ISTANBUL UNIVERSITY –
JOURNAL OF ELECTRICAL & ELECTRONICS ENGINEERING

YEAR : 2007 (387 - 391)
VOLUME : 7
NUMBER : 2

SURFACE PROPERTIES OF POLYESTERS BLENDED WITH BORAX MINERAL

Aysel ERSOY[1] **Ayten KUNTMAN**[2]

[1,2] University of Istanbul, Electrical-Electronics Engineering Department
Avcilar, 34850, Istanbul

[1]E-mail : aersoy@istanbul.edu.tr [2]E-mail : akuntman@istanbul.edu.tr

ABSTRACT

In this study the effect of borax existence on tracking and erosion resistance of polyesters has been investigated by means of defining contact angle and performing SEM analysis. Samples with different borax concentrations were tested under 4 kV AC voltage in an inclined plane tracking test apparatus prepared according to ASTM D2303 standard. The results and SEM analysis indicate that addition of borax mineral to test specimens prevents the formation of free carbon over the surface of the composite samples and hence the specimens are mostly damaged by the erosion of the surface. Also by increasing the borax ratio in polyester samples, the contact angle increases and these results also supports the change in surface behavior for erosion rather than tracking.

Keywords: : *Borax mineral, surface tracking, SEM analysis, contact angle.*

1. INTRODUCTION

Fast industrial and economic developments in today's world result in extensive usage of electrical energy and in line with this growth the need for reliable power increases day by day. Electrical transmission grid is more vulnerable to congestion and outages than ever. Generation of power is usually not close to consumers, so it has to be transmitted over long distances. Long-distance transmission of electricity is only feasible at high voltages. Utilization of high voltages for power transmission is indispensable and absolutely necessary, but it introduces isolation issues that have to be taken care seriously. In that regard need for reliably handling these high voltage levels on power transmission networks requires new studies in order to improve operation conditions of transmission line equipment ensuring efficient and safe service.

Polymeric insulators are very widely used and have been increasingly accepted by utilities as suitable replacements for porcelain and glass insulators in power transmission because of their excellent mechanical, thermal and dielectric properties. The increased usage of polymeric insulators prompted much interest in detailed investigations of their surface properties. Polymeric surfaces are often difficult to wet because of their low surface energy. However long term exposure of polymer surfaces to environmental stresses may change their chemical composition, modify their morphology, remove their weak boundary layers and increase their surface energy.

Received Date : 24.08.2007
Accepted Date: 05.12.2007

As an insulation material polyesters are widely used in industry from small electrical components to very large structures. It is necessary to study the dynamic properties of the polyester surfaces in order to elaborate a reliable test methodology, and also to increase our understanding on the degradation mechanisms of polymeric insulators [1].

In this study, in order to investigate effect of borax addition to pure polyester on its surface properties, specimens were prepared by borax addition to unsaturated polyester resin at different percentages. These prepared composite insulation specimens were artificially aged according to Inclined Plane Test. In order to have a better accuracy on the results, several factors that affects the test results such as humidity, temperature, applied voltage, contaminant flow rate, etc. were tried to be kept stable at within certain values during the test period. All tests have been performed accordingly to the ASTM D2303 test standard [3].

1.1. Surface Hydrophobicity

Surface properties are important in many material related problems. Surface property is directly related to the bulk property since a surface is a discontinuous boundary between different phases. If ice is being melted, then there are two surfaces created between three phases, i.e., liquid, gas and solid. The surface tension develops near the phase boundaries since the equilibrium bonding arrangements are disrupted leading to an excess energy which will minimize the surface area other means of minimizing the surface energy are to attract foreign materials or bonding with the adsorbent.

If a liquid is dropped on a solid surface then the liquid droplet will spread on that surface as shown in Figure 1. The shape of the water droplet depends on the material of the solid and the physical and chemical states of the surface. At equilibrium the sum of surface tensions among the three phases (gas, liquid and solid) in the solid plane should be zero since the liquid is free to move until force equilibrium is established. The relationship between surface tension and contact angle is as follows,

$$\cos\theta_c = \frac{\gamma_{GS} - \gamma_{LS}}{\gamma_{GL}}$$

where θ_c is called the contact angle, γ_{GS} is gas-liquid surface tension, γ_{LS} is liquid-solid surface tension and γ_{GL} is gas-liquid surface tension. Solid surfaces are characterized as either high or low energy surface. The high energy surface is wetted readily and allows water to spread over it in a continuous film. In this case the contact angle is zero and the surface is said to be completely wetted and is hydrophilic. On the other hand the low surface energy repels water such that the droplets stand separately. In the latter case the contact angle is high (> 90º) and the surface is said to be hydrophobic or water repellent. Water droplets tend to run off a low energy surface.

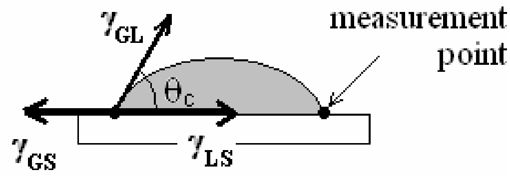

Figure 1: Determination of the static contact angle, θ_C.

Advancing contact angle for determination of hydrophobic character of the surface and receding contact angle for determination of hydropilic character of the surface were measured at both left and right sides of the drop (Figure 1). The contact angles of polymers were calculated from the average of these measurement values.

Inorganic porcelain and glass insulators have poor electrical performance in wet conditions due to mainly their hydrophilic surfaces, whereas polymer insulators exhibit superior electrical properties because of their hydrophobic surfaces. However, the hydrophobicity can be lost temporarily by corona discharges, dust, contamination and dry band arcing. After corona discharge polymer insulators can recover their hydrophobicity and keep its electrical performance [4-7].

2. EXPERIMENTAL PROCEDURE

2.1. Materials

All tests have been performed according to the ASTM D2303 test procedure under 4kV AC applied voltage and 36ml/h contaminant flow rate. Polyester samples have been prepared with 0.25% MEKP (Methyl Ethyl Ketone Peroxide) and 0.25% cobalt as an accelerator. All powder like borate minerals had diameter less than 35 µm and they were added to unsaturated polyester resin at different percentages in terms of total mass. Final products are kept in an 45 ºC oven for 4 hours and then cut in pieces obtaining the specimens which have dimensions of 100mm x 55mm x 9mm.

2.2. Inclined Plane Tracking Test Procedure

Throughout their service life outdoor HV insulators are subjected to various destructive external disturbances such as climatic conditions which basically affect rheir electrical performance. In this study several polymeric composite insulators enriched with borax mineral were artificially aged according to ASTM D2303.

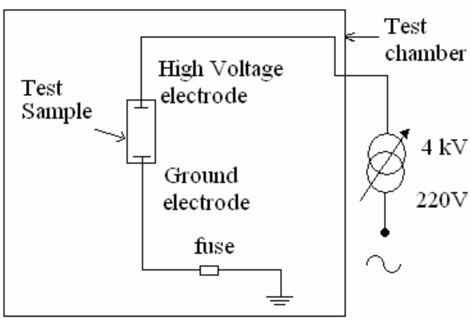

Figure 2: Test setup according to ASTM D2303 standard

A batch of 5 samples has been used to study each different percentage of borax mineral. The basic test setup has been shown in Figure 2.

2.3. Static Contact Angle

The measurement of contact angles of polyester specimens was performed according to the sessile drop technique by Goniometer (NRLCA model). All contact angle measurements were carried out in both original/untested and tested polyester specimens. A drop of distilled water with a tight syringe was placed on the polymer surface. The setup for the measurement of the static contact angle was given in Figure 3. The droplet of de-ionized water, which is placed onto the surface of the test sample, is photographed by a CCD camera. The output of the camera is connected to a PC for measuring the contact angle. The evaluation of the photograph is performed from left and right side of the water droplet which is shown in Figure 1 as measurement point.

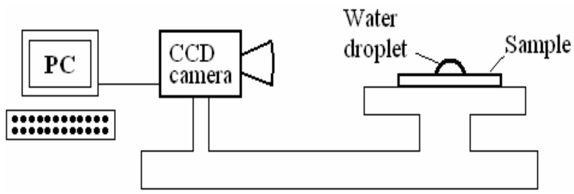

Figure 3: Experimental setup for the measurement of the static contact angle

2.4. SEM Analysis

SEM pictures of the polyester samples containing different ratios of borax were taken with a JSM 5600 on specimens sputtered-coated with a thickness of 20 nm layer of gold.

3. RESULTS AND DISCUSSION

3.1.Inclined Plane Test Measurements

Inclined plane test results revealed clearly that the borax mineral dramatically improves the breakdown time of polyester insulators. However, it changes the tracking behavior of the specimen as shown in Figure 4. In our previous studies the change of lifetime of specimens depending on borax concentrations is reported in detail [2].

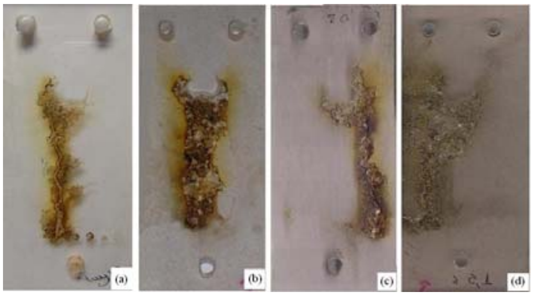

Figure 4: Polyester samples tested at 4 kV AC voltage and 36 ml/h contaminant flow rate (a) pure, (b) with 0.5% borax, (c) with 1.0% borax, (d) with 1.5% borax.

3.2. Contact Angle Measurements

Table 1 indicates the mean values of contact angle which were obtained from left and right side of water droplet placed on the test sample. For the unaged polyester samples having different borax concentrations, the contact angle was measured in the centre of the sample. It can be easily seen from Table 1 that measurement results show a relation between percentage of borax mineral in the composite polyester samples and contact angle. Contact angle increases remarkably when borax ratio increases in small amount.

Table 1: The effect of borax concentration on contact angle value.

Insulating material	Contact angle, θ_c
Polyester sample	66,23°
Polyester sample with 0.5% borax	69,95°
Polyester sample with 1.0% borax	70,96°
Polyester sample with 1.5% borax	72,77°

3.3. SEM Analysis

In Figure 5 the SEM pictures of pure polyester samples were given. In Figure 5.a the surface of unaged pure polyester was enlarged 1000 times. After the sample is artificially aged, the SEM picture of conductive paths was enlarged 25 times and given in Figure 5.b. Figure 5.c and 5.d indicate 1000 times enlarged conductive path after the inclined plane test. In pure samples it can be seen that development of degradation process seems porous like sponge.

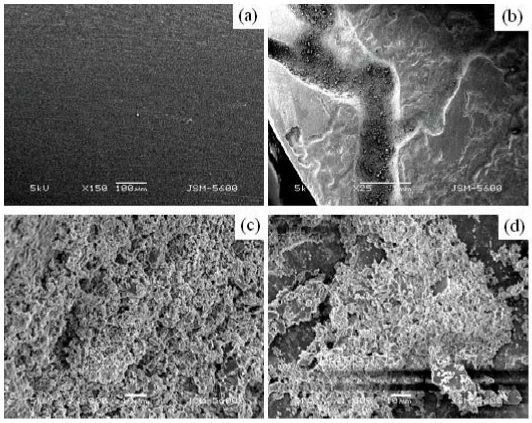

Figure 5: SEM pictures of the polyester samples (a) before IPT test and (b) after IPT test 25 times enlarged, (c) after IPT test 1000 times enlarged, (d) after IPT test 1000 times enlarged.

In Figure 6.a. the unaged polyester containing 0.5 wt% borax was given. The surface was smooth as shown in pure polyester samples. Here the tracking behavior of sample containing 0.5 wt% of borax was enlarged 25 times and shown in Figure 6.b. The porous tracking behavior was changed by adding 0.5 wt% borax to the polyester sample as shown in Figure 6.c. After the IPT test the glass like fibers can be seen in Figure 6.d.

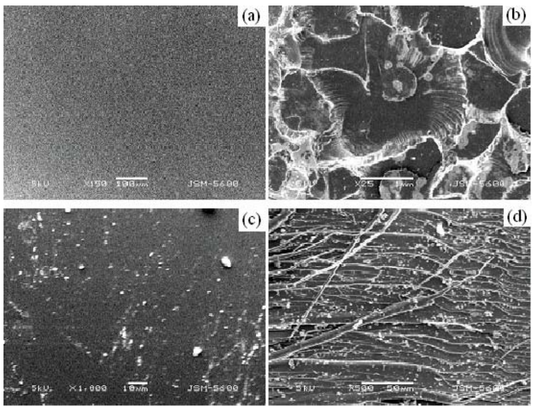

Figure 6: SEM pictures of the polyester samples containing 0.5% borax (a) before IPT test and (b) after IPT test 25 times enlarged, (c) after IPT test 1000 times enlarged, (d) after IPT test 1000 times enlarged.

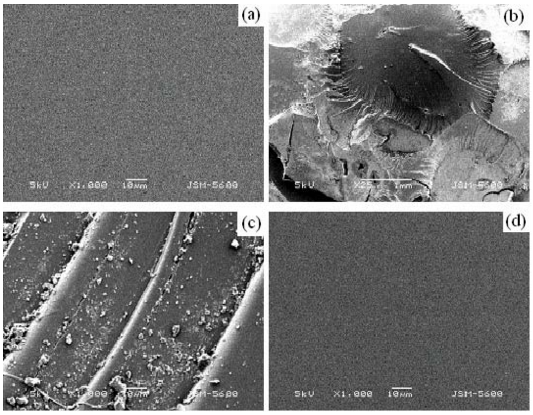

Figure 7: SEM pictures of the polyester samples containing 1.0% borax (a) before IPT test and (b) after IPT test 25 times enlarged, (c) after IPT test 1000 times enlarged, (d) after IPT test 1000 times enlarged.

When borax ratio is increased to 1.0 wt% surface of the unaged sample is the same as pure samples (Figure 7.a). After aging, the sample surface was eroded as shown in Figure 7.b. The surface picture was enlarged 25 times in Figure 7.b. While the fibrous degradation can be seen in Figure 7.c. The glass like degradation can be seen in Figure 7.d.

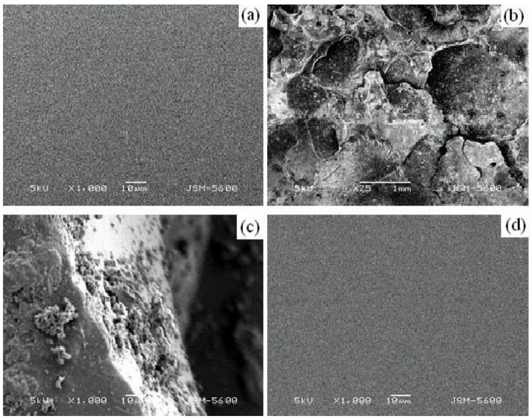

Figure 8: SEM pictures of the polyester samples containing 1.5% of borax (a) before IPT test and (b) after IPT test 25 times enlarged, (c) after IPT test 1000 times enlarged, (d) after IPT test 1000 times enlarged.

Unaged polyester containing 1.5 wt% borax was shown in Figure 8.a. It is smooth and the same as pure and samples having a small amount of borax. Here the thickness of eroded area is increased and shown in Figure 8.b. In Figure 8.c this thickness can be seen more clearly. The surface of aged samples was enlarged 1000 times and it shows glass like degradation as samples containing 1.0wt% borax.

4. CONCLUSION

In this study it has been tried to show how addition of borax mineral to pure polyester sample at some different percentages enhances the surface properties of polyester by indicating the test results obtained from artificial aging in line with ASTM D2303. Test results have been evaluated with SEM pictures as well as measurement of contact angle on specimens prepared with different ratios of borax in polyester.

The hydrophobicity of unaged surface of polyester samples increases a little by the increase in borax concentration. This increase may be caused by borax ore which was deteriorating during the sample curing.

The SEM pictures indicate how surface properties of samples differ after aging process. Before the IPT test all the samples have very smooth surfaces. However after dry band arcing borax added samples eroded rather than indicating tracking phenomenon. Figure 6, Figure 7 and Figure 8 concluded that during the IPT test continuous discharges increase the temperature of the surface of the insulator which eventually accelerates the breakdown process. When subjected to high temperatures, borax minerals produce a thin glass like sheet on the surface of the insulator, which prevent thermal degradation. Therefore, usage of this type of composite material in manufacturing of insulation equipment such as overhead line insulators might be very useful.

5. REFERENCES

[1] M.Ugur, A.Kuntman and A.Ersoy, “A Study on the ageing process for polyester resin using improved Weibull statistics”, Electrical Engineering, Springer-Verlag Heidelberg, Vol. 85, No. 5, pp. 283-288, 2003.

[2] A. Ersoy, A. Kuntman, M. Uğur, “Kaçak Akım ve Harmonik Bileşenler Kullanılarak Bor Katkılı Polimerik Yalıtkanların Yaşlanma Sürecinin İncelenmesi”, 15. Sinyal Işleme ve

Iletişim Uygulamaları Kurultayı SIU 2007, 11-13 Haziran 2007, Eskişehir.

[3] Standard test methods for liquid contaminant, inclined plane tracking and erosion of insulating materials, ASTM D2303, pp.258-270, 1983.

[4] S. M. Gubanski and A. E. Vlastos, "Wettability of naturally aged silicone and EPDM composite insulators", IEEE Transactions on Power Delivery, Vol. 5, No. 3, pp. 1527-1535, 1990.

[5] D. H. Han, H. Y. Park, D. P. Kang and H. G. Cho, "Effects of added silicone oils on the surface characteristics of silicone rubber", IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 9, No. 2, pp. 323-328, 2002.

[6] S. H. Kım, E. A. Cherney and R. Hackam, "Hydrophobic behaviour of ınsulators coated with RTV silicone rubber", IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 27 No. 3, pp. 610-622, 1992.

[7]. N. D. Geyter, R. Morent and C. Leys, "Surface modification of a polyester non-woven with a dielectric barrier discharge in air at medium pressure", Surface and Coatings Technology, Vol. 201, pp. 2460-2466, 2006..

Aysel ERSOY was born in Eskişehir in 1978. She received her B.Sc. and M.Sc. degrees in Electrical and Electronics Engineering from Istanbul University in 2000 and 2003, respectively. She is a Ph.D. student at Istanbul University at Electrical-Electronics Engineering Department. Since 2001, she has been working at Istanbul University Engineering Faculty as a research assistant. Her research interests are high voltage technique, and HV insulation materials.

Ayten Kuntman received her MSc degree in 1979 from Istanbul University and her Ph.D. degree in 1989 from Istanbul Technical University (ITU), Turkey. From 1980 to 1995 she worked as an engineer at I.T.U., Faculty of Electrical & Electronics Engineering, Microelectronics Lab. Since 1995, she has been working at the Electrical-Electronics Engineering Department of I.U. as a Professor Dr Kuntman is the author of one book and has published over 100 papers in journals and conference proceedings. Her research interests include semiconductors, microelectronic technologies and dielectric properties of polymers.