# The Preparation of Fluorine-Silicon Resin and The Research on its Anti-icing Properties

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Low-surface energy anti-icing coating can prevent icing in a passive form. It can not only delay the formation of the surface ice, but also reduce the adhesion between ice and coating significantly, without of power consumption. The research on anti-icing coatings has aroused a wide concern.

We synthesized a polymer resin which had both perfluoroalkylation and methyl-organosilicon. On base of it, the anti-icing coatings was prepared, characterizeing in good hydrophobility and poor adhesion with ice. Several methods were used for evaluating the resin and coating, including IR, Contact angle apparatus, pull-opening in the laboratory， anti-icing ability on the work site , and so on. Anti-icing mechanism, especially failure behavior, was discussed briefly in this study.

**Key words:** Coatings; Resin; Low-surface-energy; Anti-icing; Failure

## Introduction

The icing and snow accumulation is a serious problem to security service of electric system. Its damage mainly reflects in two aspects: on the one hand, it will add the load of the transmission pole tower, which will be pulled down once the icing and snow build is over-loaded; on the other hand, it can reduce the flashover voltage of insulator string and arouse icing flashover. In January 2008, for example,the long-drawn-out ice-rain and snow made the transmission line icing seriously in the south of China, resulting in heavy economic losses. So, how to prevent icing ,even to reduce the amount of icing, is a very important technology, concerning the security running of electrified netting.

## 1 Experimental Section

### 1.1 Materials

(methyl) acrylate monomer, fluorinated (methyl) acrylate monomer, silicified (methyl) acrylate monomer, modifier, BPO, butylaetate, ethyl acetate, xylol, coatings additives.

### 1.2 Synthesis of the fluorine-silicon resin

First, butyl acetate was added into a four-necked flask equipped with a condensor, a thermometer, a dropping funnel under a nitrogen atmosphere and stirred for 0.5h at 120℃. Then the monomer mixture and BPO were added slowly into the flask. After the mixtrue reacted for 8-10 hours at 120℃, the modifier wad added into the flask at 60℃,and reacted a further 0.5h. Finally, the mixture was stirred at 70-75℃ for 3-4h. The fluorine-silicon resin was obtained.

### 1.3 The main instruments

A contact anglemeter ( Dataphysics Co. OCA20)
Infrared spectrometer（Shimadzu, IR-21）
Ice adhension tester( Chongqing University)

## 2 Results and discussion

### 2.1 The structure of the resin

IR spectra of the synthesised fluorine-silicon resinwas shown as followed(Figure 1):

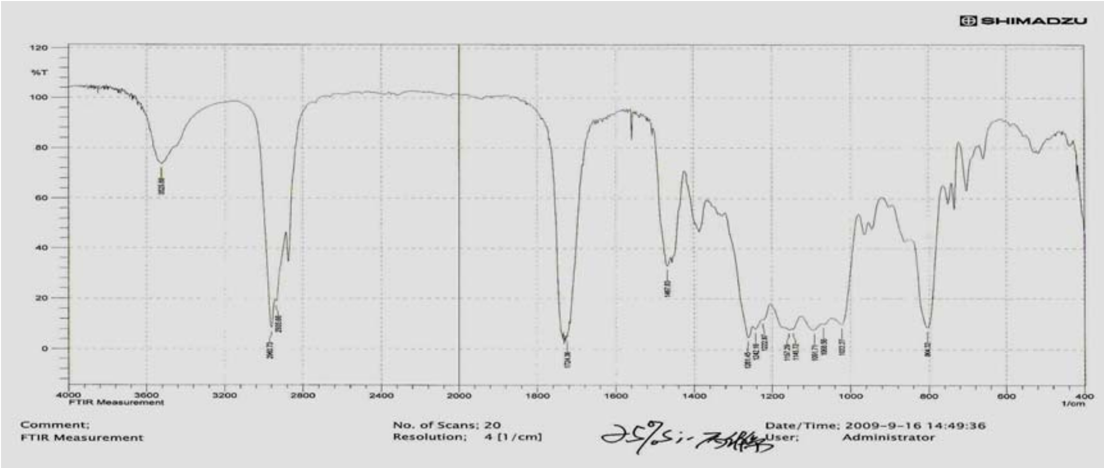



Figure 1 Infrared spectrum of fluorine-silicon resin

The spectra was characteristic of a fluorine-silicon acrylate resin, as seen by characteristic broad bands near 1150~1268cm$^{-1}$(which are due to fluoro-copolymer) and broad bands near 1022cm$^{-1}$（Si-O-Si） and strong bands near 804cm$^{-1}$( -$Me_2SiO$-）. This spectrum showed the character of a ester group, a band near 1724cm-1due to a C=O stretcring vibration and a broad and strong band near 1150cm-1 due to a C-O-C stretcring vibration.

### 2.2 The properties of the coating

#### 2.2.1 Hydrophobicity and its stability

Anti-icing property is affected by many factors. Reducing even losing of its hydrophobicity is one of the important reasons, so it is important to investigate the influence of the continued hydrophobicity to evaluate the anti-icing ability of the coating. We investigated the continued hydrophobic properties of the anti-icing coating based on fluorine-silicon resin and RTV(Room Temperature Vulcanization), as it shown in figure 2.

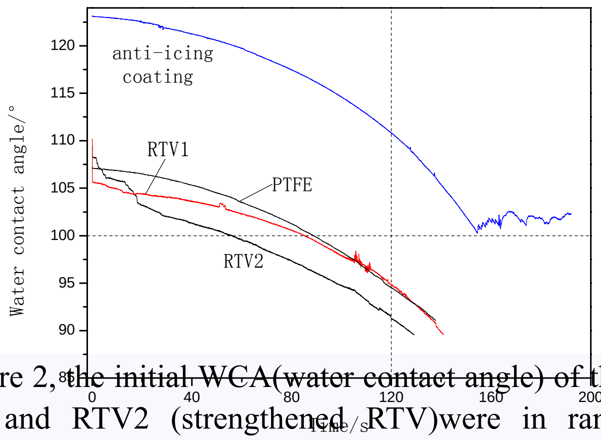



Figure 2 The change of WCA with the time

As was shown in figure 2, the initial WCA(water contact angle) of the fluorine-silicon coating was 125°, while RTV1 and RTV2 (strengthened RTV)were in range from 105° to 110°, demonstrating the former had a better hydrophobic properties than the latter at the first. With the time expanding when the drop role of droplets and the droplet evaporation on the surface of the coating, the static contact angle began to decline continuously. When the water droplet stayed for 120 seconds in the same ambient condition（20℃，RH40%）， the WAC of RTV1 was 90°, RTV2 was about 95°,while anti-icing coating was still

110°,which was correspond to the initial WCA of RTV1 and RTV2. Further investigation showed that the WCA of anti-icing coating could maintain above 100° for a relatively long time, while that of RTV would reduce continually.

Icing test under ambient condition showed that the anti-icing coating and RTV1/RTV2 could postpone the icing building-up. As time passed, RTV1/RTV2 losed the anti-icing ability gradually, and then the anti-icing coating began to lose this ability also. This phenomenon is probably due to the losing of hydrophobic ability, which is, as time went on, WCA of the surface reduced gradually to a certain value, then the anti-icing ability was deprived entirely.

### 2.2.2 Basic physical and chemical properties of coating

The conventional properties were showed in Table 1 (tested at Marine Coatings Quality Supervision And Test Center of Chemical Industry):

Table 1 The conventional properties of the anti-icing coating

| | Projects | Results | Testing method |
|---|---|---|---|
| 1 | hydrophobicity，grade | 1 | HC |
| 2 | appearance | smooth | Visual test |
| 3 | Drying time，h<br>Surface dry<br>Hard dry | <br>≤4h<br>≤20h | GB/T1728-1979（1989） |
| 4 | Resistance to bending，mm | 2 | GB/T6742-2007 |
| 5 | Shock resistance，cm | 50 | GB/T1732-1993 |
| 6 | Humid heat test，240h,grade | 1 | GB/T1740-2007 |
| 7 | High tempareture test 120℃ ，＞240h | 250h, no bubble no peeling | GJB150.3-86 |
| 8 | lightly acidic solution immersion resistance（sulfuric acid solution, PH=4），120h | no bubble no peeling | GB/T9274-1988 |
| 9 | Thermal shock （-50℃,+1h~150℃,+1h）20 cycles | no bubble no peeling | GJB150.5--86 |
| 10 | adhension，grade | 1 | GB/T1720-1989 |
| 11 | application | spraying | GB/T6753.6-1986 |

### 2.2.3 The adhesion of ice

Adhesion testing of the ice on the anti-icing coating and RTV was performed at Chongqing University（high voltgage laboratory of state key laboratory of power transmission equipment & system security and new technology). The results were shown in Table 2:

Table 2 The adhesion of ice on different surfaces

| | product | Testing temperature | Ice adhesion/MPa |
|---|---|---|---|
| 1 | Anti-icing coating1 | -3～-7℃ | 0.0035 |

| | | | |
|---|---|---|---|
| 2 | Anti-icing coating2 | | 0.00014 |
| 3 | RTV | | 0.173 |

It could clearly be found from Table 2 that the adhesion of ice on anti-icing coating was much smaller than that of RTV. It accounted for the fact that the anti-icing coating could reduce the adhesion of ice and was benefit for de-icing.

### 2.2.4 Icing test on the job

In order to investigate the icing effects, Pingshantang Icing Station on Xuefeng Mountain in Hunan province was chosen as the experiment site (elevation is 1400meter, the lowest temperature is -15℃,the maximum wind speed is 30m/s).

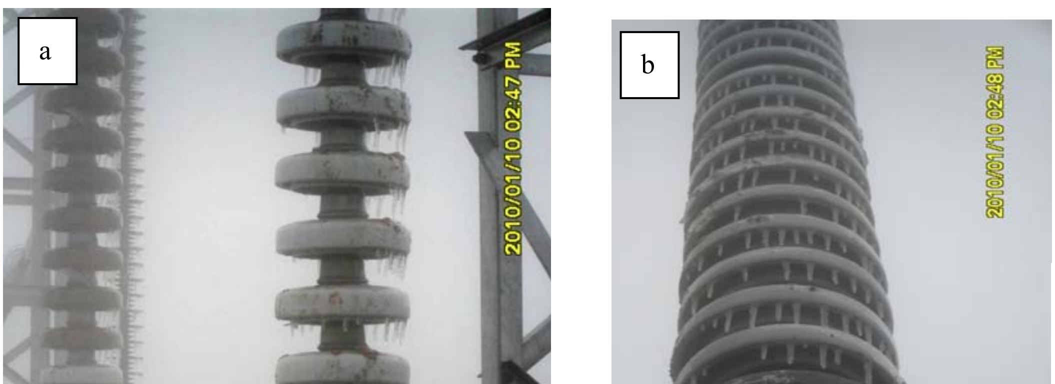

Figure 4　Appilication on the spot

Application time: January 7th, 2010

Application method: spraying

Temperature: below zero

Condition:January 8th , sunny, 5℃; January 9th, icing occurred; January 10th, glaze icing(Figure 5);January 11th,rime and blending icing



(The last insulator was coated with the anti-icing coating, and the others were naked, without coating)

Figure 5 was the picture of the glaze icing situation of the insulator string at variety distances. Since no evident icing was been found at the insulator which was coated with the icing-coatings, it could conclude that anti-icing coating blocked initial icing effectively.

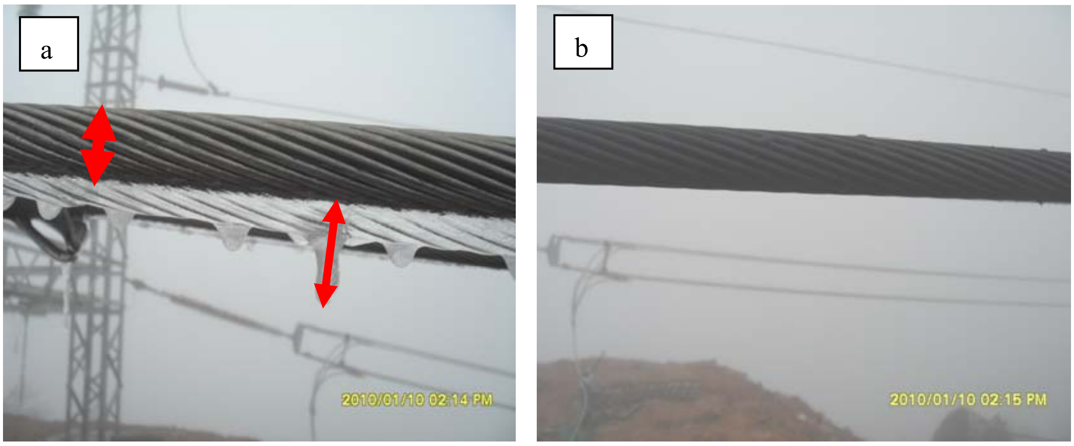



Figure 6 Glaze icing of the wire

(a: naked wire b: wire coated with the anti-icing coating)

It was showed in figure 6 that roughly 10-cm ice froze on the downside of the naked wire while there was no apparent icing on the wire coated with the anti-icing coating.


Figure 7 Rime on the insulator string

(The last insulator was coated with the anti-icing coating, and the others were naked, without coating)

It was shown that about 10-cm rime formed on the naked insulator, while the coated one just began to ice(figure 7).

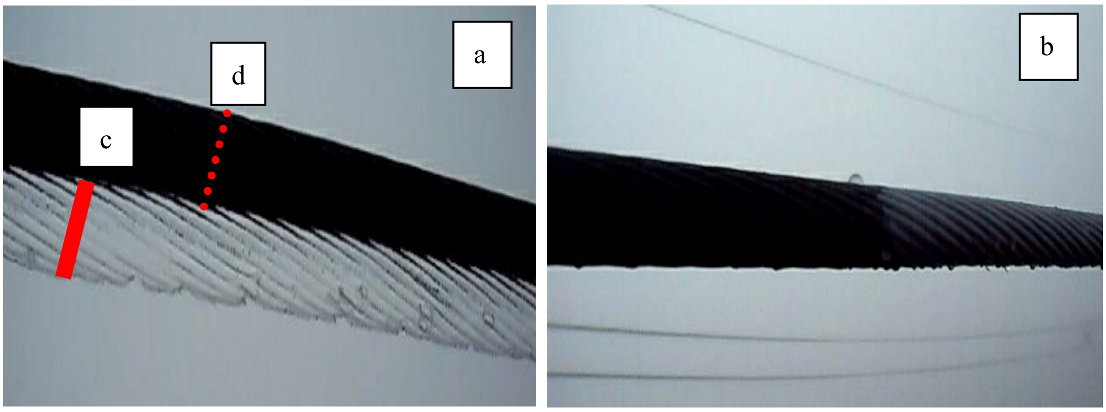



Figure 8 Blending icing on the wire

(a-naked wire b-wire coated with the anti-icing coating c-ice d-naked wire)

It was shown that roughly 5-cm ice froze on the downside of the naked wire, while there was almost no ice on the surface of the coated wire.

**3 Conclusion**

The fluorine-silicon resin was synthesized by means of radical polymerization. and its anti-icing property was investigate in the lab and in-site test. The results showed that the anti-icing coating could prevent the insulator string and wire from freezing at the first, and postpone icing effectively. But as its surface was immersed in the water or ice, the anti-icing ability of the coating would reduce until disappear.

Compared with ordinary RTV coating, the fluorine-silicon coating has a better hydrophobicity. Although it can't prevent icing build-up totally, the anti-icing coating can reduce the adhesion force to ice, which is helpful for de-icing.

The site investigation showed that the fluorine-silicon coating had anti-icing ability to some extend. It is of great value to anti-icing study that how to value the anti-icing effected in the laboratory, especially how to quickly determine what condition (such as what value the WCA reduces to) makes the coating lose its anti-icing ability.