The surface electrical analysis of Nano Polyurethane-Based Superamphiphobic composite insulation materials

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Abstract. In the early stage of this study, it was found that Polyurethane was only two ways to construct the super-hydrophobic surface. The second is to construct micro-nano structure with low surface energy materials. Specific preparation methods of superhydrophobic surfaces include heterogeneous nucleation method, plasma treatment method, etching method, sol-gel method, vapor deposition method, electrochemical method, alternating deposition method, template method, self-assembly method, solv- non-solvent method, direct film formation method, etc., and many successful examples have been achieved. The research work in this field is relatively few, and the materials involved are scattered. The research objectives are all focused on the construction of micro-nano multistage surface structures with low surface energy. At present, most of these works only test the corresponding electrical properties of superhydrophobic surfaces. In order to verify the application prospect of superhydrophobic surface in antifouling flashover, it is necessary to carry out in-depth research on its hydrophobic, fouling and discharge aspects.

1. Introduction
At present, polymer insulation materials at home and abroad began to be used in insulators in the 1940s, and in the 1950s, aluminum oxide hydrate was added to the polymer to improve the performance of electrical corrosion resistance. After that, the development was slow, and it was gradually popularized in the 1960s and 1970s [1-3], and widely used in the 1980s. Silicone rubber was widely used because it had better ultraviolet aging and thermal aging properties than epoxy resin and epdm, and its formulation and manufacturing process were gradually mature in the 1990s. At present, composite insulator and silicone rubber anti-pollution flashover insulation materials are prepared by using silicone rubber.

At the beginning of the study of polymer insulation materials, epoxy resin and epdm have been tried, and the results show that their anti-aging properties cannot meet the use requirements. With the extensive application of silicone rubber material in external insulation, the development of other kinds of organic external insulation has stagnated [4-6]. In the past two or three decades, new organic materials have been emerging, and the defects of silicone rubber insulation materials have been exposed gradually.
2. Experimental details

2.1. Materials
In this study, butyl acetate was selected as the main solvent, ethyl acetate was used to regulate the volatization rate, polyurethane was dissolved in two mixed solvents of different proportions, and poured on glass sheets to observe the surface drying time of polyurethane film under different proportions of two solvents. By observing the drying process of resin film, it can be found that when the ratio of butyl acetate to ethyl acetate in the mixed solvent is 4:1, the surface is still in the liquid state at 30min, and the resin film surface with the ratio of ethyl acetate to butyl acetate is 4:1 is already in the non-stick dry state. Considering the aging requirements of the coating, the ratio of ethyl acetate and butyl acetate was chosen to be 2:1 to 1:1. At this time, the coating could dry in about 30min.

2.2. Surface morphology test
Super hydrophobic properties are mainly closely related to the surface morphology and surface chemical composition, to identify the insulation material surface affect the performance of super double thin, need test was carried out on the surface morphology, using atomic force microscope, field emission scanning electron microscopy (sem) surface morphology of the composites is analyzed, and combining the insulation material surface structure and morphology of super double hydrophobic property were analyzed, and the phenomena of insulating materials with double drain is reasonable.

2.3. Electrical properties Characterization
The electrical properties of different resin base materials are different. This is mainly determined by the structure and composition of the material itself. However, in addition to the performance differences caused by the material properties, we found that the content of solvent also has a great impact on the electrical properties.

In Electrical properties of SiO$_2$/TiO$_2$/Polyurethane-Based Superamphiphobic composite insulation materials, the Dielectric strength and Arc resistance had been down and be analysed.

3. Results and Discussion

3.1. Modified analysis of SiO$_2$/TiO$_2$
It is excepted that the Mo$_2$TiC$_2$T$_2$ and Mo$_2$Ti$_3$C$_3$T$_2$ structures modified by -O are semiconductors, the unmodified structures and the -F and -OH modified structures are all metals.According to Figure 1 (a), the structure of Mo$_2$ScC$_2$ and Mo$_2$ScC$_2$T$_2$ (T = -F, -O and -OH) are metallic.It can be seen from Figure 1(b) that, except the -O modified Cr$_2$TiC$_2$T$_2$ structure is a metal, the unmodified structure and the -F and -OH modified structure are semiconductors [8-10].

![FT-IR analysis of SiO$_2$/TiO$_2$](image)

**Figure 1.** FT-IR analysis of SiO$_2$ before and after modification

FT-IR analysis of SiO$_2$/TiO$_2$ before and after modification is shown in Figure 2. Infrared detection could detect methylene and methyl characteristic peaks of 2850cm$^{-1}$ and 2920cm$^{-1}$, and the vibration
peaks of -OH, H-OH and Si-OH around 3300 cm\(^{-1}\), 1630 cm\(^{-1}\) and 950 cm\(^{-1}\) were significantly reduced. However, the -CF bond at 1200 cm\(^{-1}\) cannot be clearly judged because it overlaps with the stretching vibration peak of Si-O-Si.

Although using GF01 to modify SiO\(_2\) can obtain relatively excellent hydrophobic and dispersive effects, the infrared results show that a large number of hydroxyl groups on the surface of TiO\(_2\) are still retained, which is not conducive to obtaining excellent super-hydrophobic insulation materials and stable super-hydrophobic effects. It is necessary to continue to improve the effect of superbispectin, and continue to choose other types of modifiers for modification.

3.2. Surface morphology analysis of composite materials

3.2.1. AFM test. With the addition amount of modified SiO\(_2\)/TiO\(_2\) particles continues to increase, too many particles occupy the original slot position instead, and the number of effective rough structures that can retain air becomes less, so the addition amount of too many nanoparticles is not conducive to the further improvement of the effect of super biphobicity.

![AFM images before and after modification](image)

Figure 2. FT-IR analysis of SiO\(_2\)/TiO\(_2\)/Polyurethane-Based Superamphiphobic composite insulation materials before and after modification

Super hydrophobic properties are mainly is closely related to the surface morphology and surface chemical composition, to identify the insulation material surface affect the performance of super double thin, need to test, surface morphology and surface chemical composition combined with the insulation material surface structure and morphology of super double hydrophobic property were analyzed, and the phenomena of insulating materials with double drain is reasonable.

3.2.2. SEM test. SEM was used to scan the sample and observe its surface morphology, as shown in Figure 3. When the proportion of silicon oxide and titanium oxide is 15\%, the particles on the surface of insulating material are closely bonded with the resin, but the distance between the particles is large, which cannot form an effective hydrophobic surface structure, which is the reason for its poor hydrophobicity. In the surface morphology of 25\% SiO\(_2\)/TiO\(_2\) insulation material, it can be seen that the surface particles are distributed evenly, and a large number of bumps and depressions are formed, which effectively forms the surface micro-nano structure, which is also the reason for the good effect of superbiphobicity. When the content of SiO\(_2\)/TiO\(_2\) is 30\%, the surface superbipolar concave and convex structure is more significant, and a large number of embedded holes appear in the insulation material, at which time the insulation material superbipolar effect is the best.
This part studies the change of insulation material structure and performance by adjusting the time of mechanical stirring and preparing the corresponding insulation material. The morphology of insulation materials was prepared by dispersing them at different times.

### 3.3. Electrical properties

#### 3.3.1. Arc resistance

The arc resistance of the insulation material was tested by interval discharge method, and the results are shown in FIG. 4. In the figure, after 5s short interval of arc discharge, only the trace of discharge appears at the electrode shock on the surface of insulation material, but there is no trace at the arc path.

After 146s interval discharge, the insulation material surface has obvious discharge trace, the whole range color turns yellow, some points turn black; after the discharge at the interval of 180s, the discharge trace on the surface of the insulation material was more obvious, and the black spot trace at the electrode also increased.

![Figure 4. Continuous arc test of the Polyurethane composites materials](image-url)
3.3.2. Corona aging. The most commonly used corona generating device in the laboratory is needle plate electrode type. The corona generating device can discharge corona in a large area and get a relatively uniform corona area, as shown in Fig. 5.

![Electrode corona discharge device](image)

**Figure 5.** Electrode corona discharge device material

The most commonly used corona generating device in the laboratory is needle plate electrode type. The corona generating device can discharge corona in a large area and get a relatively uniform corona area. When SiO_2/TiO_2 is added to the insulation material and added to the polyurethane, the volume resistivity of the insulation material increases, the dielectric constant decreases, and the dielectric loss decreases. In the preparation of super-biophobic insulating materials, the super-biophobic structure of insulating materials is formed on the one hand by adding filler, and the insulation performance of insulating materials is improved on the other hand.

![Testing results of hydrophobic Angle and rolling Angle of resin and super double hydrophobic insulation materials after corona discharge of different voltages](image)

**Figure 6.** The testing results of hydrophobic Angle and rolling Angle of resin and super double hydrophobic insulation materials after corona discharge of different voltages.

The hydrophobicity of the insulating material is detected after the corona effect, and the results are shown in figure 6 below. In the figure 6, the charge on the surface of the resin material is dissipating gradually. The lower the voltage, the faster it dissipates, and the higher the voltage, the slower it dissipates. Moreover, the dissipation rate of charge in the direct area of the needle plate electrode is not
the slowest, but the concentration of charge is the highest at the distance of 15mm from the area. The charge dissipation rate of superbispecient insulating materials is faster than that of resin insulating materials, which is mainly manifested in the distance of 15mm from the core area of corona action. The hydrophobic Angle curves of superbispecient insulating materials all cross the hydrophobic Angle curves of resin, and the curves become very slow. The rolling Angle is smaller than the hydrophobic Angle.

4. Conclusion
The surface charge dissipates faster than the resin insulation, which may be related to the various fillers added in the super-bihydrophobic insulation. The particles such as silica and titanium oxide contained in the filler are helpful to the charge derivation of polyurethane composites. Although polyurethane superhydrophilic insulating material is easy to change under corona, its charge dissipation and recovery ability are strong. In addition, it needs to be added that the surface structure and composition of super biphobic insulation material change after corona action, and the effect on the properties of super biphobic polyurethane needs to be further analyzed.

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