AN ORGANOMODIFIED SILOXANE FOR LATEX DIPPING APPLICATIONS

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ABSTRACT

The production of elastomeric gloves is an energy-intensive process that includes drying, curing and dipping. Any reduction in energy consumption will likely reduce overall cost of production and lead to improved competitiveness. However, additives that can enable energy cost savings must also help to improve the wetting property and film formation in order to minimize defects.

In this report, we study the effect of an organomodified siloxane (OMS) on the properties of latex systems. As a result, the use of OMS showed improvements in multiple system properties, such as drying, wetting, film formation and release force on substrate in carboxy-nitrile butadiene rubber latex (X-NBR), carboxy-styrene butadiene rubber latex (X-SBR) and natural rubber (NR) latex.

1. Introduction

Like many manufacturers, latex producers constantly strive to produce better quality goods at lower overall costs. OMS are being used today in a multitude of industries including the electronics, automotive, paints, medical and food industries because of their unique properties.

In this study, Indusil* 139 silicone, a polyether-modified siloxane, helped improve the quality of latex film. Indusil 139 silicone enhanced the wetting power of the latex, which resulted in a more uniform film being formed. Further, Indusil 139 silicone helped increase drying speed and greatly reduce defects, such as pinholes and web formation, by enabling water removal from the latex during the coagulation process.

It should be noted that maintaining precise control of latex pH is paramount in preventing premature coagulation, and in some cases, addition of an organic surfactant may be necessary.

2. Materials and Methods

2.1 Organomodified Siloxane

Within the elastomeric glove market segment, polydimethylsiloxanes (PDMS) are generally referred to as "silicones" and are widely avoided because they are associated with static buildup and surface defects during production. However, not all silicone compounds are alike. The chemical structure of PDMS (see Figure 1) is different than that of Indusil* 139 silicone (see Figure 2), an OMS aqueous solution of siloxane polyether pendant copolymer. The study showed that static buildup and surface defects associated with the use of PDMS were virtually eliminated when

Indusil 139 silicone was added to the latex formulation.

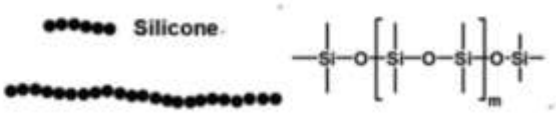


Figure 1. Polydimethlysiloxane Structure

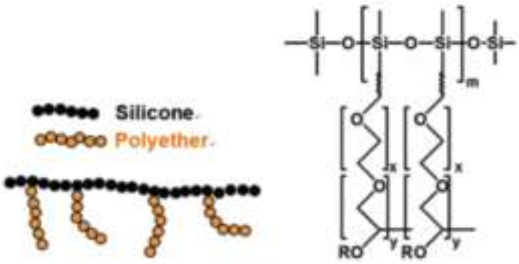
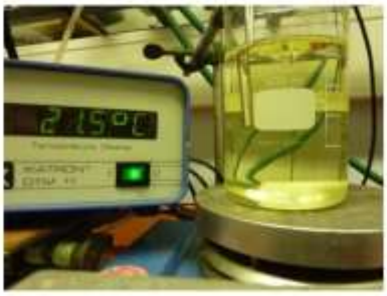


Figure 2. Indusil 139 silicone Structure

To demonstrate that Indusil 139 silicone does not contain PDMS, a photograph of Indusil 139 silicone was taken when the solution was at 21.5 °C (see Figure 3). At this temperature, the solution is transparent in nature, whereas PDMS is not soluble in water. This photograph illustrates that Indusil 139 silicone does not contain PDMS.

Table 1 shows the typical properties of Indusil 139 silicone. Indusil 139 silicone has a cloud point of 36 °C.



A clear solution at room temperature

Figure 3. Indusil 139 Silicone in Water at 21.5 °C

Test results. Actual results may vary.

Table 1. Typical Properties of Indusil* 139 Silicone

Property	Value
Viscosity (25 °C)	45 cst
Cloud point	36 °C
pH	8.0
Surface Tension, 1%, 25 °C	34.68 mN/m
Surface Tension, 0.1%, 25 °C	37.84 mN/m

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

2.2 Polymer Latex

Each latex was mixed with Indusil 139 silicone at 25 °C.

2.3 Polymer Latex Compound

Each latex compound was mixed with Indusil 139 silicone at 25 °C.

2.4 Film Formation Test

Clean glass test tubes without a surface treatment were dipped into X-NBR latex at ambient temperature for 3 seconds. Test tubes were then lifted out of the latex and excess latex was allowed to drip off.

2.5 Drying Speed Test

1.5 g X-NBR latex was placed in a petri dish and heated on a hot plate to 60 °C.

2.6 Coagulation Test

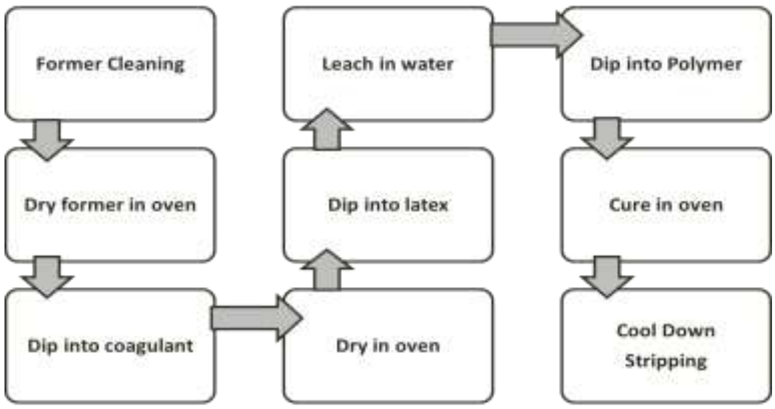
20 g latex compound was placed in a 50 mL beaker, the beaker was put into an 80 °C water bath and the coagulation temperature was determined under continuous stirring.

2.7 Atomic-Force Microscopy (AFM) Test

X-NBR gloves containing 0.5 phr of Indusil 139 silicone and gloves without the additive were analyzed according to DIN EN ISO/IEC 17025 by using an atomic force microscope.

2.8 Physical Properties of X-NBR Glove

The compounding formulation of X-NBR latex consisted of X-NBR latex, SDBS, KOH, sulphur, ZnO, ZDBC, antioxidant, TiO_2 and 0.2 phr of Indusil 139 silicone.The X-NBR glove was prepared in the lab using the process illustrated below.



2.9 Release Force Test

1 in. x 6 in. latex film was pre-formed on a ceramic plate and covered with adhesive tape of the same size in order to ensure the film would not be broken in the course of stripping. The release force was measured by 30 cm/min. stripping speed.

2.10 Adhesion Strength Test for Nylon Fabric

25 mm x 100 mm latex film was pre-formed on nylon fabric and fully bonded with metal sieve tape of the same size in order to ensure that the film would not be broken in the course of peeling. The adhesion strength was measured by 30 mm/min. peeling speed in accordance with ASTM C794-Standard Test Method for

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Adhesion-in-Peel of Elastomeric Joint Sealants.

2.11 Chloroform Extraction Test

NBR gloves were placed in 15 mL glass vials. Chloroform was added and the vials were allowed to stand at ambient temperature for 10 min. The chloroform layer was decanted into a clean glass vial and the chloroform was allowed to evaporate overnight. The dried-down extract was re-suspended with a small aliquot of chloroform and a thin film was cast onto an attenuated total reflection unit (ATR with diamond). The samples were analyzed in the transmission mode using a Bio-Rad FTS 3000MX FTIR spectrometer.

3. Results and Discussion

3.1 X-NBR Latex

The addition of 0.5 phr of Indusil* 139 silicone into X-NBR latex resulted in a reduced viscosity of the latex to approximately half the original value. Despite this, the formulation containing Indusil 139 silicone exhibited increased pick up and uniform film formation (see Figure 4) in the dipping process because surface tension was reduced, which resulted in improved wetting of the substrate. Further, the addition of Indusil 139 silicone into the latex compound resulted in increased drying speed (see Figure 5).

Table 2. Properties of X-NBR Latex with 0.5phr Indusil* 139 Silicone

	pH Value (25 °C)	Solid % (105 °C for 3hrs)	Viscosity mPas(25 °C)
X-NBR latex	8.5	44.8	41
X-NBR latex with 0.5phr Indusil 139 silicone	8.5	45.1	22

Test data. Actual results may vary.

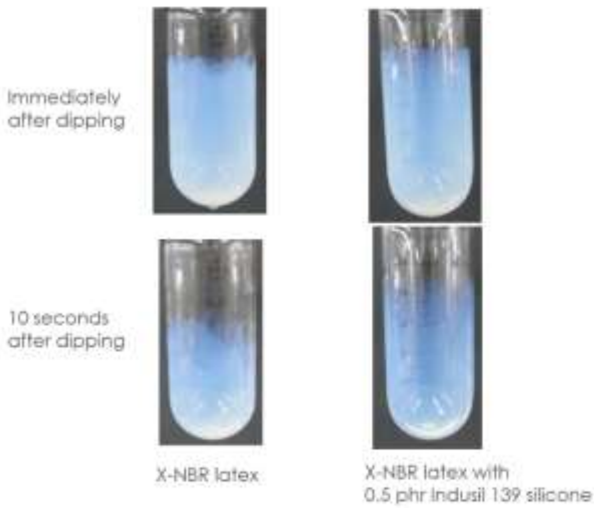

Figure 4. The Effect of Indusil 139 Silicone on Film Formation

Test results. Actual results may vary.

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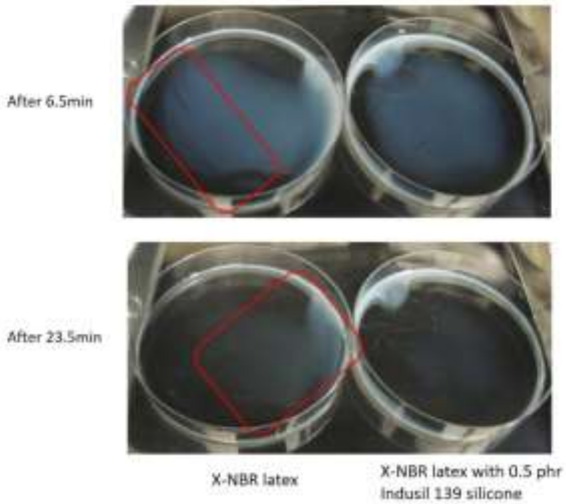

Figure 5. The Effect of Indusil 139 Silicone on Drying Speed
Test results. Actual results may vary.

3.2 X-NBR Latex Compound

Stability of latex compounds containing Indusil* 139 silicone at 0.3 wt% was measured by mixing the latex compounds with Indusil 139 silicone and filtering to determine the degree of coagulation. Coagulum was evident in the latex compound at pH of 8.03, but after adjusting the pH value to 10.77, the level of coagulum was very low. No coagulation of the compound was observed at 80 °C for 45 min. after adjustment of pH value to 10.77.

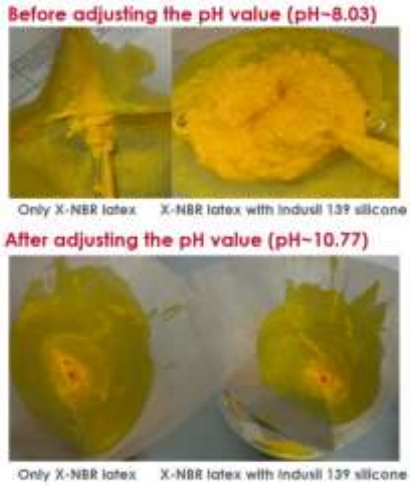

Figure 6. Stability of X-NBR Compound with 0.3 wt% Indusil 139 Silicone
Test results. Actual results may vary.

The film surface of X-NBR latex with Indusil 139 silicone was smoother (see Figure 7) and had fewer hard particles (see Figure 8) than that of X-NBR latex alone (as measured with AFM). The large number of hard particles detected in the glove that did not contain Indusil 139 silicone additive was indicative of the non-uniform coagulation process that took place. Often times, hard particles are actually filler; however, no filler was used in this latex compound. Rather, the hard particles were the result of a very high degree of coagulation within the X-NBR latex. In contrast, the coagulation process for the X-NBR latex that contained Indusil 139 silicone was

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much more uniform with an almost complete lack of hard coagulum.

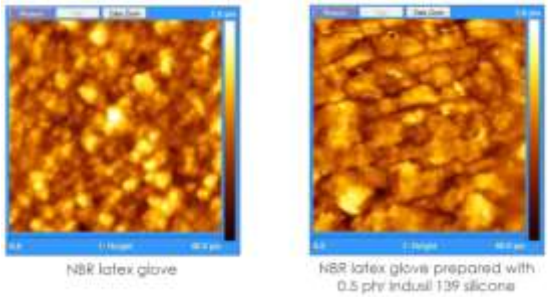

Figure 7. Surface Evenness Measured by AFM
(The darker the color, the deeper the surface)

Test results. Actual results may vary.

Figure 8. Surface Hardness Measured by AFM
(The lighter the color, the harder the surface)

Test results. Actual results may vary.

X-NBR latex containing 0.2 phr of Indusil* 139 silicone produced a softer glove while retaining tensile strength (see Table 3). These results indicate that Indusil 139 silicone helped achieve a more uniform latex film and a more homogenous coagulation.

Table 3. X-NBR Glove Physical Properties with 0.2 phr Indusil 139 Silicone

	Thickness, mm	ASTM-D6319-10					V Tear, N	EU Standard, EN 455-2 Force at Break, N
		Tensile Strength, MPa	M100, MPa	M300, Mpa	M500, Mpa	EAB, %		
Unaged								
NBR glove	0.08	24.2	2.3	5.1	14.8	613	1.0	8.0
NBR with Indusil 139 silicone	0.08	25.7	1.7	3.0	11.8	672	0.9	8.0
Aged 7 days at 70 °C								
NBR glove	0.08	25.1	2.1	5.3	20.1	519	0.9	7.4
NBR with Indusil 139 silicone	0.08	26.3	2.1	5.0	19.7	549	1.3	9.1

*Source: in-house test data used by permission of Le Inoova Sdn Bhd.

X-NBR latex containing 0.5 phr of Indusil 139 silicone reduced the release force from a ceramic plate and increased the peel force on nylon fabric (see Table 4). Indusil 139 silicone enabled the reduction in release force by lowering the surface energy of the siloxane part of Indusil 139 silicone on the surface of the latex film, and increased adhesion strength through better wetting by lowering the surface tension of the latex and penetrating into the nylon fabric.

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Table 4. Release Force of X-NBR compound film with 0.5 phr Indusil* 139 silicone from a ceramic plate and the peel force from nylon fabric.

	Release Force (g/in.)	Peel Force (N/mm)
X-NBR compound	460.1	3.85
X-NBR compound with Indusil 139 silicone	270.8	4.51

Test data. Actual results may vary.

A chloroform ($CHCl_3$) extraction study of X-NBR latex gloves containing Indusil 139 silicone showed no strong absorbance at the typical absorption wavelengths of Indusil 139 silicone that occur at 1111 and 2868cm^{-1}. Indusil 139 silicone was not extracted by chloroform. It is believed that some Indusil 139 silicone remained on the surface of NBR gloves, which provided beneficial properties such as surface smoothness and lower release force.

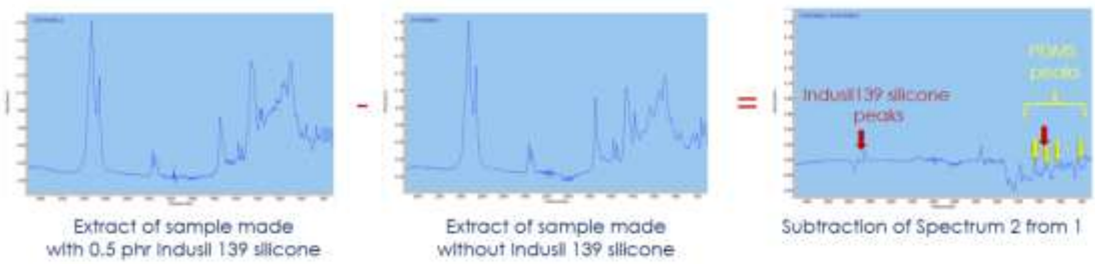

Figure 9. Chloroform Extraction Study of X-NBR Glove Containing Indusil 139 Silicone

3.3 X-SBR Latex Compound and NR Latex Compound

Similar effects of Indusil 139 silicone on film formation and drying speed were observed for X-SBR and NR latex compounds in tests similar to those reported in 3.2.

In the case of X-SBR latex, the addition of Indusil 139 silicone caused a significant increase in viscosity, which is desirable for knob formation on the underside of artificial grass carpets. Just as with X-NBR latex, the addition of Indusil 139 silicone resulted in increased X-SBR latex drying speed, without affecting its film formation.

In the case of NR latex, formulations containing Indusil 139 silicone exhibited reduced defects, increased pick up, and faster speed of drying than those without it. In order to avoid premature coagulation, pH must be tightly controlled within a narrow range that depends on the composition of the compound.

4. Conclusion

Test results showed that Indusil 139 silicone—an organomodified siloxane or OMS—provided multiple benefits to latex systems, including quick drying, good wetting and better film formation. In addition, this OMS provided better release from the former and increased adhesion on hydrophobic nylon fabric—performance not seen with PDMS.

In the presentation, we shall present further studies on latex compound stability with our OMS solution that can help glove manufacturers produce better quality gloves at lower overall cost.

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5. Acknowledgements

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