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Epoxy Polysiloxane Coatings – Isocyanate-free Topcoats with Outstanding Weathering Stability

WACKER Chemie AG, Dr. Dieter Heldmann, 02/02/2022

Table of Contents

Epoxy (Polysiloxane) Coatings in General

Characteristics of Epoxy Coatings

Epoxy Coatings offer

- Hardness and Abrasion resistance
- Room temperature curing
- Chemical resistance
- Excellent adhesion on metals
- Reduced weatherability

Epoxy coatings are two component coatings.

Two-Component Epoxy Coatings Find Numerous Applications in Marine & Protective Coatings

Corrosion Protection and Maintenance Coatings for

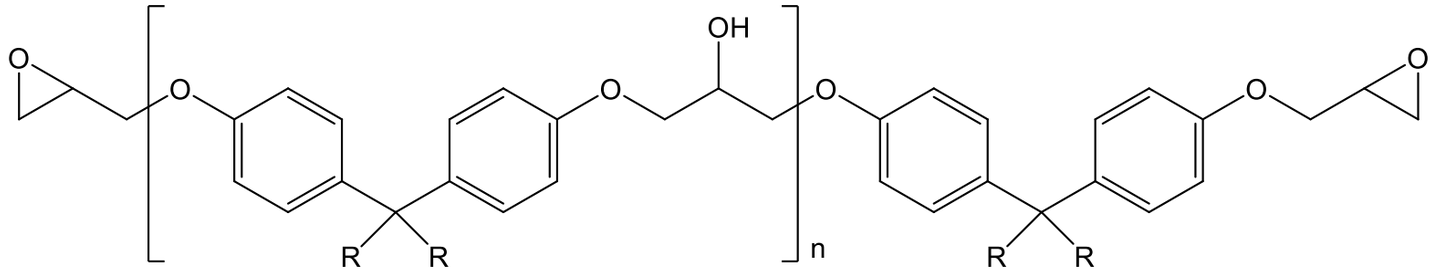
- Oil & Gas, Chemicals
  (drilling, platforms, refinery, storage tanks)
- Infrastructure
  (bridges, commercial buildings)
- Transportation
  (pipelines, cranes)
- Power generation
  (conventional & renewable)

Various Types of Epoxy Resins Are Being Used in the Coatings Industry

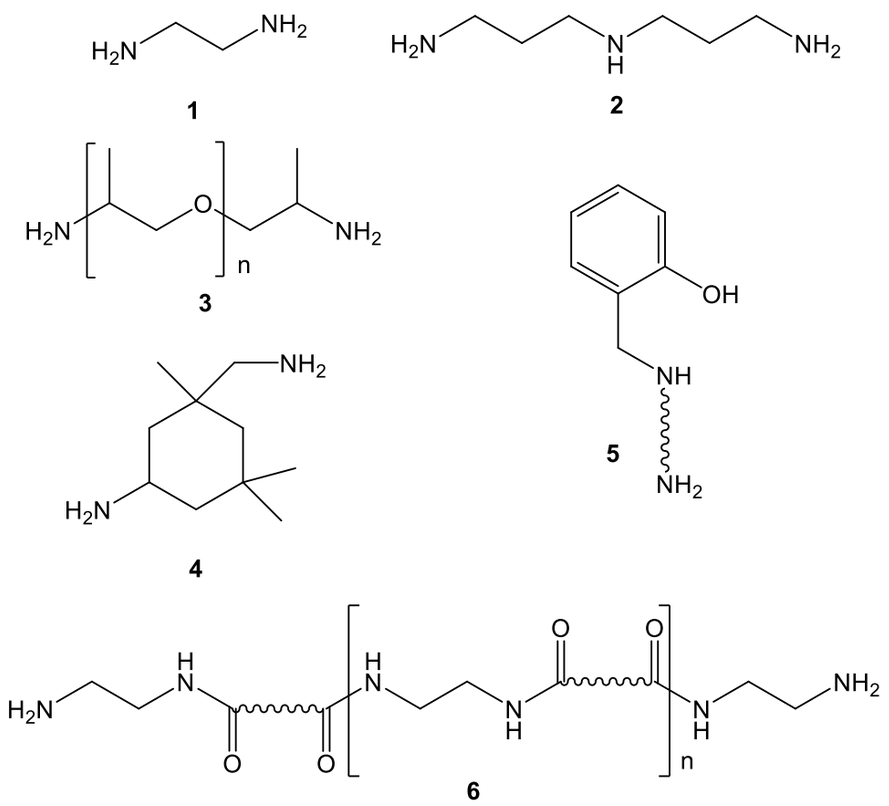
Epoxy Resins Used as a Binder for Coatings Include

- various Bisphenol A (R=CH_3) or F (R=H) types (see graph)
- cycloaliphatic epoxy resins (better weatherability)
- diverse liquid (low molecular weight) epoxy compounds (reactive diluents)

Bisphenol A type Epoxy



Amine-Functional Curatives for Epoxy Coatings



Typical RoomTemperature Curing Agents Include

- aliphatic (poly-)amines (1, 2)
- aromatic (poly-)amines
- polyether amines (3)
- cycloaliphatic amines (4)
- Mannich base (5)
- Polyamidoamine adducts (6)
- Amine adducts
  (prereacted epoxy resin)

Epoxy Coatings Suffer from Low Weatherability

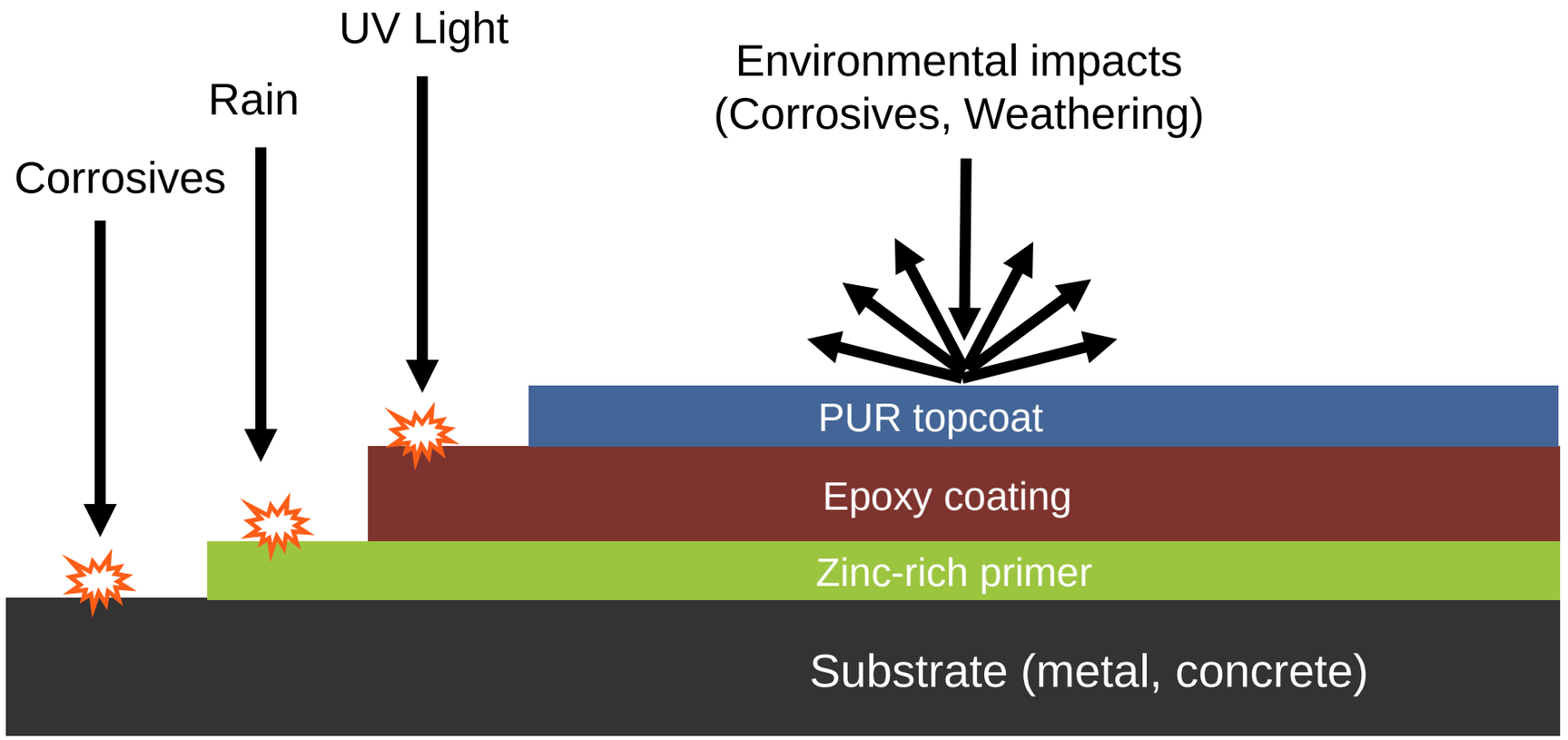
In outdoor applications, the UV component of sunlight damages the film and causes severe chalking

Standard Solution:

Apply an additional weather-resistant PUR topcoat on the epoxy coating

Standard Protective Coating Systems usually Consist of Three Coats

Every Coat Protects from a Single Impact



Epoxy Coatings Suffer from Low Weatherability

In outdoor applications, the UV component of sunlight damages the film and causes severe chalking

Standard Solution:

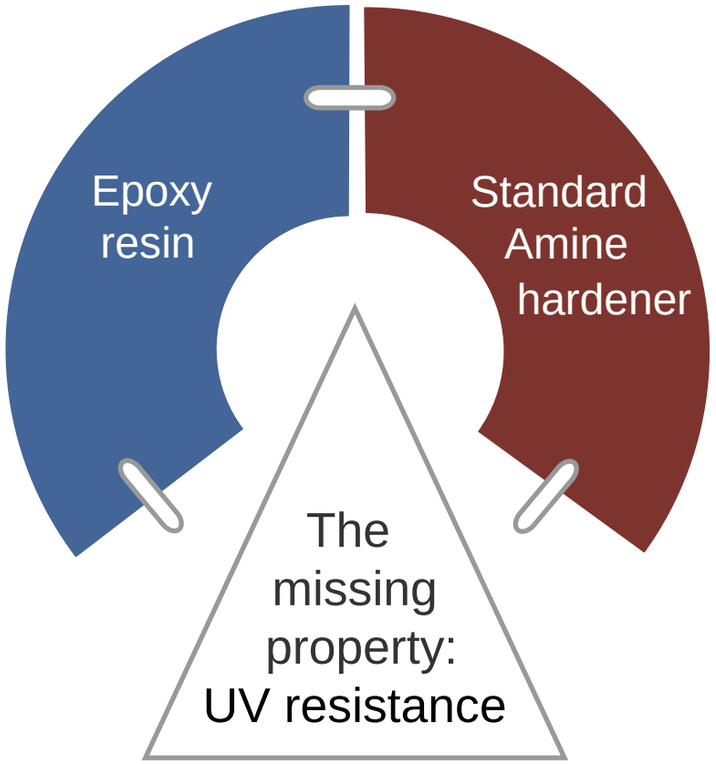
Apply an additional weather-resistant PUR topcoat on the epoxy coating

Advanced Solution:

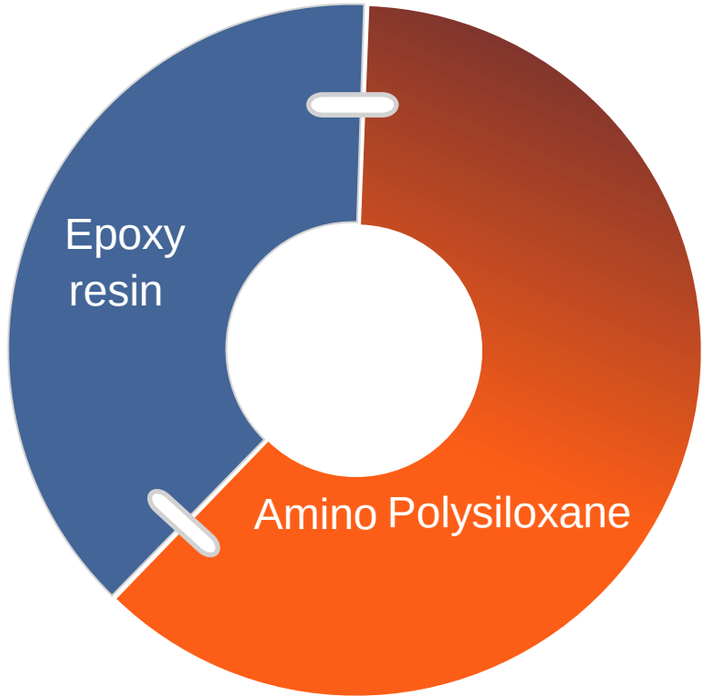
Add unique weathering stability to the epoxy coating by using silicone resins/polysiloxanes

Basic Idea: Incorporate Silicone Resin / Polysiloxane into the Binder System

Epoxy Coating



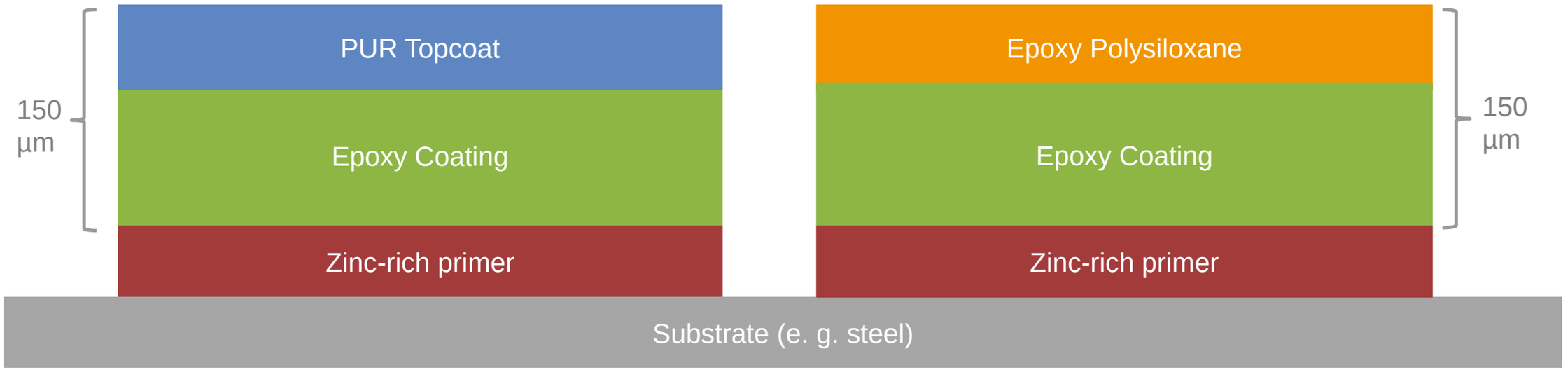
Epoxy Polysiloxane Coating



Linkage is important to close the gap!

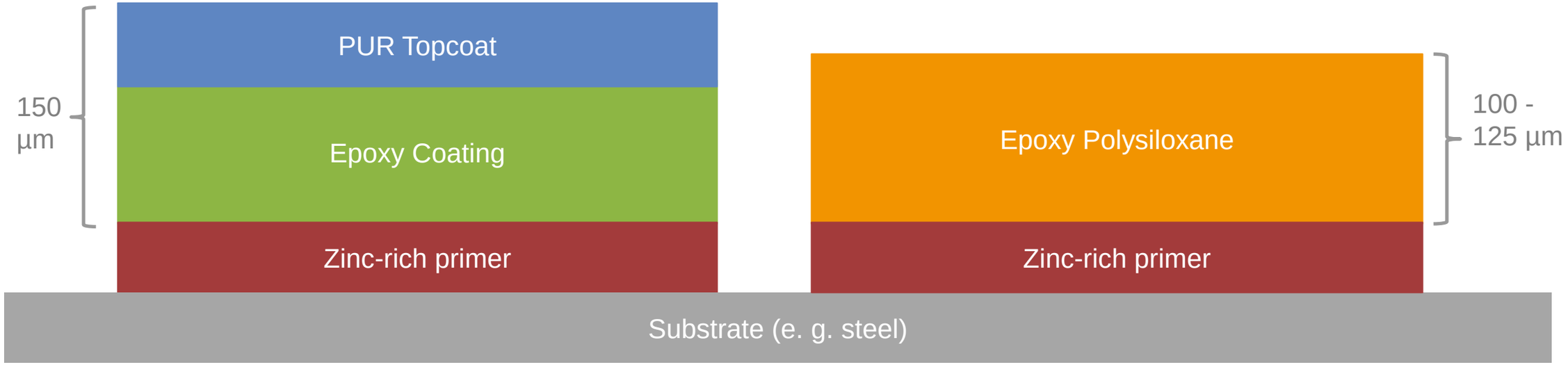
Option 1: Avoid Use of Isocyanates

Epoxy Polysiloxane Coatings can be Used as PUR Topcoat Replacement in very Corrosive Enviroments (C5)



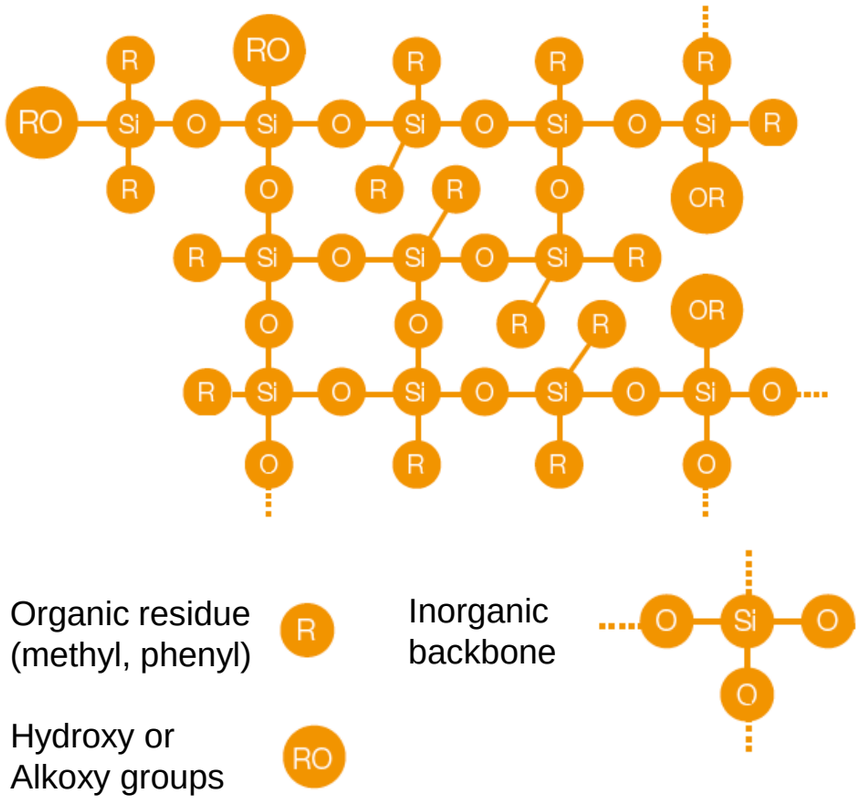
Option 2: Combine Two Coatings into One Coating

Epoxy Polysiloxane Coatings can Replace PUR and Epoxy Coats by a Single Coat in Less Corrosive Environment (C4 and below)



Chemistry of Epoxy Polysiloxanes

Conventional Silicone Resins Must be Cured by Baking at High Temperatures (> 200°C)



Typical Structure of a Standard Silicone Resin

- UV resistant inorganic backbone
- Heat curing resin type
- Polycondensation reaction of alkoxy/hydroxy groups
- Predominantely used for heat-resistant coatings
- Does not cure epoxy resins

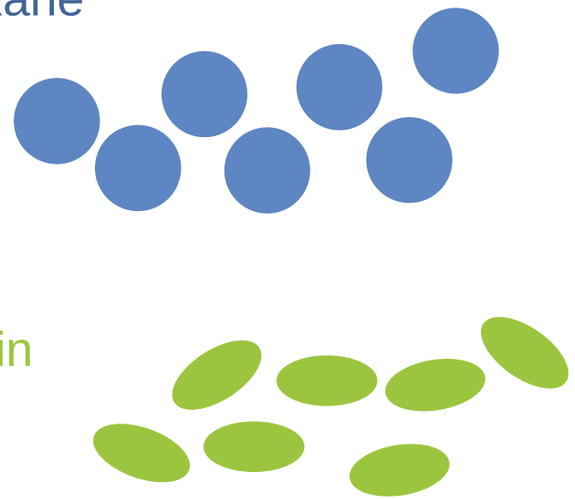
- New resin structure or technology needed

Basic Principle of Two Component Epoxy Polysiloxane Coatings[1]

1. Alkoxyfunctional Polysiloxane

+

Cycloaliphatic Epoxy Resin

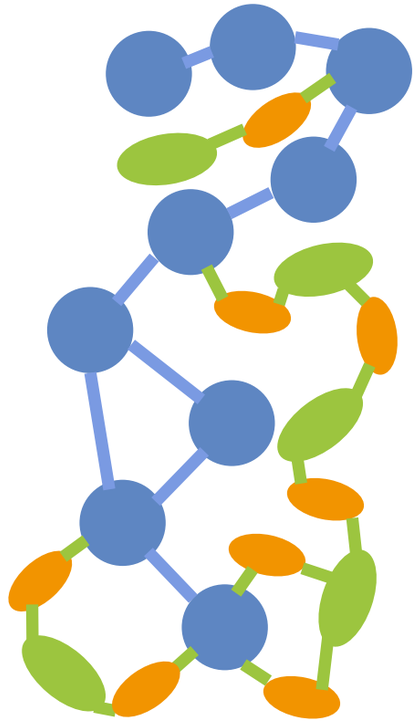


2. Aminofunctional Alkoxysilane
(+ Sn-Catalyst)

$+H_2O$

- ROH

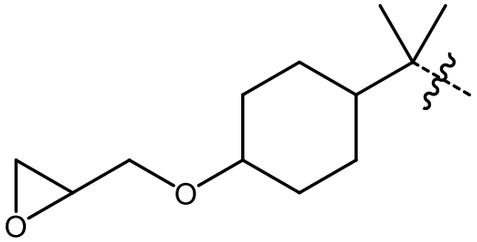
Epoxy Polysiloxane



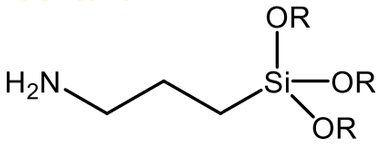
[1] US 5,804,616; US 5,618,860; US 5,275,645 (Ameron)

Cure Mechanism of Silane-based Epoxy Polysiloxane Coatings[1]

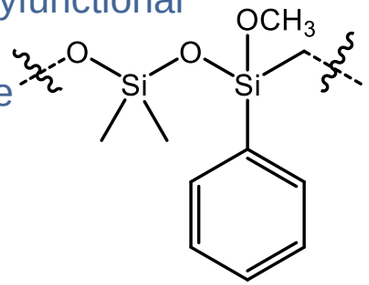
Epoxy Resin



Aminosilane



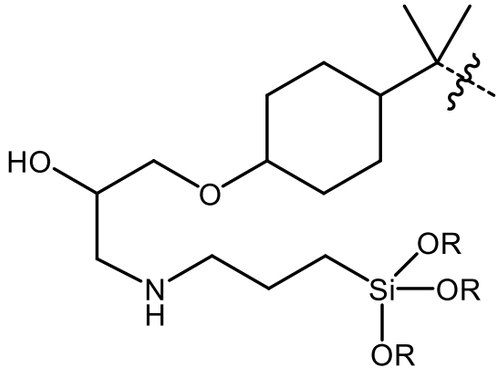
Methoxyfunctional Poly-siloxane



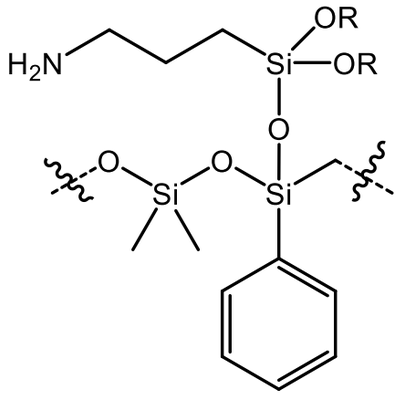
+ H_2O, Sn-Catalyst

- ROH

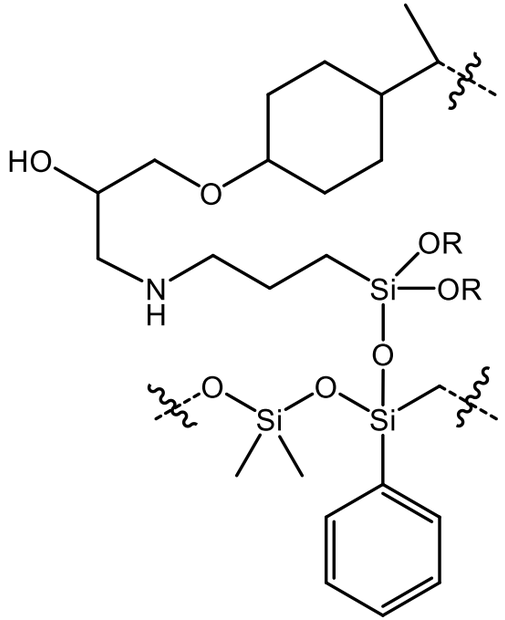
Polyaddition



Polycondensation



Cured Epoxy Polysiloxane Network



[1] US 5,804,616, US 5,618,860, US 5,275,645 (Ameron)

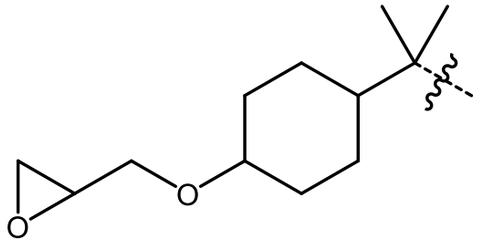
Disadvantages of Silane-based Epoxypolysiloxanes

Complex reaction mechanism (three components)

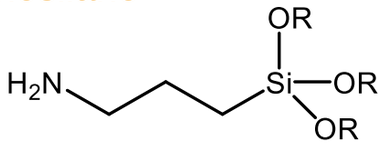
- Use of monomeric silanes
- Hydrolysis and condensation steps of Alkoxy sil(ox)anes
- Polyaddition of reactive organic groups
- Different reaction rates
- Application conditions (Temperature/relative humidity) may have an impact on film formation

Options to Reduce the Number of Components

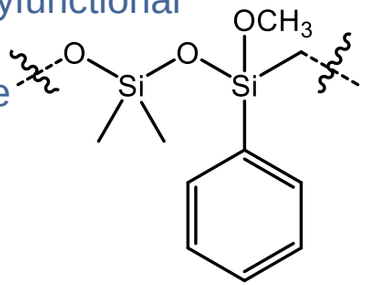
Epoxy Resin



Aminosilane



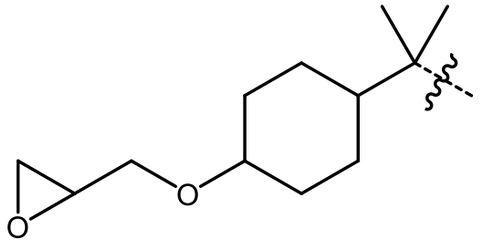
Methoxyfunctional Poly-siloxane



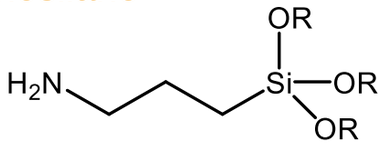
Options to Reduce the Number of Components: Silicone Epoxy Hybrid

Silicone Epoxy Hybrid

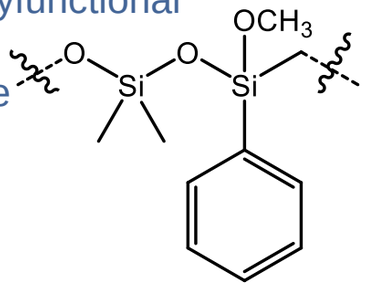
Epoxy Resin



Aminosilane



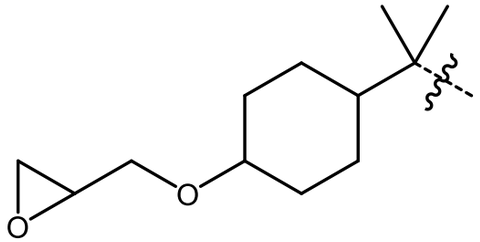
Methoxyfunctional Poly-siloxane



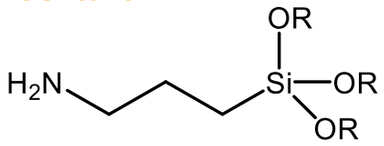
Options to Reduce the Number of Components: Amino Polysiloxane

Silicone Epoxy Hybrid

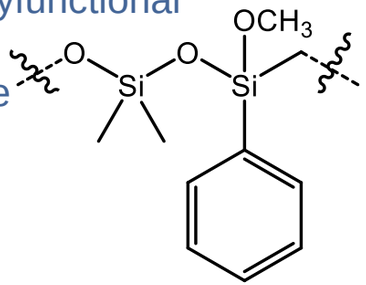
Epoxy Resin



Aminosilane



Methoxyfunctional Poly-siloxane

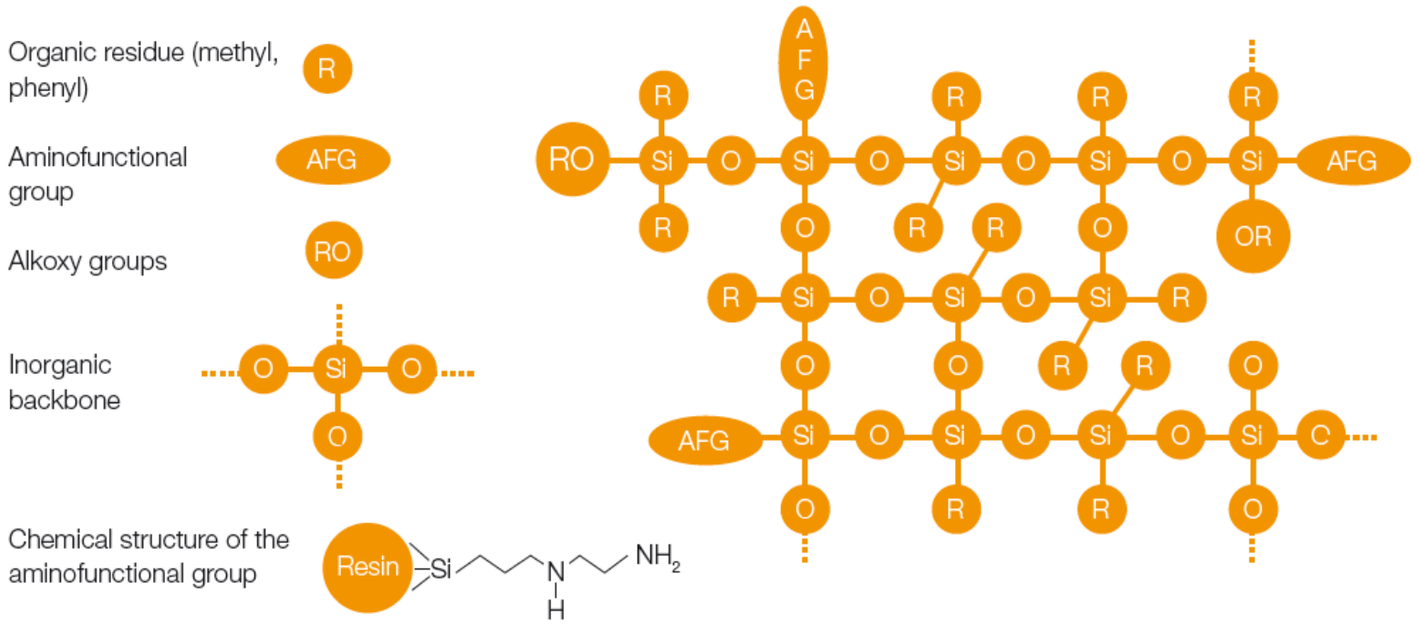


Aminofunctional Silicone Resin
Amino Polysiloxane
Amino Siloxane Resin

Typical Chemical Structure of Amino Polysiloxanes

Aminofunctional Silicone Resin (= Amino Polysiloxane)

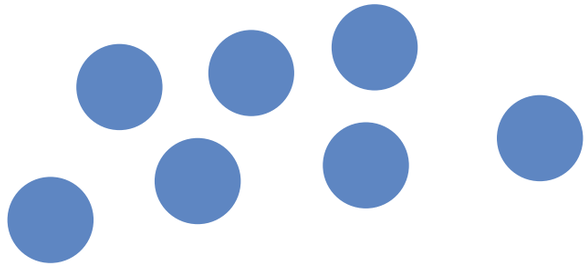
- Aminofunctional groups react with epoxide groups at room temperature
- Silicone backbone provides resistance to the UV component in sunlight



Basic Principle of Two Component Epoxy Polysiloxane Coatings with Amino Polysiloxanes

1. Cycloaliphatic Epoxy Resin

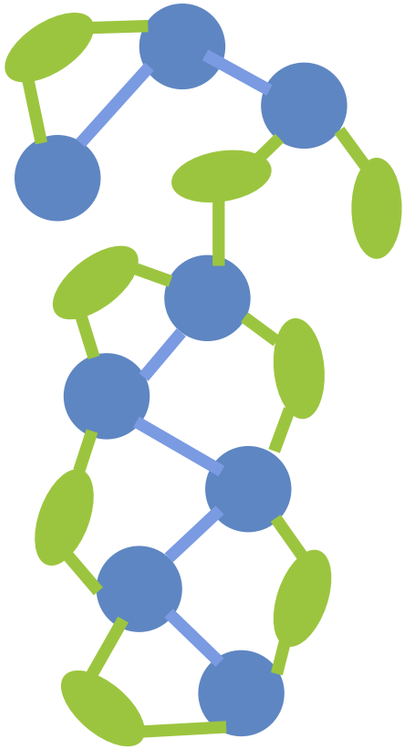
2. Aminofunctional Silicone Resin / Amino Polysiloxane



$+H_2O$

- ROH

Epoxy Polysiloxane



Correct Ratio of Resin to Curing Agent is Important

Epoxy Resin

- Epoxy equivalent weight (EEW)

  How many grams of epoxy resin contain 1 mol of epoxide groups

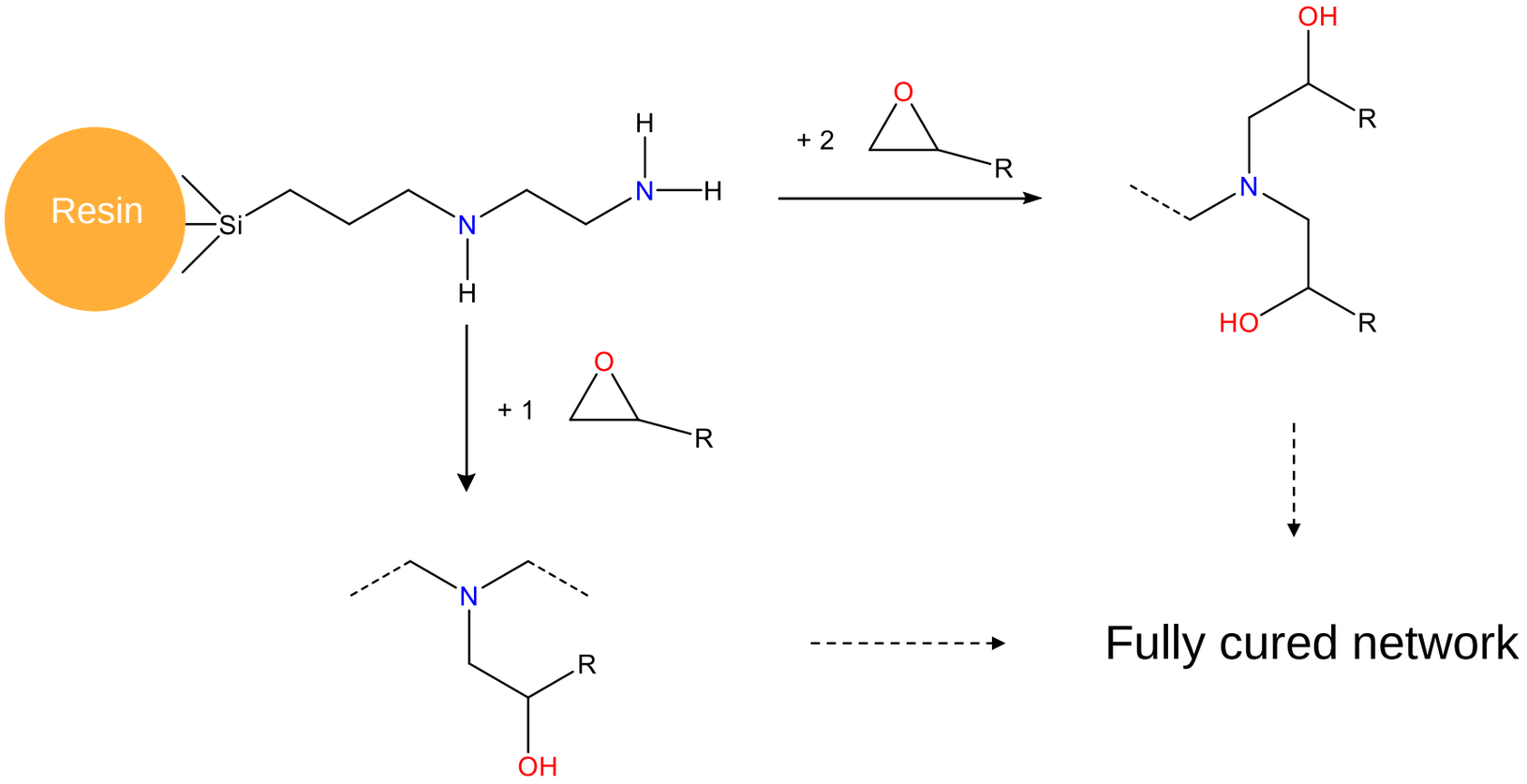
Amine Curing Agent (= Hardener)

- Amine Hydrogen Equivalent Weight (AHEW)

  How many grams of amine hardener contain one mol of N-H groups

- Calculated addition level is just a theoretical guideline,
  over- or undercured coatings in the range of 10 – 20% are possible

How to Calculate the correct AHEW for such Aminopolysiloxanes?



- 2 N atoms (= AN), but one Nitrogen can react twice with epoxy and the other one only once.

Formulation of Epoxy Polysiloxane Coatings with Amino Polysiloxanes

Basic Formulation

Epoxy Polysiloxane Coating Components

- Cycloaliphatic epoxy resin (e. g. EEW 220 g/mol)
- Pigments
- Extenders/Fillers
- Additives
- Aminofunctional Polysiloxane (e. g. AHEW 247 g/mol)

Test Formulation

Component A: Paint Base	Weight%
Cycloaliphatic epoxy resin	33
Pigment, e.g. Titanium dioxide	30
Mix and disperse thoroughly (Dissolver or bead mill)	

Component B: Curing Agent	
Aminofunctional Polysiloxane	37

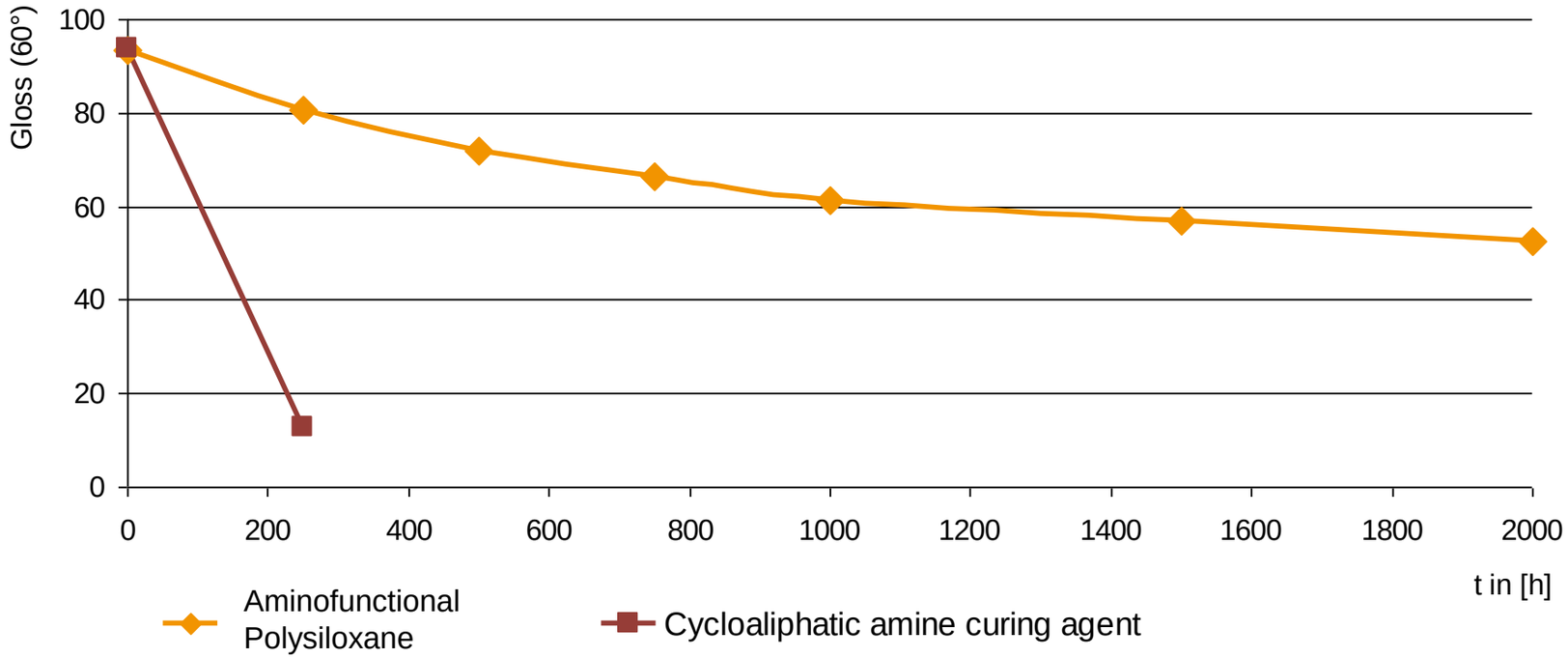
- Add and mix Comp A with B prior to use; Potlife 4 – 5 h

Exemplary Coating Performance Data

Significant Improvement of the Gloss Retention of a White Epoxy Coating

QUV-B Accelerated Weathering Test of a White Epoxy Coating Cured either

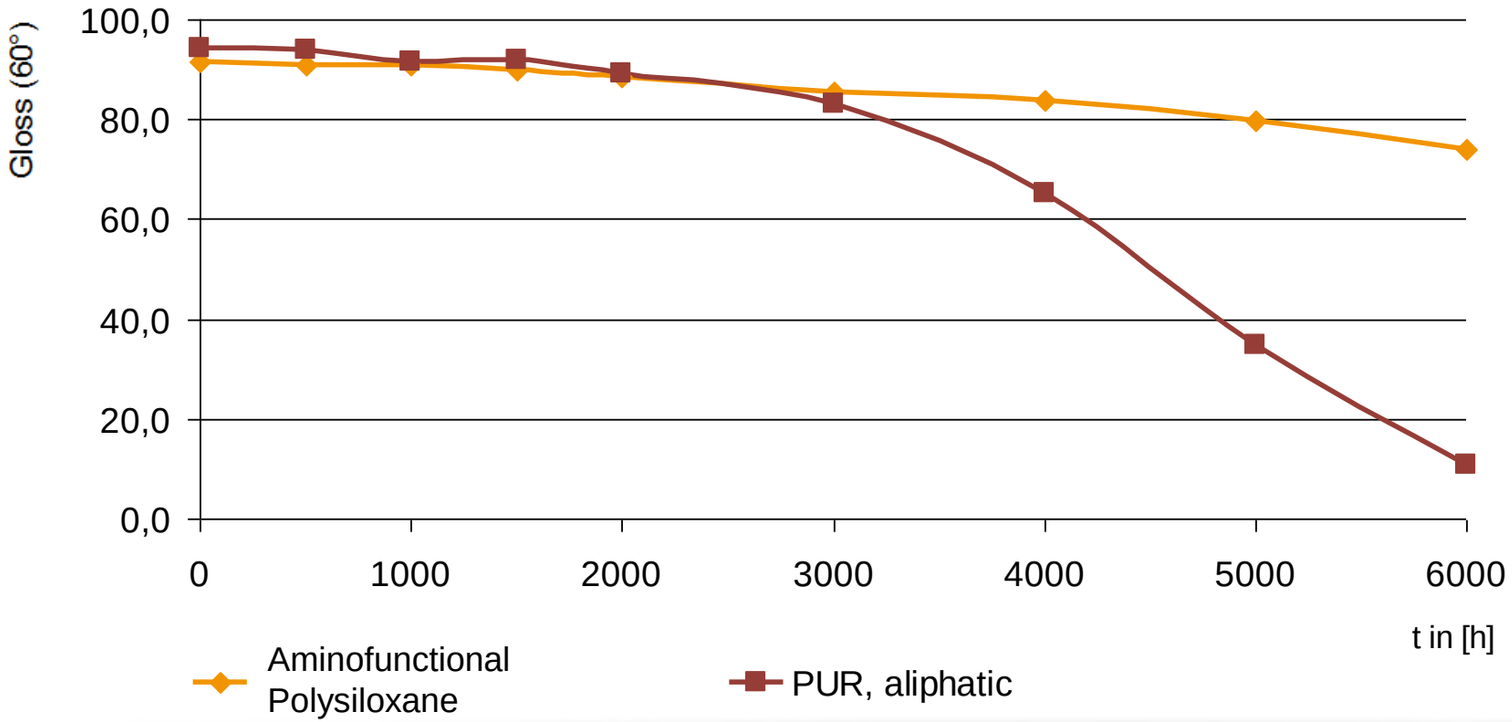
- with a commercial cycloaliphatic curing agent (reddish-brown curve) or
- with an aminofunctional polysiloxane (orange curve)



Gloss Retention Eight-times Better after 6,000 h in the Xenon Test Compared to an Aliphatic PUR Coating

Xenon Accelerated Weathering Test, Gloss Retention of a White

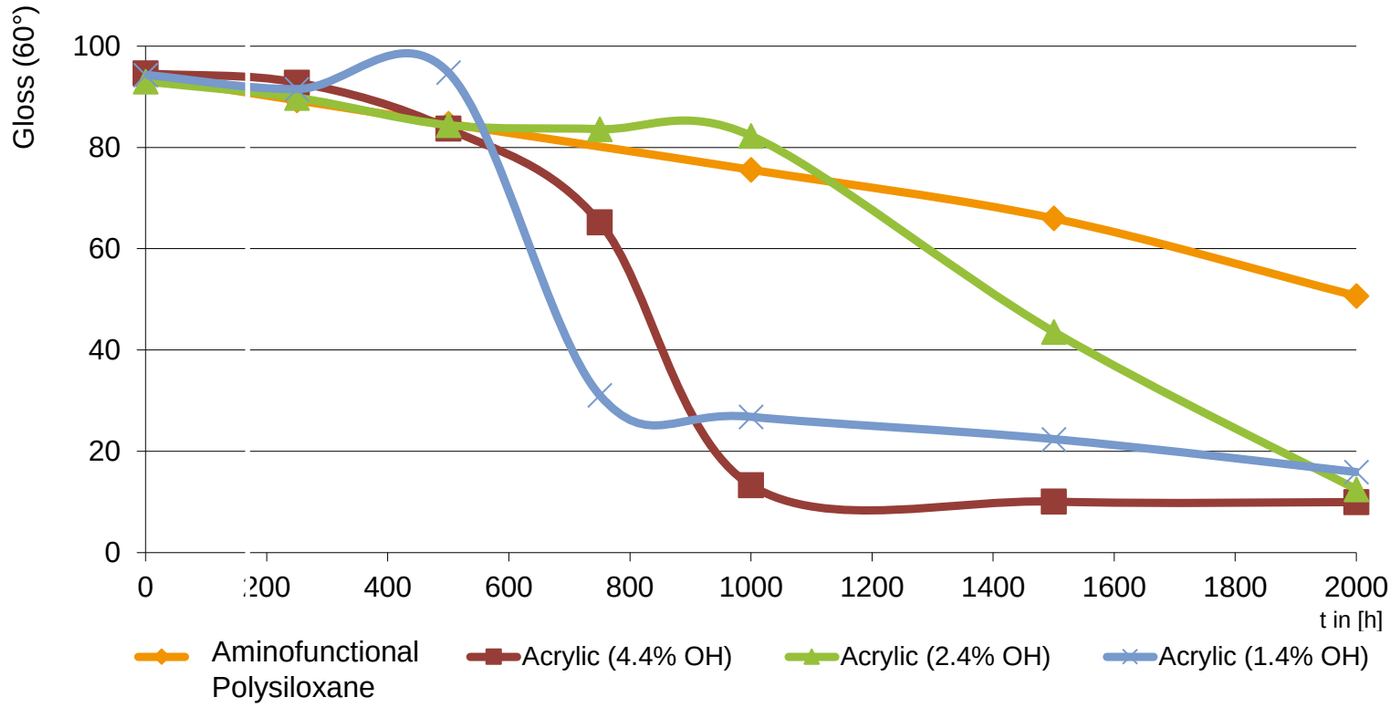
- Epoxy-polysiloxane coating (orange curve) compared with an
- Aliphatic HDI-Isocyanurate based PUR topcoat (dark red curve)



Epoxy Polysiloxane Coating Showed Better Long-Term Gloss Retention than Aliphatic PUR Coatings

QUV-B Accelerated Weathering Test of White Coatings

- Epoxy Polysiloxane Coatings (orange curve) outperforms various
- PUR Coatings (Hydroxyfunctional Acrylic resin/HDI-Isocyanurate)



Chemical Resistance is Good

Test method:
droplet on coating, covered with watch glass, 24 h, visual inspection

Binder Chemistry	Cycloaliphatic Epoxy Resin + Aminofunctional Polysiloxane
Solvent (MEK), 200 DR	No change
Hydrochloric Acid, 37%	No change
Phosphoric Acid, 85%	No change
Sulfuric Acid, 98%	Strong defect
Conc. Acetic Acid	Strong defect
NaOH 50%	No change (slight decrease in gloss*)
Ammonium hydroxide, conc.	No change

*Remark: Dipping a coated panel into 20% NaOH solution for 72h caused a decrease in gloss from 91 to 71 units (60°)

Comparison of WACKER‘s Aminofunctional Polysiloxanes

Comparison of SILRES® HP 2000 and 2020 (1)

Product properties

Name	SILRES® HP 2000	SILRES® HP 2020
Amine type and value	identical	identical
Moisture sensitive (self-condensation)	yes	yes
Additional Solvent content	10 w% Xylene	none
Typical Viscosity [mm^2/s]	100 - 400	50 - 250
Methoxy group content (SiOMe)	lower	higher
Storage stability	Average (min. 6 months)	Longer (min 12 months)
Cost	Higher	Lower

Comparison of SILRES® HP 2000 and 2020 (2)

Cured Coating (Binder system: Cycloaliphatic epoxy resin (e. g. IPOX® ER 15) + SILRES® HP20X0)

SILRES®	HP 2000 to HP 2020
Cure time	Similar (4 – 5 h)
Accelerated weathering tests (gloss retention)	
Xenon test	Similar
QUV-A	Better
QUV-B	Much better
Mechanical tests	
Pencil hardness	Comparable (5H – 6H)
Adhesion / Cross hatch	Slightly Better
Mandrel bend test	Little bit more flexible

Summary

The Advantages of SILRES® HP 2000 and HP 2020

Epoxy Polysiloxane Coatings based on SILRES® HP 2000 / 2020

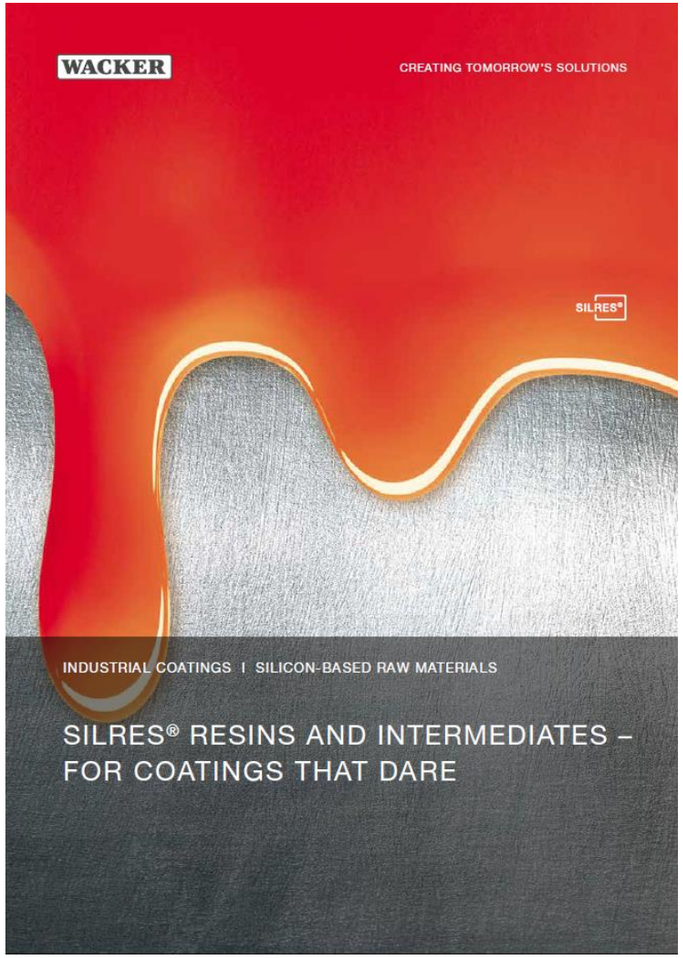
- offer excellent long-term gloss retention and weathering resistance
- outstanding solvent resistance (easy-to-clean, removal of Grafitti)
- very high hardness
- low VOC values (high solids, 100 – 250 g/l depending on desired viscosity)
- do not contain harmful isocyanates or urethane groups

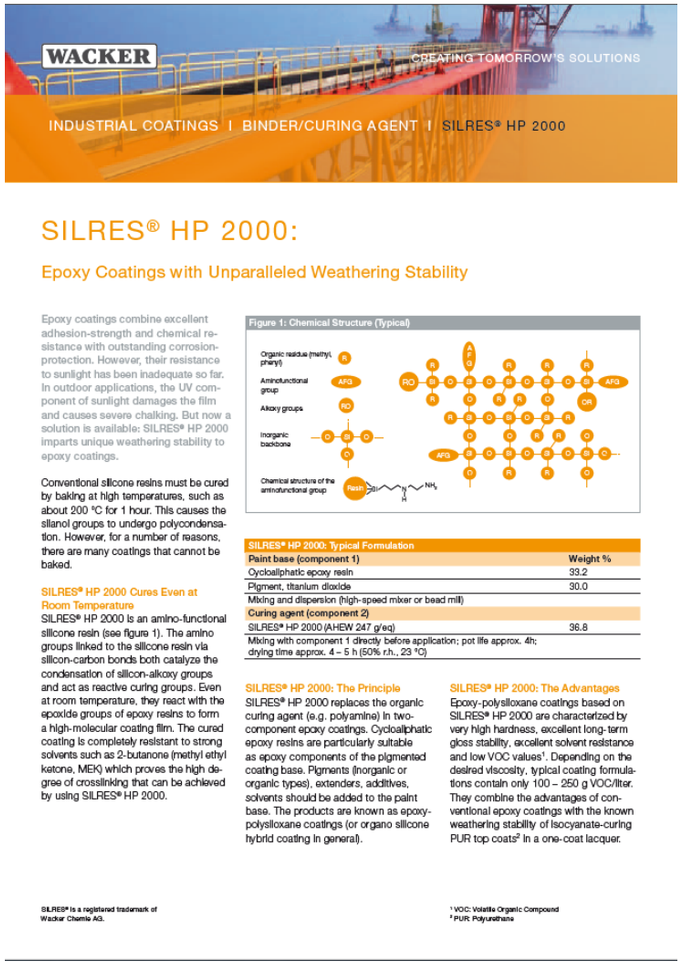
- SILRES® HP 2000 / 2020 enable the formulation of coatings that combine the advantages of conventional epoxy coatings with the known weathering stability of PUR topcoats in a single coating

Further Documents for SILRES® HP 2000/2020 at www.wacker.com

Documents

- General SILRES® Coatings brochure
- SILRES® HP 2000 Infosheet (media library)
- TDS and SDS (product search)





Thank You for Your Attention