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The effect of SiO₂ particles on electrical properties of superhydrophobic antiflash coatings

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Abstract. In this paper, the effect of SiO2 particles on electrical properties of superhydrophobic antiflash coatings was studied, which electrical properties include, the volume resistivity ($\rho_{\rm V}$), the electrical strength ($U_{\rm B}$), relative permittivity ($\varepsilon_{\rm r}$), and the dielectric dissipation factor (tan δ). This kind of superhydrophobic coating uses modified SiO₂ and TiO₂ particles to construct micro-nano composite structures on the surface of FEVE fluorocarbon resin, and its surface has superhydrophobic characteristics. The results show that, with the addition of 5um SiO₂ content, ρ_V of the coating showed a trend of first increasing and then decreasing. The amount of 20 nm SiO₂ particles added has little effect on $\rho_{\rm V}$. The content of 5um and 20 nm SiO₂ has little influence on the U_B of the coating. With the increase of 5um and 20 nm SiO₂, ε_r and the tangent of tan δ show an increasing trend. Compared with 5um SiO₂, 20nm SiO₂ has less influence on tan δ . The addition of 80nm SiO₂ has obvious significantly adverse effects on the four electrical properties of the coating.

1. Introduction

At the end of the last century, experts and scholars at home and abroad began to study the Ultra-high voltage(UHV) grid. At the beginning of this century, China's UHV grid technology has been continuously developed, and more and more UHV power grid projects have been carried out, which makes the voltage level of the power grid continuously improved. The scope of power grid construction is becoming larger and larger[1]. And power grid construction is even carried out in some areas with a harsh environment, which leads to more And more serious environmental pollution caused by power grid operation. Therefore, the above phenomenon has increased the difficulty of pollution flashover of the power grid, it is urgent to improve the ability of pollution flashover of the power grid, for its safe and stable operation[2].

To solve the traditional antifouling flash paint room temperature vulcanized silicone rubber is easy to stain and not easy to clean, experts and scholars began to study non - room temperature vulcanized silicone rubber insulating coating[3]. This kind of antifouling flashover coating is constructed with high hydrophobic property by using the layered structure of the lotus leaf surface with micro and nano structure. The coating surface detests Angle more than 150° and rolling Angle less than 10°. The coating after several years of development has made some scientific research results, but the coating is still in the stage of research and development, is still not mature, and still has not carried on the large area of engineering application. SiO₂ particles are an important particle in the construction of the micron and nano composite structure, and its electrical performance is the most fundamental characteristic to enable it to be applied in electrical engineering[4-5].

In this paper, the high hydrophobic coating adopts the widely used fluorocarbon resin FEVE as the film-forming material and uses modified particles as filler to construct the micron and nano composite structure. The coating is made into the sample which conforms to the study of electrical insulation performance. The effects of the amount of SiO_2 particles added on the electrical insulation performance of the coating were studied.

2. Sample preparation and test methods

2.1. The influence factors of discharge theory and electrical strength test characterization

In this paper, specific preparation steps of coating are shown in Figure 1, and the superhydrophobic antifouling flashover coating was made with F100 FEVE fluorocarbon resin as the film-forming material, curing agent, and other added particles mainly included modified micro-nano SiO_2 and TiO_2 particles, and other fillings. After mixing, dispersing, pouring, curing, and other processes, the coating is made into the sample needed for the electrical test, and the mold used is shown in Figure 2.



Figure 1. The preparation procedure of coating



Figure 2. Casting mold

2.2. The amount of SiO_2 particles

In this paper, the production of superhydrophobic coating, in order to achieve the physical and chemical properties required by the coating, electrical properties, weather resistance, etc., it is necessary to add several fillers in the coating, including nano SiO₂, micron SiO₂, micron Al(OH)₃, nano TiO₂, micron TiO₂, etc. The micro-nano composite SiO₂ particles are the key to ensure the superhydrophobicity of the coating. In order to ensure that the coating has a superhydrophobic structure and has other basic characteristics in addition to electrical properties, the micron SiO₂ selected in this paper is added from 0 to 40%, the nano SiO₂ selected is added from 0 to 30%. In order to control the content of other fillers unchanged and change the amount of micron and nano SiO₂ added to carry out the electrical performance research.

2.3. Electrical performance testing methods

The resistivity of materials is divided into surface resistivity and volume resistivity (ρ_V). Volume resistivity is defined as the quotient of dc field intensity and steady-state current density, that is, the volume resistance per unit volume. It is a measure of dielectric current conduction ability and is used to characterize the overall electrical conduction characteristics of materials. The experimental equipment of ρ_V is the HEST-200 volumetric and surface resistivity tester. The coating was tested for the ρ_V according to GB/T 1410—2006.

The electrical strength ($U_{\rm B}$) is defined as the maximum voltage endured per unit thickness when the sample is broken down. It is a measure of the material's ability to withstand high voltage without producing a dielectric breakdown. It is used to characterize the material's electrical breakdown characteristics. The experimental equipment of $U_{\rm B}$ is the TDM-20kW-100kV AC/DC power supply. The test electrode adopts a cylindrical brass electrode. The coating was tested for the $U_{\rm B}$ according to GB/T 1408.1—2006.

The relative permittivity constant (ε_r) is related to dielectric polarization. When the dielectric has an external electric field, it will generate an inductive charge and weaken the electric field. Taking the applied electric field in a vacuum as the base, the ratio of the electric field in the dielectric to the reduced electric field is called the relative dielectric constant. Therefore, relative permittivity is a measure of the polarization properties of materials and is used to characterize the dielectric properties of materials. The experimental equipment of ε_r and tan δ is the QS37A high voltage capacitor bridge. The test electrode adopts a cylindrical brass electrode. The coating was tested for ε_r and tan δ according to GB/T 1409—2006.

3. The effects of SiO₂ particles on electrical properties of coatings

In this paper, the size of the micron SiO₂ is 5 um, and the size of the nanometer SiO₂ is 20nm and 80nm. The changes in ρ_V , U_B , ε_r , and tan δ coatings were measured under the change of the amount of single-particle added.

3.1. The effects of 5 um SiO_2 amount added

The influence of 5 um SiO₂ additive amount on the electrical performance of a coating is shown in Table 1. The amount of other particles added to the test sample is unchanged, and the amount of 5 um SiO₂ particles added is changed. The experimental results show that, with the addition of micron SiO₂ content, ρ_V of the coating showed a trend of first increasing and then decreasing. When the addition amount reached 30% upwards, ρ_V no longer decreased significantly with the increase of the content. The permittivity increases by 20% over the base when the additive amount is 5%. This is due to the addition of SiO₂, which increases the bonding strength between resin molecules, making ρ_V increase. However, with the further increase of the content, particles agglomerate, leading to an increase of defects in the coating, resulting in a decrease in the resistivity of the coating obtained.

The amount of 5 um SiO₂ particles added has little effect on U_B , and the U_B fluctuates within a very narrow range because U_B mainly depends on the performance of the coating substrate itself.

With the increase of 5 um SiO₂ content in microns, ε_r first increased and then decreased, and there was a rule of the intermediate platform. But on the whole, the permittivity is still less than 2, which is a non-polar substance. This is because, with the increase of silicon oxide content in microns, the interface between fillers and film formers increases, resulting in the increase of interfacial polarization and the increase of ε_r of the prepared coating. As a whole, ε_r of the coating is still small because the film-forming material and micron silicon oxide used in the coating are both low ε_r substances.

With the increase of the content of 5 um SiO₂, the tan δ of the dielectric loss Angle showed an increasing trend, and when the additive amount was about 30%, the tan δ of the dielectric loss Angle increased sharply. By measuring tan δ value can reflect the insulation defects, usually of tan δ value, the greater the insulating medium under alternating electric field caused by internal energy losses, the consumed energy into heat energy, cause insulation temperature, when the temperature is too high will lead to the accelerated aging of the insulation material.

	R_{v} /×10 ¹² Ω	U_B/kV	\mathcal{E}_r	tan8/%
0	28.5	26.5	1 212	0.252
U 10	28.5	35.8	1.213	0.233
20	24.3	35.3	1.823	0.885
30	20.3	34.2	1.685	2.256
40	19.6	33.2	1.653	2.556

Table 1. The effects of 5 um SiO₂ particles on the electrical properties of coatings.

3.2. The effects of 20nm SiO₂ amount added

The influence of 20 nm SiO₂ additive amount on the electrical performance of a coating is shown in Table 2. The amount of 20 nm SiO₂ particles added has little effect on ρ_V and U_B , and they fluctuate within a very narrow range. With the increase of the amount of 20 nm SiO₂ particles added, ε_r and tan δ keep increasing, the main reason is similar to micron SiO₂. Compared with 5um SiO₂, 20nm SiO₂ has less influence on tan δ .

Table 2. The effects of 20 nm SiO₂ particles on electrical properties of coatings.

	R_{v} /×10 ¹² Ω	U_B/kV	E _r	tan8/%
0	30.6	36.5	1.252	0.212
10	35.6	37.3	1.753	0.539
20	30.4	38.5	1.886	0.651
30	31.5	36.2	2.325	0.758

3.3. The effects of 80nm SiO₂ amount added

The influence of 80 nm SiO₂ additive amount on the electrical performance of a coating is shown in Table 3. With the addition of 80nm SiO₂ to the coating, ρ_V and U_B of the coating decreased significantly. When the addition amount was 20%, ρ_V and U_B of the coating decreased by 50% and 30% compared with that of the film. This may be because the particle size SiO₂ cannot be dispersed well in the film-forming material, resulting in too many defects in the prepared coating.

With the addition of 80 nm SiO₂, ε_r of the coating increases obviously. When the addition is only 10%, ε_r of the coating reaches 2. With the further increase of the additive amount, the increase of ε_r of the coating slowed down and remained at a high value compared with the film-forming material.

With the addition of 80nm SiO₂, tan δ of the coating showed an increasing trend with the increase of the added amount. Moreover, when the added amount was only 10%, the tan δ of the coating increased by 7 times compared with that of the film. As mentioned earlier, higher tan δ more defects in the coating. Therefore, the addition of 80nm SiO₂ has obvious adverse effects on the four electrical properties of the coating.

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	R_{ν} /×10 ¹² Ω	U_B/kV	Er	tanδ/%
0	28.6	32.1	1.276	0.232
10	15.6	25.3	2.052	1.564
20	14.3	22.1	2.563	3.052
30	12.1	20.5	2.785	5.325

Table 3. The effects of 80 nm SiO₂ particles on electrical properties of coatings.

4. Conclusion

In this paper, the effects of SiO2 particles on electrical properties of coatings were studied, which was summarized as follows:

Firstly, with the addition of 5um SiO₂ content, ρ_V of the coating showed a trend of first increasing and then decreasing. The amount of 20 nm SiO₂ particles added has little effect on ρ_V .

Secondly, the content of 5um and 20 nm SiO₂ has little influence on the U_B of the coating, but the increase of 80nm SiO₂ content will reduce U_B of the coating.

Thirdly, with the increase of 5um and 20 nm SiO₂, ε_r and the tangent of tan δ show an increasing trend. Compared with 5um SiO₂, 20nm SiO₂ has less influence on tan δ .

Fourthly, the addition of 80nm SiO₂ has obvious significantly adverse effects on the four electrical properties of the coating. This may be because the particle size SiO_2 cannot be dispersed well in the film-forming material, resulting in too many defects in the prepared coating.

References

- Zhang J L, Zhou X X. Research on interregional power planning considering the power [1] consumption of renewable energy [J]. Shandong Electric Power, 2019,46(12):1-6.
- [2] Cui H, Chen Y G, Qi F, Xu Q F, Kong L. Analysis of anti-pollution flashover and anti-icing flashover measures for UHV DC transmission lines [J]. Shandong Electric Power, 2017,44(02):27-29.
- Su J J, Li J, Wang X G, Li X G. The performance and review of RTV anti-pollution flashover [3] coatings, 2015, 42(01):1-7+87.
- [4] Yin L P. Application of nano-fluorocarbon coatings in nollution[J]. Coatings Technology and Abstracts, 2015, 36(11):39-42+46.
- Zhong X, Liu H, Li C C, Zhou Y, Zhou Y Y, Pan S W, Zhu Z P. Preparation and properties of [5] modified nano - TiO 2/PTFE composite fluorocarbon antifouling flashover coating [J]. Materials Protection, 2015, 48(11): 11-14+40-41.