INVESTIGATION ON AGING IN DIFFERENT PARTS OF AN SILICON INSULATOR

M.K.Moghadam[*1], M.Keramati[2], H.Beirami[1] and M.Ehsani[2]
[1]Niroo Research Institute, Tehran, IRAN
[2]Iran Polymer and Petrochemical Institute, Tehran, IRAN
*Email: <mmoghadam@nri.ac.ir>

Abstract: In recent years polymeric insulators have been widely used in high voltage application due to their ease of handling, cost, and their good performance comparing with traditional types. Polydimethylsiloxane (PDMS) elastomer has attracted great attention because of its unique advantages.

The aim of this paper is to investigate the aging of in-field high temperature vulcanizing (HTV) silicon rubber insulator and trace its degradation under real severe climate (humid, hot, and polluted). In addition it has been tried to determine, which part of the insulator is more susceptible to environmental degradation.

For this purpose a 14 years old high voltage (230 kV) in-field insulator was chosen. Sampling was done from different directions of three sheds (top, middle and bottom).

To analyze the chemical changes and surface degradation, Attenuated Total Reflection Fourier Transform Infrared (ATR-FTIR), Energy-dispersive X-ray spectroscopy (EDX) and STRI hydrophobicity class were employed.

The results showed that the middle shed had less aging compare to top and the bottom ones. It seems to be for more powerful electrical field in two ends of an insulator. Furthermore, no drastic chemical changes occurred among different parts of an individual shed.

1 INTRODUCTION

Over the last decades polymeric insulators have been widely used in transmission and distribution power lines. They are replacing the traditional porcelain insulators because of their ease of handling, cost and their good performance. Ethylene Propylene Diene Monomer (EPDM), and Polydimethylesiloxane (PDMS) are the most famous materials, however the share market demands of PDMS insulators is more than others. [1, 2].

One of the most interesting characteristic of silicon is its surface hydrophobicity. The hydrophobic surface of PDMS prevents the developing of leakage current which can cause the flashover of the insulator [2].

Generally outdoor insulators in harsh climate are suffering from electrical discharges, corona discharges, UV radiation, acid rain and etc. these parameters lead to hydrophobicity loss and finally deterioration of insulators [3, 4]. However silicon rubber (SIR) has the ability to recover its hydrophobicity by the time after the stress removed but the rate of recovering is decreasing by aging [1, 5]. Large body of works have been done to investigate the degradation of SIR insulator from different point of views [3, 6-8]. Contact angle measurement as physical investigation and Energy Dispersive X-ray scattering (EDX), Fourier Transform Infrared spectroscopy (FTIR), X-ray photoelectron Spectroscopy (XPS) and … as useful chemical methods have been applied to discuss the aging and recovering of PDMS insulations [1, 9].

Reinders et al. reported that the most important mechanism for hydrophobicity loss, is the breaking up and evaporation of polymer chain by electrical energy from corona and arcing [10].

In this work aging in different parts of HTV silicon rubber insulator which was in service for 14 years have studied to discover the most and the least deteriorated areas. FTIR-ATR and EDX were employed for this purpose. In addition, STRI hydrophobicity class test was also done.

2 EXPERIMENTAL

2.1 Materials and sampling

A 230 KV SIR insulator (SEDIVER, FRANCE) which had been in operation for 14 years was chosen. It had been installed in hot and polluted area near the sea. Visual inspection of the insulator showed no sign of degradation but to get better insight further analysis were done. Sampling was done from three different sheds, the first one (upper shed), the middle one and the last one (near the power line). The samples were collected from 4 directions (figure 1) around the individual sheds (north or 1, east or 2, south or 3 and west or 4). Table 1 shows the sample codes.

Table 1:

Shed	Sample code			
	North	East	South	West
Top shed	T1	T2	T3	T4
Middle shed	M1	M2	M3	M4
Bottom shed	B1	B2	B3	B4

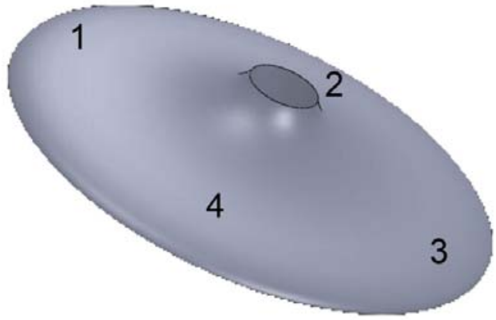

Figure 1: sample collection in an individual shed

2.2 TESTS

In order to study the changes of functional groups at the surface of SIR insulator, Fourier Transform Infrared (FTIR) spectrometer (Bruker, Retex 80, Germany.) with Attenuated Total Reflection (ATR) attachment was employed.

Energy Dispersive X-ray scattering (EDX) was applied to determine the compositional ratio of elements of the surfaces. Tescan VEGA-II, USA. Scanning Electron Microscopy was equipped with EDX. The accelerating voltage applied was 20 kV which means 10 µm of analysis depth.

STRI hydrophobicity test was also done according to STRI classification guide [11].

3 RESULTS AND DISCUSSION

In order to assess the chemical changes in different parts of considered insulator FTIR-ATR was applied. The FTIR spectrum of the first shed which refers to its four directions is illustrated in Figure 2. The absorption peak in 1005 cm^{-1} is attributed to Si-O bond. The absorption peak at 1259 cm^{-1} refers to Si-CH_3 bond and 2962 cm^{-1} to stretching C-H bond. It is believed that the CH_3 groups are one of the main reason for surface hydrophobicity of silicon rubber insulator. The Si-O bond in the backbone of silicon rubber has high bond energy and is more resistant to degradation compare to other bond in silicon chain. Thus the intensity ratio of Si-CH3/Si-O is taken as an important index to evaluate the degree of degradation. As it is presented in figure 3 there is no drastic difference among four directions of the sheds.

Also the aging condition among the three considered sheds could be compare in this figure and the Si-CH3/Si-O index shows similar results for the top shed and the bottom one however the middle shed seems to have better condition.

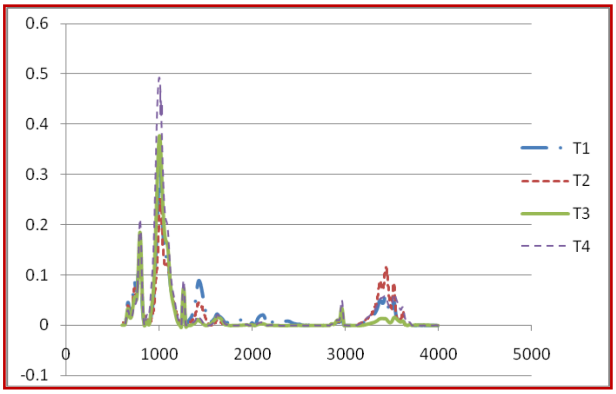

Figure 2: FTIR spectrum of different parts of top shed

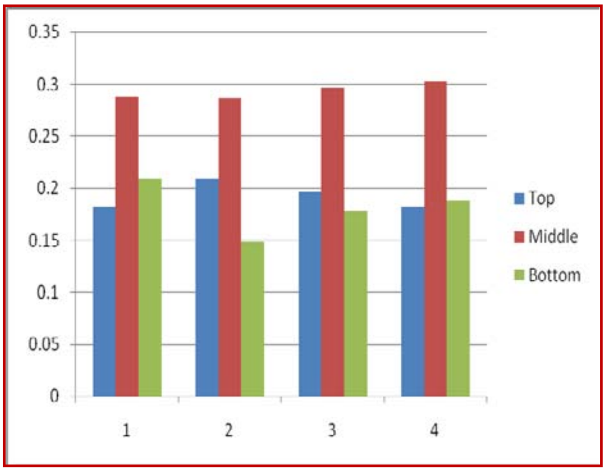

Figure 3: ratio of Si-CH3/Si-O for three sheds

Compositional ratio of elements of the surfaces was investigated by EDX. Table 3 shows the results that contains the value of C, Si, AL and O. Furthermore the ratio of O/C is calculated and presented in table 2.

Table 2:

Sample code	Elements %				Ratio
	C	O	Si	Al	O/C
T1	22.6	57.71	9.65	9.88	2.6
T2	17.68	55.69	14.23	11.75	3.1
T3	32.12	52.95	10.17	4.13	1.6
T4	14.3	53.69	14.58	16.97	3.7
M1	24.5	51.14	10.99	12.76	2.1
M2	21.02	52.09	13.64	13.24	2.5
M3	27.27	48	11.73	12.42	1.8
M4	20.85	53.15	11.7	13.87	2.5
B1	16.9	52.88	13.96	15.92	3.1
B2	15.24	46.65	21.38	16.15	3.1
B3	13.23	50.58	18.27	17.61	3.8
B4	17.97	55.25	17.28	13.87	3.1

O/C ratio can be an indication of degradation because during aging some methyl side chain groups could have been cut and evaporate. Also formation of OH groups are possible by electrical and corona discharges. Figure 4 shows the O/C ratio for three considered sheds. According to this peak one can say that the middle shed has aged less than the two others.

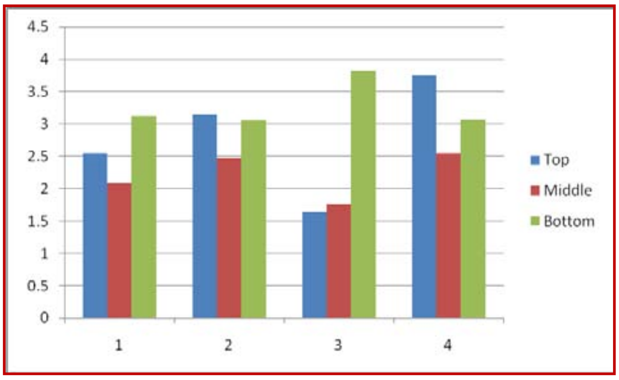

Figure 4: the ratio of O/C for three sheds

STRI hydrophobicity classifications of considered sheds are shown in figure 5. It is seen that the top shed and the middle one are categorized in HC 1 while the bottom shed is HC 2. From the figure 5 it is evident that the middle shed has better condition among the others which confirm the FTIR and EDX results. It is noticeable that although the insulator has been in service for 14 years it seems like a virgin one and no sign of severe degradation detected. The sheds surfaces still remained hydrophobic.

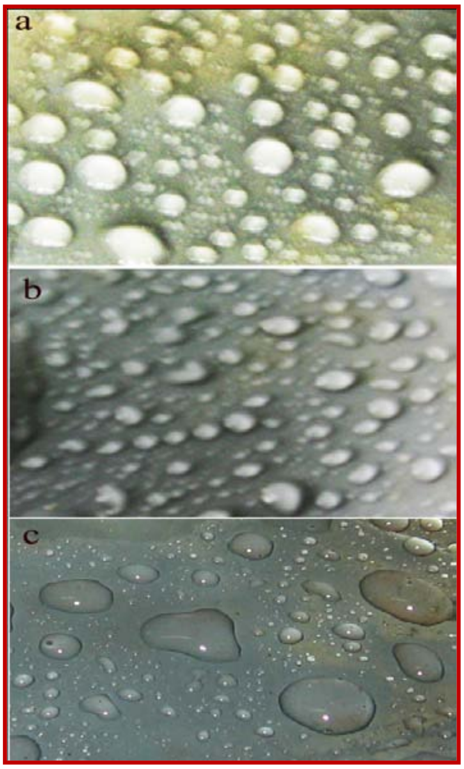

Figure 5: STRI hydrophobicity classifications test. a: Top shed, b: Middle shed, c: Bottom shed

4 CONCLUSION

Aging in different parts of 14 year old in-field insulator have been discussed. The results revealed that there are no considerable differences in aging among for directions of individual sheds but comparison of the sheds showed that the middle one has better condition than others.

The STRI hydrophobicity class test showed that the insulator has remained its hydrophobicity and the middle shed has the most hydrophobicity. The top shed and the middle shed are categorized in HC1 while the bottom shed is HC2.

5 REFERENCES

[1] H. Hillborg and U. Gedde: "Hydrophobicity changes in silicone rubbers", *Dielectrics and Electrical Insulation, IEEE Transactions on,* vol. 6, pp. 703-717, 2002

[2] M. Amin*, et al.*: "HYDROPHOBICITY OF SILICONE RUBBER USED FOR OUTDOOR INSULATION (AN OVERVIEW)", *Rev. Adv. Mater. Sci,* vol. 16, pp. 10-26, 2007

[3] Y. Xiong*, et al.*: "Surface analysis of asymmetrically aged 400 kV silicone rubber composite insulators", *Dielectrics and Electrical Insulation, IEEE Transactions on,* vol. 15, pp. 763-770, 2008

[4] J. P. Lewicki*, et al.*: "Investigating the ageing behavior of polysiloxane nanocomposites by degradative thermal analysis", *Polymer Degradation and Stability,* vol. 93, pp. 158-168, 2008

[5] J. Kim*, et al.*: "The mechanisms of hydrophobic recovery of polydimethylsiloxane elastomers exposed to partial electrical discharges", *Journal of Colloid and Interface Science,* vol. 244, pp. 200-207, 2001

[6] J. Reynders*, et al.*, "Surface ageing mechanisms and their relationship to service performance of silicone rubber insulation," 1999, pp. 54-58 vol. 4.

[7] N. Yoshimura*, et al.*: "Electrical and environmental aging of silicone rubber used in outdoor insulation", *Dielectrics and Electrical Insulation, IEEE Transactions on,* vol. 6, pp. 632-650, 1999

[8] H. Liu*, et al.*: "Characterization of a severely degraded silicone elastomer HV insulator-an aid to development of lifetime assessment techniques", *Dielectrics and Electrical Insulation, IEEE Transactions on,* vol. 12, pp. 478-486, 2005

[9] J. Kim*, et al.*: "Hydrophobic recovery of polydimethylsiloxane elastomer exposed to partial electrical discharge", *Journal of Colloid and Interface Science,* vol. 226, pp. 231-236, 2000

[10] J. Reynders*, et al.*: "Review of aging and recovery of silicone rubber insulation for outdoor use", *Dielectrics and Electrical Insulation, IEEE Transactions on,* vol. 6, pp. 620-631, 1999.

[11] Hydrophobicity Classification Guide, Guide 1, 92/1.