oxygen-hydrogen flame. The small primary particles give rise to very large specific surface areas ranging from 50 to 380 m^2/g. **Fig. 1** exhibits TEM micrograph of AEROSIL® 150. The primary particles are not isolated but are linked together by covalent bonding to give stable aggregates, which can be a few hundred nanometers in size. The aggregates further form loose agglomerates with sizes of micrometers range, which can again disintegrate when dispersed in the application.

The development of special hydrophobic grades (surface modified with silane) of AEROSIL® has enabled the production of advanced silicone sealants which helps shape the technologies of the future, for example, in vehicle construction and civil engineering.

Fig. 1: TEM micrograph of AEROSIL® 150

Table 2: Typical physico-chemical data for AEROSIL®

AEROSIL®	130	150	200	R 972	R 974	R 104	R 106	R 812 S
Surface modification	None, hydro-philic	None, hydro-philic	None, hydro-philic	DDS*	DDS*	D4*	D4*	HMDS*
BET surface area [1] m^2/g	130 ± 25	150 ± 15	200 ± 25	110 ± 20	170 ± 20	150 ± 25	250 ± 30	220 ± 25
pH [2]	3.7 – 4.5	3.7 – 4.5	3.7 – 4.5	3.6-5.5	3.4–5.0	≤4.0	≤3.7	5.5– 9.0
Tamped density [3] g/l (approximate value)	50	50	50	50	50	50	50	60
Compacted material with higher tapped density available on request?	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Loss on drying [4] % (2 h at 105 °C)	≤0.5	≤0.5	≤0.5	≤ 0.5	≤0.5	–	–	≤0.5
C content	-	-	-	0.6 - 1.2	0.9 - 1.5	1.4 - 2.0	1.5 – 3.0	3.0 – 4.0
SiO_2 [5] %	≤99.8	≤ 99.8	≤99.8	≤99.8	≤99.8	≤99.8	≤99.8	≤ 9.8
$Al2O_3$ [5] %	≤0.03	≤0.03	≤0.03	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05
TiO_2 [5] %	≤0.03	≤0.03	≤0.03	≤0.03	≤0.03	≤0.03	≤0.03	≤0.03
HCl [5] [6] %	≤0.025	≤0.025	≤0.025	≤0.025	≤0.05	≤0.02	≤0.025	≤0.025

* The data represents non-binding typical values

DDS = dimethyldichlorosilane
D4 = octamethylcyclotetrasiloxane
HMDS = hexamethyldisilazane

3 **HYDROPHILIC** AND **HYDROPHOBIC FUMED SILICA** FOR RTV-1 SILICONE SEALANTS

Silanol and siloxane groups are present on the surface of untreated AEROSIL® fumed silica. This makes the AEROSIL® hydrophilic, or have a high affinity to water and it can be wetted by water completely. AEROSIL® 150, for example, is capable of adsorbing considerable amounts of water.

The reaction of the silanol groups with organic silicone compounds results in alkyl silyl groups being chemically anchored on the surface. The resulting products are hydrophobic, i.e. are not wetted by water and absorb only very small amount of it. These products carry the suffix R (R stands for "repellent"), for example, AEROSIL® R 972. The ability of moisture uptake of hydrophilic AEROSIL® 150 and hydrophobic AEROSIL® R 972 is demonstrated in **Fig. 2**.

In RTV-1 Silicone Sealants the thickening action of fumed silica decreases with the degree of hydrophobization. Typically, higher levels of hydrophobicity result in lower thickening. However, concerning dispersibility, the more strongly hydrophobized the silica, the more easily it incorporates and disperses into formulations. Another advantage of hydrophobic fumed silica in a RTV-1 Silicone Sealants formulation is the improvement of storage stability. This can be seen in **Fig. 3**, showing the percent change in viscosity and yield point of 1-component RTV alkoxy sealant compound after storage for 56 days at 50 °C. In moisture-sensitive RTV–1 formulations, hydrophobic fumed silica is preferred because of its low moisture content and negligible moisture uptake during storage.

Fig. 2: Moisture uptake of AEROSIL® 150 and AEROSIL® R 972

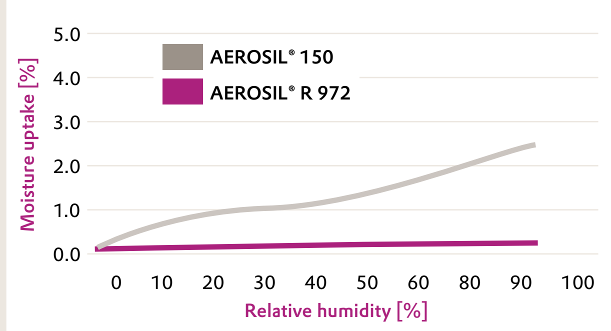
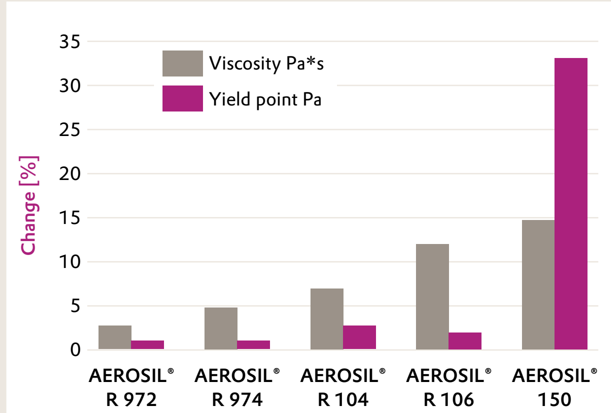


Fig. 3: Percentage change in viscosity and yield point of a RTV-1 alkoxy sealant compound after storage for 56 days at 50 °C



4 OPTIONS FOR **ADJUSTING THE PROPERTIES** OF RTV-1 SILICONE SEALANTS

In RTV-1 Silicone Sealants, the properties such as thickening impact, mechanical strength, expansion behavior and transparency can be controlled by proper selections of hydrophilic and hydrophobic fumed silica.

The plot between the degree of hydrophobization versus the BET surface area of various AEROSIL® grades is shown in **Fig. 4. Fig. 5 – 7** present the individual property that can be selectively controlled by changing the surface area or the degree of hydrophobization.

In general, the following statements can be applied for RTV-1 Silicone Sealants formulations for any changes in the surface area or in the degree of hydrophobization of the fumed silica used:

As the surface area increases …

- the thickening impact increases and the increase in the reinforcing properties is noticeable. This allows a reduction in the amount of the reinforcing filler used.
- hydrophilic silica in RTV-1 Silicone Sealants are more difficult to incorporate and disperse.
- silicone sealant compounds with higher transparency can be produced.

By hydrophobizing fumed silica …

- water uptake is significantly reduced, resulting in improved storage stability of moisture sensitive RTV–1 Silicone Sealant formulations.
- incorporation behavior and dispersibility are significantly improved.
- the amounts of crosslinkers and water scavengers used in RTV-1 Silicone Sealants can be reduced, resulting in reduced raw material costs.

With an increasing degree of hydrophobicity …

- lower viscosities are obtained in RTV-1 Silicone Sealants.
- mechanical properties are changed only slightly.
- greater freedom is possible in formulation.

Fig. 4: Degree of hydrophobization and BET surface area of various AEROSIL® grades

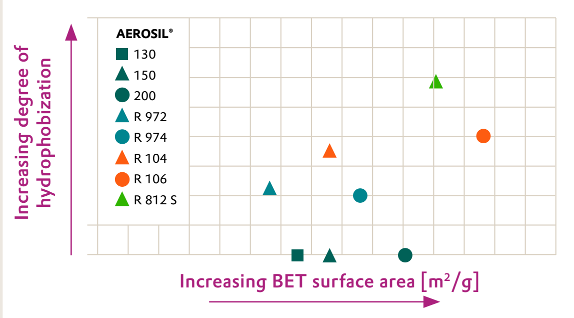


Fig. 5: Viscosity of different RTV-1 Silicone Sealants formulated with various AEROSIL® grades. (acetoxy sealing compounds, 8% filler content)

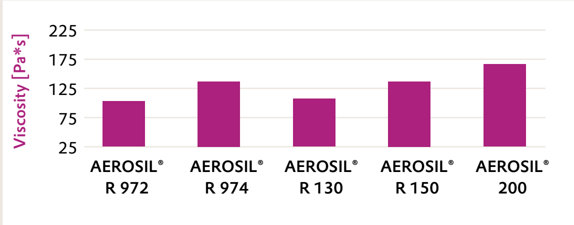


Fig. 6: Modulus 100% of different RTV-1 Silicone Sealants formulated with various AEROSIL® grades (acetoxy sealing compounds, 8% filler content)

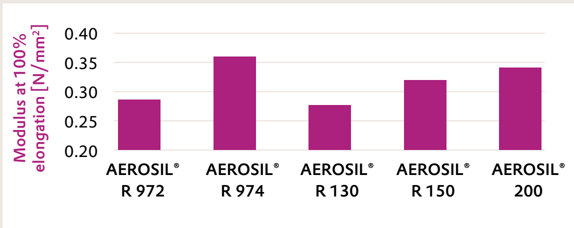
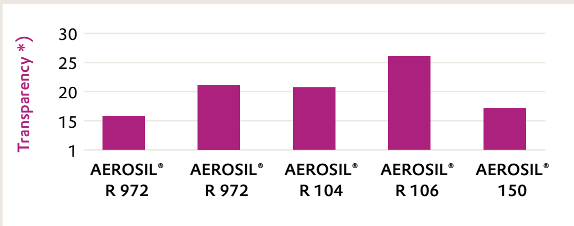


Fig. 7: Transparency of different RTV-1 Silicone Sealants formulated with various AEROSIL® grades (acetoxy sealant compounds, 8% filler content)

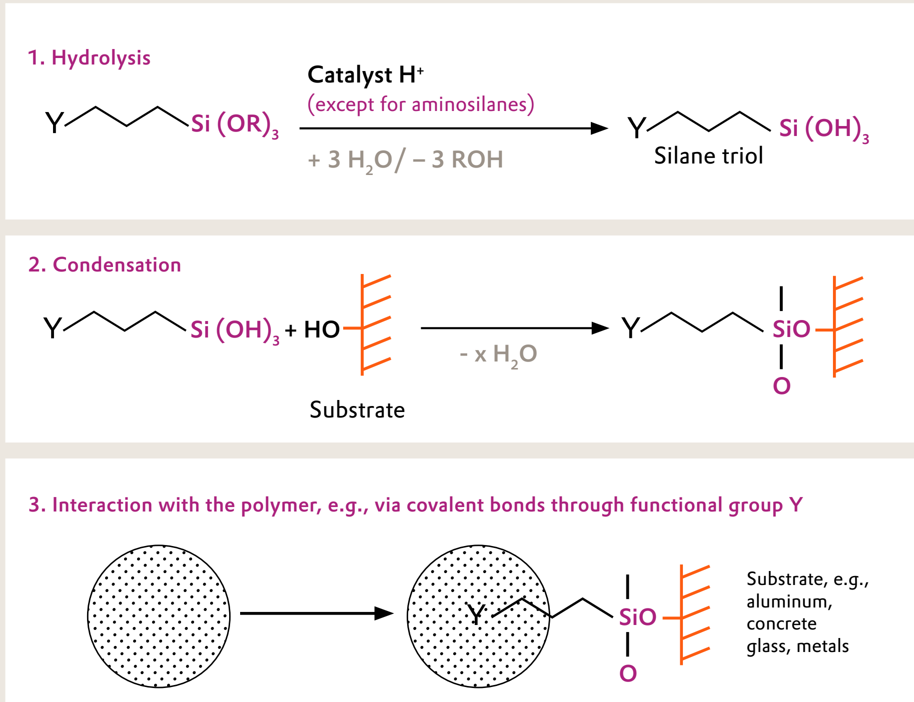


*) Higher values indicate greater transparency

5 DYNASYLAN® SILANE AS **ADHESION PROMOTER**

When used as an adhesion promoter, Dynasylan® acts as a bifunctional organosilicon compound, producing a chemical bond or interaction between a silicone sealant and the inorganic or organic substrate. For adhesion promotion, Dynasylan® can be used directly as an additive in the production of RTV-1 Silicone Sealants. For particularly challenging adhesion problems, Dynasylan® can also be applied on the substrate as a primer in aqueous or solvent-containing form.

Fig. 8: Mechanism of adhesion promotion



Tab. 3: Product recommendations, according to the types of RTV–1 silicone systems

RTV silicone type	Organofunctional silane	Chemical structure
Alkoxy systems	Dynasylan® TRIAMO	Triamino functional propyltrimethoxysilane
	Dynasylan® AMMO	Aminopropyltriethoxysilane
	Dynasylan® DAMO-T	Diamino functional propyltrimethoxysilane
	Dynasylan® 1124	Secondary aminofunctional methoxy-silane
	Dynasylan® 1146	Amino functional silane oligomer
Oxime systems	Dynasylan® AMMO	Aminopropyltriethoxysilane
	Dynasylan® DAMO-T	Diamino functional propyltrimethoxysilane
	Dynasylan® TRIAMO	Triamino functional propyltrimethoxysilane
	Dynasylan® 1146	Amino functional silane oligomer

The Dynasylan® 1146 product is particularly distinguished because of the following advantages:

- wide adhesion spectrum
- fast cure
- low tendency to yellowing
- positive influence on elasticity
- reduced VOC content
- label free

6 DYNASYLAN® SILANE AS **CROSSLINKER**

Dynasylan® organofunctional silanes can be used as crosslinkers in RTV-1 Silicone Sealants. Crosslinking occurs via a condensation reaction and influences elastic modulus, elongation and tensile strength of the final product.
In a first step, the tri- or tetrafunctional silane reacts with the hydroxy groups of the oligomeric siloxane to form functionalized organopolysiloxane chains as shown in **Fig.9**.
During the curing process these functionalized organopolysiloxane chains react with moisture and a crosslinking reaction is initiated via condensation reaction of the terminal hydroxy groups at the end of the functionalized organopolysiloxane chains as shown in **Fig.10**.

Fig. 9: Example of the reaction of functionalization of a silicone polymer

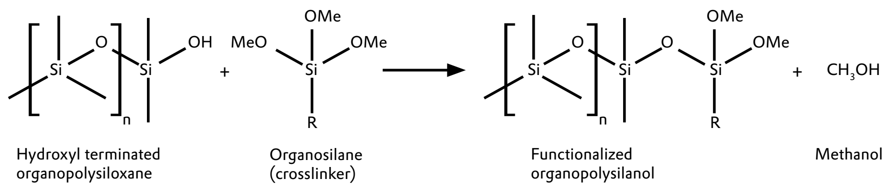
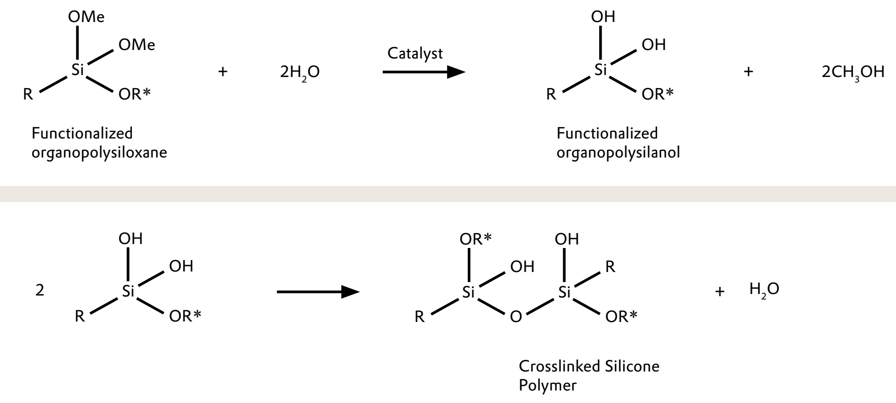


Fig. 10: Example of a crosslinking reaction in the presence of moisture to provide a crosslinked (elastic) silicone polymer



Tab. 4: Product recommendations for RTV–1 alkoxy systems

RTV silicone type	Organofunctional silane	Chemical structure
Alkoxy systems	Dynasylan® A	Tetraethoxysilane
	Dynasylan® P	Tetra-n-propoxysilane
	Dynasylan® 40	Ethylpolysilicate
	Dynasylan® VTMO	Vinyltrimethoxysilane

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