Coatings Trends & Technologies SUMMIT

Waterborne Silicone Resin for High Temperature Resistant Coatings

MOMENTIVE®

SOLUTIONS FOR A SUSTAINABLE WORLD™

September 2024

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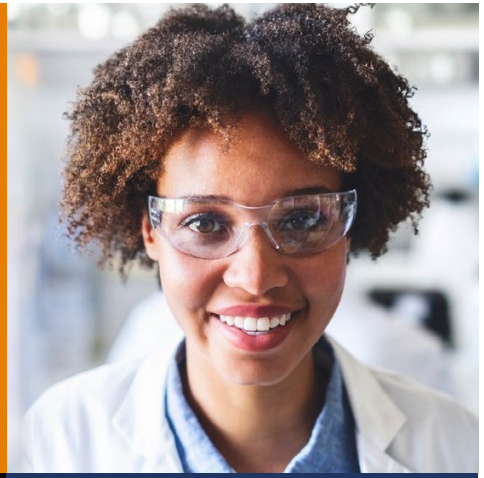
At Momentive, we create **solutions for a sustainable world™.**

Technology and innovation focused, with 3,400 patents serving high-growth applications

Strategic, with a clear path forward, focused on earned growth and operational excellence

Customer oriented, with a diverse customer base of over 4,000 customers in over 100 countries



GOLD 2023 ecovadis Sustainability Rating

Global, with 40+ locations in 20+ countries and more than 5,000 employees

A ~$2.3BN LEADER IN SILICONES & SPECIALTIES

Committed to protecting and prioritizing the well-being of our people, customers, communities and planet

Offering Trend-Driven Solutions

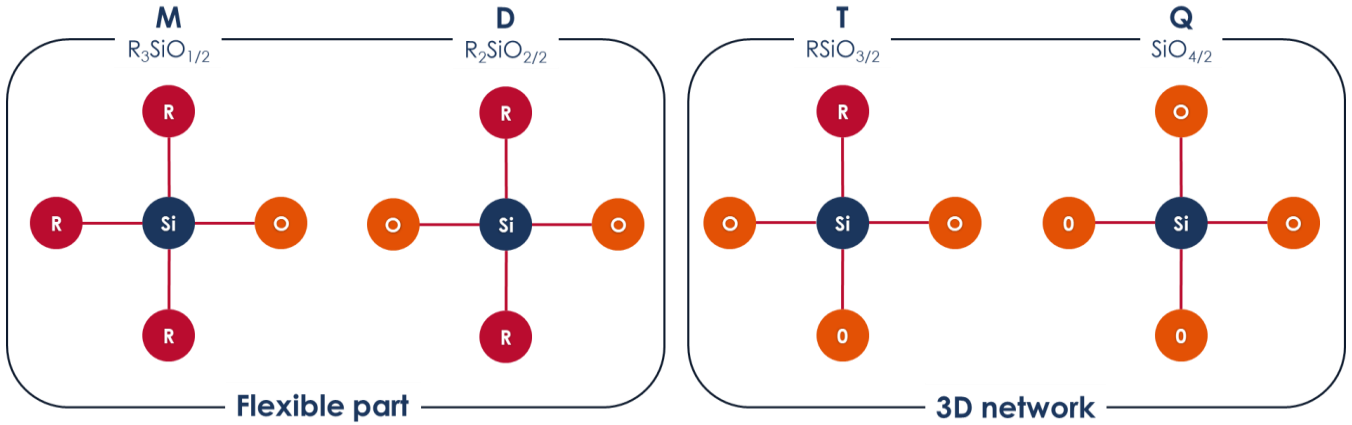
	Mega trends	Changes	What do we enable?
	**Sustainability**	Tightening VOC limit 250g/L → zero VOC	▪ **Lower VOC products (WB, 100% solids)** ▪ **Products that enable lower VOC solutions** ▪ Formulated without PFAS
	**Energy conservation**	Longer service life	▪ Better protection (corrosion, water, UV resistance) ▪ **Durable performance**
	**Urbanization**	Safer environment Comfort living	▪ **Low HAP's** ▪ Aesthetics ▪ "Smart coatings" – anti-graffiti, self cleaning, anti fingerprint etc.

Heat Resistant Coatings

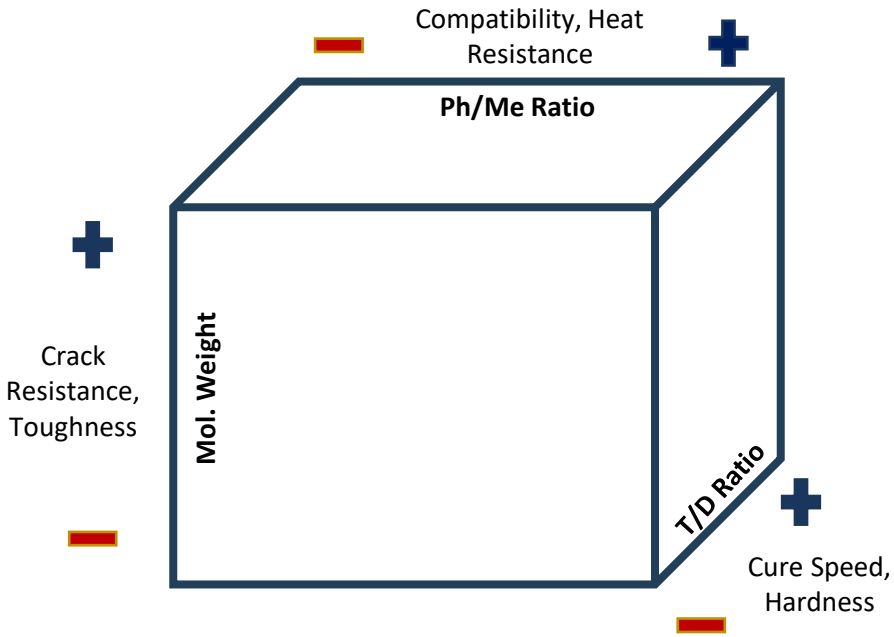
~ 200ºC	~ 250ºC	~ 350ºC	~ 600ºC
Water-based: • Acrylic Latex • Modified Silicone Emulsions **Solvent-based:** • Methyl Silicone Resins	**Water-based:** • Modified Silicone Emulsions **Solvent-based:** • Methyl/Phenyl Silicone Resins	**Water-based:** • **Waterborne Silicone Emulsion A** + Inorganic filler (TiO_2) **Solvent-based:** • Methyl/Phenyl Silicone Resins + Inorganic filler (TiO_2)	**Water-based:** • **Waterborne Silicone Emulsion A** + Inorganic filler (aluminum and iron oxides) **Solvent-based:** • Methyl/Phenyl Silicone Resins + Inorganic filler (aluminum and iron oxides)

Silicone Resins Introduction

Cross-linked film-formers with excellent hardness, thermal/water/UV resistance and dielectric properties.



R -Me / -Ph / -OR



Ph	Thermal resistance and organic compatibility
Me	UV resistance
OR	Cross-linking
T/Q	Hardness
D	Flexibility
Mwt	Toughness, crack resistance

Typical properties are average data and are not to be used as or to develop specifications

Waterborne Silicone Emulsion A

Introduction

- Lower VOC[1] phenyl-methyl silicone resin emulsion
- Sole or co-binder to formulate waterborne high-temperature resistant coatings
- Coatings can be air-dried but need 150-250 ˚C curing for 30-60 mins for maximum performance
- Thermal Cure can be achieved without catalyst

Key Features and Typical Benefits

- High thermal resistance, up to 600˚ C with suitable pigments
- Excellent adhesion
- Excellent corrosion resistance

Potential Coating Applications


Automotive


Industrial


Home

Typical Physical Properties

Property	Value
Solids Content	~50 Wt%
Appearance	Milky white liquid
Viscosity, 25°C (sp 64, 100 rpm)	~3000 cp
Density, 25°C	1.09 g/ml
pH	5-7
VOC (EPA method 24)	**~25 g/L**
Solvent Content (GC)	**<2%**

Typical properties are average data and are not to be used as or to develop specifications

[1]VOC was measured utilizing EPA method 24.

Dry Time Recordings:

Competitive Silicone Resin 1 (slight haze)

Competitive Silicone Resin 2

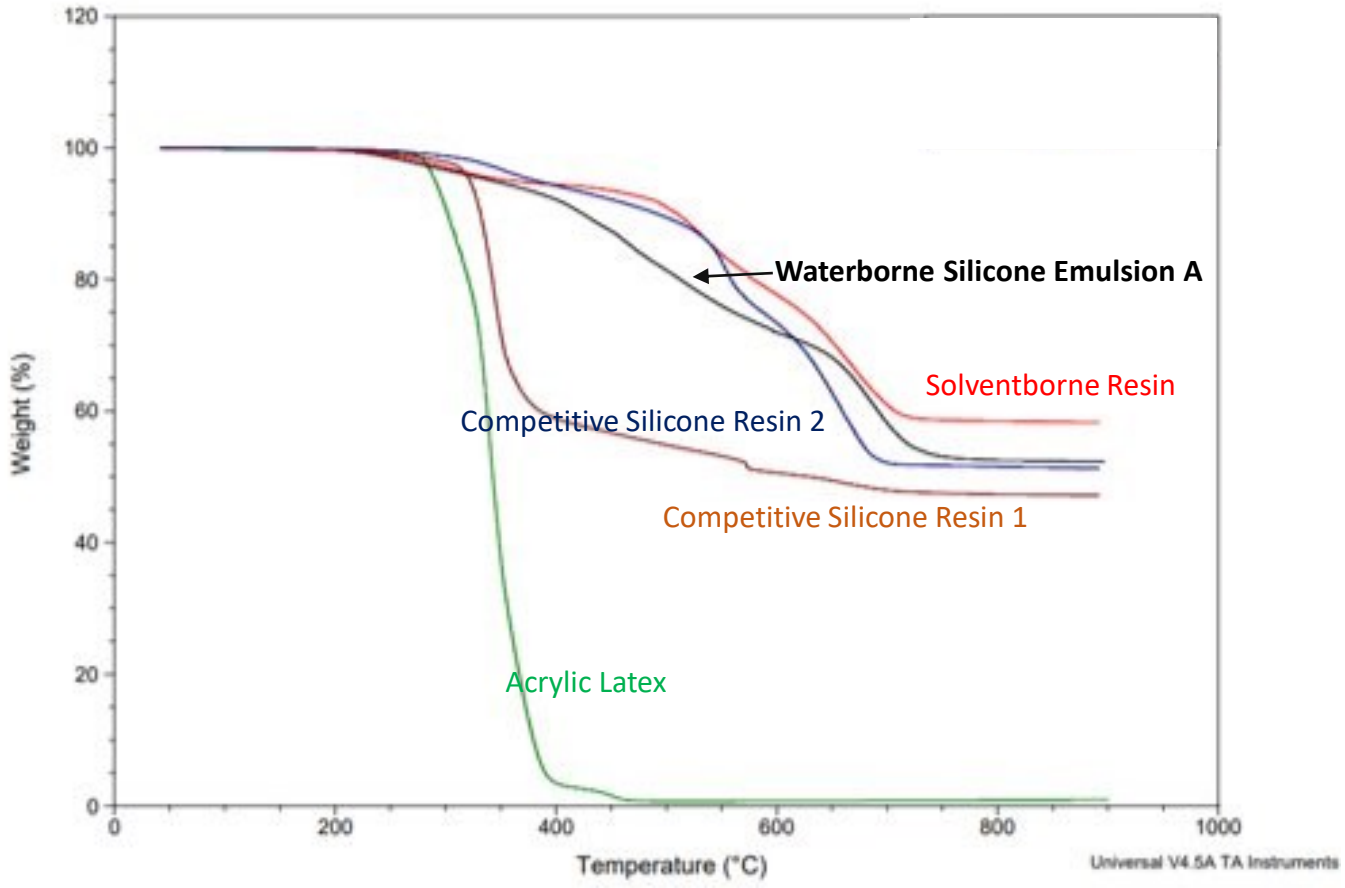
Competitive Silicone Resin 3 (haze)

Waterborne Silicone Emulsion A

	Set-to-Touch (min)	Tack-Free (min)	Hard-Dry (min)
Competitive Silicone Resin 1	5.0	7.0	15.0
Competitive Silicone Resin 2	5.0	15.0	> 6 hours
Competitive Silicone Resin 3	5.0	10.0	> 6 hours
Waterborne Silicone Emulsion A	10.0	15.0	> 6 hours

Typical properties are average data and are not to be used as or to develop specifications

Thermal Resistance from TGA



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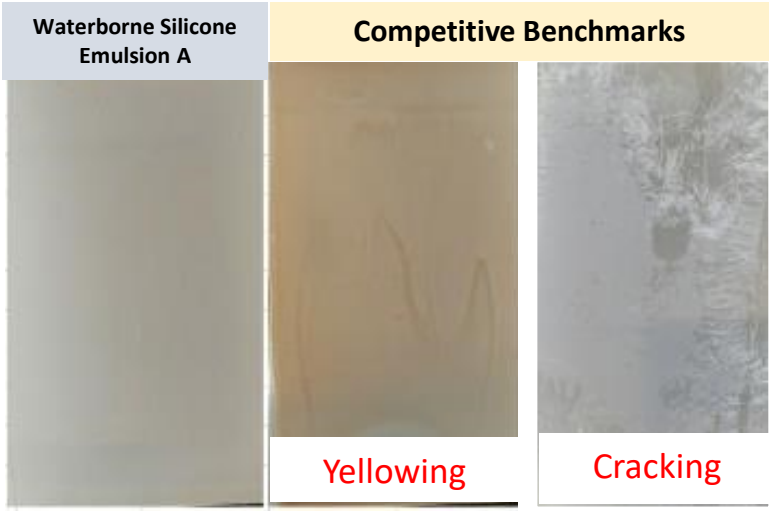
Neat Resin on Stainless Steel (250˚C, 30 min)



Typical properties are average data and are not to be used as or to develop specifications

Instrument: TA TGA Q5000
Test Condition: Ramp 10˚C/min (Air)
Sample Conditions: Fully dried at 100 ˚C

Waterborne Silicone Emulsion A has higher thermal resistance/degradation temperature than competitive silicone resin

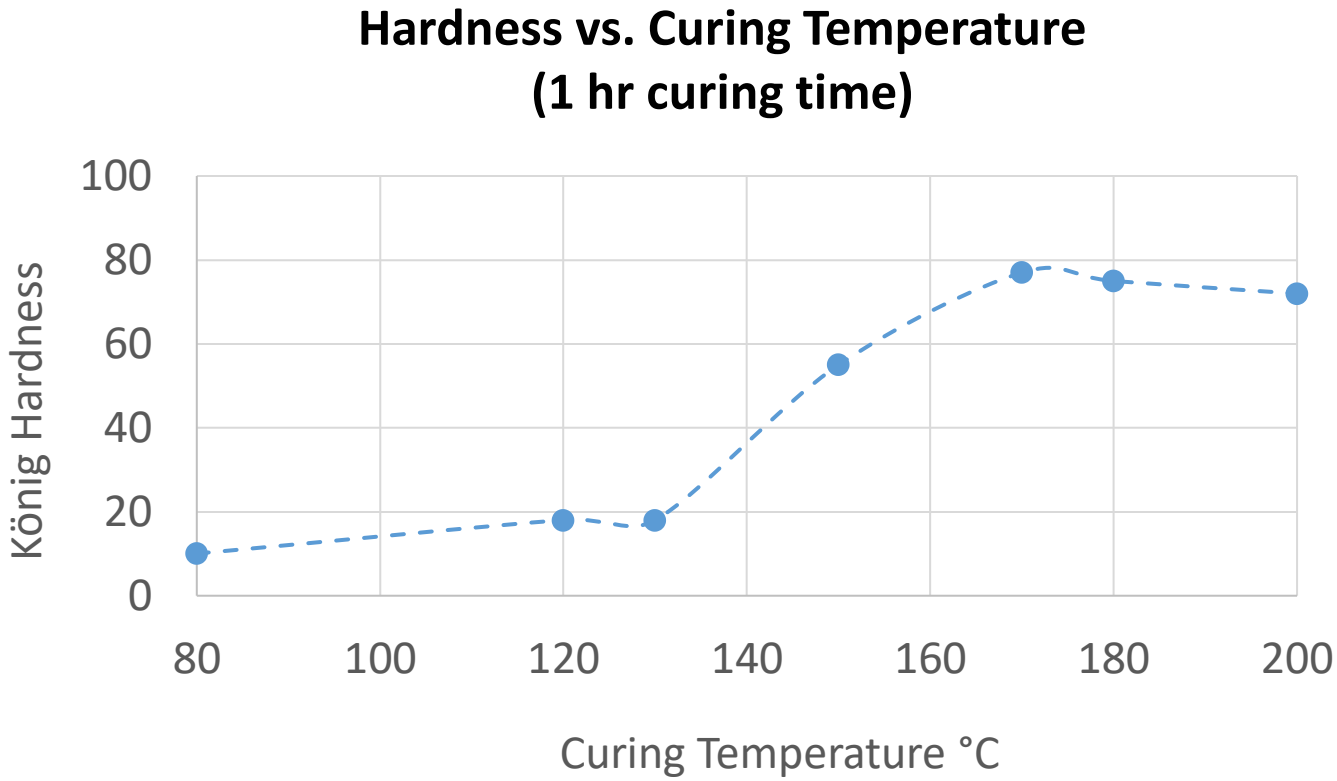
Thermal Curing Profile: TiO_2 Formulation

Ingredients	%Wt
Mill Base	
Water	27.32
Dispersing agent	0.66
Wetting agent	0.66
Titanium Dioxide	30.6
Let Down	
Waterborne Silicone Emulsion A	**40.66**
Epoxy Silane	0.08
Total	**100.0**

Product formulations are included as illustrative examples only. Momentive makes no representation or warranty of any kind with respect to any such formulations, including, without limitations, concerning the efficacy or safety of any product manufactured using such formulations.

Formulation and Application Process:

- Formulation mixed in speed mixer
- Film applied on stainless steel substrate with DFT ~100 microns
- Films cured at different temperatures for 1 hr



Typical properties are average data and are not to be used as or to develop specifications

Curing recommended at >150 ˚C for full hardness development (tack-free after RT drying)
Drying time can be reduced at higher temperatures

Model Formulation: Iron Oxide Pigment

Fe-Oxide Dispersion

Ingredients	% Wt
Water	55.00
Dispersant	10.00
Base	0.01
Defoamer	1.00
$(Fe, Mn)_2O_3$	114.00
Water	5.00
Micaceous Iron Oxide	34.30
Total	**219.30**

Topcoat Model Formulation

Ingredients	% Wt
Waterborne Silicone Emulsion A	10
Fe-Oxide Dispersion	6
Flash-rust inhibitor	0.25
Total	**16.25**

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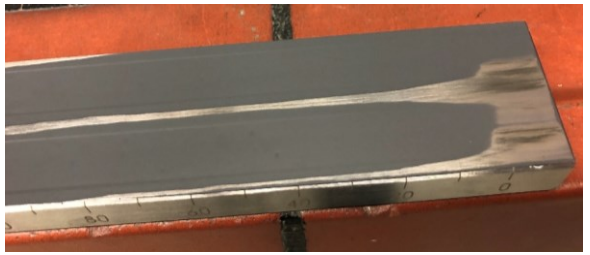
Formulation Process:

- Dispersion ingredients mixed first at 500 rpm, followed by 1000 rpm in Cowles mixer, and finally grinding with Zr-beads for 45 mins at 1000 rpm.
- Topcoat formulation prepared by blending dispersion with **Waterborne Silicone Emulsion A** and additives.
- Additional water can be added to tune viscosity.



Typical properties are average data and are not to be used as or to develop specifications

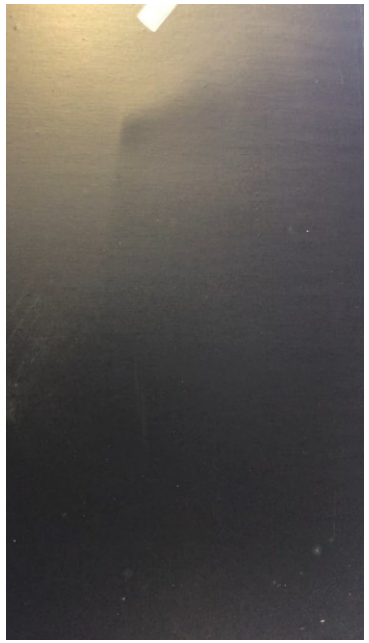
Application:

- Substrate: Aluminum (3000-series), High Strength Industrial
- Spray application with gravity-feed gun (1.4 mm nozzle, 1.1-1.2 bar pressure)
- DFT ~15-25 micron
- Curing: 250 ˚C for 30 min

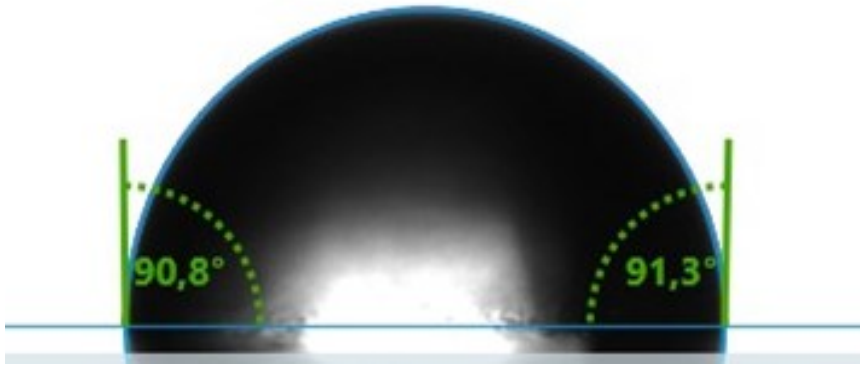
Results: Iron Oxide Pigment

Water Contact Angle and Surface Energy

Water Beading



AFTER High Temp Exposure (450 ˚C for 30 min)



FREE SURFACE ENEGY (mN/m)	**33.65**
DISPERSIVE COMPONENT	32
POLAR COMPONENT	1.66

AFTER 2000 hr of QUV-B (ASTM G-154)

FREE SURFACE ENEGY (mN/m)	**33.5**
DISPERSIVE COMPONENT	34.1
POLAR COMPONENT	2.09

Typical properties are average data and are not to be used as or to develop specifications

Reduced surface energy maintained after QUV-B exposure

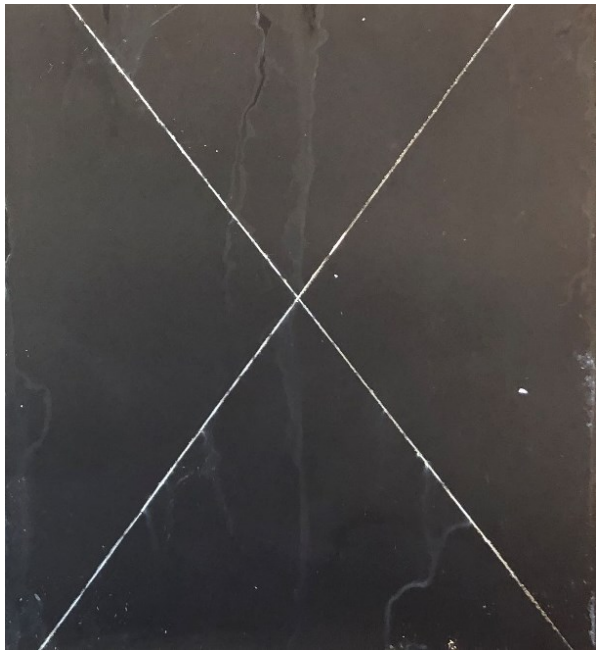
Results: Iron Oxide Pigment

Chemical Resistance, Mandrel Bend, Corrosion Resistance and Adhesion

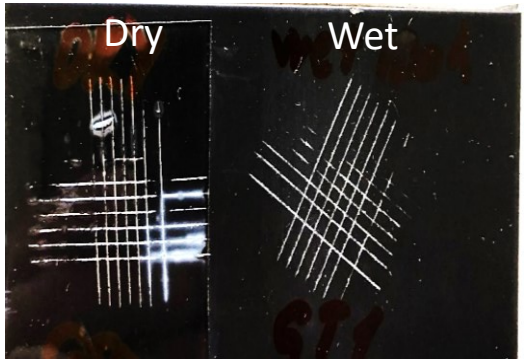
Probe substances: THF; Heptane; Fluid Oil; KOH(10%); Cleaner; Gear Box Oil

Bending elasticity of coating film baked at 450C

Corrosion Resistance on Aluminum (3000 hr NSST)



Wet Adhesion-After 240 hr at 40˚C, 100% humidity



Typical properties are average data and are not to be used as or to develop specifications

Excellent chemical resistance to a variety of fluids
Excellent flexibility in bending test
Excellent adhesion and corrosion resistance

Model Formulation and Results: Iron Oxide & Talc

Model Formulation

Ingredients	% Wt
Water	20.44
Pigment Dispersant	0.57
Non-ionic Surfactant	0.26
Talc	3.28
Iron oxide	30.66
Waterborne Silicone Emulsion A	**44.79**
Total	100.0

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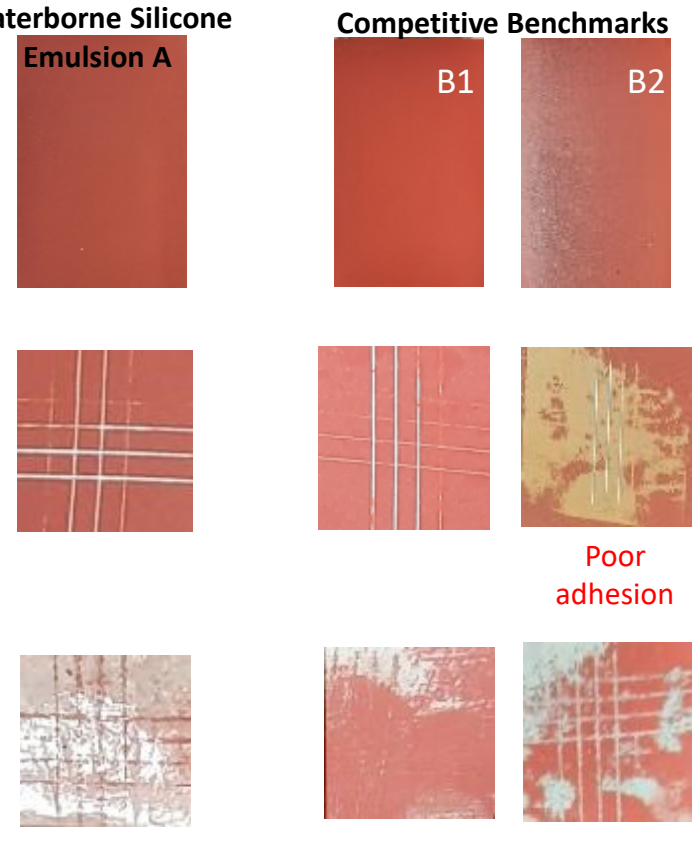
Formulation and Application Process:

- Formulation mixed in speed mixer
- Film applied on stainless steel substrate with DFT ~100 microns
- Films cured at 250 ˚C for 1 hr
- Adhesion: Cross-hatch tape pull
- Chalking: Tape applied over coating and pulled. Red pigments on tape indicate higher chalking.



Typical properties are average data and are not to be used as or to develop specifications

Excellent film quality and thermal resistance with Waterborne Silicone Emulsion A

Model Formulation and Results: Aluminum Pigment

Model Formulation

Ingredients	Wt%
Waterborne Silicone Emulsion A	**49.7**
Aluminum Powder	16.6
Water	8.4
Glycol Ether (DPNB/BG)	25.1
Wetting Agent	0.1
Defoamer	0.1
Total	**100**

Product formulations are included as illustrative examples only. Momentive makes no representation or warranty of any kind with respect to any such formulations, including, without limitations, concerning the efficacy or safety of any product manufactured using such formulations.

Cured Film Properties (200 ˚C for 30 min)

Parameters	Results
Pendulum Hardness (Konig, sec)	213
Pencil Hardness	H
Adhesion	0 (excellent)
Yellowness (b)	0.6

Typical properties are average data and are not to be used as or to develop specifications

Dry film Appearance

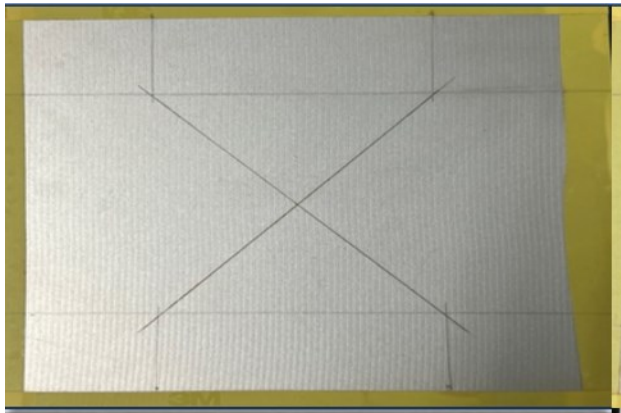
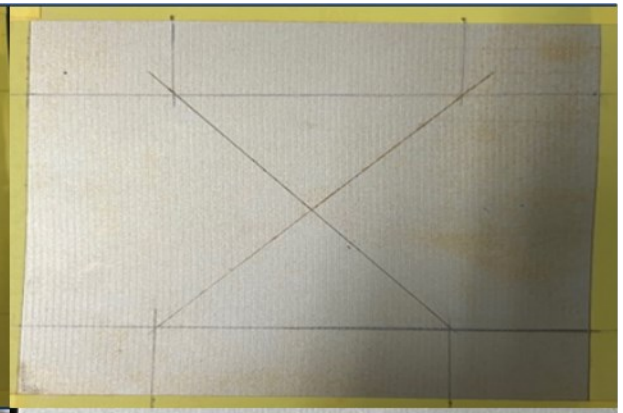
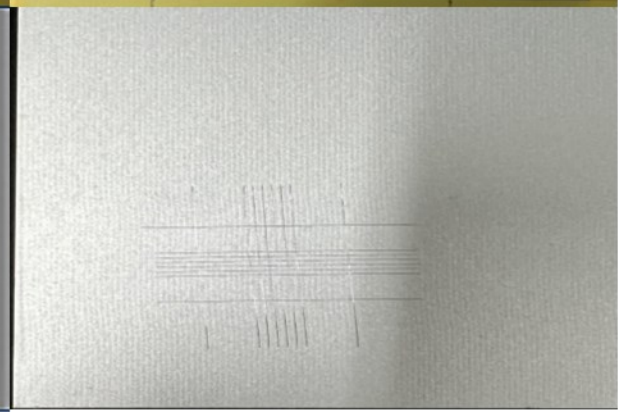
Formulation and Application Process:

- Aluminum Paste: Mix aluminum powder, water, DPNB at 650 rpm for 20 min (keep separately)
- In a different container, mix defoamer, wetting agent and CoatOSil P905 at 850 rpm for 5 min
- Add Aluminum paste and mix at 850 rpm for 25 min
- Add additional water/DPNB to tune viscosity
- Film applied with wire applicator, WFT ~100 microns, and cured at 200 ˚C for 30 min

Results: Aluminum Pigment

Thermal Ageing

Performance Post Thermal Ageing

	400 ˚C for 240 hrs	600 ˚C for 240 hrs
Corrosion (Salt Spray, 240 hrs)		
Cross-hatch Adhesion		

Excellent thermal resistance up to 600 ˚C
Properties retained after thermal ageing

Typical properties are average data and are not to be used as or to develop specifications

Model Formulation: Zinc Aluminum Pigment

Model Formulation

Ingredients	% Wt
PART A	
Dipropylene glycol	30
Dipropylene glycol monomethyl ether	30
Butyl glycol	30
Non-ionic Silane Dispersing Agent	**3**
Surfactant	2
Surfactant	2
Nitropropane	6
Epoxy Silane	**3**
ZnAl-paste	140
Mix at 2000 rpm for 3 hrs	
TOTAL	**246**
PART B	
Silica	123
Waterborne Silicone Emulsion A	**123**

Product formulations are included as illustrative examples only. Momentive makes no representation or warranty of any kind with respect to any such formulations, including, without limitations, concerning the efficacy or safety of any product manufactured using such formulations.

Formulation Process:

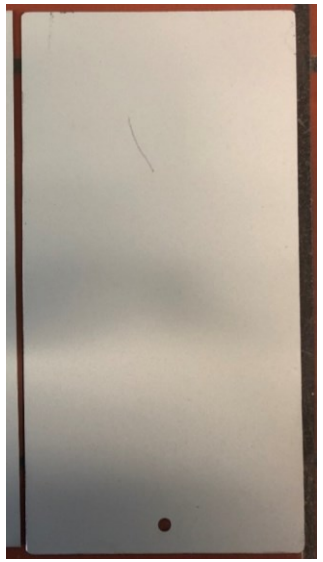
- ZnAl paste prepared at 2000 rpm for 3 hrs.
- Topcoat formulation was preparade by cold blending of ZnAl paste PART A and resin PART B
- Induction period before spraying ~1 hr.
- Pot-life of the formulation ~12 hr. Exceeding pot-life may result in premature hydrolysis of Zn in water

Application:

- Topcoats were spray applied (gravity-feed gun, 1.4 mm nozzle, 1.1-1.2 bar spray pressure)
- Substrate: Cold rolled steel
- DFT: 15-25 micron
- Curing: 250 ˚C for 30 min

Model Formulation: Zinc Aluminum Pigment

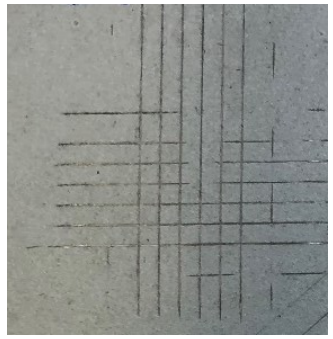
Film Appearance after Curing



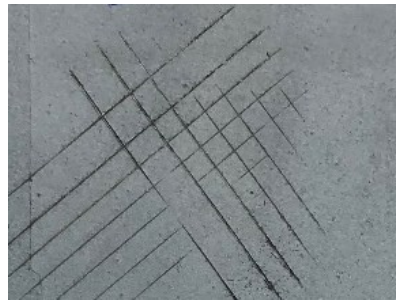
Corrosion Testing (NSST, 240 hrs)

Adhesion Testing

Dry



Wet



After 240 hr at 40˚C, 100% humidity

Typical properties are average data and are not to be used as or to develop specifications

Waterborne Silicone Emulsion A based formulation demonstrated:

- Good compatibility with ZnAl dispersions and colloidal silica gels
- Excellent spray-ability and good appearance
- **Excellent dry and wet adhesion**
- **Good corrosion resistance on mild steel**

Summary and Conclusions

- **Waterborne Silicone Emulsion A** is a lower VOC[1], waterborne silicone resin emulsion for applications where high thermal resistance is desired.
- As a coating resin, **Waterborne Silicone Emulsion A** demonstrated:
  - ✓ Good compatibility with Aluminum, Zinc, Iron Oxide, TiO_2, Talc and Silica based pigments
  - ✓ Excellent sprayability and appearance
  - ✓ High hardness after thermal curing (tack free after RT drying)
  - ✓ Excellent adhesion, corrosion and moisture resistance

[1]*VOC is measured utilizing EPA Method 24*

Questions?

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THANK YOU!

