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Research Progress of Corona-Resistant Polyimide Composites

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Abstract

Polyimide film is widely used in slot insulation of motor due to its excellent performance in insulation. In variable frequency motor, corona discharge caused by impulse over-voltage will cause rapid aging of pure polyimide material and breakdown in a short time, so improving the corona resistance of polyimide film is the main way to extend the life of variable frequency motor. Adding inorganic particles, such as alumina, silicon oxide, titanium oxide, aluminum nitride and Zinc Oxide, can effectively prolong the corona resistance life of polyimide. This paper reviews the research progress and mechanism in this field.

Keywords

Polyimide film, corona resistant, mechanism.

1. Introduction

Hu et al. Prepared polyimide/alumina composite films by in-situ dispersion. The mechanical test results show that with the increase of alumina content, the tensile strength and elongation at break of the composite film show a significant downward trend, and are lower than that of the pure film; the dielectric property test shows that with the increase of alumina content and frequency, the dielectric constant shows a downward trend; the dielectric loss of the composite film is higher than that of the pure film, and shows a downward trend at low frequency The results of dielectric properties test show that the breakdown field strength and corona resistance of the composite films can be significantly increased when the inorganic content is between 10 wt% and 20 wt%. Li Hongyan et al. Prepared polyimide/alumina composite films by modifying alumina particles and then in-situ dispersion and analyzed their properties. The results show that when the alumina content is less, the alumina in the film presents a uniform distribution state; while when the alumina content is larger, the alumina distribution in the film presents obvious agglomeration; the corona resistance test shows that the corona resistance time of the film is in positive proportion to the alumina content, and the introduction of alumina improves the corona resistance life of the film. Ma et al. Prepared a series of polyimide composite films with different Al2O3 content by sol-gel method under ultrasonic condition. The results show that the alumina particles are uniformly dispersed in the polyimide matrix, and the composite films exhibit good thermal stability, mechanical properties and corona resistance with appropriate alumina content. Xia Xu et al. Prepared two polyimide composite films with alumina on the upper and lower surfaces, and proposed the corona resistance mechanism of three-layer composite films. In the process of corona discharge, alumina in the upper and lower composite layers can reduce the surface resistance of the film, and form corona barrier layer on the surface of the film. In the middle layer, the volume resistivity of the film is increased relatively, and the carrier barrier is formed with the surface layer, so that the electric field stress is concentrated in the upper and lower composite layers. Liao Bo et al. Prepared silicon

dioxide/polyimide composite films by in-situ dispersion method, and studied the effect of silicon dioxide doping on the mechanical properties, breakdown field strength and corona resistance of the composite films. The results show that the higher the content of silica in the film, the lower the elongation at break of the film, while the breakdown field strength first increases and then decreases, and the corona resistance of the composite film is improved obviously.

Kong Yunan et al. Prepared polyimide/titanium dioxide composite films with different contents by in-situ dispersion method. The experimental results show that the dielectric constant and dielectric loss of the composite films increase with the increase of titanium dioxide doping amount, while the breakdown field strength first increases and then decreases. Under the same test conditions, the corona aging life of the composite films increases with the increase of doping amount Titanium dioxide particles have a strong ability to withstand corona. After compounding with polyimide, they can form an interface phase with polyimide, which improves the trap energy level inside the material, makes the material conducive to the diffusion of space charge and the loss of heat. In addition, in the aging process, the surface area of the material can be aggregated to form a shielding layer to prevent the internal damage caused by discharge. Therefore, the corona aging life of the material is improved Life. Feng Yu et al. Prepared the polyimide/titanium dioxide nanocomposite film by in-situ dispersion method. The performance test and characterization results show that the trap density in the composite film is increased due to the introduction of titanium dioxide, and the doping amount is 5 In addition, the UV absorption capacity of the composite film is significantly improved. Under corona discharge, the surface of the composite film shows the decomposition of polyarylamine and the gradual accumulation of titanium dioxide particles, and the accumulation of titanium dioxide on the surface acts as a screen The effect of corona erosion. Therefore, the corona resistance of the composite film is improved by the synergistic effect of many factors. Zhao et al. Studied the effect of titanium dioxide and film thickness on corona aging in polyimide composite films. They believed that the aggregation of titanium dioxide on the film surface during Corona process was an important factor to improve the corona life of the films. Cha Junwei et al. Also studied the influence of the aggregation of titanium dioxide in the polyimide/titanium dioxide composite film on the corona damage of the film surface, and discussed the relevant mechanism; they also prepared the polyimide/zinc oxide composite film with the uniform distribution of nanoparticles through in-situ dispersion; studied the influence of doping content and aging time on the film, and studied the film's The results show that the corona resistance of the films is greatly improved with the increase of ZnO content, the breakdown field strength is decreased, but it still meets the actual needs, and the aging mechanism of the corona resistance is discussed by analyzing the characteristics of the electric field and ZnO particles.

Chen Minghua et al. Prepared single-layer and three-layer polyimide/aluminum nitride composite films with different components by in-situ dispersion method, and studied the corona resistance of the polyimide composite films prepared by different layers. The results show that the three-layer composite film with the upper and lower layers as the composite layer and the middle layer as the pure layer has better corona resistance than the single-layer composite film while maintaining good mechanical properties; and the polyimide film is Co doped with montmorillonite and aluminum nitride, the results show that the composite film with 7% doping amount has excellent corona resistance. Xu Yue et al. Studied the influence of frequency and temperature on the damage of polyimide film by corona resistance test system. The results show that the corona aging life of polyimide film is nonlinear attenuation relationship with applied voltage frequency at different temperatures; the increase of temperature will make the discharge experience three processes: significantly enhanced, stable and violent again; the increase of frequency will lead to the number of discharges The corona

resistance life of the material is shortened. Kozako et al. Studied the effect of surface discharge on polyamide materials by using IEC (b) electrode. The results show that inorganic nanocomposites have greater anti corona ability than pure organic materials, and only 2 wt% of the addition is enough to improve the change of surface roughness caused by corona discharge. In order to find out the effect of adding inorganic nanoparticles on the corona resistance of polyimide films, Gao Bo et al. Studied the corona resistance mechanism of DuPont composite films from three aspects: film structure, dielectric property and thermal conductivity. The experimental results show that the film has a three-layer structure, and inorganic nanoparticles are mainly distributed in the upper and lower layers of the film, which can resist corona on the surface and protect the polyimide molecules in the interlayer during the corona aging process; at the same time, nanoparticles can accelerate the rate of charge decay, which makes it difficult for charges to accumulate to form local electric field distortion; it can also be mentioned that The high thermal conductivity of the film makes it easier for the heat to escape and reduces the probability of corona breakdown in advance due to the high local field strength and heat accumulation. Chen Hao et al. Studied the corona resistance mechanism of the polyimide composite film by corona pretreatment. The results showed that the corona resistance life of the polyimide composite film would be improved under the appropriate corona pretreatment conditions.

Luo Yang et al. Studied the morphology and structure changes of polyimide film surface and cross section under different discharge aging stages, and found that the corona degradation of polyimide film has a process from surface to part; discharge erosion is the essential cause of polyimide degradation, and the ether bond (C-O-C) and C-N-C bond on the main chain of polyimide molecule are formed during discharge aging Fracture occurs under use. In order to study the changes of polyimide molecules under corona discharge, and to understand the micro mechanism of thermal degradation of polyimide molecules, they also used molecular dynamics software to study the micro degradation mechanism of polyimide molecules. It was found that the ether bond (C-O-C) on the main chain structure of polyimide molecules and the carbon nitrogen bond (C-N) on the imide ring (C-N-C) were weak It is easy to break during the thermal process, which results in the decrease of polymerization degree of polyimides. The software analysis also shows that there are two different degradation paths of polyimides. Although the degradation paths are different, the final degradation products are mainly water, nitric oxide, carbon monoxide, carbon dioxide, nitrogen dioxide and other volatile gases. Sun Zhi et al. Studied the characteristics of charge generation and attenuation on the surface of pure polyimide film and polyimide composite film by electric field force microscope. The analysis shows that the charge injection in the composite film is more difficult than that in the pure film, which is due to the doping of inorganic components, which can reduce the accumulation of the injected charge and play the role of homogenizing the electric field, thus prolonging the corona resistance life of polyimide.

Lei Qingquan et al. Studied the conductivity and current characteristics of pure polyimide film and composite film before and after corona aging. The results show that the ohmic region current of the pure film is significantly lower than that of the composite film before corona aging, while the space charge limited current region current of the pure film is significantly higher than that of the composite film; after corona aging, the trap carrier density and the electrical aging threshold of the composite film increase, while the corresponding value of the pure film decreases. Zhang Peihong studied the dielectric properties, high field conductivity, electrical aging threshold and the influence of partial discharge on the surface morphology of the nanocomposite polyimide film. The structure of DuPont 100cr corona resistant polyimide film was analyzed by SEM and AFM. Compared with the surface morphology of the original and corona resistant polyimide film after corona aging, the corona resistant polyimide film was obtained The reason why the imide film is resistant to corona may be that the inorganic

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substances with high thermal conductivity concentrate on the surface of the film, which can even lead away the heat generated by corona and reduce the probability of thermal breakdown of the film. At the same time, the damage caused by corona discharge mainly concentrates on the surface of the film, and the inorganic substances on the surface have better ability to resist the damage caused by corona discharge, so the material is improved Corona resistance. According to Yi et al, the reason for the improvement of corona resistance of the material is that the addition of inorganic nanoparticles can increase the density of the shallow traps, which can make the injected electrons trapped by the traps and form a shielding electric field on the surface of the material. Kaufhold et al. Believe that the main reason for the breakdown of turn to turn insulation material of variable frequency motor is due to partial discharge, because after no partial discharge, even if the electrical stress and thermal stress on the material are greatly increased, the material does not break down; and when there is partial discharge, the polyimide film will be broken down in a short time. Tanaka et al. Proposed a multi-core model based on the barrier protection of layered nano materials. Under the action of layered nano materials, the damage channel of corona discharge was extended, thus improving the corona resistance of the materials. Tanaka also proposed the relationship between corona resistance and dielectric constant, and believed that when corona discharge was concentrated on nano materials with higher dielectric constant, the corona resistance of composite materials was significantly improved, because inorganic nano particles had strong corona resistance. Yin et al. Believe that the improvement of corona resistance of composite materials is not caused by a single factor, but by the combined effects of electric field homogenization, thermal stability improvement, electron and UV shielding caused by inorganic particles. The study of Liu Li and Yin Jinghua shows that the size and content of inorganic particles and the structure of the film have a great influence on the corona resistance of the composite film. Fan Yong et al. Studied the corona aging mechanism of polyimide and the influence of air humidity on the corona resistance of the material. They found that the corona resistance time of the material decreased with the increase of humidity. The corona resistance of the film was investigated from the environmental factors.

There is no consistent point of view in the study of corona resistance mechanism of polyimide composite films. The main reasons of damage and failure of polyimide films caused by corona discharge are as follows[1-12].

1. Thermoelectron theory. Under the condition of high electric field, the carrier is injected into the material, and expands continuously, forming collision ionization, thus producing positive ions and free electrons. The electric field will affect these charged particles, separate positive and negative particles and prevent them from combining again, and accelerate the movement of charged particles. When electrons with high charge volume ratio are accelerated to a higher rate, they will further collide with neutral atoms to produce positive ion pairs and more electrons. These pairs of electrons and positive ions then undergo the same separation process, producing electron avalanches. In these processes, the energy of the plasma is further converted into the initial electron separation energy, resulting in further avalanche and finally breakdown.

2. Trap theory. According to the trap theory, there are different trap energy levels in different depths in polyimide film. For pure polyimide film, there are a lot of deep traps. Strong electric field makes the carrier enter the material and easy to be captured by the deep traps in the material. Therefore, a strong space charge accumulation can be formed near the carrier which is easy to be injected, which is easy to cause a more serious electric field Distortion is easy to cause premature breakdown.

3. The destructive effect of corona. The continuous corona discharge will produce a large number of highly active substances, such as ultraviolet, high-energy electron beam, ozone, nitride and so on. These substances will cause the film to age, degrade the organic molecules on

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the film surface, and finally degrade to form the volatilization of small molecules and form a large number of defects on the film surface. With the aging process, the damaged area of the film increases and gradually develops to the inner part to form a discharge channel, which eventually develops into a through channel, making the film breakdown.

4. Multi-core model. In the process of corona aging, the surface layer of the material and the outer layer of the spherical particles are first destroyed. With the further development of corona, the carriers entering the film form zigzag transport channels through the interface layer of the substrate and particles, which extends the carrier propagation path and avoids the accumulation of space charges. Therefore, polyimide materials The corona resistance of the material is improved. Through studying polyamide and layered silicate, kozako et al. Also believed that nano particles formed a kind of multi-core structure in the film.

5. Synergy. According to this theory, the final breakdown of polyimide film is not caused by a single factor, but by corona discharge, thermal effect and space charge accumulation. First of all, corona discharge will damage the surface of the film, and the high active substances produced by the discharge will cause the loss of film quality and thin film thickness; second, corona discharge will inject a large number of charges into the film, which can not be released from the inside of the phone invisibly makes the film subject to greater electric field strength; finally, there will be a large number of heat release in the corona discharge process, which The sample will form thermal shock to the insulating material, which will make the film unable to withstand high temperature and produce serious thermal aging. The superposition effect of these factors may lead to the advance of corona breakdown of the film.

6. Space charge accumulation. When the rising speed of wave crest increases, the carrier inside the injected material can not be released in time and form space charge. A large amount of space charge will accumulate between the electrode and the insulating material and form a superimposed electric field. Therefore, the accumulated space charge will form a stronger electric field strength and make the insulating material unable to bear it, and make the insulating material happen prematurely under the strong electric field caused by space charge Through the experimental study of space charge accumulation under simulated frequency conversion, it can be seen that space charge accumulation has a significant impact on the corona aging life of polyimide materials.

7. Heat accumulation. Corona discharge can only be produced in the presence of air, but the polyimide material in the inverter motor can still break down when there is no air. Although the temperature has a certain influence on the strength of corona discharge, it is not the main factor that affects corona discharge, and the temperature in the inverter motor will directly affect the damage of polyimide materials. In addition, the damage of insulating materials in the variable frequency motor can occur in a very short time, which is not consistent with the corona aging process of materials, so the breakdown damage in a short time is likely to be caused by the thermal accumulation of materials.

2. Conclusion

In the process of preparation and research of corona resistant polyimide composite films, researchers put forward many models and related mechanisms to explain the reasons for the rise of corona resistance of composite films, but there is no internal relationship between various mechanisms, nor a unified understanding. The preparation of corona resistant composite films is also limited to in-situ dispersion and sol-gel method. No corona resistant composite films have been prepared by ion exchange method. The occurrence of breakdown of polyimide films under corona discharge has not been reported, and the degradation kinetics of polyimide under corona discharge has not been reported. Therefore, it is of great significance to study and explain the mechanism of improving the corona resistance of inorganic materials

by preparing polyimide composite films and analyzing the degradation dynamics of polyimide under corona discharge.

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