# Graphene Oxide Addition With Low Fraction Improving Surface Charge Inhibition Performance of Epoxy/SiC Coating Under DC Stress

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**ABSTRACT** Surface charge accumulation under DC stress is a critical factor in reducing the insulation performance of epoxy-based nanocomposite. Surface coating has been used to inhibit the charge accumulation, but the inhibition mechanism of the coating material is still unclear. In this paper, graphene oxide (GO) and silicon carbide (SiC) have been selected as fillers to prepare the coating material with epoxy as the base material. The role of GO on surface charge inhibition performance of epoxy/SiC coating has been estimated. The test results showed that the charge inhibition performance and the flashover voltage increase with the growth of nano-SiC content from 1 wt% to 5 wt% in the epoxy/SiC coating. As regards the epoxy/(SiC+GO) coating, the charge inhibition performance and flashover voltage reduce as the SiC content increases. It is suggested that the charge inhibition performance of epoxy/SiC coating can be improved with a low content addition of GO. The variation of trap distribution in the coating material caused by the GO should be responsible for the enhanced charge inhibition behavior.

**INDEX TERMS** Epoxy/$Al_2O_3$ nanocomposite, surface charge, coating, graphene oxide, SiC, trap distribution.

## I. INTRODUCTION

Thanks to its excellent insulation and mechanical properties, epoxy resin has been widely used in a broad range of applications in electric power, electronics, and aerospace industry [1]. In the equipment installed in high voltage direct current (HVDC) transmission system, such as gas insulated transmission line (GIL) and/or gas insulated switchgear (GIS), the epoxy-based insulator has been widely used [2]. It has been observed that as DC voltage is applied to an insulator for a certain period of time, free charges are accumulated on the surface to form the surface charge, which not only distorts the distribution of electric field but also provides seed charges for the development of surface discharge, thus the flashover voltage is reduced [3]. From the viewpoint of safety, it is necessary to find an effective way to suppress the surface charge accumulation.

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Currently, several methods have been proposed to restrict the charge accumulation. H. Fujinami *et al.* have reported that the normal component of electric field was reduced along the surface of insulator with optimized shape by which the charge accumulation could be limited [4]. Fukuda *et al.* have demonstrated that the shield rings at both ends of the insulator could mitigate the electric field distortion near the triple junctions (TJ) and surface charge density was reduced [5]. Mohamad *et al.* have found that the conductivity along the surface of epoxy was enhanced by fluorination treatment, which led to the enhancement of charge dissipation rate. And charge dissipation rate was affected by the fluorination time [6]. H. T. Baytekin *et al.* have reported that free radical scavenger could be used to accelerate surface charge dissipation on various types of polymers including acrylate-based adhesive Scotch tape, poly (dimethyl siloxane) (PDMS) without reducing the surface resistivity. It has been found that surface charge almost dissipated completely in 10 min [7]. Gao and Du have found that the inhibition of surface charge

on epoxy could be achieved by gamma-ray irradiation, the dissipation rate of surface charge was accelerated with the growth of total irradiation dose [8]. Shao *et al.* have investigated the surface modification of epoxy by atmospheric pressure dielectric barrier discharge (AP-DBD) plasma, it was revealed that surface trap was shallower and surface charge dissipation was accelerated if the epoxy was treated by plasma for an appropriate time [9]. Inorganic particle addition into polymer has been investigated to restrict the charge accumulation by Du *et al.*, it was pointed out that the inhibition of surface charge on composites material could be reached by selecting proper type and content of inorganic particle [10]. Compared with the methods stated above, surface coating is more available a way to suppress surface charge for epoxy insulators which have been already installed in electrical equipment. Cross and Sudarshan have found that $CuO_2$ coating could improve the insulation performance of spacer insulation through a reduction in secondary electron emission yield (SEEY) [11]. Tu *et al.* have demonstrated that $EP/SiO_2$ coating could inhibit surface charge accumulation by shallowing surface trap of test sample, by which the charge dissipation was accelerated [12].

Although surface coating has been reported to have a positive effect on surface charge suppression, the mechanism for the limitation of charge accumulation is far from fully understood. In this work, the effect of surface coating on surface charge suppression on epoxy/$Al_2O_3$ nanocomposite has been estimated. The nano-sized graphene oxide (GO) and silicon carbide (SiC) have excellent properties in restricting the charge deposition due to the surface effect, small size effect and quantum effect of nano-composite coating. And the role of GO and SiC in inhibiting the charge accumulation has been demonstrated through the way of surface trap measurement [10]. It was found that with low content addition of the GO particle which has a single layer structure with an enormous specific surface area over 2000 $m^2$/g, surface trap could be deepened so as to limit the accumulation of surface charge.

## II. EXPERIMENTAL SETUP

### A. SAMPLE PREPARATION

The 2 mm-thick EP/$Al_2O_3$ sample was prepared by employing diglycidyl ether of bisphenol A (E44, Tianjin Yanhai Chemical, China) as the base material and 20-nm $Al_2O_3$ (Nanjing Haitai, China) as the filler with the content of 1 wt%. In order to estimate the effect of coating on surface charge suppression, two groups of coating materials were prepared. The EP/SiC coating (Coating A) was attained by employing epoxy as base material and 50 nm $\beta$-SiC (Xuzhou Hongwu Nanometre, China) as filler with the content of 1, 3, and 5 wt%, respectively. The Coating B containing both the SiC and 1 nm-thick GO nano-particles (Beijing Deke Daojin, China) was with the GO content of 0.1 wt% and the SiC content of 1, 3, and 5 wt%. The composition of EP/$Al_2O_3$ nanocomposite, Coating A and Coating B are depicted in detail in TABLE 1.

**TABLE 1.** Composition of epoxy insulation and coating materials.

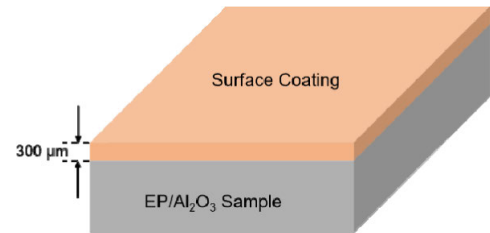| Sample | EP | $Al_2O_3$(wt%) | SiC(wt%) | GO(wt%) |
|---|---|---|---|---|
| Reference sample | 100.0 | 1.0 | 0 | 0 |
| Coating A | 100.0 | 0 | 1.0, 3.0,5.0 | 0 |
| Coating B | 100.0 | 0 | 1.0, 3.0,5.0 | 0.1 |



**FIGURE 1.** Deposition of the coating material.

The inorganic particles were dried in a temperature controllable drying chamber at 120 °C for 24 h prior to the preparation process, which were then mixed into the liquid EP. By means of magnetic force stir and ultrasonic vibrator, uniform dispersion of the particles within polymer could be obtained. The hardener (LMW polyamide 651#, Tianjin Yanhai Chemical, China) of suitable mass was put into the mixture and stirred in a water bath at 50 °C for 10 min, after which the new mixture was cast into the preheated mold and degassed in a vacuum chamber for 1.5 h. Following that, the samples were kept in the heating cabinet at 70 °C for 3 h and 120 °C for 3 h, by which the EP/$Al_2O_3$ test sample with radius of 50 mm could be obtained. As shown in Fig.1, surface coating (Coating A or Coating B) was then deposited onto the sample surface by natural deposition method. Finally, the sample with the presence of coating was kept in the heating cabinet at 70 °C for 3 h and 120 °C for 3 h for the curing of coating. The thickness of the coating was 300 $\mu$m. Before test, the sample was cleaned by ethyl alcohol and dried in a desiccator at room temperature for 24 h.

### B. ELECTRODE ARRANGEMENT AND TEST PROCEDURE

In order to investigate the surface charge accumulation behavior under DC stress, a pair of finger-shaped electrodes were designed and were attached on the surface of test sample by conductive adhesive. The schematic diagram of the electrode configuration was depicted in Fig.2. The electrodes were made of copper foil with end radius of 15 mm, length of 60 mm and thickness of 55 $\mu$m. The area between the two electrodes was 30 mm×30 mm, which was capable of being scanned after the surface charge was accumulated. One of the finger-shaped electrodes was connected with HVDC source (SA503, Dongwen HVDC Source, Tianjin), while the other one was grounded.

The surface charging test was conducted in air at room temperature with relative humidity of 30%. The DC voltage of ±10 kV was applied between the electrodes for 30 min.
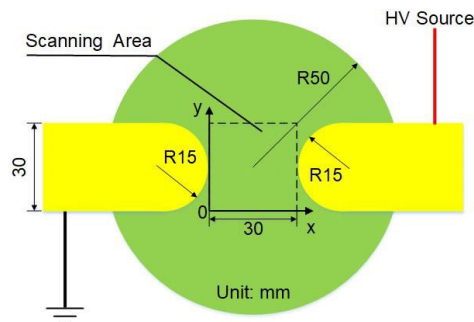
**FIGURE 2.** Schematic diagram of electrode arrangement.

After the charging process, the surface area was scanned with a Kelvin type probe that was equipped with an electrostatic voltmeter (P0865, Trek, USA), the probe was positioned 3 mm above the surface. The scanning time was less than 90 s, in which the charge dissipation was considered to occur negligibly. The scanning accuracy of the Kelvin type probe is ±0.1% of full scale. The average potential of a circle area with the diameter of ∼3 mm is measured by the probe.

After the sample being charged, the normal electric field is generated by the accumulated surface charges. The surface charge density could be calculated by measuring the surface potential after voltage removal. For thin specimens used in this work, a linear relationship between the surface charge density and the surface potential measured by the probe has been proposed as follows [13],

$$\sigma = \frac{\varepsilon_0 \varepsilon_r}{d} u \qquad (1)$$

where $\sigma$ is the surface charge density, $\varepsilon_0$ is the vacuum permittivity, $\varepsilon_r$ is the relative permittivity of specimens, $d$ is the thickness of the specimens, and $u$ is the surface potential measured by Kelvin probe. Accordingly, the charge density could be calculated. Although Equation (1) gave only rough estimation on the density, it is acceptable for comparison by using the charge densities.

With the purpose of better understanding the role of surface coating on surface charge accumulation behavior, isothermal surface potential decay (ISPD) measurement has been carried out to exhibit surface trap distribution of test samples. A detailed description of test circuit of ISPD measurement has been presented in our early publication [14]. The ISPD test was performed at 40 °C with relative humidity of 25% in this work.

In order to obtain surface morphology feature of the coated sample with different nano-filler contents, Scanning Electron Microscope (Nanosem430, FEI, USA) was performed to observe the micromorphology of the samples. Thermal electrons were accelerated under voltage of 10 kV, the energy of electron beam was 10 keV with beam spot 3, and the magnification was 10000.
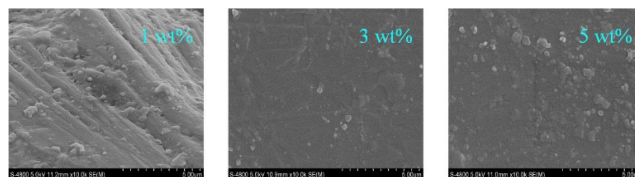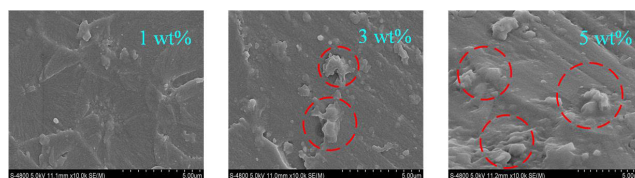
## III. RESULTS AND DISCUSSION
### A. SEM ANALYSIS
EP/Al₂O₃ samples covered by coatings with various SiC contents have been inspected through SEM to show the
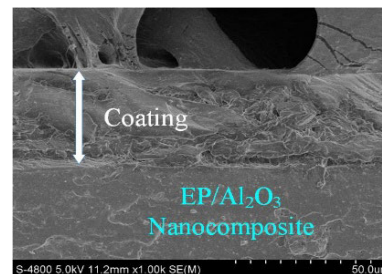


(a) Microscopic profile of coated sample (Side View).



(b) SEM photo for the EP/SiC coating with various SiC contents.



(c) SEM photo for the EP/(SiC+GO) coating with various SiC contents.

**FIGURE 3.** SEM photos for the samples.

micromorphology of the materials, the typical images are presented in Fig.3. The microscopic profile of the cross-section at the interface between EP/Al₂O₃ sample and the coating is depicted in Fig.3(a). It can be observed that the coating is tightly pasted on the EP/Al₂O₃ surface, which indicates that compatibility of the coating and the substrate material is acceptable. The particle dispersion within the EP matrix is illustrated in Fig.3(b) and Fig.3(c). For the Coating A, as shown in Fig.3(b), the dispersion of nano-sized SiC is uniform. No obvious agglomeration within the matrix can be found, which suggests that the dispersion of the particle is reasonably acceptable. For the Coating B, as depicted in Fig.3(c), the combined addition of SiC and GO leads to quite different dispersion manner as compared with the case mentioned above. No obvious agglomeration occurs as the SiC content is 1 wt%, however, agglomeration tends to form as the SiC content increases to 3 wt%. Such a behavior is considered to be induced by the interaction between SiC and GO, which will have remarkable influence on trap distribution.

### B. SURFACE CHARGE ACCUMULATION ON EPOXY NANOCOMPOSITE COATED WITH EP/SIC
The typical surface charge distributions on the composite sample coated by EP/SiC with different filler contents under 10 kV are shown in Fig.4. The black triangle marked in each figure refers to the position of maximum charge density. As indicated in Fig.2, the edge of the grounded electrode is at (0, 15), while the edge of HV electrode is at (30, 15). It can be observed in Fig.4(a) that positive charges
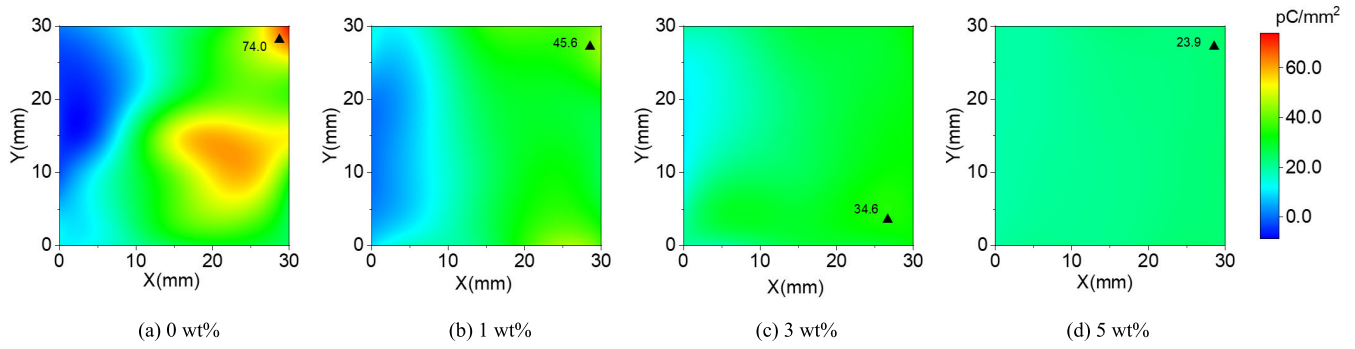
(a) 0 wt%　　　　(b) 1 wt%　　　　(c) 3 wt%　　　　(d) 5 wt%

**FIGURE 4.** Typical surface charge distribution of sample with 300 $\mu$m-Coating A under 10 kV DC voltage.



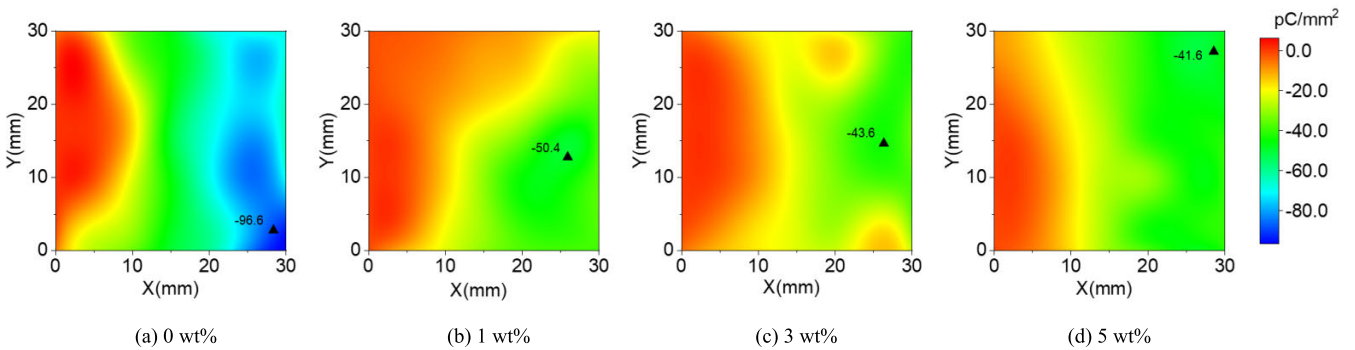(a) 0 wt%　　　　(b) 1 wt%　　　　(c) 3 wt%　　　　(d) 5 wt%

**FIGURE 5.** Typical surface charge distribution of sample with 300 $\mu$m-Coating A under -10 kV DC voltage.

are accumulated on most area of the sample surface without the coating, and a few negative charges appear near the grounded electrode. However, for the sample coated by the EP/SiC coating, no negative charges are accumulated on the surface. Typically, taking the sample coated by EP/SiC with 1 wt% filler content as an example, it can be found that a large number of charges are deposited on the surface around the HV electrode and the surface charge density reduces towards the grounded electrode. With the increase of the SiC content from 1 to 5 wt%, the maximum charge density decreases obviously from 45.6 to 23.9 pC/mm$^2$. As a comparison, the un-coated sample surface holds the maximum charge density of 74.0 pC/mm$^2$ which is much higher than those coated by EP/SiC. It reveals that with the presence of the coating, surface charge accumulation could be suppressed and the suppression performance is improved with the filler content.

Similar distribution of surface charge can be found for the sample stressed with -10 kV, which is depicted in Fig.5. The charge accumulation is again suppressed significantly with the presence of EP/SiC coating, and the maximum charge density decreases with the growth of SiC content in the coating. Surface charge accumulation behavior have been reported to be closely related to surface trap distribution [15]. Accordingly, ISPD method has been employed to estimate the change in trap distribution over the coated samples with different SiC contents. The typical trap distribution for hole and electron for the coating materials is shown
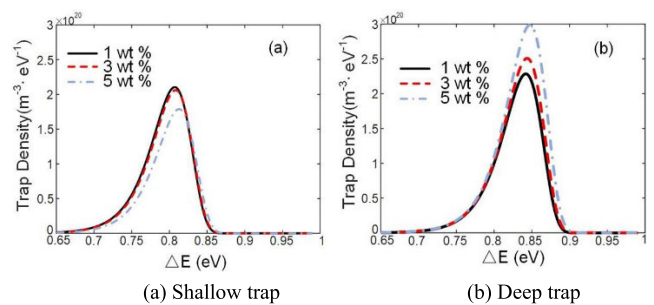


(a) Shallow trap　　　　(b) Deep trap

**FIGURE 6.** Trap distribution for hole of sample.

in Fig.6 and Fig.7. As shown in Fig.6(a), with the growth of the SiC content, the shallow trap center becomes deeper monotonously. The trap centers are 0.803, 0.815 and 0.823 eV with the SiC content of 1, 3, and 5 wt%, respectively. In Fig.6(b), the deep trap center exhibits similar behavior as the shallow trap center, where an increase trend appears with the growth of SiC content. Meanwhile, it is noticed that the density of deep trap in the EP/SiC coating increases from $2.25 \times 10^{20}$ to $3.00 \times 10^{20}$ m$^{-3}$ •eV$^{-1}$ with the growth of SiC content, which indicates that more deep traps are introduced into the coating material.

For the electron trap distribution shown in Fig. 7, the centers for both shallow and deep traps tend to move right with the increase of SiC content, which reveals that the electron trap gradually becomes deeper with the SiC content.
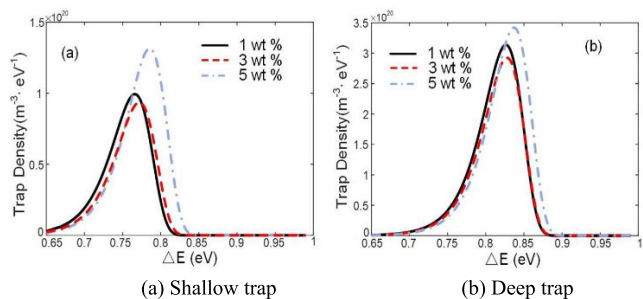
(a) Shallow trap      (b) Deep trap

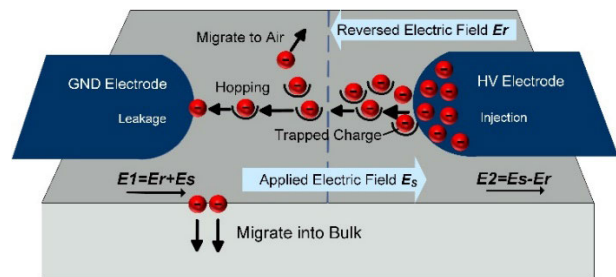**FIGURE 7.** Trap distribution for electron of sample.



**FIGURE 8.** The mechanism of surface charge accumulation with the finger-shaped electrode.

The generation of surface charges includes the following two mechanisms. One mechanism is gaseous ionization near electrode, which happens in high field area such as the triple junction (TJ). The other one is contact injection from the electrode, by which the charges with same polarity of the electrode could be injected onto the polymer surface [16]. For the electrode configuration used in this work, as reported in [17], the contact injection should be the main reason for the charge accumulation. Previous investigation revealed that the migration of surface charge is mainly due to hopping conduction with very low mobility [18]. The charge generated are transported to the sample surface through surface conduction under electric field, and it would be captured by trap and becomes the surface charge. The charge density would gradually decrease from the HV electrode to the grounded electrode due to the capture of traps along the surface. Therefore, a large number of charges would stay close to the HV electrode, leading to the formation of charge distribution feature shown in Fig.4 and Fig.5.

A schematic diagram for the mechanism of surface charge accumulation is shown in Fig.8. After the charges are accumulated, the mathematical expression for the electric field in different regions are depicted in the figure. $Es$ is the applied electric field, and $Er$ is the reversed electric field created by the trapped charges. $E2$ is the superimposed field between the HV electrode and the position of charge peak, $E1$ is the superimposed field between the grounded electrode and the charge peak. For the simplicity of description, the formation of negative charge is considered as an example. As the charges are injected, they are transported towards the grounded electrode under electric field generated by applied DC stress and the charges themselves. The reversed electric field $Er$

created by the trapped charges would be a disincentive to the charge injection from the electrode. When doped with higher SiC content, more charges would be trapped near the HV electrode and the charges are difficult to move towards the counter electrode owing to the deepening of trap level and the increase of trap density, which leads to the increase of the $Er$ to suppress further charge injection from the electrode. Though more charges are trapped near the HV electrode, the suppression of both of further charge injection and movement towards the counter electrode could lead to the decrease of the charges on the whole. As a result, less amount of surface charge is accumulated with the increase of SiC content in EP/SiC coating as shown in Fig.5.

### C. SURFACE CHARGE ACCUMULATION ON EPOXY NANOCOMPOSITE WITH EP/(SIC+GO) COATING

The typical surface charge distributions on samples with EP/(SiC+GO) coating under ±10 kV is shown in Fig.9 and Fig.10. The red and the blue color area in each figure refers to the region of positive and negative charge, respectively. It can be seen that bipolar charges are accumulated on the surface with the presence of GO, which is different from the unipolar charge accumulation as EP/SiC is coated on the composite surface. Typically, taking the sample coated by EP/(SiC+GO) with 1 wt% SiC content as an example. As depicted in Fig.9(a), it can be found that under 10 kV, the positive charges are accumulated near the HV electrode whilst the negative charges are deposited near the grounded electrode. It is observed that the maximum positive charge density increases with the growth of the SiC content. As a comparison, the sample coated by EP/(SiC+GO) with the SiC content of 1 wt% holds the minimum positive charge density of 38 pC/mm$^2$, which is lower than that of sample coated by EP/SiC.

Similar distribution of surface charge can be found for the sample stressed with -10 kV, which is shown in Fig.10. Hence, it is concluded that homo-charges are accumulated around each of the electrode, the reasons why there are bipolar charges accumulated on the surface are discussed later. The results in Fig.10(a) show that the maximum of negative charge density is -38.6 pC/mm$^2$ as the sample coated by EP/(SiC+GO) with the SiC content of 1 wt%, which is also lower than that of sample coated with EP/SiC. Such a result indicates that the surface charge suppression performance of EP/SiC is improved by the addition of GO with low fraction.

The distribution of hole and electron traps for EP/(SiC+GO) coating are shown in Fig.11 and Fig.12. It's worth mentioning that the energy levels and density of deep and shallow traps differ among different types of material. For the hole traps, it is observed that the deep trap level tends to decrease with the increase of SiC content. The deep trap centers are 0.941, 0.935 and 0.925 eV with the SiC content of 1, 3, and 5 wt%, respectively. For the electron traps in EP/(SiC+GO) coating depicted in Fig.12, the trend of shallow trap density and deep trap level are similar to that of hole traps. With the growth of SiC content, the deep trap
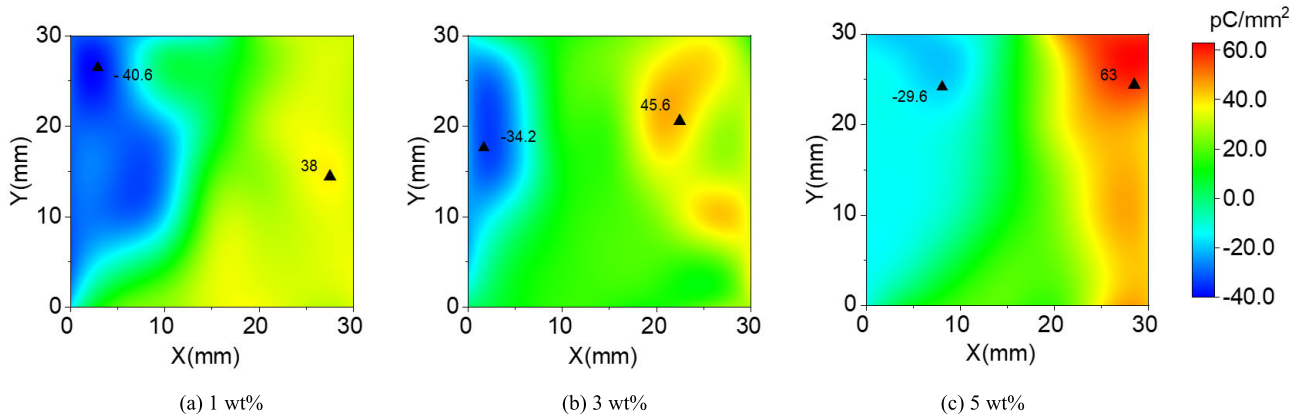
(a) 1 wt%                                    (b) 3 wt%                                    (c) 5 wt%

**FIGURE 9.** Typical surface charge distribution of sample with EP/(SiC+GO) coating under 10 kV DC voltage.
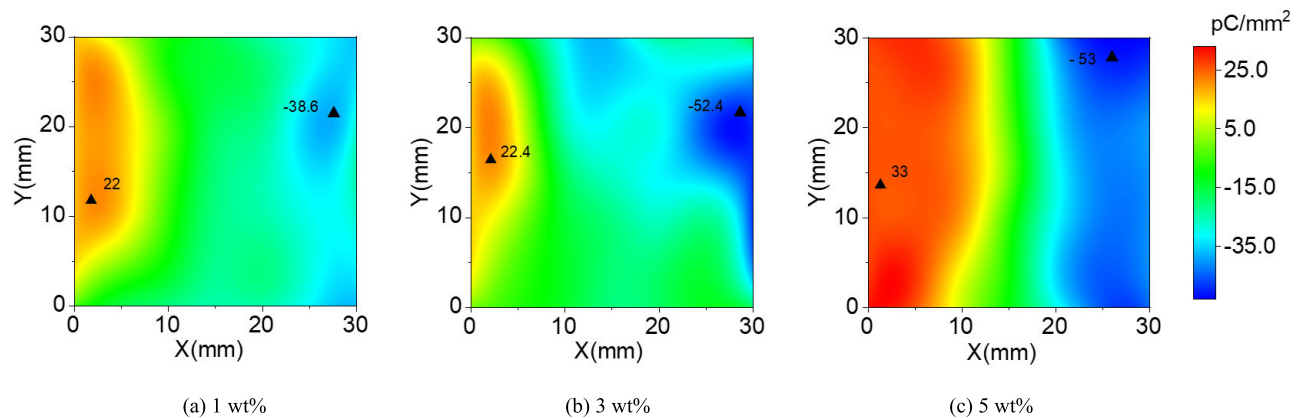


(a) 1 wt%                                    (b) 3 wt%                                    (c) 5 wt%

**FIGURE 10.** Typical surface charge distribution of sample with EP/(SiC+GO) coating under -10 kV DC voltage.



(a) Shallow trap              (b) Deep trap
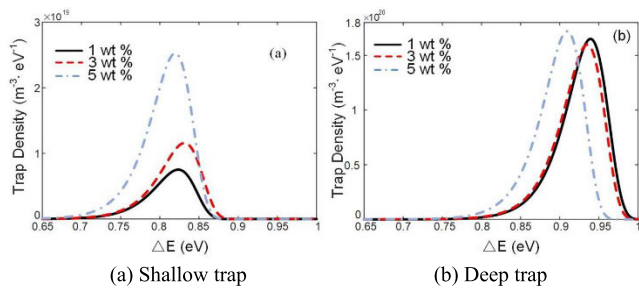
**FIGURE 11.** Trap distribution for hole of sample.



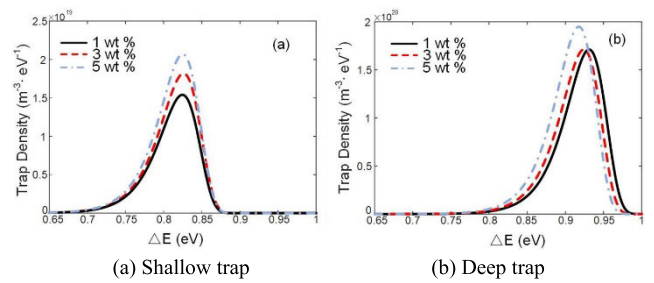(a) Shallow trap              (b) Deep trap

**FIGURE 12.** Trap distribution for electron of sample.

center moves left from 0.935 to 0.911 eV. Meanwhile, it can be found that the density of shallow trap increases with the growth of SiC content for both hole and electron traps. This result indicates that the shallow traps are introduced into the coating material as SiC content increase with the presence of GO.

It is reported that the GO plays a significant role to the performance of polymers on suppressing charge accumulation. B.X. Du *et al.* have found that certain content of GO nanoparticles could introduce large quantities of deep carrier traps in LDPE/GO [19]. Zhang *et al.* have found that epoxy resin filled with GO has lower apparent mobility,

deeper trap depth and larger number of trapped charges compared to pure EP [20]. GO is an oxide of graphene, while graphene has an enormous specific surface area of 2630 m$^2 \bullet$g$^{-1}$, thereby GO retains the advantages of large specific surface area of graphene [21]. GO also has another name called functionalized graphene. In the oxidation process of graphene, oxygen-containing functional groups are introduced into the material. Those oxygen-containing functional groups, such as hydroxyl or carboxyl, can be combined with other substances through hydrogen bond, covalent bond, electrostatic adsorption and other interactions under appropriate conditions [22]. After the nanoparticles are dispersed
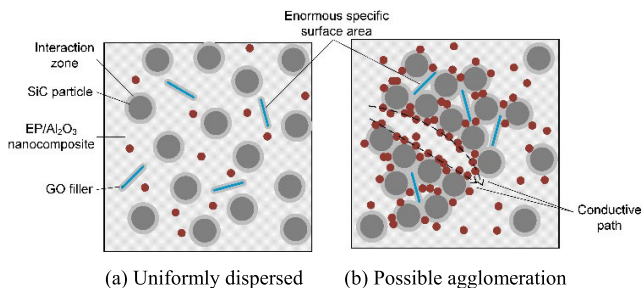
(a) Uniformly dispersed    (b) Possible agglomeration

**FIGURE 13.** Formation of a conductive path of charges.



(a) Positive voltage    (b) Negative voltage

**FIGURE 14.** The relationship between the filler content of SiC and the flashover voltage for EP/SiC coating.



(a) Positive voltage    (b) Negative voltage

**FIGURE 15.** The relationship between the filler content of SiC and the flashover voltage for EP/(SiC+GO) coating.

in the EP, a small amount of GO filler can form a nanometer filler/polymer interface zone with a large number of charge traps in the composite through nanometer effect, as depicted in Fig.13(a), because of its large specific surface area and oxygen-containing functional groups [23]. In this work, it can be observed that the trap level of deep traps in EP/(SiC+GO) coating is higher than that in EP/SiC coating, especially when the SiC content is 1 wt%. It is suggested that trap density and trap level become increased with the presence of GO of low fraction. Compared Fig.11(b) with Fig.6(b), it can be observed that deep trap level of hole increases to 0.941 eV from 0.841 eV. As shown in Fig.12(b), it is found that deep trap level of electron increases to 0.935 eV from 0.830 eV as well. It should be stated that the trap density measured is that occupied by carriers rather than the real ones, accordingly, it would be more helpful to use trap depth to analyze the charge accumulation behavior than use trap density. Therefore, it is concluded that deep traps are introduced into the coating with the presence of GO of low fraction.

On the one hand, the increased deep trap makes homo-charge easily get caught in traps around both electrodes. On the other hand, charges are difficult to migrate along the surface, which leads to the reduction of charge recombination. Therefore, the bipolar charges are left behind on the surface. With the presence of GO of low fraction, the introduced deep traps make it difficult for charges near the HV electrode to escape, and it leads to the increase of the $E_r$ to suppress further charge injection, as shown in Fig.8. Consequently, the maximum of charge density on EP/(SiC+GO) coating is lower than that of EP/SiC coating.

However, it should be mentioned that the maximum of charge density increases with the growth of SiC content as the EP/(SiC+GO) coating is used. The possible mechanism of the phenomenon is illustrated by schematic diagram in Fig.13(b). It is considered that GO fillers are easily attached by SiC particles to form agglomeration because of its large curvature and abundant oxygen-containing functional groups, which contributes to the sorption of SiC [22]. The agglomeration becomes more evident as the SiC content increases, as shown in Fig.3(c). The agglomeration leads to an overlap of the interaction zone between the polymer and nano-filler, and possibly introduce physical defects acting as shallow traps, which result in the formation of a conductive
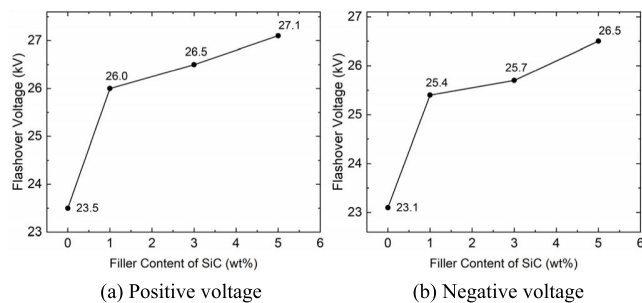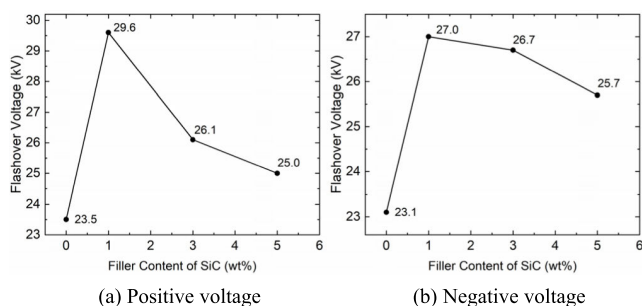
path for charges [12]. Such a path will encourage the migration of charges trapped close to the electrodes, leading to further accumulation of charges with higher density. In short, it is considered that the charge accumulation would be remarkably encouraged due to the agglomeration that is induced by the presence of GO and SiC of higher content.

## D. CHANGES OF DC FLASHOVER VOLTAGE FOR EPOXY NANOCOMPOSITE WITH COATING

The purpose of inhibiting surface charge accumulation is to promote surface insulation strength. Flashover voltage is an important index to reflect surface insulation performance of the insulator. The typical flashover voltage of the composite sample coated by EP/SiC and EP/(SiC+GO) with different filler contents are shown in Fig.14 and 15.

For the EP/SiC coating, as shown in Fig.14(a), The flashover voltage under positive voltage without coating is 23.5 kV. It is observed that the flashover voltage tends to increase with the increase of SiC content. The flashover voltages are 26.0, 26.5 and 27.1 kV with the SiC content of 1, 3, and 5 wt%, respectively. As shown in Fig.14(b), the trend of flashover voltage is similar to that of positive voltage. The flashover voltage under negative voltage without coating is 23.1 kV. As the coating is applied, it increases to 25.4, 25.7 and 26.5 kV, as the SiC contents are 1, 3 and 5 wt%.

For the EP/(SiC+GO) coating, as shown in Fig. 15, the positive flashover voltages are 26.9, 26.1 and 25.0 kV, as the SiC contents are 1, 3 and 5 wt%. Under negative voltage, as the SiC contents are 1, 3 and 5 wt%, the flashover voltages are 27.0, 26.7 and 25.7 kV, respectively. Considering the trend of flashover voltage and surface charge density, it can be

concluded that the flashover voltage increases with the decrease of maximum of the surface charge density for both coatings. In short, flashover voltage is improved by the coating through the suppression of surface charge accumulation.

## IV. CONCLUSION

In this paper, the EP/SiC and the EP/(SiC+GO) coatings have been prepared to investigate the effect of coating on surface charge accumulation of EP/$Al_2O_3$ nanocomposite with finger-shaped electrode system. The influence of GO and SiC particles on the charge accumulation has been demonstrated. The main conclusions are summarized as follows,

1. The coatings could inhibit the surface charge accumulation effectively, and the inhibition performance is related to the SiC and the GO particles. With the presence of the EP/SiC coating, the maximum surface charge density decreases with the SiC content. However, for the EP/(SiC+GO) coating including GO of 0.1 wt%, the minimum charge density appears with SiC of 1 wt%, the maximum charge density in such a case is lower than that with the EP/SiC coating.

2. For the EP/SiC coating, with the growth of the SiC content from 1 to 5 wt%, the depth and the density of trap for both electron and hole tend to increase. For the EP/(SiC+GO) coating, as the SiC content is 1 wt%, the deep trap is introduced owing to the addition of GO. However, with the growth of SiC content from 1 to 5 wt%, the trap depth tends to decrease because of the agglomeration.

3. For both EP/SiC and EP/(SiC+GO) coating, reduction of maximum surface charge density could increase the flashover voltage of epoxy nanocomposite.

In summary, it is found that surface charge accumulation could be inhibited by EP/SiC coating in such a way that deeper traps are introduced to suppress further charge injection. Furthermore, the addition of GO with low fraction would enhance the inhibiting performance of EP/SiC coating. Such a finding is helpful for surface charge inhibition of EP based insulator under DC stress.

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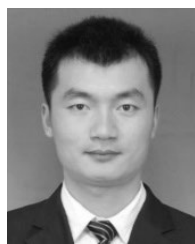
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