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SURFACE CHARGE INFLUENCE ON THE BREAKDOWN VOLTAGE IN HE

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ABSTRACT

Electrostatic charging can occur by the accumulation of charge carriers on dielectric surfaces due to electrical discharges. The charges accumulated on dielectric materials in an electrical discharge device change the potential distribution, so that the electric strength of the device can be decreased. Some areas inside of the electrical discharge devices are electrically charged during the discharge, even after switch-off, charges remain for a significant time on the dielectric surface. At a new attempt to ignite the discharge, it is seen that the value of the breakdown voltage is dramatically modified. The influence of the charge accumulation on the dielectric surfaces was investigated using a discharge device that allows dielectric surface polarization. The breakdown voltage values as a sensitive measurement of the accumulated charges on the dielectric walls of the discharge device were measured.
Keywords: Plasma, He gas discharges, charge accumulation on dielectric surfaces.
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HELYUM ATEŞLENME VOLTAJINA YÜZEY YÜKLERİNİN ETKİSİ

ÖZET

Elektrostatik depolanma elektriksel deşarjlar nedeniyle dielektrik yüzeyler üzerine yük taşıyıcılarının depolanması ile oluşabilir. Bir elektrik deşarj cihazı içindeki dielektrik materyaller üzerine depolanan yükler, cihazın elektrik alan şiddetinin azalmasına neden olacak şekilde potansiyel dağılımını değiştirir. Deşarj süresince, hatta deşarj sona erdikten sonra, elektriksel deşarj cihazının içinin bazı kısımları elektriksel olarak yüklenir, bu yükler dielektrik yüzey üzerinde uzun bir süre kalırlar. Bundan sonra deşarj yeniden ateşlenmeye çalışılırsa, ateşlenme voltajı değerinin önemli derecede değiştirilmiş olduğu görülür. Dielektrik yüzeyler üzerine yük depolanmasının etkisi, dielektrik yüzey polarizasyonuna izin veren bir deşarj cihazı kullanılarak incelenildi. Deşarj cihazının dielektrik çeperlerine depolanmış yüklerin hassas bir ölçümü olarak ateşlenme voltajı değerleri ölçüldü.
Anahtar Sözcükler: Plazma, helyum gaz deşarjları, dielektrik yüzeyler üzerine yük depolanması.

1. INTRODUCTION

The plasma state which is the fourth state of matter can be produced in the laboratory by raising the energy content of matter regardless of the nature of the energy source. Thus plasmas can be

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generated by mechanical, thermal, chemical, radiant, nuclear, and electrical energies, and by the combination of them. The easiest way to inject energy into a system in a continuous manner is with electrical energy; and that is the reason why electrical discharges are used to produce the most common man-made plasmas. Most electrical discharge reactors are made of cylindrical insulating tubes (generally glass or alumina) and are provided with two disc-, plate- or needle-shaped electrodes [1-2]. The electrodes can be covered by insulating surfaces in some electrical discharge reactors, as in the dielectric barrier discharges [3]. Breakdown voltage is the minimum value of the high voltage applied between the electrodes in order to ignite the gas plasma in an discharge reactor. The dependence of the breakdown voltage on the product between electrode distance and gas pressure is depicted by the so-called Paschen curves.

Electrical discharges at high voltage-electrodes may lead to accumulation of charge carriers on insulating surfaces. The formation of surface charges influences the potential distribution in electrical devices and the electric strength of the device can be decreased [4-8]. The insulating areas inside the electrical discharge devices are electrically charged during the discharge, even after switch-off, charges remain on the insulating surfaces for a significant time. At a new attempt to ignite the discharge, the value of the breakdown voltages is dramatically modified.

A plasma display panel (PDP) is essentially a matrix of micro-discharges which are controlled in a complex way by electronic drivers. Each pixel of a PDP is composed of three elementary UV emitting discharge cells. The plasma in each cell of an alternative current (ac) PDP is generated by dielectric barrier discharges (DBDs) operating in a glow regime in a rare gas mixture [9]. Such charge accumulation behavior has been used in the last two decades to develop the plasma display panels with intrinsic memory [10]. Indeed, at the ignition of a matricial barrier discharge pixel, electrical charges start to be accumulated on the dielectric surface at a time shorter than half a period of the applied 10-100 kHz ac voltage. The electric field in the inter-electrodic space becomes zero and the discharge is extinguished. Oscillograms of the current and applied voltage show a short current pulse with a half width of the order of μs. In the next half period when the polarity of the applied voltage is changed, the breakdown voltage is reduced with the potential difference created by the accumulated charges on the dielectric surfaces.

The results concerning the accumulated charge effect on the breakdown voltage in He gas discharges were presented in [11, 12]. We have measured the breakdown voltage at various values of the polarization potential. In this study, Paschen curves of He gas discharges were established with and without applying polarization potential.

2. EXPERIMENTAL DEVICE

The experimental device used in Ovidius University of Constanta is shown schematically in Fig. 1. It consists of a glass device with two 15 mm long cylindrical electrodes with 4 mm inner and 16 mm outer diameters. The distance between electrodes is 50 mm. The glass envelope with a diameter of 25 mm has a tube diameter reduced to a capillary tube with 6 mm diameter along 20 mm length centered at equal distance from the electrodes.

At the tube axis a 0.5 mm diameter tungsten wire is mounted, and it is covered tightly all along with a thin layer of pyrex glass. The 6 mm capillary glass tube is covered with an aluminum foil. In order to polarize the dielectric surface inside the capillary tube and to accumulate electrical charges, a dc voltage with an established value can be applied between central glass insulated wire and the aluminum foil.

The discharge device is connected to a vacuum-pumping system with an end vacuum lower than 10^{-5} torr. Various gases at known pressures can be introduced into the discharge device, including gas mixtures. New gas tubes can be mounted to the system.

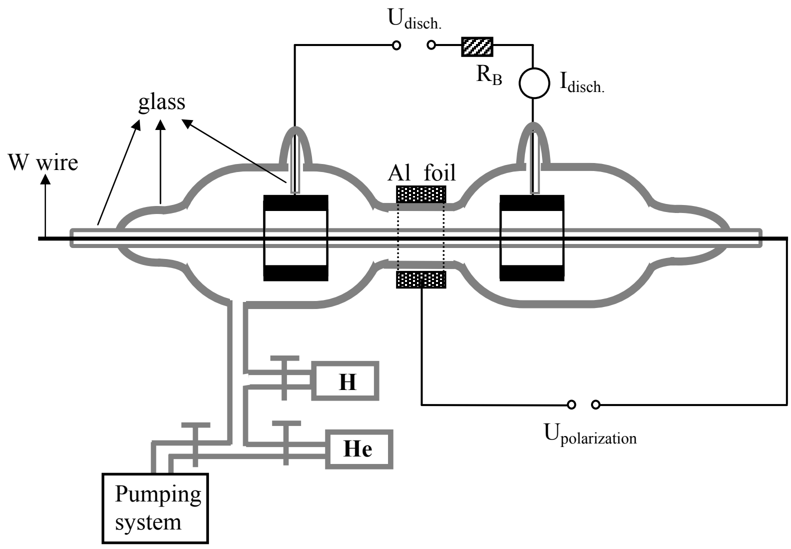

Figure 1. Schematically experimental device. H and He gas tubes besides various gas tubes can be mounted to the system

3. RESULTS AND DISCUSSIONS

We selected as parameters of the experiment the nature of the gas (or gas mixture), the gas pressure, the value of the applied polarization potential, wall polarity (+ or -), time of the discharge duration before breakdown voltage measurement, and interval of time between discharge switch-off and breakdown voltage measurement.

The experiment was established only in He filling various pressures, the wall polarity was negative, and the polarization potential was U_{pol} =550 V. When the polarization potential was applied, the discharge current was fixed between 20 and 25 mA. The time interval between the discharge switch-off and a new measured breakdown voltage was of 20 s. The time duration of the discharges to charge the dielectric wall was 45 s. The voltage pulses are shown in Fig. 2. In Fig. 3 are given the obtained experimental results for the breakdown voltage versus product of pressure and distance between electrodes, i.e. p times d. For each given set of data we measured breakdown voltage ten times and used the average value as breakdown voltage for the measured breakdown voltage. We repeated the experiment when polarization potential is zero. These results are also given in Fig. 3 as U_{pol} =0. In these reference measurements, the duration time of discharge and the time between two measurements was 20 s (see Fig 2.). In all these measurements, data corresponding to zero value of the polarization voltage were taken also with the central wire and aluminum foil connected to the circuit.

As can seen in Fig. 3, values of the breakdown voltage measured when the polarization voltage was applied are lower than those of in case of that polarization voltage was not applied. These observed dependences show the polarization potential change the value of the breakdown voltage. Our explanation to these observed dependences is charge accumulation on the dielectric wall of the discharge tube during the discharge time due to the applied polarization voltage. In addition, the difference between values of breakdown voltages measured with polarization and without polarization is higher in low pressure than high pressures.

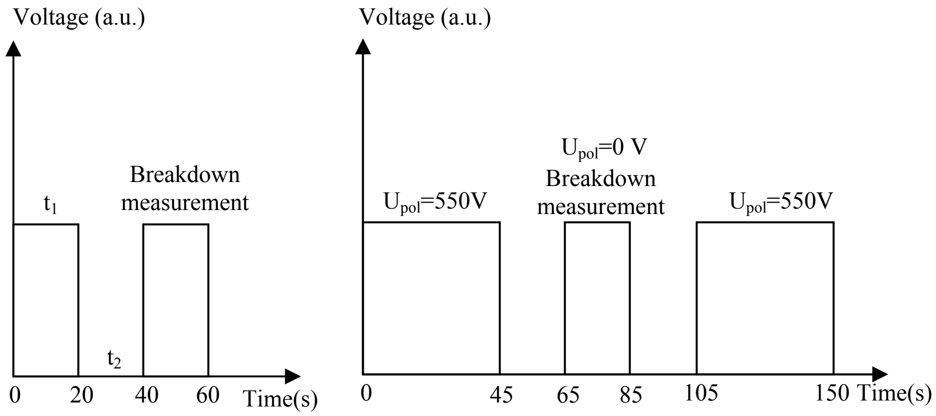

Figure 2. (a) The voltage pulses when polarization potential was not applied. **(b)** The voltage pulses when polarization potential was applied. t_1 indicates duration time of discharge, t_2 indicates time between two measurements

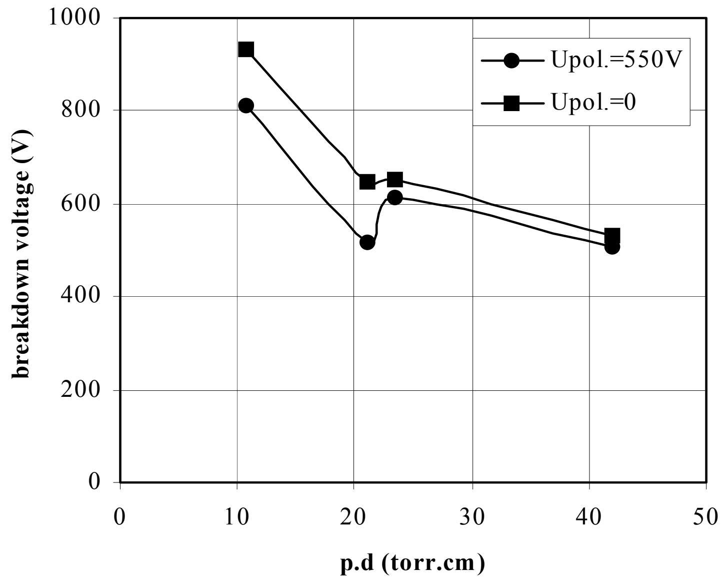

Figure 3. Breakdown voltage versus p times d obtained applying polarization voltage and without polarization voltage. "Upol" indicates the polarization potential

4. CONCLUSIONS

Obtained experimental results prove the strong influence of the wall polarization voltage on the value of the breakdown voltage. These results show the open possibilities to study the charge accumulation on the dielectric wall of the discharge devices using breakdown voltage value change.

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