
Experimental studies of streamer diameters and velocities in dielectric liquid with positive and negative polarity.

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Abstract

A streamer in dielectric liquid (transformer oil) is consist of charged particles (electron, positive and negative ion). It has many properties such as: streamer velocity, streamer diameter, mean electron energy, number of streamers branches and current density. Some of these properties have been detected by using the photographic technique to get a data and it should be in a good agreement with theoretical and experimental results. The streamers diameters and streamers velocity are increased with voltage.

1. INTRODUCTION

The experiment of electrical discharge in dielectric liquids is very important to get the properties of streamers. These experiments show bubble motion away from the cathode, with separation velocities on the order of 10's m/s. This separation is similar for single bubbles generated at the cathode and for bubble chains developing into low-density channels. Experiments at reduced hydrostatic pressure reveal a critical pressure below which low density channel expansion occurs, further corroborating the presence of a gas phase. Finally, the pressure dependence of the breakdown voltage due to the expansion of the low density channels is examined and a model for this dependence is presented. The experiments conducted confirm the presence of a gas phase channel, its correlation with single bubble dynamics, and its importance to final breakdown.

Electrical breakdown in dielectric liquids is of high technical interest due to the use of liquids as an insulator in high voltage systems and in the development of pulse power technologies. However, the desire to make systems more compact for increased energy densities and portability requires a comprehensive understanding of liquid breakdown as it pertains to insulating and switching mediums. To date a fundamental understanding of the phenomena has distinguished between two processes of liquid breakdown in the DC regime, an anode initiated process and a cathode initiated process. Most models of the cathode initiated process begin with an electron avalanche in the liquid phase preceding the formation of a gas bubble. Most of the energy associated with the electron avalanche is used in either the vaporization of the liquid or reduction of tinsel strength between the cathode and liquid forming a bubble. Once the initial bubble is formed it is believed an electron avalanche occurs in the gas phase and can then generate a chain of bubbles which

has been seen on a small scale in. Thus bubbles are believed to be the building block for low density channel formation in cathode initiated self breakdown in liquids [1,2]. The properties of the streamers have been studied by using the photograph technique to get properiate photos which is used CCD (Camera Channel Display) camera to get photos (CCD camera is device to shoot photos with short time) which connected to the computer, photograph technique to convert the vidios to pictures for studying the properties of the streamers such as diameter and velocity. The operators change these properties are the polarity, voltage and the shape of electrodes.

2. Theoretical part

By using the photo technique the diameter of streamers have been measured as shown in table. The difference between the streamers in gases and liquids in pressure where in gases the pressure has been taken in many ranges because of the gas have a compressability property i.e the gas can be change its volume and hence change its pressure according to the general law of gases [1]:

$$PV = nRT \dots\dots\dots(1)$$

Where P = pressure of charged medium (mbar), V = volume (cm³), n = moles number, R = general constant of gases, and T = absolute temperature.

Increasing of the ionized molecules is increased in two probability:

- (1) The number of ionized molecules of gas are increase by increasing voltage because of the electrons number which are have energy is equal or more than the ionization energy of a gas are increase for this reason the ionized gas molecules numbers are increase.
- (2) In the other hand the ionization probability of more than one of gas molecule by a same electron is high because of the electron energy is equal or greater than two ionization energy of gas and hence in above cases; the number of ionized gas molecules are increase by voltage increasing.

$$v_d = \mu E \dots\dots\dots(2)$$

Where v_d = the drift velocity of electron, μ = electron or ion mobility, E = electric field. And the relation between the applied voltage and the electron velocity (electron energy) as shown below[4].

$$v_e = \sqrt{\frac{2eV}{m_e}} \dots\dots\dots(3)$$

Where v_e =electron velocity, m_e = electron mass, e=electron charge, V=applied voltage. And the electron velocity is given by[3].

$$v_e = \sqrt{\frac{2KT}{m_e}} \dots\dots\dots(4)$$

By comparing between eq (3) and eq (4) we note that the term (KT) is equal to (eV) and both refers to the electron energy. The current density J is depend on the electron density n_e (cm⁻³) and the current density means the number of electros

per unit area ($\text{sec}^{-1}\text{cm}^{-2}$), the relation between the electron density and current density is given by:

$$-n_e e v_e = J \dots\dots\dots(5) [4]$$

Where n_e =electron numbers density, J =current density,

Ohm's law is given by:

$$J = \sigma.E \dots\dots\dots(6)$$

Where σ = surface charge density

Electrons number increase by voltage increasing. From eq's (5) and (6) the electrons number increase by voltage increasing[3].

3. Experimental part

The experimental setup consisted of a power supply, cell to contain the dielectric liquids, two electrodes, micrometer, CCD camera and dielectric liquid as shown in figure (1).



Fig. (1)The setup of experiment.



Fig. (2) Device of studying of the breakdown phenomena: (1) vent to pressure balance; (2) pin electrode; (3) micrometer; (4) glass tube; (5) plane electrode; (6) body of cell; (7) support cell; and (8) base of device.



Fig. (3) The CCD which is used in experiment.

A- Power supply.

The power supply with features Tesla industrial, Voltage: 0-10000 (V), Current DC: 3 m (A), and Power: 30 (watt).

B- Liquid cell.

The cell of liquid produce from clear polymer this cell consist of tube with diameter 5 cm and length 9 cm, vent by diameter 1 cm to balance the pressure, Two square ends are also produced from the same polymer where each end have a hole to pass the electrode through it to go to the dielectric liquid.

C-Electrodes.

Electrodes with (pin-plane), as shown in fig.(2), where the pin with diameter 0.1 mm produced from tungsten which connected to the micrometer to control the distance between anode and cathode. The plane is a disk with a diameter 40 mm produced from stainless steel.

D- CCD camera.

The CCD camera as shown in Fig. (3) has a features; System: windows2000 or windows XP or higher version, White or Black Color, USB is used to adapt with PC, Picture Element: High resolution CMOS chip, 640x480 pixel, and Power: It is freely plugged and unplugged with no extra power

The camera was triggered simultaneously and connected to computer and it is capture 20 shot by second.

4. Results and discussion

A first observation of streamer diameters as a function of voltage is given in figure (4.a) for a 2 mm pin-plane gap. The transition from thin to thick streamers with increasing applied voltage as discussed in table (1) is nicely shown.

Table (1) the values of velocity and diameter with voltage and polarity.

V (KV)	polarity	D (mm)	v (cm.sec ⁻¹)
3	+	0.4	40
	-	0.3	
5	+	0.6	50
	-	0.5	
7	+	0.7	56
	-	0.6	
10	+	1	80
	-	0.8	

Where the energy of charged particles is increase if the applied voltage is increased, when the electron is located in an electric field, the electron is accelerated by this field and hence the velocity of it is increased and this behavior is satisfied by eq,s (2,3,4).

Behaviour of diameters as shown in figures (4). where the streamers diameter have gradeually increasing with increase voltage and this behavior to agree with eqs (5,6) where the voltage increasing leads to increase of current density and hence the number of charged particles have a large value and increasing in

diameter. Fig (6) the streamer diameter has been noted is increased by voltage increasing such as it (0.4) mm at voltage 3KV and (1) mm at 10KV.

In negative streamers the behaviour of diameters is same to the positive type but the diameters are less than that in negative streamers for example the streamer diameter at -3KV equal to (0.3) mm and increase to (0.8) mm at -10KV , this is shown in fig (5).

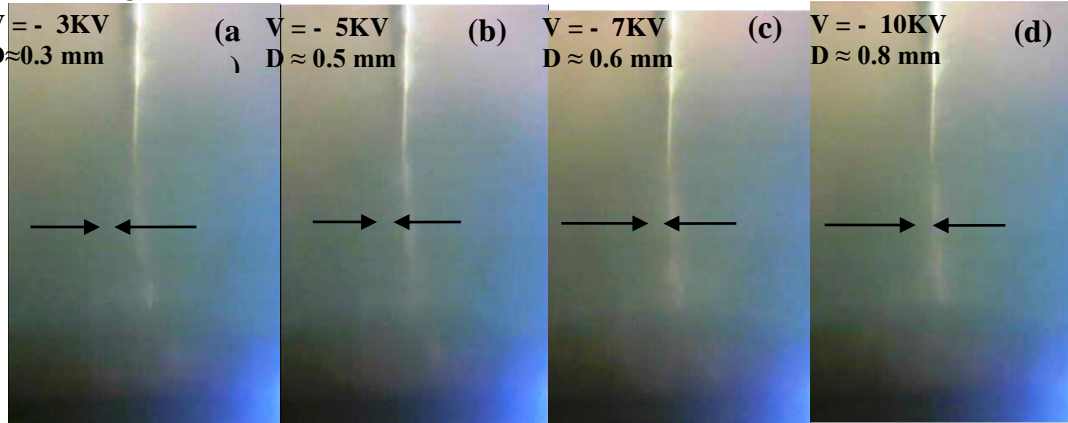


Fig.(5): The diameters of streamers at deffirent positive voltages.

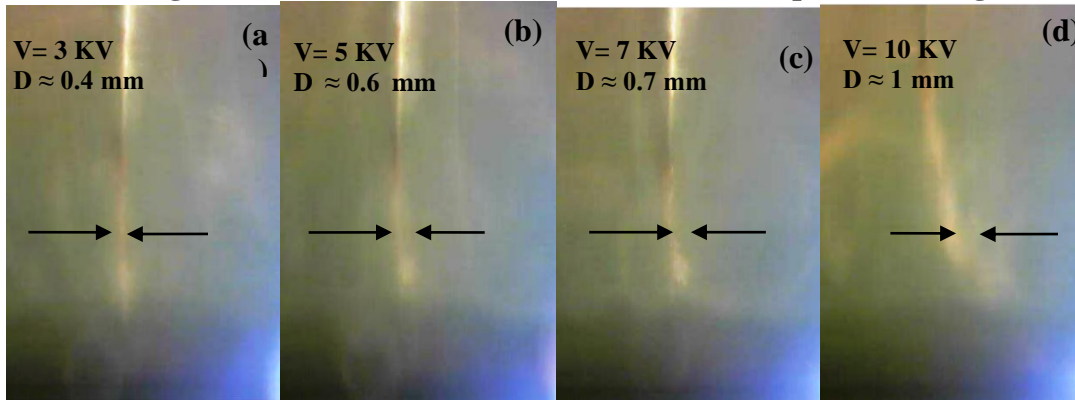


Fig.(6): The change of streamers diameter by applied negative voltage.

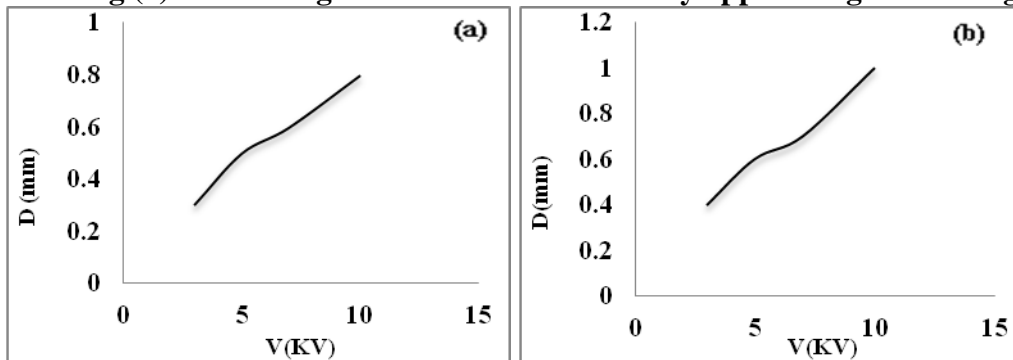


Fig.(6): The behaviour of the streamer diameter with(a) negative (b) positive voltage applied.

B -Velocity

The velocity has been detected by the same technique and it is measured as shown in table (1). Figure (8) is explained the positive streamer velocity with

different voltage values where the velocity of positive streamer has been detected by using the photographic technique and calculating the time with distance in different state. Figure (7) is illustrated the streamer velocity increase with voltage increase because the energy of charged particles increase by voltage increasing and this behavior except with eq (3).

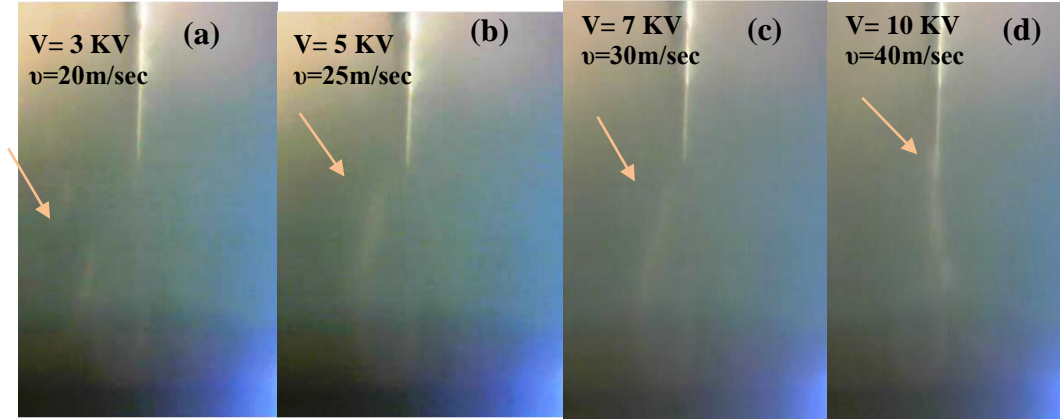


Fig.(8): The velocity of streamer in many voltages.

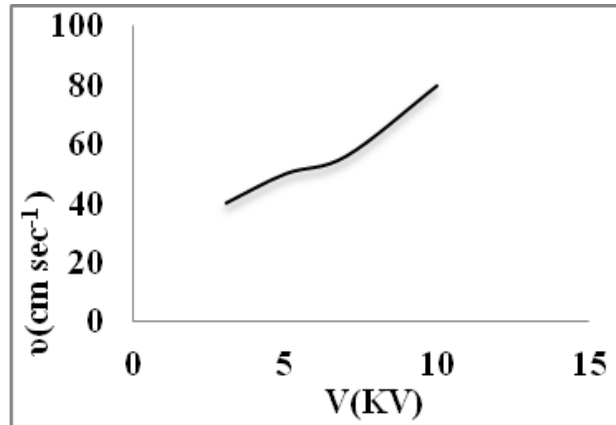


Fig.(7): The behaviour of the streamer velocity with applied voltage.

5. Conclusions

The diameter of streamers increase with the applied voltage because of the number of ionized molecules increase with increasing of applied voltage. Velocity of streamers increase with applied voltage because of the energy of charged particles increase with applied voltage (Electric field) according to eq (2).

References

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