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EFFECT OF ANTI-ICING RTV COATING ON DELAYING THE TRANSFER OF SOLUBLE SALT IN ICE LAYER UNDER LOW TEMPERATURE

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Abstract: Power system icing disasters have already caused many serious problems in China, leading to great economic losses. Research shows that soluble salt in freezing water and on the surface of insulators has the trend to transfer outwards to ice surface. Thus the melted water on the surface dissolves the soluble salt and has a relatively high conductivity, which decreases the flashover voltage of iced insulators. By applying a semiconducting RTV silicone coating the ice accumulation can be reduced, and a new theory that the semiconducting RTV coating can delay the transfer of soluble salt in ice layer under low temperature was also proposed. Experimental results are presented to validate the theory. The results show that the coating reduces the amount of soluble salt and delays the transfer process.

1. INTRODUCTION

Field experience shows that icing flashover occurs at an operating voltage even when the icing water has a relatively low conductivity and with slightly melting on the surface, this phenomenon leads to a conjecture that soluble salt in ice layer has the trend to transfer outwards to the surface. Experiments investigating the typical transfer process of soluble salt from different sources are designed respectively.

A semiconducting RTV silicone rubber is formulated to reduce ice accumulation [1]. The mechanism of hydrophobicity transfer shows a phenomenon that dirt adsorbs low molecule weight (LMW) silicone chains on it [2-3]. Thus, a new theory that semiconducting RTV coating can delay the transfer of soluble salt in ice layer under low temperature was proposed and verified.

2. RESULTS AND DISCUSSION

Fig.1 shows the test method.

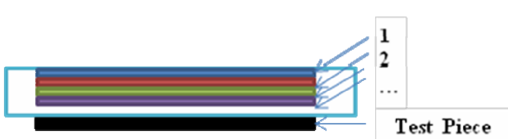

Figure 1: Sampling schematic diagram

Fig. 2 shows the distribution of conductivity in ice layer covered on the surface of polluted glass insulator and semiconducting RTV coated insulator.

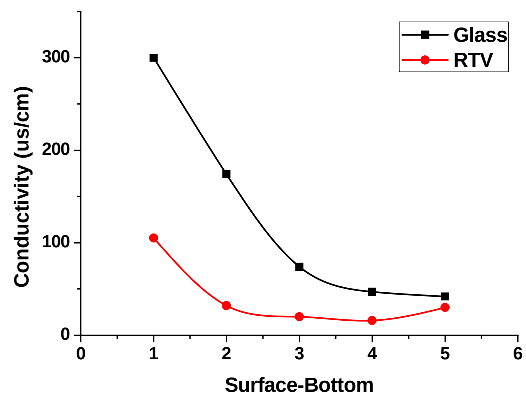

Figure 2: Salt distribution in ice layer

3. CONCLUSION

1) Soluble salt in icing water transfers to the surface of ice cube during the freezing process.
2) Soluble salt on the surface of ice-covered insulators transfers to the ice layer outer surface by accumulation of salt aggregation.
3) Icing water conductivity can't be equal to surface melted water conductivity, operating condition in melting state is even worse.
4) Application of a kind of semiconducting RTV silicone coating can delay and weaken the transfer of soluble salt in ice layer under low temperature, which reduce the melted water conductivity and increase flashover strength.

4. REFERENCES

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Effect of Anti-icing RTV Coating on Delaying the Transfer of Soluble Salt in Ice Layer under Low Temperature

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***Abstract*—Power system icing disasters have already caused many serious problems in China, leading to great economic losses. Research shows that soluble salt in freezing water and on the surface of insulators has the trend to transfer outwards to ice surface. Thus surface melted water dissolves the soluble salt and has a relatively high conductivity, which decreases the flashover voltage of iced insulators. By applying a semiconducting RTV silicone coating the ice accumulation can be reduced, and a new theory that the semiconducting RTV coating can delay the transfer of soluble salt in ice layer under low temperature was also proposed. Experimental results are presented to validate the theory, which show that the coating reduces the amount of soluble salt in ice layer and delays the transfer process.**

Keywords-Anti-icing; Insulator; Salt Transfer; Mechanism; Semiconducting RTV Coating.

I. INTRODUCTION

In the recent years, power system icing disaster occurs frequently in China. It may cause many serious problems such as insulator flashover, insulator string breakage failure, tower collapse and even blackout, leading to not only great economic losses, but also tremendous threat to the national security [1-4]. Therefore it is urgent to deal with the increasingly serious power system icing disasters.

Plenty of work has been done on the mechanism and control measures for power system icing disaster [3-4]. According to M. Farzaneh's work [5], typical icing flash process can be described as follows. Melted water forms a continuous conducting channel on the surface of ice-covered insulators, then joule heat generated by leakage current build several dry areas on the ice surface, leading to serious distortion of voltage distribution on the insulator string. When the electric field strength is big enough to break through the air gap, and with proper leakage current, icing flashover occurs [5].

Since icing flashover is an extremely complex process, it will be affected by many factors.

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Chongqing University works a lot on these factors, especially icing water conductivity. Study result shows that as the water conductivity increases, the flashover stress decreases [6]. However, whether the icing water conductivity can be equal to the surface melted water still remains an issue needed to be discussed. Field experience shows that icing flashover occurs at an operating voltage even when the icing water has a relatively low conductivity and with slightly melting on the surface, this phenomenon leads to a conjecture that soluble salt in ice layer has the trend to transfer outwards to the surface. Since icing water and surface of insulators are the two major sources of soluble pollutant, experiments investigating the typical transfer process of pollutant from each source are designed respectively.

In order to deal with the increasingly serious power system icing problems, a semiconducting RTV silicone rubber is formulated by adding conductive filler particles such as carbon black and carbon fiber to reduce the resistance of the rubber [7]. By combining the joule heat property of semiconducting glaze and hydrophobicity of RTV coating, this material shows an obvious effect on reducing ice accumulation and delaying the formation of ice [7]. The mechanism of hydrophobicity transfer shows a phenomenon that dirt adsorbs low molecule weight (LMW) silicone chains on it [9-10]. Thus, we guess semiconducting RTV silicone coating can delay the transfer of soluble salt in ice layer under low temperature, which reduce the melted water conductivity and increase flashover strength. A number of experiments have been carried out to validate the new theory.

II. SALT TRANSFER IN FREEZING WATER

A. TRANSFER PROCESS

This experiment aims to study the transfer of soluble salt in water during the freezing process. It can be observed by testing the surface melted water conductivity. If the melted water conductivity is larger than the icing water, then shows an obvious trend of salt transfer to the ice surface.

1) Test Method and Procedure: 12 portion of NaCl solution were prepared in cylindrical shaped containers with 60ml volume and 4cm bottom diameter. The volume of each sample is 50ml and the conductivity is 3500us/cm. Analytical reagent (AR) NaCl used in the experiment is produced by Guangzhou chemical reagent factory, and the conductivity of purified water is 1.79 us/cm. (All the solution conductivity mentioned in this paper is converted to the value at 20℃ according to IEC 507:1991 [8].)

Icing water froze at -18℃ with 30% humidity. Samples were taken on the upper surface of the ice cube in accordance with the schedule shown in table I. A 10ml sample was taken on each ice cube following the sampling schematic diagram shown in fig. 1. Melted water conductivity and temperature were measured immediately after sampling.

TABLE I. SAMPLING SCHEDULE.

Sampling Schedule (Day)	0.5	1	1.5	2	3	4

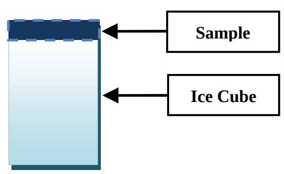


Figure 1. Sampling schematic diagram.

Environmental parameter control and standard operation are extremely important for accuracy of the test results. Measures such as sampling temperature control and equipment cleaning are taken to ensure the accuracy. Before each test, sampling on pure ice to make sure that the test method won't affect the results. Sampling on two salt ice cubes each time, when difference between this couple of results isn't too much, take the average result to avoid mistake.

2) Results and Analysis: Fig. 2 shows the change of conductivity for surface melted water, icing water and pure ice sample. Conductivity of the melted samples on the upper surface is almost twice as large as the conductivity of icing water. Considering the hindering effect of gravity, this phenomenon fully indicates the trend of soluble salt in icing water transfer to the surface during freezing process.

No big differences are found between each couple of data, which means that no data mistake exists in the test results. The test method won't affect the result, since conductivity of pure ice sample is almost the same as purified water.

Data curve of melted sample doesn't change much during the testing period, which indicates that salt transfer happens in the early freezing time. Thus, prophase observations of salt solution freezing process are needed to explain the change of distribution in ice layer of soluble salt.

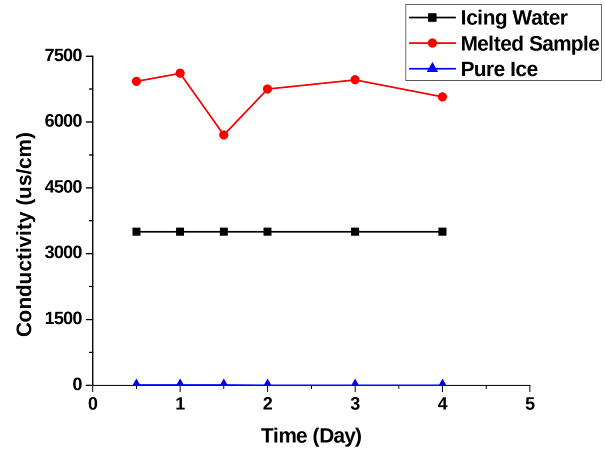


Figure 2. Salt transfer in freezing water.

B. PROPHASE OBSERVATION

1) Test Method and Procedure: Experimental conditions are the same as before except for the sampling method. In order to observe the change of soluble salt distribution in ice layer, samples are taken from three parts of the ice cube: upper layer, center without surface and lower layer. Fig. 3 shows the sampling schematic diagram, and photos are taken to analyze change of the ice structure. Table II shows the new sampling schedule.

TABLE II. SAMPLING SCHEDULE.

Sampling Schedule (Hour)	0.5	1	1.5	2	3	12	24

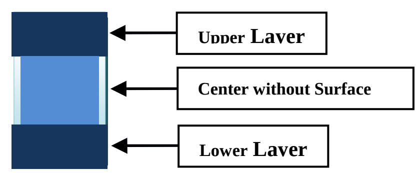
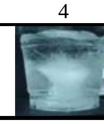


Figure 3. Sampling schematic diagram.

2) Results and Analysis: Changing of ice structure shown in table III suggested that it takes 4 hours for freezing salt solution becoming a dense ice cube, which means that samples of 'center without surface' mentioned above were still liquid in the early 3 hours. Fig. 4 shows volume change of sample in different phase for different parts of ice, combined with data in table III, indicates that icing water freezes from outside to the inside.

TABLE III. CHANGE OF ICE STRUCTURE.

Time(Hour)	1	1.5	2	4
Structure				

Melted water conductivity shown in Fig. 5 suggested that conductivity of salt solution in central part increases sharply with rapid decrease of volume. However, conductivity of samples from other parts is far lower than the icing water, which means that soluble salt was filtered in the remaining solution during the freezing process.

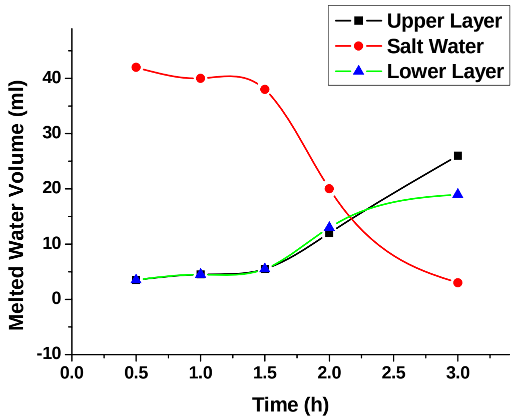


Figure 4. Melted water volume.

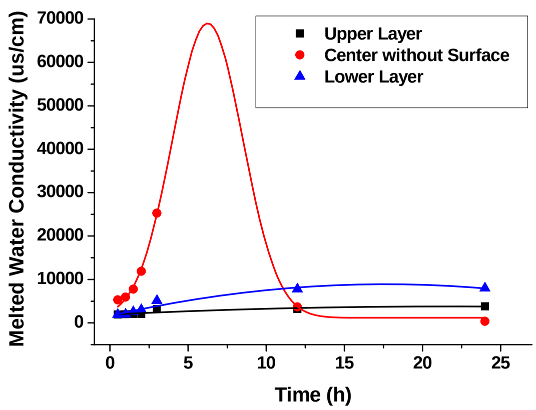


Figure 5. Melted water conductivity.

After icing water completely cured, conductivity of central part extremely decreases. Meanwhile, salt amount on the surface part increases gradually and becomes larger than the center in the end. This phenomenon suggested that soluble salt in icing solution started transferring the minute water starts freezing. Curves in fig. 5 also show that conductivity in lower layer is bigger than the upper surface, which proves the effect of gravity on the transfer process.

III. SALT TRANSFER IN ICE LAYER

This experiment aims to study the transfer of insulator surface soluble salt in ice layer. By comparing distribution of soluble salt in ice layer on different kinds of insulator surface, analyze the influence of the semiconducting RTV silicone coating on the transfer process.

1) Test Method and Procedure: 20 pieces of glass with specification of 100*100*3mm^3 were used in the experiment. Half of them were covered with a 0.3mm thick layer of semiconducting RTV coating to simulate the insulator surface. A comparison experiment including 2 tests were carried out under the condition listed in table IV.

TABLE IV. TEST CONDITION.

Test	Test 1	Test 2
Surface material	glass	RTV
Temperature (℃)	-5	-5
Humidity	30%	30%
Diatomite NSDD (mg/cm^2)	1.0	1.0
NaCl ESDD (mg/cm^2)	0.02	0.02

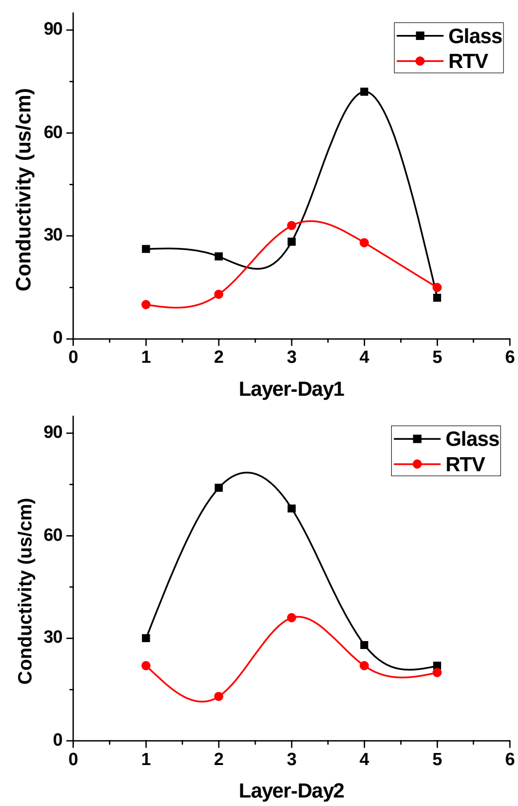
Test pieces were covered by one piece of pure ice with a size of 100*100*14 mm^3. Samples were taken following schematic diagram shown in fig. 6, size of the sample on each layer is 100*100*2mm^3. Sampling schedule is provided in table V, other requirements were the same as experiments before.

TABLE V. SAMPLING SCHEDULE.

Sampling Schedule (Day)	1	2	3	4	5

Figure 6. Sampling schematic diagram.

2) Results and Analysis: Fig. 7 shows the change of conductivity distribution in ice layer on two kinds of materials. Make the number of sample layer (defined in fig. 6) as abscissa and melted sample conductivity as ordinate.



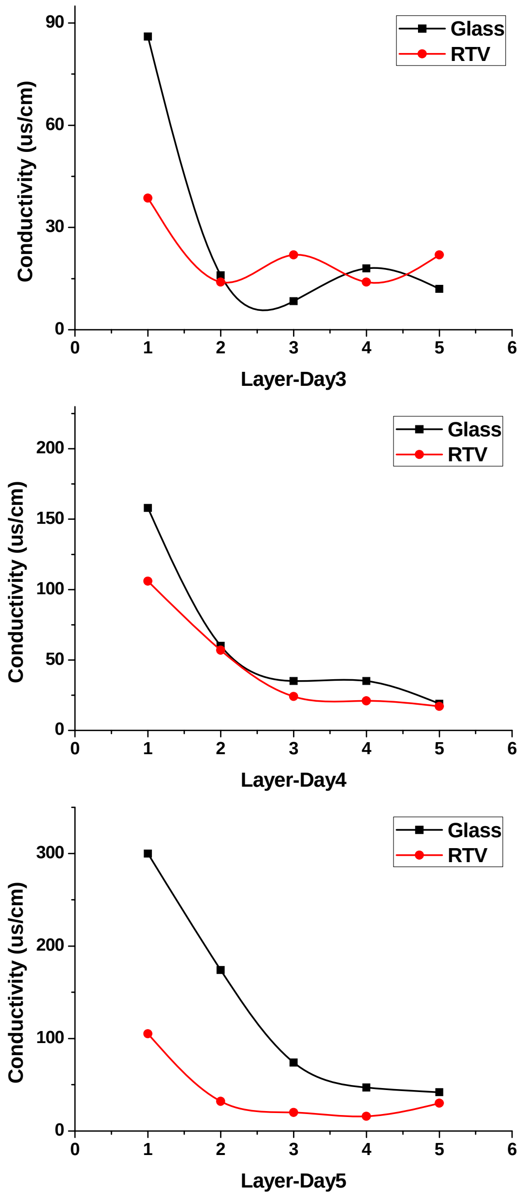


Figure 7. Salt distribution in ice layer

Curves in fig. 7 show a conductivity peak movement from bottom to the surface, which indicates that soluble salt on the insulator transfer in an aggregation form. The whole transfer process can be described as an accumulation of salt aggregation, leading to the final distribution state that most salt aggregated on the ice surface.

Cooperation between those two curves shows that both conductivity peak value and salt transfer speed for coated insulator are lower than the glass one, which means semiconducting RTV silicone coating can delay and weaken the transfer of soluble salt in ice layer under low temperature.

IV. CONCLUSIONS

Clear explanations for the icing flashover accidents happened on the operation scene, when insulator strings were covered by slight ice layer and with low icing water conductivity, are provided by the experiment results mentioned above.

First, soluble salt in icing water transfers to the surface of ice cube during the freezing process.

Second, soluble salt on the surface of ice-covered insulators transfers to the ice layer outer surface by accumulation of salt aggregation.

Thus, icing water conductivity can't be equal to surface melted water conductivity, operating condition in melting state is even worse.

Application of a kind of semiconducting RTV silicone coating can delay and weaken the transfer of soluble salt in ice layer under low temperature, which reduce the melted water conductivity and increase flashover strength.

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