*ISSN : 2249 - 8877* 

Volume 7 Issue 1



Research & Reviews On Polymer

Full Paper

RRPL, 7(1), 2016 [020-029]

# Preparation and characterization of heat and corrosion resistance paint based on epoxy-silicon system

Vikrant V.Shertukde\*, Sushil V.Patil Department of Polymer and Surface Engineering, Institute of Chemical Technology, Mumbai, Matunga, Mumbai 400 019, (INDIA) E-mail: vikrantsher@rediffmail.com

# ABSTRACT

Industrial application such as Chimneys, Automobile silencers, Boilers, Exhausts where normal operating temperature exceeds above 300-400°C, at this high temperature general industrial paints does not stands satisfactory and needs a special development of paint which can sustain this high temperature successfully. In the market scenario presently silicone based heat resistant paints are available up to 600 - 700°c, but their cost is too high. The silicone structure is stable to oxidation, although it is susceptible to some rearrangement at elevated temperatures. The epoxyresin offers the advantages of mechanical toughness and adhesion while the silicone component provides the coating with its hardness properties. Therefore it is propose to prepare the paint which can sustain this temperature successfully at lower cost. This study will present an overview of the development of the silicone-epoxy blending system which offer heat and corrosion resistance. Silicone resin is blended withepoxy and mf resin at various compositions having pigmentation like aluminium paste and Tio<sub>2</sub>. Paint is characterized for Heat resistances by heat stability, optical microscope and spectrophotometer, Corrosion resistance by salt spray and electrochemical impedance spectroscopy (EIS), Solvent resistance, Chemical resistances, and Mechanical properties. Heat and Corrosion resistance paint based on epoxy-silicone was prepared successfully. It can resist the heat up-to 500°C as per ASTM specification D2485 and salt spray test as per the ASTM specification B 117 for 240 hours. The development of this paints system couldreduce the cost involved in the heat and corrosion re-© 2016 Trade Science Inc. - INDIA sistant applications.

#### **INTRODUCTION**

There are many alternative are available for paint such as wallpaper, plastic sheet, chrome and silver plating. No coating material is more versatile than paint, which can be applied to any surface, however

# KEYWORDS

Silicone-epoxy; Aluminium paste; Tio<sub>2.</sub>

awkward it's shape or size, by one process or another. Paint is a loosely used word covering whole variety of materials: enamels, lacquers, varnishes, undercoats, surfaces, primers, sealers, fillers, stoppers and many others. Heat-resistant paint are often based on an inorganic silicone resins and aluminium

21

pigments that require heat activation to chemically cure and harden the paint for service use. Historically, this paint did not cure at room temperature. They remained tacky and did not dry to the touch, causing premature failures<sup>[3]</sup>. The U.S. Navy has modified this paint to allow room temperature application and cure by adding acrylic resin to the chemistry. This formulation reduces the VOC content of paint allows the paint to skin over and not feels gummy, even though the silicone resin is not fully cured. The paint will still harden when exposed to high temperatures. Heat-resistant paint are gaining popularity with the introduction of more sophisticated automotive and aircraft exhaust equipment, smoke stacks, stoves, furnaces, space heaters and incinerators. Chimneys are also in need of heat resistant paint. In addition to making your chimney look more attractive, heat resistant paint will also keep your chimney from dangerously overheating, which could potentially create a major safety issue. The same principal applies to kilns; many kilns are painted with heat resistant paint in order to keep these in good working condition for as long as possible. Steam pipes are painted with heat resistant paint to allow them a longer life and keep them from becoming corroded or rusted as well<sup>[3]</sup>.

# MATERIALS

Epoxy resin based on Bisphenol A having 75% NVM, MF resin having 65% NVM was supplied by Alfa Paint Pune. Phenyl Methyl Silicone Resin having 55% NVM was supplied by Momentive Performance Materials Mumbai. BYK103 used as a wetting and dispersing agent Aluminium Paste, zinc octate, xylene, MIBK and Butyl Cellosolve acetate are used AR grade.

# EXPERIMENTAL

# **Preparation of paint**

Formulated quantity of resins was mixed with 1:1:1(v/v) mixture of xylene, butyl cell solve and methyl isobutyl ketone (MIBK) solvent in the ratio of 10:2 and stirred for 5 to 10 mins up to complete dissolution. Pigments and additives like driers and

dispersing agent were added in the blended material and the mixture was mixed thoroughly under high speed disperser for half an hour.

# Formulation

Total eighteen number of paint sample was prepared by varying the ratio of epoxy-silicone and having different pigmentation. ES05, ES08, ES14 and ES17 showed highest heat resistant. In which ES05 and ES14 have equal % of epoxy-silicone with Al paste and Tio<sub>2</sub>respectively. ES08 and ES17 have equal % of epoxy-silicone, 05% MF with Al paste and Tio<sub>2</sub>respectively.

# **Application of paint**

MS panels were cleaned well by using diluted acids and Alkalis following wet and dry sanding with sand paper. After sanding of the panels were washed with the water to removes the any traces of the chemicals left. Paint was applied at specific thickness and Flash off was given for five min. After flash off it were backed in oven for the 30 min at 150°C. After drying it was marked with name of for various testing's and ageing time 48 hrs was given to ensure the complete curing reaction.

# **Mechanical properties**

The mechanical properties such as cross cut adhesion, scratch hardness, pencil hardness, flexibility and impact resistance of the coated mild steel panels were determined as per the IS specification.

# **Chemical resistance**

The Resistant to chemical such as Acid, Alkali, Salt water, Water of the coated mild steel panelswere determined by as per specification.

# Solvent resistance

The solvent resistance of painted panels were determined by (a) immersed in common solvents like xylene, acetone, toluene and trichloroethylene and kept for 24 hours,(b) Rub resistance and they were taken out, dried and examined for discoloration, chalking or detachment of the film.

# Heat resistance

# Heat stability

# Full Paper

This test was carried out to check the heat stability of the painted panels at various temperatures by varying the duration.

# **Optical microscope**

Thermal degradation of epoxy-silicone coating was further studied using Optical Microscope on heat-treated panels.

#### Spectrophotometer

The values of A, B, L, "E, whiteness Index and Yellowness Index of after and before heat treated panels was taken using spectrophotometer

#### **Corrosion resistant**

#### Salt spray

For this test both untreated and heat treated panels are kept in salt spray cabinet. Test solution 5 % NaCl solution in deionized water having pH 6.5 to 7.2 used for this test. Compressed air having pressure 0.7 to 1.4 bar is used for formulation of fog. Test chamber temperature is maintained  $35^{\circ}\pm 2^{\circ}C$ .

#### EIS

The anticorrosive performance of the both untreated and heat treated panels was evaluated on AMETEK Versa STAT 3 instrument. All electrochemical measurements were carried out at room temperature in 3.5% NaCl solution. Test system consisted of three electrode cells, in which calomel electrode, a platinum electrode and a coated panel as reference, counter and working electrode respectively. The exposed area of the coated panels to the NaCl solution was  $7 \text{ cm}^2$  in all the cases.

#### **QUV** weatherometer

This test was carried out as per ASTM G154 in QUV chamber which had combination of heat, moisture, and ultraviolet light to accelerate the natural weathering of paint sample, the selected sample painted panels are placed in that chamber for 10 day cycle. The day by day reduction of gloss is measured by glossometer. The crosscut adhesion and visual defect are evaluated after completion of cycle.

#### **RESULT AND DISCUSSION**

# Heat stability and resistance

ES05 shows heat stability up to 350°C for 1 hrs and heat resistance up to 500°C for 15 min without any failure in adhesion but small amount of discoloration seen at panel surface as compare to this ES8shows heat stability and resistant same as ES5 but without any defect, discoloration and failure in adhesion on panels because presence MF with Couse better crosslinking in epoxy-silicon blend. ES14and ES17 show highest heat stability that is 250°C for 1 hrs with some discoloration but without any defects on panels. Figure No 1. Show the graphical representation of heat treatment.

# **Optical microscope**

In case of aluminium pigmented system that is









Figure 2 : Microscopic image of ES5 before and after heating



Figure 3 : Microscopic image of ES8 before and after heating



Figure 4 : Microscopic image of ES14 before and after heating

ES5 and ES8, panels are treated at 500°C for 15 min. In cased of Tio2 pigmented system that is ES14 and ES17, panels were heated at 300°C for 15 min. the images showsquit similar inferences in case of ES5 and ES8. But in case of ES14 and ES17 it shows decolourization as has been observed visually, indicating the fact that the coating failed. But the visual examination did not show any evidence for such Research & Reviews On

Polymer



Figure 5 : Microscopic image of ES17 before and after heating

Sample no	]	L		Α		В		Yellowness		Whiteness	
	BH	AH	BH	AH	BH	AH	DE	BH	AH	BH	AH
ES05	86	71	-0.26	-0.10	-0.38	2.25	05.23	1.7	3.4	70.5	60.11
ES08	84	68	-0.24	013	-0.34	3.11	05.11	1.8	4.5	68.7	55.00
ES14	91	69	-0.10	-0.30	1.26	4.33	24.12	2.4	9.30	77	18.36
ES17	92	70	-0.10	0.90	1.61	4.88	25.12	2.1	8.10	76.4	15.00

 TABLE 1 : Results of spectrophotometer

failures. For instance, no micro cracks were evident visually. The comparative images are shown in Figure 2, 3, 4, 5 respectively for ES05, ES08, ES14 and ES17.

#### Spectrophotometer

The values of A, B, L,  $\Delta E$ , whiteness Index and Yellowness Index was taken using spectrophotometerfor all four sample, without heating painted panels value refer as a standard value, panels are heated at 500°C for 15min for ES5 and ES8. For ES14 and ES17 panels are heated at 300 °C for 15 min. Then value is taken against the respective standard value, the difference in  $\Delta E$  in not too much large in case of aluminium pigmented paint system but in case of Tio2 pigmented system there is huge difference because too much discoloration is occurring. Results are showed in TABLE No 1.

#### Salt spray

This study was done by comparing the salt spray resistance of paint sample before and after heating, ES5 and ES8, panels are treated at 500°C for 15 min. ES14 and ES17, panels were heated at 300°C

**Research & Reviews On** Polymer for 15 min. It was observed ES05 and ES08 paint contain Al paste had clear panel without any blister and failure of adhesion but some blister are observed in heat treated panels with loss of gloss but without failure in adhesion. In case of ES14 and ES17 blister are observed after heat treatment so only without heat treated panels are tested showed excellent. Result showed in Figure 6, 7 and 8.

#### EIS

The electrochemical impedance spectroscope analysis of all four panels both with and without heat treated panels were evaluated for anticorrosive properties by Bode plots, painted panels of ES05 and ES08, are heated at 500°C for 15 min and ES14 and ES17 are heated at 300°C for 15 min. result shows the difference between impedance value is not too much large that means the heat treated panels also shows the excellent corrosion resistance. Result showed in Figure 9, 10, 11 and 12.

#### **QUV** weatherometer

This test is carried out to evaluate the UV Resistance of all four sample were placed into cham-

25





Figure 6 : Result of salt spray of ES05 before and after heat treated panels





Figure 7 : Result of salt spray of ES08 before and after heat treated panels



Figure 8 : Result of salt spray of ES14 and ES17 without heat treated panels





ber for 10 days. The reduction of gloss and nail hardness of coating were measured in two days interval. The results are showed in TABLE No 2

#### **Chemical resistance**

Acid, Alkali, Salt water and water resistance of all four sample before and after heat treatment was carried out. In case of acid and alkali resistance without heat treated panels does not shown any type of defect or loss of gloss as compare to this heat treated panels showed loss of gloss but without any defect or loss of adhesion. in case of water and salt water resistance panels are remain unchanged. Results are shown in TABLE No 3.

#### Solvent resistance

The solvent resistance of both heat treated and untreated painted panels was evaluated taking Suf-

Research & Reviews On Polymer





Figure 12 : Bode graph of ES17 before and after heat treatment

ficient quantity of Solvents was taken on to beaker. All sample showed good resistance to all solvent this is due to high crosslinking possibility. The rub resistance evaluated by rubs methods. The coated films showed excellent solvent resistance even after 200 cycles of xylene rub and 150 cycles of MIBK rub. Result is showed for solvent resistance TABLE No 4 and Rub resistance in TABLE No 5. E-EX-

#### CELLENT; G-GOOD.

#### **Mechanical properties**

Cross cut adhesion, Scratch hardness, Flexibility and Impact resistance of the coated and with and without heat treated mild steel panels were determined as per the IS specification. results are showed in TABLE No 6



			TABLE 2	: Resu	ilts of QUV	V weath	nerometer				
Sample No	INTIAL CLOSE	Day2		Day4		Day6		Day8		Day10	
	IN HAL GIOSS	Gloss	Adhesion	Gloss	Adhesion	Gloss	Adhesion	Gloss	Adhesion	Gloss	Adhesion
ES05	110	92	Pass	77	Pass	62	Pass	55	Pass	50	Pass
ES08	97	90	Pass	76	Pass	64	Pass	56	Pass	49	Pass
ES14	111	91	Pass	74	Pass	69	Pass	51	Pass	42	Pass
ES17	102	89	Pass	75	Pass	63	Pass	55	Pass	43	Pass

#### TABLE 3 : Results of chemical resistance

Sample No	Aci	d Resistance	Alka	ali Resistance	Water R	esistance	Salt water Resistance	
	BH	AH	BH	AH	BH	AH	BH	AH
ES5	Pass	Loss of gloss	Pass	Loss of gloss	Pass	Pass	Pass	Pass
ES8	Pass	Loss of gloss	Pass	Loss of gloss	Pass	Pass	Pass	Pass
ES14	Pass	Loss of gloss	Pass	Loss of gloss	Pass	Pass	Pass	Pass
ES17	Pass	Loss of gloss	Pass	Loss of gloss	Pass	Pass	Pass	Pass

Sample NO	Xylene		Toluene		Benzene		MIBK		Butyl Acetate	
	BH	AH	BH	AH	BH	AH	BH	AH	BH	AH
ES5	E	G	Е	G	Е	G	Е	G	Е	G
ES8	Е	G	Е	G	Е	G	Е	G	Е	G
ES14	Е	G	E	G	Е	G	Е	G	Е	G
ES17	Е	G	E	G	E	G	Е	G	Е	G

#### TABLE 5 : Results of rub resistance

Sample NO	Xyl	Xylene		Toluene		Benzene		MIBK		Butyl Acetate	
	BH	AH	BH	AH	BH	AH	BH	AH	BH	AH	
ES5	200	100	200	100	200	100	150	75	150	75	
E \$8	200	100	200	100	200	100	150	75	150	75	
ES14	200	100	200	100	200	100	150	75	150	75	
ES17	200	100	200	100	200	100	150	75	150	75	

**TABLE 6 : Results of mechanical properties** 

Sample Name	Cross Cut		Scratch 1	Hardness	Flexi	bility	Impact Resistance	
	BH	AH	BH	AH	BH	AH	BH	AH
ES05	5B	5B	2.5 kg	2.5 kg	Pass	Pass	Pass	Pass
ES08	5B	5B	2.5 kg	2.5 kg	Pass	Pass	Pass	Pass
ES14	5B	4B	2.5 kg	1.0 kg	Pass	Fail	Pass	Fail
ES17	5B	4B	2.5 kg	1.5 kg	Pass	Fail	Pass	Fail

#### **CONCLUSION**

Heat and corrosion resistant paint is useful for where the need of resistant to heat with corrosion. HCRP gives a plenty of advantages like it protects the surface of object form corrosion, wearing of material & poor weather ability. It preserves the surface of object from corrosive environment as well as paint is widely used for decorating & gives aesthetic look. It improves weather ability, durability and UV resistance; it gives a good adhesion on variety of surfaces.

From all the preparation method & testing of

28

Full Paper

Research & Regiens On Polymer

29

samples we can conclude that, the Epoxy-Silicone based paint with different pigmentation gives a very good properties like heat resistance up to 400-500°C, corrosion resistance in both case before and after heat treatment, UV resistance, chemical resistance, solvent resistance and mechanical resistance. Epoxy-Silicone based paint gives very good properties it can sustain up-to 500°c temperature with Aluminium paste and up to 350°c with titanium dioxide. Small addition of MF resin can useful in case of mechanical properties with 240 Hrs pass Salt Spray so can be usedwere corrosion resistance is required along with heat like for chimney stacks, pipes, petrochemicals, water tanks, boiler fronts, duct work, piping & furnace structure, heat exchanger, evaporator, boilers, furnaces etc.

# REFERENCES

- [1] L.Mathivanan, S.Radhakrishna; Heat-resistant anticorrosive paint from epoxy-silicone vehicles, Anticorrosion methods and materials, **44(6)**, 400–406 (**1997**).
- [2] Ying Zhang, Xin Yang et al.; Synthesis and properties of optically clear silicone resin/epoxy resin hybrids Polymer Int, **61**, 294–300 (**2012**).
- [3] Bentley, John, Gerald Patrick; Introduction to paint chemistry and principles of paint technology, CRC Press, (1997).

- [4] Dr.P.V.Thorat, Miss.Sandhya Warulkar et al.; International journal of engineering science & advanced technology, **3(5)**, 243-250 (**2013**).
- [5] Talbert, Rodger, Paint technology handbook, CRC Press, (2007).
- [6] Tracton, A.Arthur ed., Coatings technology handbook, CRC press, (2005).
- [7] Malshe, C.Vinod, Meenal Sikchi; Basics of paint technology part I. Prakash C.Malshe, (2008).
- [8] NPCS Board; Manufacture of paint, Varnish & Allied Products, NIIR; (2013).
- [9] Wei Huang, Ying Zhang et al.; Studies on UV-stable silicone–epoxy resins, Journal of Applied Polymer Science; 104, 3954–3959 (2007).
- [10] Xin Yang, Wei Huang et al.; Synthesis, Characterization, and properties of silicone–epoxy resins; Journal of Applied Polymer Science, **120**, 1216–1224 (2011).
- [11] X.Yuan, Z.F.Yue et al.; EIS study of effective capacitance and water uptake behaviors of silicone-epoxy hybrid coatings on mild steel; Progress in Organic Coatings, **86**, 41–48 (**2015**).
- [12] https://www.nstcenter.biz/writeup.Heat Resistant Coatings.
- [13] https://www.newagepublishers.com/samplechapter/ 001424.pdf
- [14] https://www.intexa.com/downloads/hightemp.pdf
- [15] https://www.automotivesolutions.net.in/heat-resistant-paints.html