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# Behaviour of modified insulator surface material under electric stress

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## Abstract

Performance of electrical insulators is strongly dependent on their surface properties. In practice manufactures and utilities are using different means to improve them. New materials the insulators or coatings have been used in electric power systems. Also new technologies are tested to modify insulators glaze, mainly plasma processes. During these processes some changes in the constitution of glaze has to be done and then a new hydrophobic layer is created. Some electrical and physical properties of modified (silicon rubber and fluorourethane coatings, plasma technology) and non-modified real insulators glaze have been presented. These investigations have shown that plasma processes are able to improve the surface properties of the glaze. Since the electrohydrodynamic behaviour of water droplets on the outdoor electrical insulation surface is very important, observations have been done by using a high-speed photo camera.

Keywords: insulator, glaze, hydrophobicity, flashover, water drops

## 1. Introduction

The performance of outdoor insulators is critical for the reliability in the operation of electrical power systems. When they are subjected to the influence of atmospheric conditions and especially in the presence of some kinds of contaminants the flashover along the insulators sometimes occurs. There are a few preventive methods available to overcome contamination causing insulators flashovers: *temporary solutions* (periodic washing and cleaning, silicon grease coating), *permanent solutions* (increase the leakage distance, silicon rubber coatings RTV or HTV, fluorourethane coating, polymer insulator - silicon rubber)/1,2,3,4/. None of the solutions mentioned above can be considered very satisfactory for the lack of their longevity.

The surface of insulator should ensure not only high dielectric properties but also a low coefficient of friction, antielectrostatic properties and low surface energy. A lot of experiments have shown that in the case of conventional insulators the hydrophilic properties of glaze are responsible for the insulator surface dielectric breakdown processes. A hydrolysis of silicon oxide during manufacturing technology of glaze make their surface highly hydrophilic. Such high energy surface is wetted readily and allows water to spread over it in a continuous film and makes it easier to develop surface flashover especially in a contaminated area and during wet atmospheric conditions.

To decrease the value of the material surface energy a new, alternative to the mentioned above, i.e. plasma technology has been studied /5,6/. Herein, some investigations of ceramic samples modified by plasma processes are reported. The results for the ceramic are compared with other low energy materials: the silicon rubber RTV /SR./ and the fluorourethan /FU/. The behaviour of the water drop on the highly hydrophobic materials under electric stress have been studied by using a high-speed photo camera. The electrohydrodynamic behaviour of the water drop has been recognized as very important for the development of the flashover/7,8 9/.

## 2. Plasma polymerization processes

The polymer formation that take place when a glow discharge of suitable monomer vapour is sustained is referred to as plasma polymerization /PP/ or glow discharge polymerization. The polymer formed by PP can take the form of a thin film on an exposed surface /10,11/. The polymers formed are unique materials that cannot be prepared by other conventional means of polymerization. The PP is a promising approach to the development of polymeric coatings and surface treatments for the variety of applications in the electrical and electronics industries /11/. The ions of working gas bombarding the glaze surface cause the emission /sputtering/ of surface atoms /sodium, potassium and others/ being responsible for creating of the hydrophilic properties of glaze. Then after the injection of a suitable monomer /low molecular compound with silicon - oxygen bonds/ into a plasma reactor, various components of the plasma interact with the surface of the substrate promoting their electrochemical interaction. In the case of organo-silanes monomers in a final stage the stable and hydrophobic layer is created on the substrate surface.

## 3. Experimental procedure

The glazed ceramic samples with a diameter of 110 mm and 5 mm thickness were used in the experiments. After cleaning and drying each sample at a temperature of 110° C for 1.5 hours they were placed inside a bell-jar reactor with parallel plate electrodes inside it the PP was conducted. The parameters and the steps of PP were described somewhere else /6/. As it was shown in /5/ during PP, the concentration of hydrophilic elements are reduced and hydrophobic groups are chemically firmly bonded on the surface to form a new low energy layer.
In order to compare the plasma modified glaze with other materials a few samples were covered with SR and FU coatings being applied world-wide in high contaminated areas. The samples were then placed inside the fog chambers into which very fine 2.3 μm deionized water mist was injected. The mist was generated by an ultrasonic fog generator. Inside the small chamber /21x18x9 cm/ the surface resistivity was measured.

The measurements of AC flashover in a non-uniform electric field and the observation of the behaviour of the water drop were carried out inside the fog chamber /51x50x 60 cm/ which is shown in Fig.1. The chamber is twice bigger in volume than that used in /6/. The voltage was being raised at 2 kV/s until flashover occurred. It was measured with a capacitive divider. Before and after the high voltage tests the values of the contact angle were measured. In this study an attempt was made to determinate the time of the hydrophobic recovery of the tested materials on the path of spark channels.
The behaviour of the water drop of up to 30 μl volume, which was placed with a precision syringe between electrodes, was observed by means of a high-speed photo camera Pentazet 16. The camera has a speed of 300 - 3000 frames per sec. The electrode were supplied with an AC 60 kV/10 kVA test transformer.

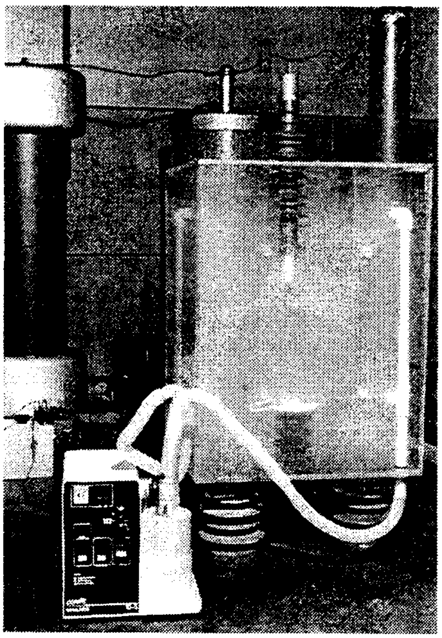

Fig.1. The AC high voltage arrangements.

**4. Results and discussion**

The modified glaze repellence was first studied by using a deionized water drop of 6 μl and measurements of the contact angle by the optical method. In order to investigate the loss of hydrophobicity and the recovery time the above studies were repeated after the high voltage tests. The initial values of the contact angle were as follows: SR (115°), FU (91°), HMDSO (88° - 92°) and HMDS (90° - 93°). The values have proved that the low energy layer was built on the glaze during PP.

The measurements of the leakage current after 15 minutes of wetting in the fog chamber showed that all the coatings tested at DC voltage being equal 3 kV had the same range of the current. But at 10 kV the PP materials had about 3 times lower value of the leakage current: SR and FU (0.19 mA), PP materials (0.04 - 0.06 mA).

The surface resistivity measurements were made at 10 V DC voltage between two alumina foil electrodes of 100 mm length placed on the samples at a distance of 10 mm. The results discussed above are shown in Fig. 2. After the first minute of wetting them a significant decrease of their surface resistivity was observed for all types of samples although, it is only about 2 - 3 orders for coatings and PP films in comparison with 5 orders for non-modified samples. Moreover, for the clean glaze and the coatings there is a slow decrease of resistivity in the function of the wetting time. It is difficult to explain a noticeable slow increase of resistivity for PP modified samples.

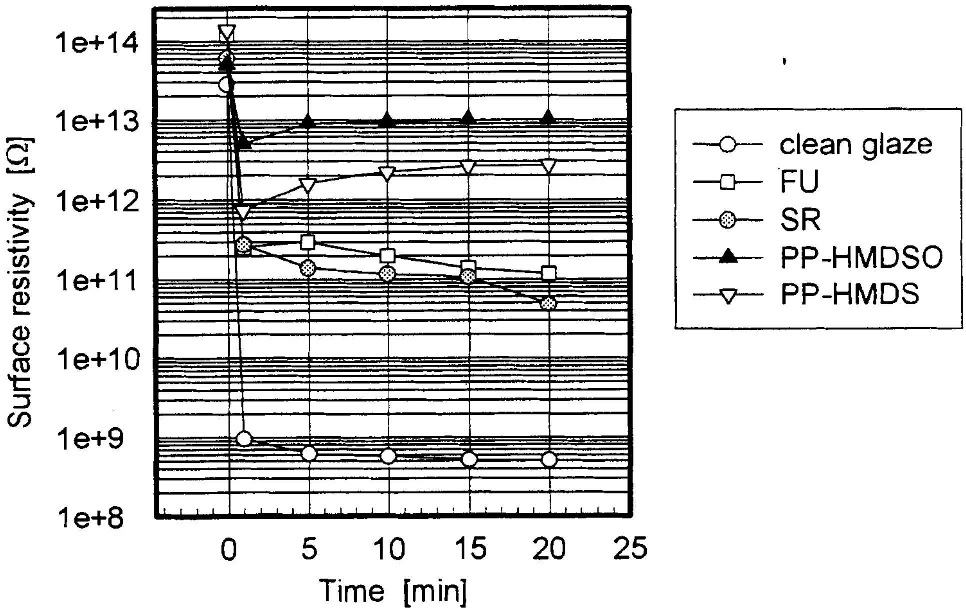


Fig. 2. Surface resistivity versus the wetting time in the small fog chamber: SR - silicon rubber coating, FU - fluorourethan coating, PP - plasma modified samples.

The AC flashover was measured in the fog chamber (Fig.1.) for a period of 30 minutes, i.e. since the time the fog generator was switched on. The tests were carried out for a finger like electrodes at a distance of 50 mm. The results are shown in Fig.3. An observation was taken that during the tests the non-modified (hydrophilic) surface was wetted readily by big droplets and after the second application of voltage the water spread over the surface on a wide area in continuous film. For the coated and PP modified samples the surface was covered by very fine droplets. The loss of hydrophobicity was noticed after four flashovers (20 minutes of wetting), and the water film developed only along the path of flashovers. The results obtained showed that the coatings and PP films gave a very similar level of breakdown voltages. It is obvious that the simultaneous wetting and flashovers cause the loss of hydrophobicity. The repeated study of the contact angle after the high voltage tests indicated a 20 - 24 hours time to recover the 80% of the initial value of the contact angle.

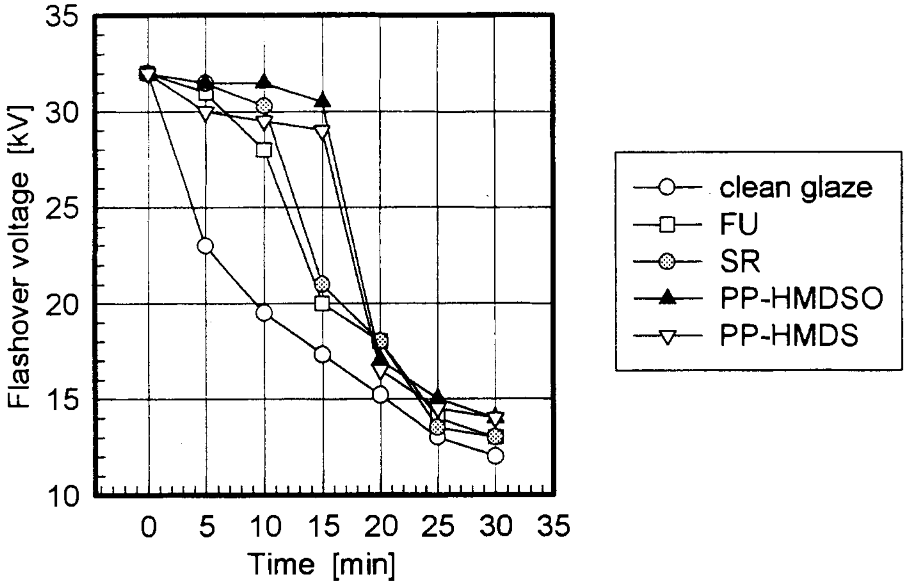


Fig.3. AC flashover voltage versus of the wetting time in the fog chamber.

The observations of the behaviour of the water drop on the hydrophobic surfaces stressed by an AC electric field have shown that:

- when a single deionized water drop was located between electrodes with a quasi-uniform electric field, the drop instability was not observed. Before the flashover the vibrations of the drop shape took place. That event is in agreement with the model in which the drop triggers the surface flashover /7/.

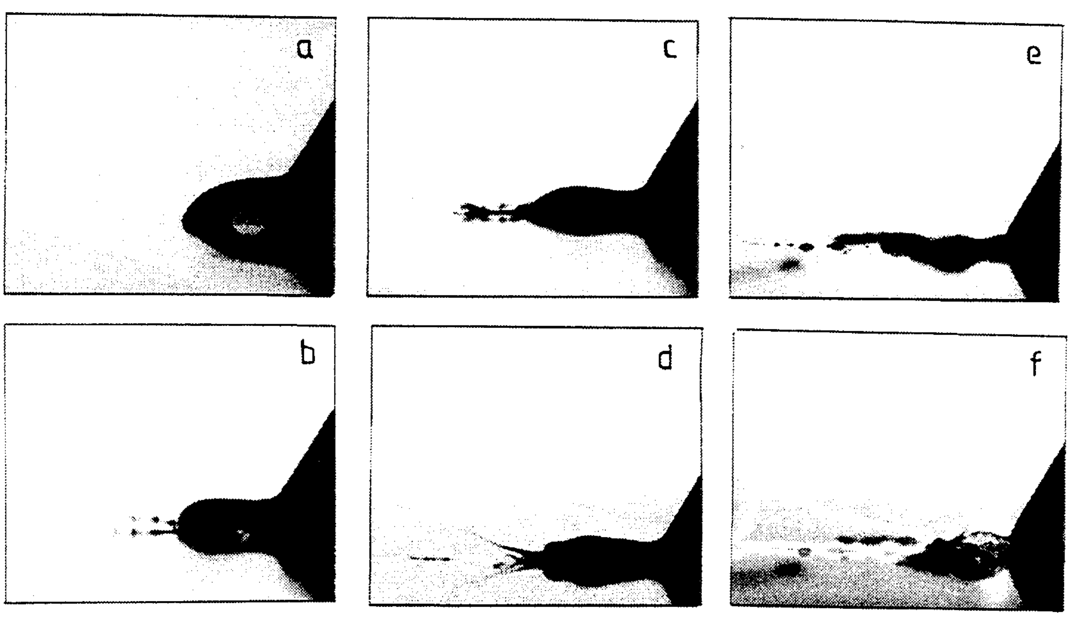


Fig.4. The instability of the water drop located on the hydrophobic surface before the flashover: drop volume 20 μl, AC non-uniform electric field.

- when two or more (up to five) drops were placed uniformly between electrodes at the distance between the drops being bigger than their diameter, the similar behaviour was observed just as mentioned above.
- in case when the drop was in contact with the sharp-ended electrode the electrohydrodynamic events related to the instability of the drop took place before the flashover. In Figs.4a - c a deformation, an injection of fine droplets from the "cone" shape end of the drop and in Figs.4d - f a rapid elongation of the drop and the flashover took place, respectively.
- in case when the hydrophobic surfaces (SR, FU, PP) were wetted in the fog chamber and covered with very fine droplets (distance smaller than diameter), the electric field increasing in time caused the coalescing of the droplets and finally the formation of water channels triggering the flashover - Figs.5a - c.

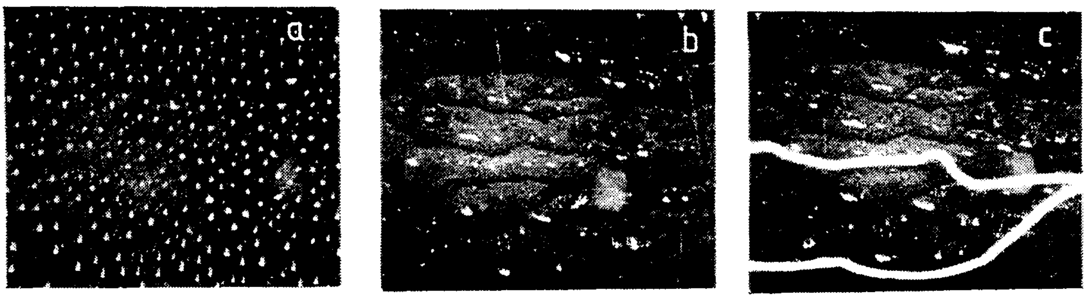


Fig. 5. The formation of the water channels and the flashover under AC voltage.

## 5. Conclusions

The investigated electrical and physical properties of the glaze of the high voltage insulators after plasma modification have similar properties to other tested hydrophobic materials used in the energy power technology. The values of the surface resistivity, the leakage current and the flashover voltage for the PP films were at the same range as for the silicon rubber and fluorourethan coatings. It means that the suitable plasma of glow discharges is able to build a stable, well adhesive to the glaze and highly hydrophobic layer. Even though, PP films are considered as chemically very stable and have various advantageous characteristics such as high hardness, mechanical toughness, and thermal stability for a new application a lot additional investigations have to be done.

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