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CREATING TOMORROW'S SOLUTIONS

COMPOSITES I SILICONE RESINS

SILICONE RESINS FOR INSULATION COMPOSITES

Though the role they play is often not a visible one, silicone resins are an essential ingredient in composites. Whether for toasters, hairdryers, trains or the subway – composites are used in a truly broad range of applications that accompany us as a matter of course in everyday life.

Composites: Their Uses and Constituents

Composites are often used as mechanical, load-bearing building components for structural-design purposes. They also provide electrical and/or thermal insulation. Composites have a diverse range of applications in the manufacturing sector (e.g. machine-making and electrical industries) and are also used in the consumer goods industry.

They consist of a matrix material and a binder. Examples of matrix materials include mica and glass, synthetic and mineral fibers, as well as their corresponding woven or nonwoven fabrics. The binder is always a resin.

Silicone Resins in Composites

The beneficial properties of silicone resins are numerous:

- Excellent electrical insulation over a wide temperature and frequency range
- Water-repellent, highly resistant to moisture
- Gas-permeable
- Biocompatible, food grade, chemically pure, durable

Silicone resins provide the following advantages over other resin technologies:

- High heat resistance
- Flame retardant
- No toxic vapors in the event of fire
- Media resistance
- Radiation resistance
- Weathering resistance
- Low content of Volatiles and Volatile Organic Compounds (VOC)

WACKER's Portfolio for Composites

WACKER supplies resin compounds based on a variety of silicone resin technologies:

- Solvent-based resin formulations
- Solvent-free liquid resins (100% active-ingredient content)
- Solid resins (100% active-ingredient content)

To obtain the final (solid) resin structure, subsequent curing must take place.

Curing: Important Information

- To cure completely, silicone resins normally require elevated temperatures, e.g. 150 to 200 °C.
- Curing can be speeded up considerably by the addition of catalysts.
- Increasing the curing temperature and the amount of catalyst will reduce curing time.
- Complete curing requires at least 3 to 5 times the gel time.
- Postcuring is not normally needed to reduce the VOC content further – provided that the silicone resin has already been fully cured.

Silicone resin flakes

Silicone resin powder

Liquid silicone resin

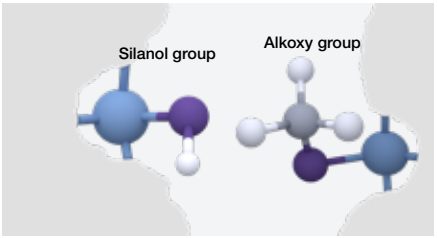
Chemical Classification and Processing of Silicone Resins

The type of curing mechanism makes it necessary to distinguish between condensation-curing and addition-curing silicone resins.

The Crosslinking Chemistry Underlying Condensation-Curing Silicone Resins

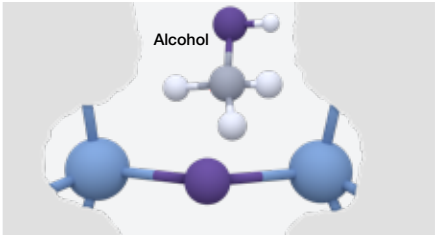
Curing Characteristics

- Crosslinking via alkoxy and/or silanol groups
- Release of byproducts, such as water or alcohol
- Curing catalysts: metal salts, acids, bases
- Typical conditions for complete curing: >150 °C for several hours



Criteria for Making a Decision

- Very robust, relatively stable reaction chemistry
- Normally release of 0.5 to 3 wt % byproducts
- Slight shrinkage during curing

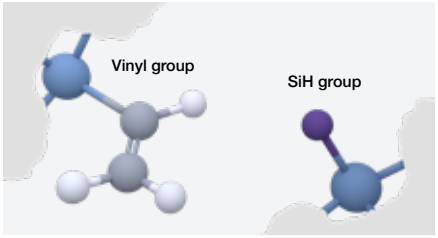


Crosslinking process

The Crosslinking Chemistry Underlying Addition-Curing Silicone Resins

Curing Characteristics

- Crosslinking via SiH and vinyl groups
- Suitable curing catalysts: platinum compounds
- Typical conditions for complete curing: >120 °C for several hours



Criteria for Making a Decision

- No release of byproducts during curing
- No weight loss
- Almost no shrinkage during curing
- Platinum-based curing catalysts are sensitive to disruptive influences caused by catalyst poisons, such as organic compounds that contain sulfur or nitrogen

Crosslinking process

SILRES® Silicone Resins for Composite Laminates and Tapes

SILRES® silicone resins are key components of composites intended for electrical-engineering or structural-design applications. Silicone-resin-bound laminates based on mica, glass fiber or mineral fiber permanently withstand even extreme temperatures, yet retain their electrical and water-repellent properties, as well as their high mechanical strength.

What is more, at temperatures of 600 °C and higher, the silicone resin binder can be transformed into a ceramic based on silicon, oxygen and carbon, during which process the organic content undergoes partial pyrolysis. The matrix part of the composite remains largely unchanged and stays firmly bound in the partially ceramified binder, which results in extremely heat-resistant composites such as micanite sheets for electric heating elements.

Due to their predominantly inorganic nature, silicone resins lose much less weight when undergoing pyrolysis than organic resins do. Shrinkage caused by pyrolysis tends to be low as a result. This low weight loss is essential for dimensionally stable, mechanically strong composites, as well as for the dimensional accuracy of ceramic or sintered molded products based on inorganic matrix materials.

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Mica paper

Glass/mica composite tapes are made up of a support layer (usually a glass-fiber fabric) and a layer of mica paper which is impregnated by means of silicone-resin-based formulations and which is secured to the support layer. The silicone-resin-bound mica tapes obtained in this way exhibit excellent dielectric properties and are flame retardant and extremely resistant to heat. This makes them ideal for insulating safety-relevant electrical conductors that are exposed to considerable thermal stress, as encountered in refractory safety cables and the stator coils of traction motors and generators.

Mica and glass-cloth laminates

Mica laminates

Glass-cloth laminates

Mica tape

Mica Composites	Fiber and Woven-Fabric Laminates	Mica Tapes
• Mica paper grades • Mica laminates: – For structural-design purposes (flexible and rigid sheeting, piping/tubing, rods and various other molded articles) – For micanite sheets (forming part of electric heating elements in toasters, hair dryers, hot-air fans, etc.) • Function of silicone resin: binder in the mica matrix • Product recommendations: **– SILRES® MK FLAKES** **– SILRES® MK POWDER** **– SILRES® K** **– SILRES® H44**	• As a mechanical component of electrical assemblies such as switches, relays, PCBs • For structural-design purposes (flexible and rigid sheeting, piping/tubing, rods, grooved/slotted wedges and various other molded articles) • Function of silicone resin: binder in the fiber and woven-fabric matrix • Product recommendations: **– SILRES® MK FLAKES** **– SILRES® MK POWDER** **– SILRES® K** **– SILRES® H44** **– SILRES® H60**	• For the electrical insulation of electrical conductors, e.g. in fireproof safety cables or in the preformed coils of traction motors and generators • Function of silicone resin: Impregnation agent and binder for the mica-paper and support-fabric layer • Product recommendations: **– SILRES® 64558 VP** **– SILRES® REN 50**

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Product Overview							
	SILRES® MK FLAKES	**SILRES® MK POWDER**	**SILRES® K**	**SILRES® H44**	**SILRES® H60**	**SILRES® 64558 VP**	**SILRES® REN 50**
	Methyl silicone resin	Methyl silicone resin	Methyl silicone resin	Phenyl silicone resin	Phenyl silicone resin	Silicone PSA premix	Phenyl silicone resin
	Condensation curing	Condensation curing	Condensation curing	Condensation curing	Addition curing	Condensation curing	Condensation curing
Uncured Product							
Delivery form	Flakes	Powder	Solution	Powder	Liquid	Solution	Solution
Solvent	–	–	Toluene	–	–	Toluene	Xylene/ n-Butanol
Solids content [wt. %]	100	100	50	100	100	40	50
Viscosity, kinematic [mm^2/s]	–	–	8	–	–	–	160
Viscosity, dynamic [mPas]	–	–	–	–	1,000	1,800	–
Density [g/cm^3]	–	–	1.00	–	1.12	0.95	1.02
Softening point [°C]	35 – 55	35 – 55	–	45 – 60	–	–	–
Additional curing catalyst required	Yes	Yes	Yes	Yes	No	Yes	Yes
Cured Product							
Carbon content [%]	Approx. 18	Approx. 18	Approx. 20	Approx. 46	Approx. 47	Approx. 29	Approx. 47
Ash residue after pyrolysis at 1000 °C [%]	Approx. 82	Approx. 82	Approx. 79	Approx. 77	Approx. 56	Approx. 46	Approx. 76
Typical Applications							
Mica paper	●	●	●				
Mica laminates	●	●	●				
Mica tapes						●	●
Laminates and composites based on fibers or fabrics	●	●	●	●	●		

These figures are intended as a guide and should not be used in preparing specifications.

SILRES®

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