New Epoxy-Siloxane Hybrid Binder for High Performance Coatings

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Summary: The novel chemistry achieved by condensation reaction of an aliphatic epoxy with a polysiloxane results in an epoxy-siloxane hybrid binder whose unique physical characteristics allow its use as a durable binder for the protective coatings industry.

The new epoxy-siloxane coating system enables the zinc primer to be protected by a single topcoat. This results in reductions in application time, less overspray and a much simplified maintenance for corrosion protection. Furthermore the reduced number of coats and overspray results in about 70 % less solvent emission to the atmosphere.

Keywords: silicone-epoxy; corrosion protection; polysiloxanes; coatings; high performance polymers.

Introduction

Fighting corrosion can be an expensive and daunting problem [1]. Protecting objects such as oil platforms, bridges and storage tanks, ship decks, steel constructions, concrete walls and floors from corrosion requires high costs and investment of labor [2].

One of the best methods of protecting objects under varying conditions is though the use of protective coatings [3].

Coating systems traditionally used in the protective coatings industry rely almost entirely on organic binder systems [4]. Due to the variety of service conditions, a multiple coat system is most often required. A typical multiple coat system consists of a zinc-primer, a corrosion-resistant epoxy mid-coat and a weather-stable polyurethane coating [5].

New Silicone-Epoxy Hybrid Resins

A specific focus of the paint industry is the reduction of costs for corrosion protection. A special benefit as a result would be the combination of two coating layers in a single layer system (figure 1).

By exploring the inorganic silicone-based chemistry a siloxane hybrid polymer has been developed which combines the properties of organic and inorganic compounds in a new class of binders for protective coatings.

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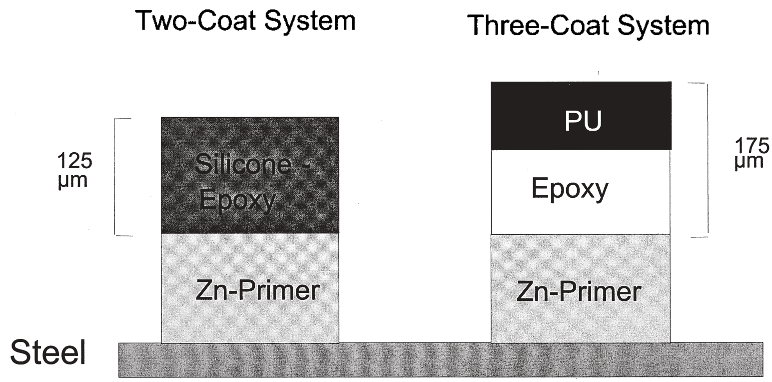

Figure 1: Profile of Anti-corrosion Coating Systems

Polysiloxanes exhibit excellent stability to heat and UV-radiation exposure due to the very stable [-(Si-O)$_n$-Si-] –backbone (figure 2) [7-13].

The idealized polysiloxane polymer structure is illustrated in figure 2:

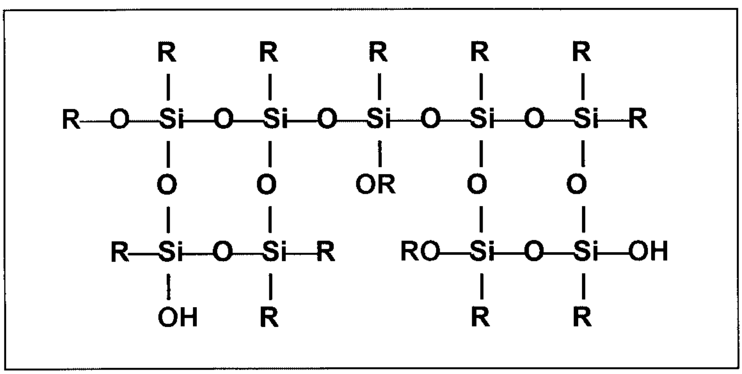

Figure 2: Idealized Polysiloxane Polymer Structure

By fine-tuning of the molecular weight, the degree of branching, the organic substituents R and the functionality, the resulting reactivity and the technological profile of the polymer can be adjusted [6].

The novel chemistry achieved by condensation reaction of an aliphatic epoxy with a polysiloxane results in an epoxy-siloxane hybrid binder [14] whose unique physical characteristics allow its use as a durable binder for the protective coatings industry.

Test Results of the Hybrid System as 2-K Corrosion Protection Coating

The quality and durability of the epoxy-siloxane hybrid coating is demonstrated in comparison with a three coat system of a traditional coating system in accelerated corrosion testing such as salt spray, water condensation exposure and UV exposure.

The new silicone-epoxy binder was tested by using the formulation in table 1:

Table 1. Formulation of a 2-component silicone-epoxy corrosion resistant coating

Component A	p.b.w.	Component B (Hardener)	p.b.w.
Pos. 1 Silicone-Epoxy Binder[1]	32.4	Pos. 11 AMEO[8]	16.0
Pos. 2 Tinuvin 1130[2] (1:1 in butanol)	2.0		
Pos. 3 Tinuvin 292[2] (1:1 in butanol)	1.0		
Pos. 4 Heliogen Blue L6901F[3]	1.6		
Pos. 5 Kronos 2160[4]	24.5		
Pos. 6 Talc AT extra[5]	2.0		
Pos. 7 TEGO® Airex 900[6]	0.5		
Pos. 8 Aerosil R8200[7]	1.0		
Pos. 9 Butyl Acetate	3.0		
grinding in a bead-mill			
Pos.10 Silicone-Epoxy Binder[1]	32.0		

1 Tego Chemie Service: Resin (SILIKOFTAL ED)
2 Ciba: UV absorber
3 BASF: pigment
4 Kronos: titanium dioxide
5 Norwegian Talc: Filler
6 Tego Chemie Service: Deaerator
7 Degussa: Fumed Silica
8 Degussa: 3-Aminopropyl triethoxysilane

The resulting application data are reported in table 2:

Table 2. Application data of the silicone-epoxy coating

Application data		
Pot life (25 °C)		4.5 h
Drying times (25 °C)	To touch	4 h
	Dry through	8 h
Adhesion to the primer	Cross hatch DIN 53 151	Gt 0
Hardness	Pencil hardness	F
	Pendulum hardness (König) DIN 53 157	86
Gloss	60° angle	87
Recoat time (25 °C)	Minimum Maximum	6 h 48 h

The new two coat system consisting of 75 microns of a zinc epoxy primer topcoated with 125 microns of an epoxy-siloxane hybrid coating (reference: 125 microns epoxy- + 50 microns polyurethane-coating) has been tested and passed the following performance tests (table 3):

Table 3. Comparison of the Test Results after 5000 h Weathering

Test	**Zinc Dust/ Silicone-Epoxy** 200 microns dried film thickness	**Zinc Dust/ Epoxy + P.U** 250 microns dried film thickness
Salt Spray Test – DIN 53 167 5,000 hours[1]	2	1 - 2
Humidity Test – DIN 50 021 5,000 hours[1]	1	1 - 2
QUV Weathering, 5,000 hours Lamp UV-B, Cycles 4 h/4 h Gloss Retention: Initial Gloss – 90 % (60°angle)	30%	10%
Colour Retention (delta E)	4.5	10.5
Chalking[1]	1	5
Note: Substrate: Bare Steel Surface Preparation: Sand Blasted to SA 2.5 Drying/Ageing before Test: 10 Days Air Dry at Room Temperature		

[1] Rating: 1 (excellent) ... 3 (satisfactory) ... 6 (poor)

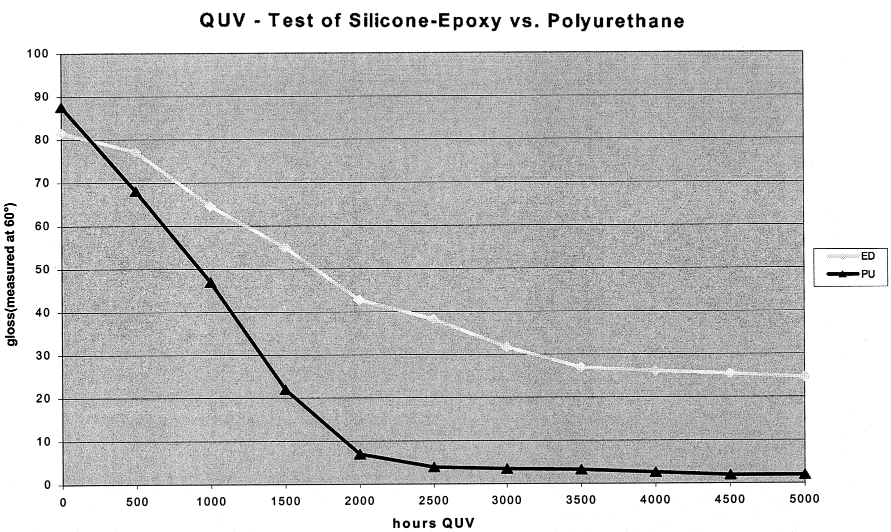

Figure 3: Comparison of the QUV-Test Results after 5000 h Weathering

Tests were carried out on sand blasted bare steel substrates. The coatings were air dried for ten days at room temperature before testing.

These tests in combination with the specified acceptance criteria are currently considered as severe performance test requirement for protective coating systems in the coatings industry.

Coating systems based on silicone-epoxy resins have been evaluated for gloss and colour retention through accelerated weathering via QUV testing. Gloss and colour retention are two of many factors that help to describe the weatherability of a coating and its ability to withstand weather-related effects such as sunlight, humidity, wind and temperature.

The qualitative comparison of gloss and colour retention showed that the epoxy-siloxane based coating outperformed the polyurethane based coating system.

Table 4. Chemical resistance after 24 hours and 7 days exposure

Chemicals	**Zinc Dust/ Silicone-Epoxy** 200 Microns Dried Film Thickness		**Zinc Dust/ Epoxy + P.U** 250 Microns Dried Film Thickness	
	24 h	7 days	24 h	7 days
Sodium hydroxyde (50 %)	2	3	2	5
Ammonium hydroxyde, conc.	2	3	3	4
Hydrochloric acid 1 molar	4	4	2	5
Sulfuric acid 1 molar	2	4	4	6
Nitric acid 1 molar	2	3	4	6
Citric acid 1 molar	1	2	2	3
Acidic acid 1 molar	2	5	2	4
Acetone	1	1	1	1
MIBK	1	1	1	2
Xylene	1	1	1	1
Butyl acetate	2	2	2	2
Ethyl alcohol	1	1	1	1
White spirit	1	1	1	1
Substrate: Bare Steel Surface Preparation: Sand Blasted to SA 2.5 Drying/Ageing before Test: 10 Days Air Dry at Room Temperature				

Rating: 1 (excellent) ... 3 (satisfactory) ... 6 (poor)

The high solids epoxy-siloxane coating can be used in various applications, including storage tank exteriors, offshore platforms, marine structures, bridges, exteriors of ships, structural steel, concrete walls and floors and the exteriors of railway coaches (figure 4).

♦ storage tank exteriors	♦ offshore platforms	♦ marine structures
♦ ship decks	♦ wind generators	♦ drilling rigs
♦ exteriors of ships	♦ structural steel	♦ bridges
♦ concrete walls and floors	♦ exteriors of railway coaches	

Figure 4. Applications for Silicone-Epoxy Based Coatings

In addition the epoxy-siloxane coating provides also excellent anti-graffiti and dirt-repellent properties. After the removal of the graffiti no residues of the graffiti remain and no change in gloss can be noticed (figure 5).

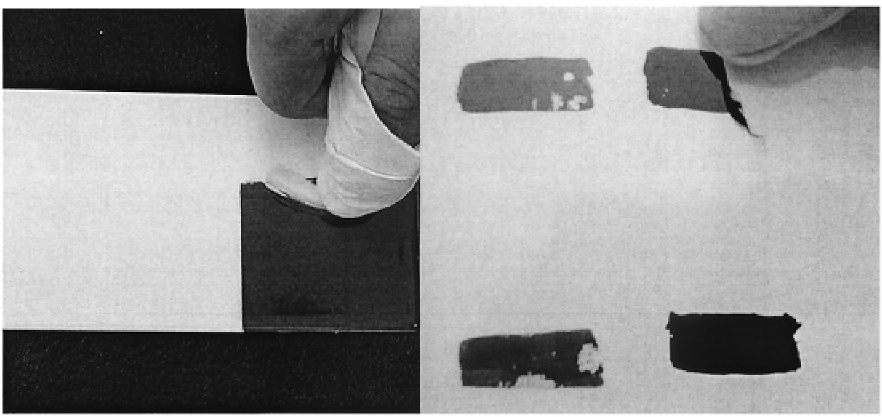

Figure 5: Graffiti- and Dirt-Resistance of the Silicone-Epoxy Coating

Correspondingly this new class of binders enable a new class of dirt resistant coatings [15]. In this respect the antifouling and anti-icing properties still have to be investigated.

Cost-effective and Enviromental-friendly System

This new epoxy-siloxane coating system enables the zinc primer to be protected by a single topcoat based on the innovative new polysiloxane hybrid binder, which combines the advantages of organic polymers and silicones in a single polymer.

This results in reductions in application time, less overspray and a much simplified maintenance for corrosion protection [16]. Furthermore the reduced number of coats and overspray results in about 70 % less solvent emission to the atmosphere.

Conclusion

The novel chemistry achieved by condensation reaction of an aliphatic epoxy with a polysiloxane results in an epoxy-siloxane hybrid binder whose unique physical characteristics allow its use as a durable binder for the protective coatings industry.

With the epoxy-siloxane hybrid resin, the advantages of the epoxy binder are combined with the strength of the polysiloxane providing a two component ambient curing thermosetting coating, which can be formulated to ultra high-solids and very low VOC.

The development of the aliphatic epoxy polysiloxane hybrid polymers has stimulated the formulation of a coating which can revolutionize the protective coatings industry by:

- Over 90% paint-solids, providing reduced VOC;
- high build application characteristics with standard application equipment;
- tolerance of high-humidity and/or low temperatures during curing;
- excellent colour and gloss retention by outperforming polyurethane topcoats;
- maximum corrosion resistance in a two coat system;
- excellent resistance to a wide variety of chemicals;
- cost-effective alternative to organic multi-coat systems;
- compliance with regulations regarding health, safety and environmental protection, reduction of solvent emissions, avoidance of health-damaging resins, crosslinkers or heavy-metal containing substances.

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