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

دراسات تجريبية لأقطار و سرع القنوات البلازمية في السوائل العازلة للفولتيات الموجبة و السالبة

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Abstract

Plasma streamers in dielectric liquid (transformer oil) consists of a 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 has been detected by using the photographic technique to get a data it must be in a good agreement with the theoretical and experimental studies. The streamers properties are detected in this paper. The streamers diameters increase with the increase of voltage, and the streamers velocity has the same behavior of the diameter.

الخلاصة

القنوات البلازمية في السوائل العازلة (زيوت المحولات) تتكون من الجسيمات المشحونة (الأيونات الموجبة و السالبة والألكترونات).هناك اكثرمن خاصيَة للقنوات البلازمية مثلا (السرعة,القطر, عدد فروع القنوات, كثافة التيار) بعض هذه الصفات درست باستخدام تقنية التصوير و نتيجة لهذه الدراسة قد تبين انها مطابقة للدراسات النظرية و العملية. وفي هذا البحث تم التوصل الى ان القطر و السرعة للقنوات البلازمية تزداد بزيادة الفواتية المسلطة .

INTRODUCTION

1. Theoretical part:

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 [1].

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 media [1]. 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 [1,2]. Thus bubbles are believed to be the building block for low density channel formation in cathode initiated self breakdown in liquids.

1.1 The properties of the streamers.

The properties of the streamers have been studied by using the technical photo such as CCD camera which connected to the computer, computational programs to convert the videos to picture for studying the properties of the streamers such as diameter and velocity.

The operators that change these properties are the polarity, voltage and the shape of electrodes.

A- Diameter.

By using the technical photo and some of computational programs the diameter of streamers have been measured as shown in table(1).

The difference between the streamers in gases and liquids is pressure. In gases the pressure has been taken in many ranges because they have a compressibe property i.e the gas can be change its volume and hence change its pressure according to the general law of gases:

$PV = nRT$ ....(1)

where P = pressure (mbar), V = volume (cm^3), n = moles number, R = general constant of gases, and T = absolute temperature.

Liquids can not be compressed and that means the pressure in liquids is equal to atmosphere.

The increase of the ionized molecules of gas is increased in two probabilities:

(1) The number of ionized molecules of gas are increased by increase of voltage because of the electrons number which have energy is equal or more than the ionization energy of a gas. It may increase for this reason the ionized gas molecules numbers.
(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 more than two ionization energy of gas. Hence in above cases the number of ionized gas molecules increases by voltage increase.

$\nu_d = \mu E$………………(2)

where υ_d is the drift velocity of electron, μ is electron or ion mobility, E is electric field

The relation between the applied voltage and the electron velocity (electron energy) as shown below [4].

$$v_e = \sqrt{\frac{2eV}{m_e}} \qquad \text{..................(3)}$$

where v_e is electron velocity, m_e is electron mass, e is electron charge, V=applied voltage

And the electron velocity is given by [3].

$$v_e = \sqrt{\frac{2KT}{m_e}} \qquad \text{..................(4)}$$

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 depends on the electron density n_e (cm^{-3}). The current density means the number of electrons per unit area ($Amp.cm^{-2}$),the relation between the electron density and current density is given by [4].

$-n_e\, e\, v_e = J$ ....(5)

where n_e is electron numbers density, J is current density,

From the references of electrical engineering, the current density is direct proportional with the electric field, the equation of current density is given by [3].

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

where σ is surface charge density

From last eq's the electrons number increases by voltage increase. From eq's (5) and (6) the electrons number increases by voltage increase.

2. Experimental part:

2.1 Experimental apparatus

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) shows the setup of experiment

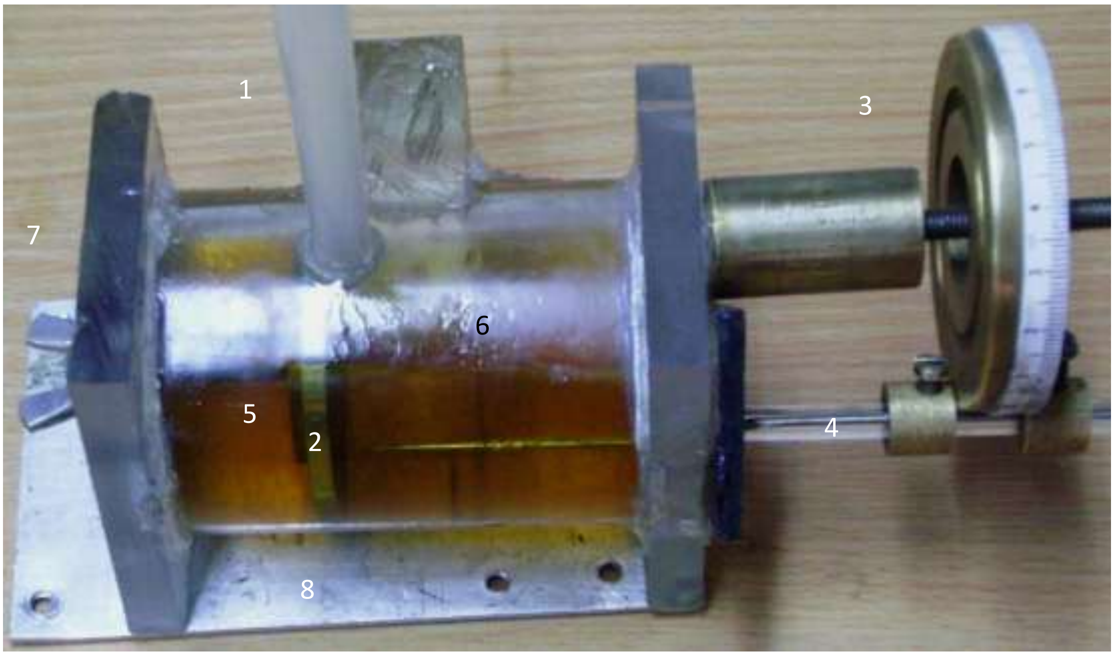


Fig (2) shows the set up of the device to study of the breakdown phenomena in dielectric liquids such as: (1) vent to pressure balance; (2) pin electrode; (3) micrometer; (4) glass tube; (5) plane electrode; (6) body of cell; (7) support cell; and (8) base of device.

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 produced from clear polymer this cell consists 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 so as to pass the dielectric liquid.

C-Electrodes.

Electrodes with (pin-plane), as shown in figure (2), where the pin with diameter 0.1 mm produced from tungsten which is 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 figure (3) has 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 with a computer and it is capture 20 shot by second.

Fig (3) shows the CCD which is used in experiment

3. Results and discussion:

A -Diameter

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 increase of applied voltage as discussed in table (1) is clearly shown.

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

Table (1): the values of velocities and diameters streamer with polarity and voltage.

V (KV)	polarity	D (mm)	υ ($cm.sec^{-1}$)
3	+ -	0.4 0.3	40
5	+ -	0.6 0.5	50
7	+ -	0.7 0.6	56
10	+ -	1 0.8	80

The behaviour of diameters as shown in figures (4.a),and (4.b). Where the streamers diameter have gradually increased with increase of voltage. This behavior agrees with eqs (5,6) where the voltage increase leads to increase of current density. Hence the number of charged particles have a large value and increase in diameter. Figure (6) the streamer diameter in positive voltage is increased by voltage increase. For example it is (0.4) mm at voltage 3KV and (1) mm at 10KV.

In negative streamers the behaviour of diameters is the same to the positive type, but the diameters are less than that in negative streamers. For example the streamer diameter at – 3KV equals (0.3) mm and increases to (0.8) mm at -10 KV. This is shown in figure (5).

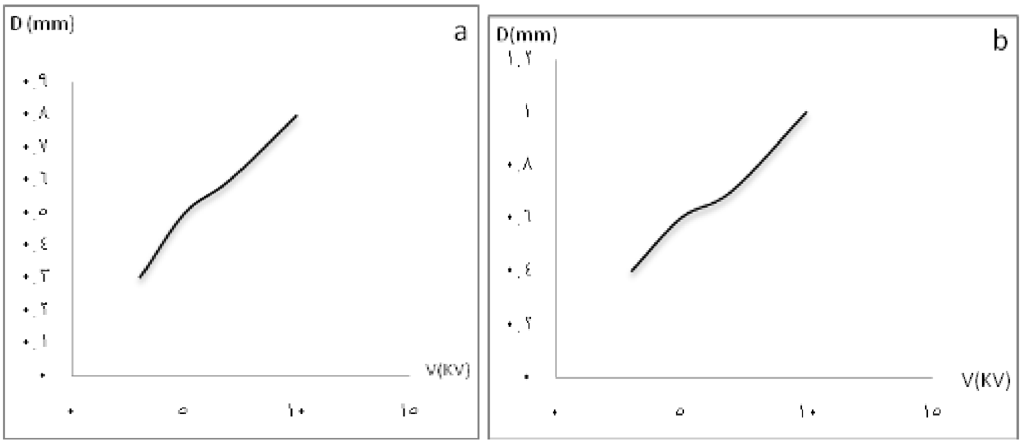
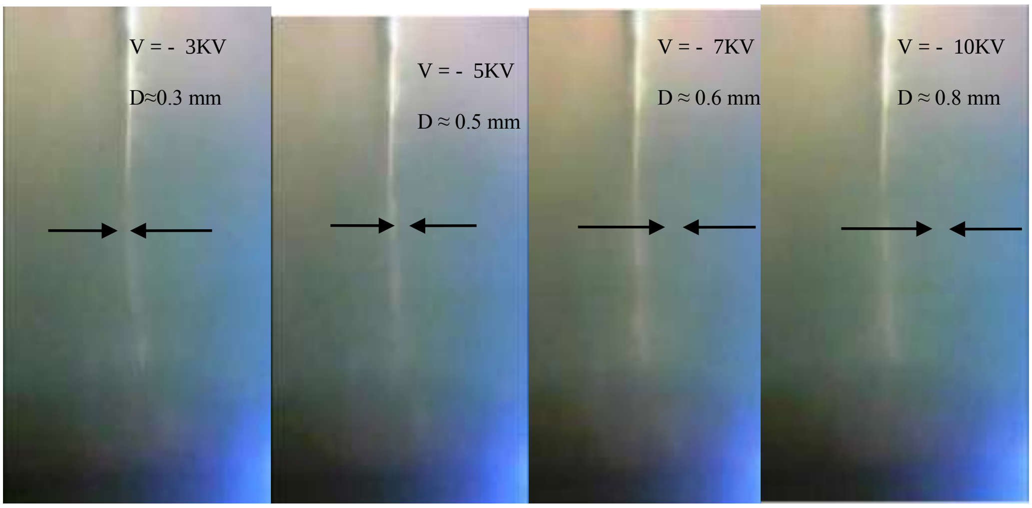
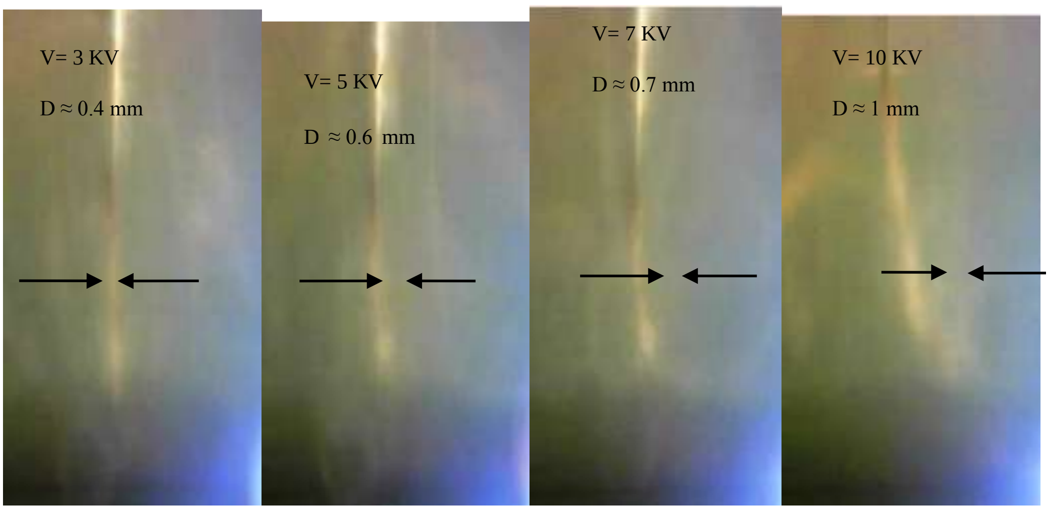


Fig.(4): The behaviour of the streamer diameter with(a) negative (b) positive applied voltage.



(a) (b) (c) (d)

Fig.(5): The diameters of streamers at diffirent negative voltages.



(a) (b) (c) (d)

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

B -Velocity.

The velocity has been detected by a same technicals and it is measured as shown in table (1).

Figure (8) explained the streamer velocity in different values of positive voltage 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) illustrated that the streamer velocity increases with voltage increase because the energy of charged particles increases by voltage increase and this behavior is an agreement with eq (3).

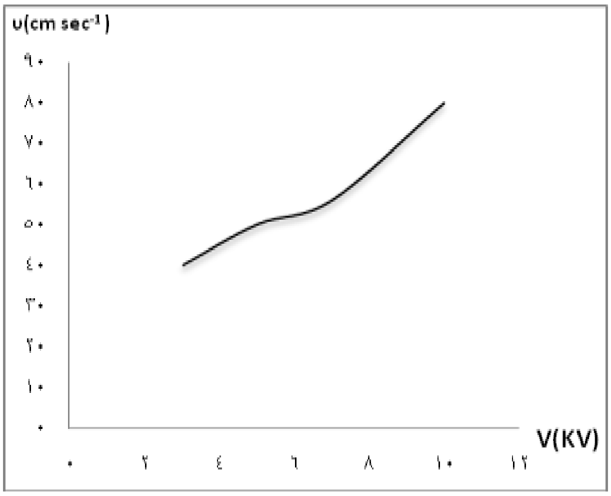
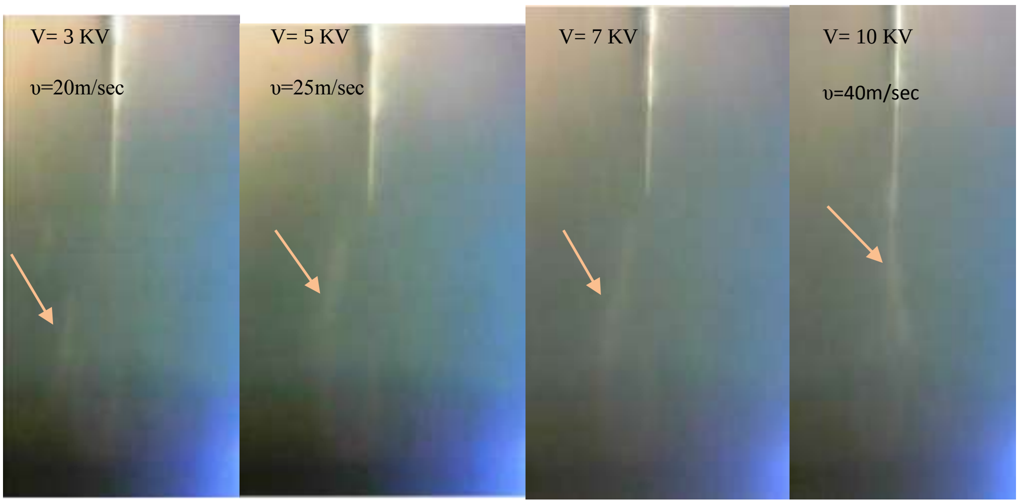


Fig.(7): The behaviour of the streamer velocity with applied voltage.



(a) (b) (c) (d)

Fig.(8): The velocity of streamer at defferent positive voltage.

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