한국전기전자재료학회 2003년도 춘계학술대회 논문집

Effect of Surface Charge in Hydrophobicity of Insulating Material and Decay of Surface Voltage after Corona Charging

Chang-Su Huh*, Bok-Hee Youn**, You-Jin Seo* and Sun-Mook Hwang*

*INHA University, **LG Cable Ltd.

Abstract

This paper presented the effects of accumulation of surface charges on hydrophobicity level and the surface states of silicone polymer used for outdoor insulator treated by ultraviolet irradiation and corona discharge through measuring surface voltage decay of a corona-charged specimen were investigated. The surface resistivity by the method of the surface potential decay was compared with the value by the three electrodes methods. From this study, it was found that the accumulation of surface charges above a critical surface voltage on silicone insulating materials could lead to the temporary loss of surface hydrophobicity. In addtion, uv stress lead to a longer decay time of surface charges. We could conclude that the effects of surface charges on hydrophocity level and the changes of surface state by various artificial treatments were understood through a trend of surface potential decay.

Key Words : hydrophobicity, surface voltage decay, surface charging, silicone rubber

1. Introduction

Surface voltage decay measurement after corona charging have been used to investigate the effect of surface charge on hydrophobicity levels of insulating material and the degradation process by UV due to the sensitivity of this method to surface chemical and morphological states[1-3]. In addition, Moreno and coworker have used it to investigate the performance of several polymer outdoor insulator formulations under ac and dc electrical stresses.

This paper presents the effects of accumulation of surface charges on hydrophobicity level and surface characterization of silicone polymer treated by UV and corona discharge with the measurement of the surface voltage decay after corona charging. Surface resistivity was derived by observing the rates of surface voltage decay and contact angle and XPS analysis were used to investigate surface characteristics. Based on this result, surface voltage decay with various surface states was discussed on the relation of surface degradation and specific chemical states of silicone insulator treated by artificial aging factors.

2. Experimental

2.1 specimen and measurement

The reference material considered in this work is high temperature vulcanized silicone rubber, which have widely been using for outdoor composite insulator. The apparatus for corona charging had already been used in other literature[4]. In addition, to detect the chemical structure of samples surface, XPS was used. XPS conditions are the X-ray source of Mg-K

(1253.6 eV), 300 W (15 kV) and high vacuum of ~5×10-8 torr. XPS high resolution scan spectra have the resolution of 0.08 eV.

2.2 UV and corona discharge treatment

UV treatment of samples surfaces was conducted in a UVB type Q-panel accelerated weathering tester. The irradiance of lamp at 313 ㎚ wavelength and chamber's temperature were fixed at 0.65 W/m2/㎚ and 50℃, respectively. A paralle-plane electrode system was used for corona discharge exposure. Exposure out corona discharge was conducted in a similar method to that described in other literature.

3. Results and Discussion

3.1 Effect of surface charges accumulation on hydrophobicity level

Figure 1 to Figure 3 showed the surface voltage decay and changes of hydrophobicity of silicone rubber as a function of voltage applied on grid electrode. It is found that that the accumulation of surface charges above a critical surface voltage on silicone insulating materials could lead to the temporary loss of surface hydrophobicity.

3.2 Surface voltage decay

Figure 4 and 5 showed the results of surface voltage decay on UV and corona discharge treated specimen as a function of treatment duration. Surface voltage decayed with an exponential function and the longer decay time corresponded to the treated samples with a longer UV exposure time. However, the longer was the corona discharge exposure time, the shorter decay times was showed in corona treated samples.

3.3 Surface resistivity

The relation between surface voltage decay and surface resistivity has been studied by other researchers. Because of the decay of surface voltage with the exponential function, we calculated the characteristic time constant of the voltage decay.

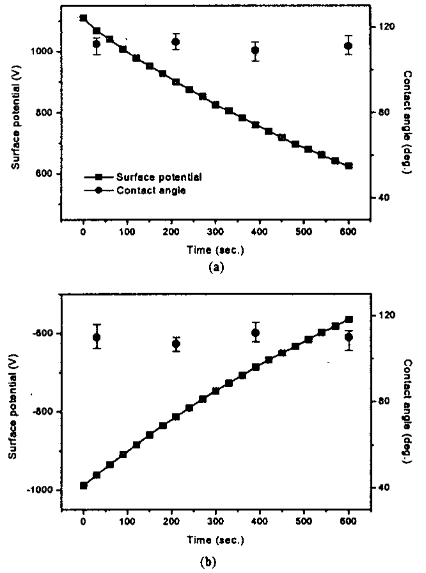

Fig. 1. Surface voltage decay and changes of hydrophobicity in the case of grid voltage of 1 kV (a) positive polarity (b) negative polarity

A theoretical investigation of the surface voltage decay by surface conductivity shows that the surface resistivity ρs is related to the time constant τ of the voltage decay[5].

Based on the above results, the surface resistivity by the method of surface voltage decay was compared with the values by the three electrodes method for the only case of positive polarity. The results were shown in Figure 6 and Figure 7.

Based on the above results, the surface resistivity by the method of surface voltage decay was compared with the values by the three electrodes method for the only case of positive polarity. The results were shown in Figure 6 and Figure 7.

It was found that a good agreement between the two methods for surface resistivity was obtained. Surface insulating properties change electrically in proportional to the degree of

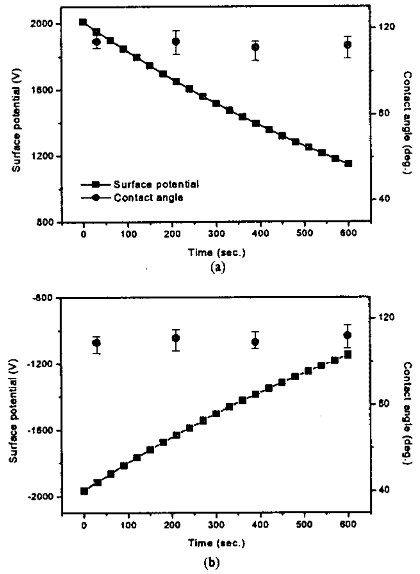

Fig. 2. Surface voltage decay and changes of hydrophobicity in the case of grid voltage of 2 kV (a) positive polarity (b) negative polarity

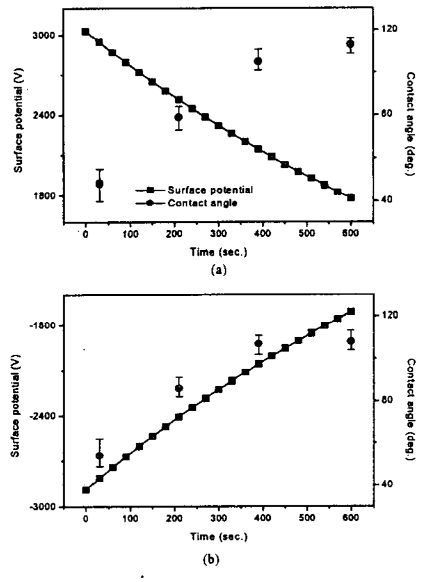

Fig. 3. Surface voltage decay and changes of hydrophobicity in the case of grid voltage of 3 kV (a) positive polarity (b) negative polarity

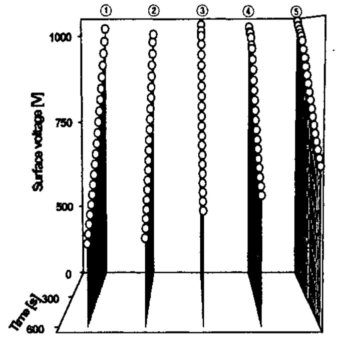

Fig. 4. Surface voltage decay with increasing in time of UV irradiation

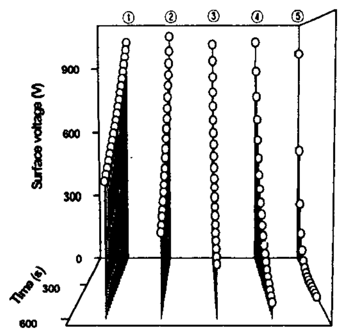

Fig. 5. Surface voltage decay with increasing in time of corona exposure

surface activation. The change of the surface resistivity was due to the changes of surface states on HTV silicone rubber by aging factors.

From a view of structural point, an important observation made from these results is that photo-oxidative degradation in silicone rubber is dominated by cross-linking, which is in contrast to surface oxidization through chain scission reactions by corona discharge. Photo-oxidation reaction on HTV silicone rubber by UV irradiation constitute of more the bridging and recombination of oxygen than chains scission. This cross-linking leads to the increase in molecular weight, the decrease in free volume in

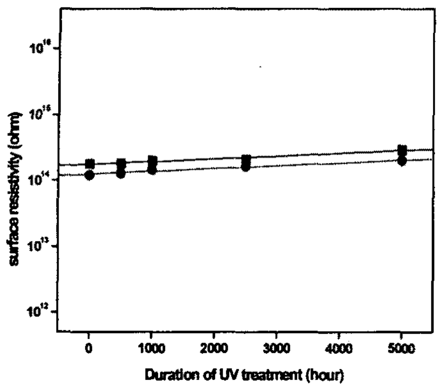

Fig. 6. Surface resistivity of UV treated samples

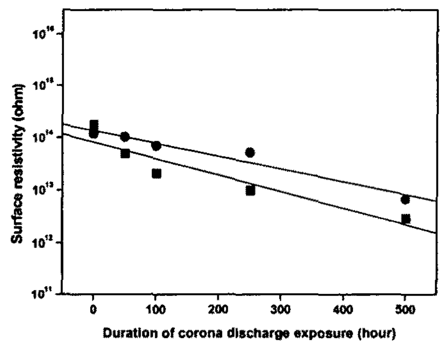

Fig. 7. Surface resistivity of corona discharge treated samples

oxidized surface layer and considerably larger in density. Thus, this oxidized layer retains injected charges for a long time. However, the accumulation of surface charges has been identified as a factor leading to the temporary loss of generic hydrophobicity. Therefore, long decay time of surface voltage after corona charging on samples have adverse effects on surface hydrophobicity. The above changes by UV irradiation may facilitate easy accumulation of surface charges. So, it was thought that the slow decay of surface charges due to photo-degradation could affect the loss of hydrophobicity while a polymeric outdoor insulator was used in service.

In terms of its effect on the mechanism leading to the fast decay of surface voltage by exposing out corona discharge, corona degradation of HTV silicone rubber mainly involves oxidative attacks of the side-chains. This reaction leads to a generation of very reactive silyl radicals and methylene side radicals. The series of changes in the surface properties mentioned above resulted from the change to activated surface, in which many radicals and polar groups were induced by the scission of side chains under corona discharge. Apparently, after the change to the activated state, excited species on the surface recombine with oxygen and become polarized. Therefore, the artificially injected corona charges facilitate the movement and recombination with polar groups. Therefore, charge-decay occurs rapidly in proportion to the activated degree of the surface with time elapses.

3.4 Contact angle and XPS

The effects of UV irradiation and corona discharge exposure on the contact angle of the samples surface were measured. It is observed that UV treated specimen does not appear to change significantly with longer UV irradiation, in which the contact angle of the untreated sample showed 108° and this decrease to 98° even after UV radiation for 5000 hour. For corona discharge treatment, this decreased to 41° after 500 hours. The above decease in the contact angle could be explained by the fact that the surface changed to the oxidized layer having more oxygen groups of high energy. It is found that corona discharge permit more the above effects than UV irradiation on HTV silicone insulating materials. The hydrophobic property of silicone rubber is mainly due to the methyl groups of side chains. The polar components causing the loss of hydrophobic level by various factors originate mainly the form of hydroxyl and carbonyl groups. The decrease of contact angle is due to the increase of the surface free energy, which originate from polar components.

High-resolution spectral peaks for the range of untreated and treated materials are studied by analysis of the Si2p peak envelops, a typical peak fitting for uv-treated sample and for corona discharge treated one. But, this paper did not present this result. The envelopes from the oxidized surfaces can be resolved into two components. The major peak in the spectrum at 102.1 eV is due to Si bound to two oxygen atoms. There is another peak at 103.4 eV due to Si bound to three or four oxygen atoms. The latter associated the highly oxidized surface with a silica-like structure. The inorganic silica-like structure peak increased with longer UV irradiation and corona exposure. The above results mean that surface layer was oxidized by two degradation factors. It is observed that corona discharge permit more changes of peaks than UV irradiation. For the UV irradiation and corona exposure, scission of C-H and Si-CH3 bonds, particularly Si-CH3 bonds that are weaker than C-H bonds, lead to the formation of very reactive silyl radicals and methylene side radicals, and then crosslink by bridging of oxygen and/or form hydroxyl and carbonyl groups at broken side chains. Therefore, both degradation factors caused the formation of oxidized layer of Si bound to three or four oxygen. Although both artificial treatment lead to the same oxidative products, which was confirm with XPS analysis, we could distinguish the difference of main reaction of oxidative damages between them by measuring the surface voltage decay after corona charging.

4. Conclusion

We obtained the following results from surface analysis on degraded HTV silicone by UV irradiation and corona discharge exposure using surface voltage decay, surface resistivity, contact angle and XPS analysis.

1. For corona charging on unaged silicone rubber, it is found that the accumulation of surface charges lead to a temporary loss of hydrophobic level. However, this exists a critical surface voltage on silicone insulating materials.
2. In corona charging on aged silicone rubber, surface voltage decayed with an exponential fuction and the longer decay time corresponded to the treated samples with a longer uv exposure time. On the other hand, the longer was the corona discharge exposure time, the shorter decay times was showed in corona treated samples.
3. Corona discharge permit more the effects than UV irradiation on the loss of hydrophobic level of HTV silicone insulating materials and the silica-like structure layer is formed by oxidation due to UV irradiation and corona discharge exposure. In considering the different decay trend of surface voltage, we obtained the facts that photo-oxidative degradation in silicone material is dominated by cross-linking, which is in contrast to surface oxidization through chain scission reaction by corona discharge.

5. References

[1] J.S.T. Looms, *Insulators for HIGH VOLTAGE*, Peter Peregrinus, 1988

[2] R.S. Gorur, E.A. Cherney, J.T. Burnham, *Outdoor insulators*, Ravi S. Gorur, Inc., 1999.

[3] V.M. Moreno, R.S. Gorur, Ac and dc Performance of Polymeric Housing Materials for HV Outdoor Insulators , IEEE Trans. Dielectrics and Electrical Insulation, Vol. 6, No. 3, pp. 342-350, 1999.

[4] B.S. Lee, D.C. Lee, Surface Degradation Prop erties of Ultraviolet Treated Epoxy/Glass Fiber, IEEE Trans. Dielectrics and Electrical Insulation, Vol. 6, No. 6, pp. 907-912, 1999.

[5] A. Crisci, B. Gosse, J.P. Gosse, V.O. Dureault, Surface-potential decay due to surface conduction , The European Physical Journal applied physics, Vol 4, pp. 107-116, 1998