Test Study on Performance of Endothermic Highly Hydrophobic Anti-Icing Materials

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Abstract. In this paper, the solar spectrum selective endothermic coating with CoCuMnOx as the light absorbing pigment is prepared to absorb sunlight efficiently. After optimizing the thickness of the coating, the endothermic coating material with absorptivity of 0.928 and emissivity of 0.198 is obtained. The roughness value of the coating is 0.64 μm, which ensures that the coating has a higher sunlight absorption rate without the need for an antireflection layer. Icing flashover tests were carried out on insulators coated with endothermic highly hydrophobic anti-icing materials. The ice lightning voltage of ceramic insulators (3 pieces) was increased by 13.68%, and that of glass insulators (2 pieces) was increased by 22.96%. Compared with ceramic insulators, glass insulators coated with anti-icing materials have better protection effect.

1. Introduction
Icing poses a great threat to power transmission lines. When the insulators of power transmission lines are bridged by ice, creepage distance decreases, and leakage current increases significantly, causing repeated flashover, which is easy to cause the lines to fail to operate normally [1]. In 2008, 384 35kV lines and 240 35kV substations in Hunan power grid were damaged and shut down due to the ice disaster. The loss of urban and rural 10-35kV distribution network was extremely serious, resulting in 6.824 million residents' power failure. The direct economic loss of Hunan Power Company was as high as 3.29 billion yuan [2].

At present, the anti-icing measures for insulators mainly include the adoption of "big and small umbrella skirt" flower arrangement umbrella structure and the application of anti-icing paint [3-6]. Although changing the umbrella structure of insulator (increasing the umbrella diameter and the umbrella spacing) can delay the bridging time of ice ribs and improve the lightning pressure of ice, the occurrence of ice ribs is easy to cause local electric field distortion, accelerate the aging of umbrella skirt and reduce the anti-icing performance. Compared with the change of umbrella structure, the application of anti-ice coating is simple, flexible and low in cost [7]. Hydrophobic anti-icing coating only has certain effect on light icing, and when the umbrella skirt surface is covered by ice layer, the anti-icing performance of hydrophobic coating gradually weakens [8]; Semiconductor heating type anti-icing paint is also in a heating state during non-ice age, which has great influence on insulator life.
and insulation performance. Therefore, it is urgent to develop a new composite insulator anti-icing coating with long-term anti-icing performance.

In this paper, the solar spectrum selective endothermic coating with CoCuMnO\textsubscript{x} as light absorbing pigment is prepared to absorb sunlight efficiently. The effectiveness of the anti-icing material is verified by the insulator icing flashover test.

2. Test Sample Preparation

The preparation materials of the solar spectrum selective endothermic coating with CoCuMnO\textsubscript{x} as the light absorbing pigment include cobalt nitrate, manganese nitrate 50% solution, copper nitrate, polyethylene glycol 200, citric acid, ammonia water and absolute ethyl alcohol (all are analytically pure); Epoxy resin modified polyurethane, diluent and curing agent.

CoCuMnO\textsubscript{x} was mixed with epoxy resin modified polyurethane at a mass ratio of 5: 4, adding a proper amount of diluent, ball milling and dispersing for 12 h, and the ball mill running speed was 400 rpm. After ball milling, a curing agent is added, and the mass ratio of the curing agent to the epoxy resin modified polyurethane is 1: 4. Stir to obtain solar spectrum selective absorption coating.

The morphology and size of CoCuMnO\textsubscript{x} were observed by JSM-6701F cold field emission scanning electron microscope (FE-SEM) with an operating voltage of 5 kV. The thickness of the coating was measured by Germany's QuaNix 4500 coating thickness gauge, and its weatherability experiment was carried out in Q8UV3 ultraviolet accelerated weatherability test box manufactured by dongguan hongzhan instrument co., ltd. The solar absorptivity (\(\alpha_s\)) and emissivity (\(\varepsilon_T\)) of the coating are calculated from the reflectivity of ultraviolet/visible/near infrared region (0.3~2.5\(\mu\)m) and infrared region (2.5~20 \(\mu\)m), respectively. The reflectivity of the two bands was measured by Lambda 950 UV/Vis/NIR spectrophotometer (equipped with 150 mm integrating sphere) manufactured by Perkin Elmer Company and TENSOR 27 infrared spectrometer (equipped with A562-G/Q integrating sphere) manufactured by Bruker Company respectively.

3. Result and Analysis

3.1. Morphology and structure characterization

Figure 1 is an FE-SEM and appearance photograph (inset) of CoCuMnO\textsubscript{x} powder obtained after calcination. According to XRD analysis results, it is calculated by Scherrer formula (the expression is \(D=K\lambda/BC\cos\theta\), where \(k\) is scherrer constant and its value is 0.89; \(D\) is the grain size (nm); \(B\) is the integral half-height width, which needs to be converted into radians (rad) in the calculation process; \(\Theta\) is the diffraction angle; \(\lambda\) is the X-ray wavelength and 0.154056 nm, which is a famous formula for XRD analysis of grain size). The particle size of calcined CoCuMnO\textsubscript{x} is 14 nm. However, it can be seen from Figure 2 that the particle size is much larger than 14 nm, which may be due to agglomeration between particles during calcination at 500 c. From the appearance photos of the powder, it can be seen that dark black CoCuMnO\textsubscript{x} was obtained in this experiment, which is helpful to absorb sunlight efficiently.

In order to obtain the solar spectrum selective endothermic coating, it is necessary to coat the prepared coating with CoCuMnO\textsubscript{x} pigment as the light absorbing pigment on the metal substrate (such as Al and Cu) with low emissivity and high thermal conductivity. In this experiment, polished aluminum plate was chosen as the substrate, and the coating was sprayed on the aluminum plate to obtain the solar spectrum selective endothermic coating.
Figure 1. FE-SEM photograph and powder appearance photograph of CoCuMnOx powder obtained after calcination

Figure 2. Solar absorptivity ($\alpha_s$) and emissivity ($\varepsilon_100$) of coatings with different thicknesses

It can be seen that the coating has a rough surface with a roughness value of 0.64 μm in Figure 3, which ensures that the coating has a higher solar absorptivity without the need for an antireflection layer.

3.2. Anti-icing performance test

Icing and flashover tests were carried out on ceramic insulators (3 pieces) and glass insulators (2 pieces) coated with endothermic highly hydrophobic anti-icing materials to verify their anti-icing performance. Samples ①~④ are ordinary porcelain insulator, porcelain insulator coated with anti-icing material, ordinary glass insulator and glass insulator coated with anti-icing material respectively, as shown in figure 4~6.
The conductivity of the ice-covered water is 200 μs/cm, the ice-covered time is 50min, and the ice lightning pressure is recorded every 10min. The icing process of ceramic insulator and glass insulator is shown in the following figure, and the ice lightning pressure in each period is shown in the Table 1.

Figure 4. Insulator test sample

Figure 5. Icing process of porcelain insulator

Figure 6. Icing process of glass insulator
Table 1. Flashover of insulator icing test results

| Time/min | Ice flashover voltage /kV |
|----------|--------------------------|
|          | Sample ① | Sample ② | Sample ③ | Sample ④ |
| 10       | 40        | 36.2      | 38        | 44        |
| 20       | 39        | 46.3      | 38        | 43        |
| 30       | 39.2      | 48        | 38.7      | 49        |
| 40       | 39.5      | 47.6      | 40        | 56        |
| 50       | 41.2      | 48        | 47.8      | 57        |
| **Average value** | **39.78** | **45.22** | **40.50** | **49.80** |

As can be seen from the above figure and Table 1, during the initial icing period of the insulator, due to the hydrophobic effect of the anti-icing coating, the amount of ice covered by the test article ② is less than that of the test article ①. However, due to the fact that the ice covered water droplets are not easy to stay on the surface of the hydrophobic coating and flow along the surface of the umbrella skirt toward the umbrella rim, the thickness of the ice covered increases. When the surface of the insulator is covered by the ice ribs, the anti-icing coating has little effect. When the ice is covered for 50 min minutes, the amount of ice covered by the test article ① and the test sample ① of the test sample ② is about 13.68% higher, which may be due to the leakage current generated under the applied voltage gradually melting the ice, and the surface adhesion of the ice of the test sample ② is small and easy to fall off, resulting in the increase of the ice lightning pressure. Compared with porcelain insulator, glass insulator coated with anti-icing material has better protection effect, and the ice lightning pressure test sample ③ of sample ④ coated with anti-icing material is about 22.96% higher.

4. Conclusion
The solar spectrum selective endothermic coating with CoCuMnO\textsubscript{x} as the light absorbing pigment is prepared to absorb sunlight efficiently. The conclusions are as follows:

1) A solar spectrum selective endothermic coating using CoCuMnO\textsubscript{x} as a light absorbing pigment is optimized in coating thickness to obtain an endothermic coating material with an absorptivity of 0.928 and an emissivity of 0.198;

2) Compared with porcelain insulator, glass insulator coated with anti-icing material has better protection effect, and the ice lightning pressure increases by nearly 23% after coated with anti-icing material.

Footnotes should be avoided whenever possible. If required they should be used only for brief notes that do not fit conveniently into the text.

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