Nonlinear resistivity and Charge transport characteristics of Sir/sic composites

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Abstract: In order to the effect of nonlinear resistivity on space charge and surface charge properties of Sir/si C Composites, the nonlinear resistivity, space charge and surface charge potential of sir/sic composites with different Si C particle content under different voltage were measured. The change of nonlinear resistivity under different voltage and the influences of nonlinear resistivity on charge tion and dissipation were analyzed. The results indicate that resistivity of Sir/sic composites does not present obvious nonlinearity when the SiC content is lower than 10. The resistivity experiences a nonlinear change with the increasing electric field when the SiC content exceeds% and th e threshold field of nonlinear resistivity declines when the SiC content rises. In the spaces charge polarization process, low resistivity suppresses the accumulation of spaces charge in Sir/sic s while in depolarization process, low resistivity accelerates the dissipation of space charge. The acceleration effect is also found in surface charge dissipation of Sir/sic. Generally, this paper looked into the change of nonlinear resistivity and charge property of Sir/sic Composites, providing Referencesfor the application of nonlinear resistivity materials in DC cable accessories.

Keywords: HVDC Cable accessories Silicone rubber; SiC particles; Nonlinear resistivity; Space charge; Surface Potential decay

Introduction

High temperature vulcanized silicone rubber with excellent electrical properties , Good mechanical performance and high temperature performance , widely applied to high voltage direct Stream cable terminals and connector attachments [1]. Although high voltage HVDC transmission technology Fast development [2] , But cable attachments because of their complex structure , Guide The accumulated charge under the Single polarity electric field can result in the partial the electric field Distortion , still become partial discharge in DC cable and insulation Accelerated aging Multiple Links [3-8]. also , High voltage DC cable on op in the line, the transient state of a device such as a converter transformer, , voltage increases the accumulation of electrical charges in cable attachments. . These reasons cause the charge characteristics of silicone rubber insulating material to become cable accessories should be Use the research focus in the procedure .

Previous studies have shown that , the inorganic filler (For example zinc oxide , carbon silica and carbon black particles) mixed with polymer matrix , can get resistorsrate or conductivity changes with electric field strength of nonlinear dielectric [9-12] , To change the charge characteristics and electric field distribution of insulating materials. For example , varlow studied the electrical properties of epoxy zinc oxide composites attributes , The analyzes the material's nonlinear body conductivity , Surface charge ,Effect of electrical tree and trace properties . The results in a non-line material at the same time as the insulating properties at normal voltages , its table

The surface charge dissipation and the resistance to the electrical tree feature have significantly improved [a] . this outside , Corelle and others have studied the composite material with nonlinear resistivi-ty effects on uneven electric fields . the electric field simulation results also indicate that the non-linear resistivity materials have a significant effect on improving the distribution of space electric fields fruit [9]. This kind of non-linear material can mitigate the distortion of the local electric field by the resistance of the field changing with the electric fields rate or conductivity , and thus also as electricity Field gradient materials in cable attachment insulation Use the . can infer , non-line Sexual resistance to uniform local electric field , improving electrical charge properties of insulating materials The plays an important role in . Although many studies have involved sic stars The content of the particles , kinds of factors such as nonlinearity of silicone rubber composites effect of the resistivity feature , but its nonlinear resistivity to silicone rubber complex The effect of the charge characteristics of a composite material with the is not yet clear . So this article will use the to add sic particles to silicone rubber polymers. composite materials with nonlinear resistivity , To explore the silicone rubber compound material charge characteristics . The influence of sic particle content on the material 's non-linear resistivity and charge properties of the materials is analyzed in the article .

1. Experiment Settings

1.1 Sample Preparation

This paper uses two-roll blending and hot-pressing molding to prepare high temperature vulcanized Silicone rubber matrix . sample matrix via silicone rubber , silica the strong agent , structure Control agent and mixture of vulcanizing agents are composed of . text with average size 0.45| Am a-sic particles as nonlinear fillers . for SiC particles on24h after dry treatment , through double roller Machine do not follow it ten, ,1,⑻% quality ratio of to silicone rubber

glue matrix blending , such as 100% The represents the 100g Silicone Rubber matrix mixed with 100g SiC particles formed mixtures . add mixture to temperature degree 433K „pressure 10MPa Hot Pressing 15min after , at temperature degree 473K Environment Curing 4h, final thickness is 300pm sample [. diagram 1 show | ⑻% the SiC particle contentsir/sic Composite cross section SEM Chart , can be considered SiC granule "" is well dispersed in the silicone rubber matrix .

1.2 DC resistivity measurement

This paper uses a three-electrode system to measure silicone rubber composite straight Flow resistance . ammeter Select Keithley 6517B type electrometer , measurement range 1 FA ~20mA. three electrode system high voltage electrode diameter to 80 mm, measuring electrode diameter 50 mm, protection electrode inner diameter is 54mm. Test record 30min Current data , and take the most after 1min Average of current measured values as dielectric blocking current . Experimental measurements for each group of samples repeat five times , take average The resistance current value of the sample for this group , to ensure resistance current measurement accuracy and repeatability . sample resistivity p can be from the following formula evaluates to :

N $(d + g)^2U$ ^ 4l1 ~

where : I is a resistor current ; U is the experimental voltage ; L for sample thickness ; D to measure electrode diameter ; G for measuring electrodes and protecting electrode spacing .

1.3 space charges

This article uses the PEA method Space charge test system for different SiC particle content sir/sic composite space charge measurement [/]. First apply a DC field to the sample , polarized time to 30min , measures the distribution of space charge at the end of polarization . then remove the DC electric field plus the high voltage electrode and the ground electrode by on the sample. Road , depolarization time is 10min, measuring null after depolarization charge distribution between . Experimental measurements for each group of samples repeat five times to guarantee The accuracy of the experimental data .

1.4 surface potentiometric measurement

measurement of surface potentials using Trek ⑻ b-5c Probes and Trek 347-3hce electrometer . the test sample is placed on the grounded brackets disk, The tray can move quickly through the rails between the charging electrode and the measuring probe . The experimental device diagram has been reported in the literature . [[]. sample charge process continues 10min, When the charge ends , Sample pass the Moving through the guide to the probe to measure the surface potential of the specimen drop curve ,Measurement process continues 20min .

2. Experimental results and discussions

2.1 relative permittivity

Table 1 shows different SiC particle content sir/sic Composite material on Hz Conditions for permittivity and SiC particle content Relationship . results show ,SiC The increase in particulate content is significantly greater The dielectric constant of silicone rubber composites . This is due to silicon rubber non-polar Media , and SiC crystals are polar materials , With has a higher relative dielectric constant (about 9.66~10.03 . SiC particle The addition of silicone rubber composite material inside the introduction of a large number of extreme sex , The strongly reinforced the polarization effect of composites . on the other hand , Influence of free volume on dielectric constant of composite materials , based on

Simha-somcynsky equation and Clausius-mosotti equation ,Micro

Adding metric particles reduces the free volume of the composites [a] , from Decrease in volume causes the molecular weight of the unit volume to be greater , on polarization rate in certain cases , relative dielectric constant greater .

2.2 DC resistance

different SiC particle content sir/sic Composite Direct current blocking features are shown in the diagram 2 ,. for 0% sample , when applying lower power field , Its resistive current and applied voltage obey Ohm 's Law , can to assume that its resistivity does not vary with the electric field . when imposing electric field over 20kv/mm when , sample resistivity increases with electric field The appears visibly reduced . This is due to the apparent space charge limiting current that appears in the sample with a clear (space-charge-limitied Current , SCLC effect [] . ten% sample DC resistance characteristics vs . 0% samples with very similar trends , on Lower electric field block basically remain unchanged , and occurs in a higher electric field SCLC effectproduces resistance nonlinearity reduction . according to classic percolation theory [, when conductive or semi conductive particles in polymers are filled with lower contentwhen , with larger padding particle spacing , Thus in space each other standalone , This makes it difficult for carriers to send between adjacent fill particles Health Migration ,At this point the resistance of the composite is still dependent on the polymer base The resistance characteristics of the body are .

for SiC content is 30% , 50% and 1 (8)% Three group of tries

- like , The DC resistors in the different fields are much less than 0 and 10% Sample . compares these three sets of samples with the 0 and Ten % non-linear power of specimen

diagram : Fig. 2

resistance threshold electric field can be found , critical electric field of nonlinear resistor is obvious Lower . in nonlinear resistor zone , Nonlinear resistivity p the relationship between and an electric field E can be expressed in the following way :

$p = AE^p$ (2)

where a is with sample area , constant coefficients for parameters such as thickness , and for resistivity nonlinear coefficients .

to (2) Logarithmic transformation , The can have a linear formula as follows :

LG p = LGA + ^lg E (3)

(3) , can calculate the resistivity nonlinear coefficient . to different SiC content sir/sic composite specimens do the same as above behind , to Get the threshold electric field and Absolute value of nonlinear coefficients , as Table 2 is shown . can see that the,SiC content is 30%,50% and 1⑻% Three Group sample threshold electric field difference do not4.0,1.4 and 0.9kv/mm, far less than 0 and ten% try sample threshold electric field (20.0 and 15.0kv/mm . at the same time , with SiC Increase in content , nonlinear threshold electric field decreasing , Nonlinear system the absolute value of the number is increased. for SiC content greater than 30% samples of the „ when The specimen is in the Ohm area ,carrier difficult to traverse at SiC The barrier of the Silicon Rubber matrix interface . But when the electric field intensity exceeds the threshold value field „ tunneling effect [[],large number of carriers at this time to pass SiC particle and Silicone rubber substrate interface , thereby reducing on macro sir/sic composite resistivity , causes nonlinearitygenerate resistivity . addition , when SiC particle content rises over Chongqing percolation theory threshold when , SiC particles close to each other in composite materials ,Even form a continuous conductive network , thereby facilitating the transfer of carriers lose , The also reduces the material's resistivity on a macroscopic scale .

This article has an electric field strength of 50kv/mm under the condition of , meter with PEA space charge measurement system to different content SiC Sample Spacecharge Cumulative characteristics measure , Its results as shown in 3 is shown in . diagram 4 show corresponding sir/ SiC The electric field distribution of composite materials . from Diagram 3 See , for 0% SiC Sample , in specimen The section is close to the anode region with a large number of heterogeneous space charge accumulations , in The space charge accumulated within the entire specimen is mainly in the negative space the main charge . This is the negative result of electrode injection and dipole group polarization.

Picture 3 and Diagram 4 , You can find the sample internal space at the end of polarizationaccumulation of charges ,causing a serious abnormality in the distribution of the electric field inside it change . This is due to a large number of negative space charges near the anode . after the internal electric field and the outside Application electric field superimposed , significantly greater strong sun The electric field of a nearby area ; and the area near the cathode due to the same polarity power The presence of the load , The electric field is weakened , To form the negative inside of the specimen distribution of electric fields .

for 10% SiC Sample , in 50kv/mm Sample internal under

space charge distribution and 0% sample Similar . but with 0% sample internal space charge density comparison ,ten % space charge inside the specimen density decreased . compare The distribution of the electric fields in 4 in the chart , visible its maximum electric field strength exceeds 90kv/mm, electric field distortion condition still very serious .for the 30% sample for nonlinear resistor characteristics ,
and 0 and 10% Sample compared to , The amount of space charge accumulated internally is specified Show less . maximum space charge density of approximately 5.5c/m^3 , far lower to 0 and 10% The maximum space charge density of the specimen . at the same time , from empty The degree of electrical field distortion caused by the accumulation of electric charges between is further weakened . Second Add big SiC particle content , accumulation of space charge inside sample The amount is further reduced . when SiCcontent increase to 1 ⑻% when , Polarized procedure ends , Its interior also has little apparent space charge cumulative phenomenon , maximum space charge density is only0.8c/m ^{3} . from the angle of the power field intensity from the point of view of the " no", with SiC increase in particle content test internal electric field distortion significantly weakened , The distribution of the electric field tends to be evenly . 1⑻% The sample has the most evenly distributed field , the is very close to the ideal. the electric field distribution . According to the results of the experiment above , ,SiC Particle fill , causes a nonlinear descent of the resistivity , can be effective restraining space charge accumulation , improving electric field distribution . with SiC content increased significantly , space charge suppression is more pronounced .

diagram 5 for sample in 50kv/mm Polarization 30min after , to 10min go to polarization different SiC of the content sir/sic Composite The space charge distribution of the is . to see , for 0% sample , A large amount of negative space charge is accumulated inside the specimen , especially Yang very near area , maximum space charge density is greater than 2c/m ^{3} . for 10% Sample , the sample still has a large number of negative charge accumulation , most large charge density more than 1c/m^3 . for 30% sample , part of the space charge has basically dissipated , A small amount of negative charge accumulation only in proximity to both sides of the electrode area , maximum charge density is only 0.5c/m^3. continues to be large SiC particle content , depolarization process Hollow dissipation of charges further accelerated . when SiC content up to ^0% (,) residual space charge in sample is further reduced . The space charge depolarization process for the adhesive specimen of the GUI Oak , is shown , when SiC content is super over 30%when , sir/sic to form a charge transfer in composite materials

- Migration of the earth electrodes to the ground electrode . combines the above two reasons , as Corona voltage increases , sample surface charge to earth electrode migration faster . The results of the experiment also show that , increase corona voltage although Increase Charge injection procedure , but the speed of charge dissipation speeds up at the charge to play a major role in the accumulation process , In turn, it causes its initial surface to be electrically bit down . This is also 1⑻% Potential drop at different voltage of specimen curve not showing crossover cause of the phenomenon .

3. Conclusion

This article describes the SiC particle content to sir/sic Composite Non-linear The effect of the resistance has been studied , Analyzing nonlinear resistivity causes , also studied different levels of SiC particles to try The effect of the sample charge accumulation and dissipation process , Conclusion: :

1) SiC Increase of particle content , result in sample internal free body product reduction ; SiC particle self high dielectric constant , causes sir/sic Composite dielectric constant with SiC The pellet contains Increase of the amount increases .

2) sir/sic composite resistivity and electric field strength non- linear Relationship . SiC Increase in particle content will cause nonlinear resistors The rate of sharp decline and the absolute value of the resistivity nonlinear coefficients is added to the .

3) on 50kv/mm electric field , space charge in the sir/sic Composite accumulated under SiC particle suppression , to cause The weakening of the internal electric field in the sample . space charge dissipation is shown "Show" , sir/sic residual space charge in composite specimens clear is less than SiC Sample filled .

4) sir/sic composite surface charge accumulation with SiC increase in particle content and decrease by , and its attenuation rate is the same as the SiC The increase in the amount of the grain is added to . high SiC particle content sir/ SiC composite , because of the existence of its nonlinear resistor , under high field strength for surface charge accumulation plays a restraining effect .

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