

Electrical Breakdown Phenomena IN N-Pentane

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Abstract:

This paper shows the effect of electrode material and electrode polarity on the electrical breakdown processes in n-pentane. It is shown experimentally that the influence of electrode material and electrode spacing which produce other important physical parameters such as work function of electrode material, kind of streamers and dielectric constant of the liquid inside the cavity, act as control factors on the processes leading to electrical breakdown in hydrocarbon liquids.

ظواهر الانهيار الكهربائي في N-PENTANE

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ملخص البحث :

هذا البحث يناقش تأثير مادة القطب ونوع القطبية على عمليات الانهيار الكهربائي في السوائل الهيدروكربونية. وقد أظهرت التجارب العملية هذه التأثيرات التي أنتجت عوامل فيزيائية مؤثرة كدالة الشغل لمادة القطب، نوع الدفع و ثابت العزل الكهربائي للمادة العازلة. علما بأن جميع هذه العوامل تؤثر بوصفها عوامل مسيطرة على العمليات التي تؤدي إلى الانهيار الكهربائي في السوائل الهيدروكربونية.

Introduction:

During the last years, the investigation of d.c electrical breakdown phenomena in hydrocarbon liquids show that electrical breakdown depends on different parameters such as, electrode geometry, potential across the gap, gap spacing and the material of electrodes [Forster 1982a], which has been investigated in this work extensively.

In reading the literature on electrical breakdown of insulating materials one finds a lack of uniformity of experimental conditions. No matter what the nature of the dielectric between two metal conductors or electrodes, the breakdown of the material separating them is a statistical process. The probability depends to a large extent on fermentation factors, as well as on the conditions prevailing at the metal-dielectric interfaces. These conditions will influence the transfer of electrons from the electrodes into the dielectric [Forster 1982a].

The other important factor in breakdown processes in hydrocarbon liquids is the kind of streamers growth development through the gap and the velocity of these streamers. The increase in charge transfer of the discharge pulses with applied voltage is suggestive of the development of longer and more intense streamers in the dielectric liquids at the elevated electrical fields [Pompi et al. 2000].

In the case of streamers development under divergent field conditions (point cathode) the published results agree on the following aspects ; The streamers(usually more than one) originate at the cathode surface. Below breakdown voltage the streamers stop growing and never reach the anode. At and above breakdown voltage, secondary streamers appears to emanate from the primary ones. This growth process will continue provided the metal can supply sufficient quantities of electrons and applied potential remains constant or increases[Forster 1985].Since

the envelope of this region has been shown to be conductive, it can be considered as an extension of the cathode. Thus, the field in front of this low density region will increase as the region moves towards the anode, which is leading to local breakdown (partial discharges). Thus the primary streamer reaches its maturity and no breakdown of the gap will occur unless some disturbance sets in, such as an electro hydrodynamic instability. The occurrence of this instability is much probably in liquids containing impurities than in the highly purified ones [Kelley & Hebner 1981].

The local field in front of such an instability will increase as the secondary streamer moves rapidly towards the anode, this local field would allow ionization of the liquid and thus further speed up the growth process until a conducting channels bridges the gap and causing an electrical breakdown of the liquid [Forster 1985].

Less agreement exists in explaining the positive streamer growth under convergent field conditions (point anode) than in the case of negative one. Forster proposes that the positive streamer growth involves the extraction of thermalized excess electrons from the liquid into the anode metal [Forster 1982b]. In this model, the convergent field is visualized to focus such thermalized electrons around the point and thereby creates a very intense field near the anode which leads to field ionization and hence breakdown of the liquid caught between the electrons cloud and the anode surface. Once such a breakdown channel is formed, it can be considered, in view of its conductivity, to be an extension of the anode into the liquid [Kelley & Hebner 1981]. This process then repeats itself at a frequency and direction that depends on the regional availability of these excess electrons and the local field. While these events occur near the anode, electrons injection continues in the low field region of the cathode surface.

In general, the electrically intrinsic parameters such as breakdown voltage and leakage current are predominately determined by the conduction mechanisms in the dielectric. Also the energy barrier at the metal/dielectric interfaces might control the electron injection from metal into the dielectrics [Tsun Liu et al. 2003].

Experimental :

The data reported here were taken with a point-plane gap having different materials of electrodes (Al, Ag, Cu), with an inter electrode spacing which was adjustable by means of traveling microscope up to 0.1 mm. The dc voltage applied to the gap was obtained from power supply up to 12 Kv, and the electrical fields act on the cavity are either divergent or convergent ones.

Detailed description of the apparatus can be found else-where Luqman 1990, the dielectric liquid used in this investigation is n-pentane purified by means of chemical distillation described in Louis 1988.

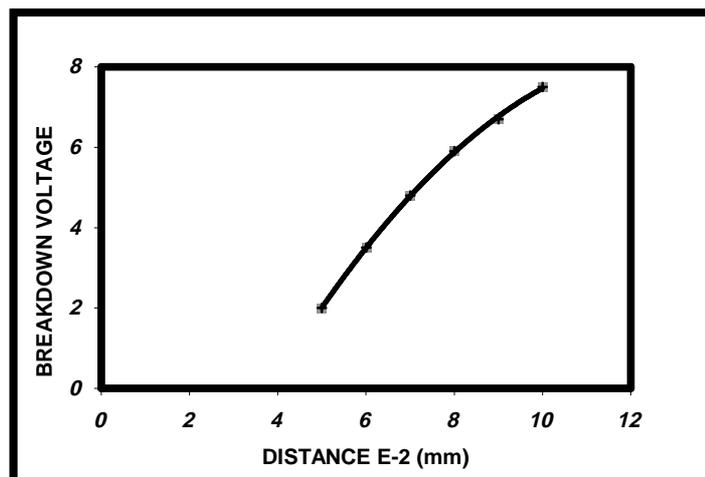
Result and Discussion :

A distilled n-pentane was used in this investigation as a dielectric material between the two electrodes of the test cell. The electrode materials used are Aluminum, Copper and Silver. The conduction current growth has been studied as well as breakdown onset potential in each kind of electrodes system.

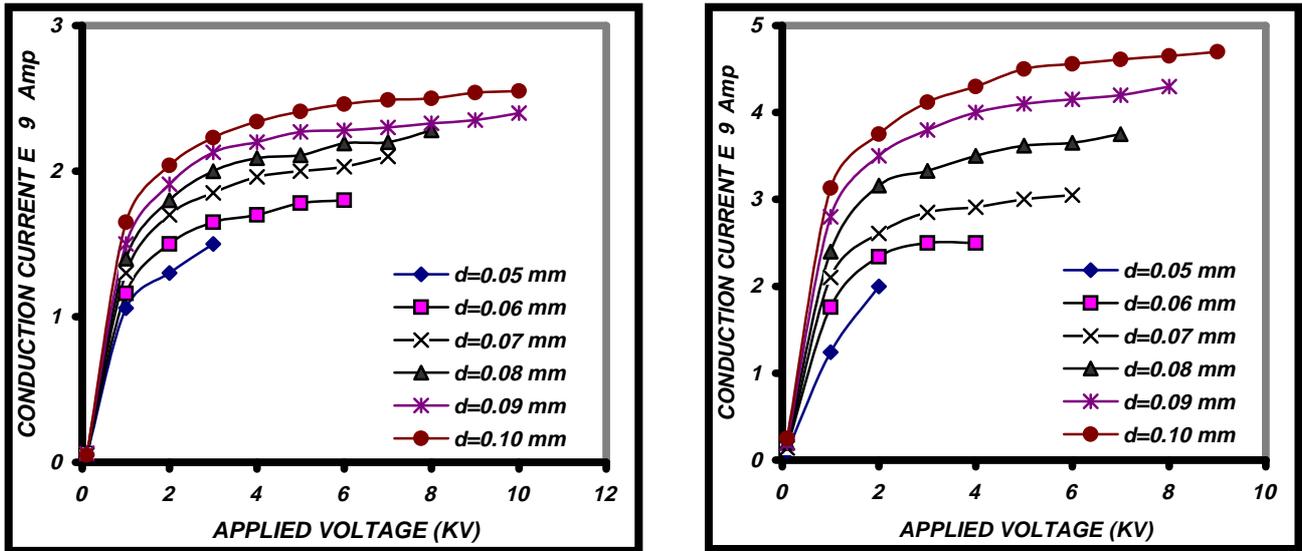
In general, the conduction current and the breakdown potential as a function of applied field is significantly dependent on many physical parameters such as, applied voltage, dielectric medium, gap spacing, electrode material and polarity of electrode. Since the cathode point electrode has no clear effect on breakdown voltage for different electrode materials the measurements are taken on the anode one. The effect of

electrodes materials is then clearly seen to be large when the point electrode is positive, but when the point electrode is negative the effect of the liquid predominates, as clearly shown in the study of Haitham 1998.

This phenomenon was clearly shown in figure (1), where the breakdown voltage increased when the electrode spacing increased too at different electrode materials, which can be explained by using Suedu relationship ($I=I_0e^{\alpha dE}$) where I_0 and α are two functions of field strength. Figure (2) shows the current voltage characteristic curves in several electrode materials at convergent field conditions in n-pentane having different electrode spacing, which is clearly shown to be increasing in conduction current as applied voltage and electrode spacing are increased. Before breakdown and in saturation region we can see a linear dependence of the conduction current on the applied voltage under the influence of all parameters used in this study. This relationship shows that the phenomena of ionization in dielectric liquids under such conditions are bulk processes and that surface processes (e.g. diffusion) have little significance.

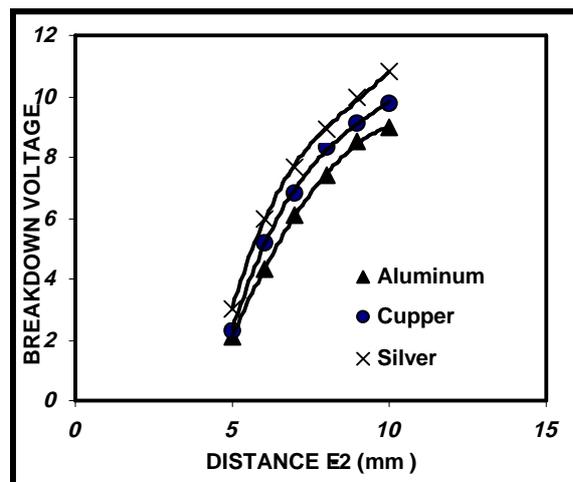


Figure(1): The dependence of breakdown voltage on electrode spacing for Al, Ag and Cu in divergent field conditions



Figure(2): Typical graph of current voltage characteristics in n pentane under the influence of convergent field conditions for Ag and Al respectively

Figure (3) shows the dependence of breakdown voltage on electrode separation for a number of electrode materials. As can be seen the breakdown voltage of each electrode material increased from Al to Ag, such behavior can be attributed to the work function and the boundary condition of metal-liquid interface, where the irregularities of the cathode surface and the layer of positive ions next to the cathode may also affect the work function of the electrons passing from the cathode into the liquid at constant temperature.



Figure(3): The dependence of breakdown voltage on electrode spacing for different electrode material in convergent field conditions

When an electric field of intensity E acts on substance of a dielectric constant ϵ at a distance $x = \frac{1}{2}(e/\epsilon E)^{1/2}$ from the metal surface there is a maximum potential energy which reduces the work function of an electron injecting from the metal to the liquid by the value $(eE/\epsilon)^{1/2}$. From figures (1) and (3), we can also see the kinds of streamer initiation (negative and positive streamer) may affect the value of breakdown voltage, such behavior can be attributed to the formation of a conduction channels through the gap spacing which leads to increasing a given potential, then makes the breakdown processes quicker.

Conclusion :

The preceding discussion has pointed out physical processes that appear to be common to electrical breakdown in dielectric liquids. These processes lead directly or indirectly to the development of streamers, effect of electrode materials, gap spacing, electrode polarity and the irregularities of electrodes which contributes to electrical breakdown. The kind of electric field has clear influence on producing a change in the value of electrical breakdown potential to a extent for the different electrodes materials as stated in the discussion.

Also the work function of electrode material and, the dielectric constant of substance between electrodes, which are found to be affected as control factors on the processes leading definitely to electrical breakdown.

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