Streams and plasma parameters experimental studies in He-CO gas mixtures

Hamid K. Radam

Department of Physics, College of Science, University of Baghdad

Abstract

DC glow discharges were generated between a thin cylindrical anode and a flat cathode, streamers are thought to propagate by photo-ionization; the parameters of photo-ionization depend on the He: CO ratio. Therefore we study streamers in He (90%, 80% and 70%) with (10%, 20% and 30%) CO respectively. The streamer diameter is essentially the change by increase for similar voltage and pressure in all He-CO mixtures.

Keywords

Streams

plasma parameters

He-CO gas

Article info

Received: Mar. 2010

Accepted: Apr. 2010

Published: Nov. 2010

دراسة تجريبية للقنوات الكهربائية و معلمات البلازما لخليط He-CO

حامد كريم ردام

قسم الفيزياء – كلية العلوم – جامعة بغداد

الخلاصة

التفريغ المضيء يتولد بين الأنود الأسطواني و الكاثود المستوي، حيث تتولد القنوات الكهربائية بواسطة التأين-الضوئي ؛المعلمات للتأين-المضيء يعتمد على نسب الهيليوم و أول اوكسيد الكاربون. لذلك درسنا القنوات الكهربائية للهيليوم بنسب(٩٠%،٨٠%،٧٠%)مع أول أوكسيد الكاربون بنسب (١٠%،٢٠%،٣٠%) على التوالي). وجد ان قطرالقنوات الكهربائية يزداد عند زيادة الفولتية المسلطة ونقصان الظغط و لجميع النسب.

Introduction

When a high electric field is applied to a non-conducting medium like air , electric breakdown might concentrate in narrow, rapidly growing ionized channels, so called streamers [1]. Streamers are the first stage of electric breakdown, when a high voltage is applied to gas volumes . The discharge can later develop into spark or lightning, but it also can stay completely in the streamer phase. An example of a discharge that remains essentially in the streamer phase is a sprite discharge. Streamers enhance the electric field at their tip to values above the breakdown value and create a region of active local ionization dynamics[2].

Streamers are usually produced in the gas phase between metallic electrodes in high-voltage (HV) systems. Nevertheless, they may also occur between electrodes fully or partially covered with a dielectric barrier , on the interface between gaseous and liquid phases, and they may even be produced in liquids[3].

Atmospheric pressure corona discharges are widely used in technology. Streamers, which are the basic building blocks of these discharges, focus a large part of the energy of the reactor into a small volume. T he appearance of stream discharges varies greatly, taking on many different forms that depend on the voltage polarity. A positive streamers emerge from pointed electrodes at lower voltages than negative ones [4,5], While negative streamers naturally propagate through electron drift (possibly supported by additional mechanisms).

Streamers in different media at various densities

Streamer discharges determine the early stages of sparks and lightning; they occur in various ionizable media in a large range of pressures and temperatures. In corona applications, they are widely used for surface charging in copiers and printers, for the removal of dust in electric precipitators and for ozone

production and gas and water cleaning [6,7]. Glow discharges at higher pressures are hardly attainable due to instabilities which lead to a glow to arc transition (GAT). as the pressure is increased Atmospheric pressure DC glow discharge the current density increases until it reaches the threshold for the development of instabilities leading to a transition to the arc phase. [8].

The distributions of speed and velocity are characterized by a mean energy, $\langle \varepsilon \rangle$, which is linked by the form of the distribution to the kinetic temperature, KT . Pressure, P, in a gas is a measure of the density of thermal energy associated with the number of gas atoms per unit volume, n_g. Thus,

$$P = n_g KT \qquad \ldots\ldots\ldots\ldots.(1)$$

(SI units: P is in Pa when n_g is in m−3 and KT is in J .

At room temperature the average speed of atoms is,

$$\bar{\upsilon} = \sqrt{\frac{2KT}{M}} \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

At a pressure of 1 Torr (130 Pa) the random flux of atoms at room temperature is,

$$\Gamma = n\sqrt{\frac{KT}{2\pi M}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

At a pressure of 1 Torr (130 Pa) the distance travelled by atoms between collisions is,

$$\lambda = \frac{1}{4\sigma n_g} \;, \sigma = \pi r_{Ar}^2 \qquad \ldots..(4)$$

The frequency of collisions between gas atoms at room temperature is ,

$$\nu = \frac{\bar{\upsilon}}{\lambda} \qquad \ldots\ldots..(5)$$

A flow of neutrals arises when there are gradients in pressure (i.e. gradients in density and/or temperature).

Elastic and inelastic collisions

By far the most common encounter in gases is between pairs of particles (binary collisions). When particles interact (collide) momentum and energy must be conserved. There are three clear classes of event.

(i) Elastic: momentum is redistributed between particles and the total kinetic energy remains unchanged, e.g.

$e^-_{fast} + A_{slow} \rightarrow e^-_{less\ fast} + A_{less\ slow}$.

(ii) Inelastic: momentum is redistributed between particles but a fraction of the initial kinetic energy is transferred to internal energy in one or more of the particles (i.e. excited states or ions are formed), e.g.

$$e^-_{fast} + A \rightarrow e^-_{slower} + A^*$$

$$\rightarrow e^-_{slower} + A^* + e^-.$$

(iii) Super elastic: a third class also needs to be anticipated—here there is more kinetic energy after the collision. Momentum is conserved and internal energy in the particles entering into a collision is transferred into
kinetic energy, e.g.

$$A^*_{slow} + B_{slow} \rightarrow A_{faster} + B_{faster}\ .$$

Measuring streamer diameter and velocity

From the images taken, the streamer diameter is determined with the following method:

• A straight streamer channel section is selected.

• In this section, several perpendicular cross sections of the streamer are taken.

• These cross sections are averaged so that they form one single cross section.

A diameter of at least 10 pixels in the image is required to be sure that the streamer diameter is measured correctly and camera artefacts are negligible. The streamer propagation velocity has been measured with
two different methods. The first method is as follows: we take short exposure images of streamers while they propagate in the middle of the gap. We then choose the thinner, straighter and longer streamer sections in each picture. The thinner streamers are ensured to be in focus, the longer streamers are assumed to propagate almost in the photograph plane. This method could be improved by using stereo photographic technique [2].

Experimental part

Experiments found in literature show that streamers created under different circumstances (different experimental setups and/or investigators) have different diameters, velocities and/or branching behavior. [2].

The main characteristics of a plasma discharge such as the breakdown voltage, the voltage current characteristic and structure of the discharge depend on the geometry of the electrodes and the container, the gas used, the pressure in the chamber, the electrode material and the external circuit. Typical voltage current characteristic of DC discharges are highly nonlinear[8].

The experimental setup as shown in figure (1), where it is consisted of a DC voltage power supply, camera tape, vacuum device which consist of rotary pump with range $1*10^{-3}$ mbar, diffusion pump with range $1*10^{-5}$, chamber to contain a gas, pressure gauges such as pirany gauge, pinning gauge, electrodes, bottles as a gas savers to save Argon, Helium and CO gases, micrometer5μ step connected to the one of electrodes to change the distance between cathode and anode.

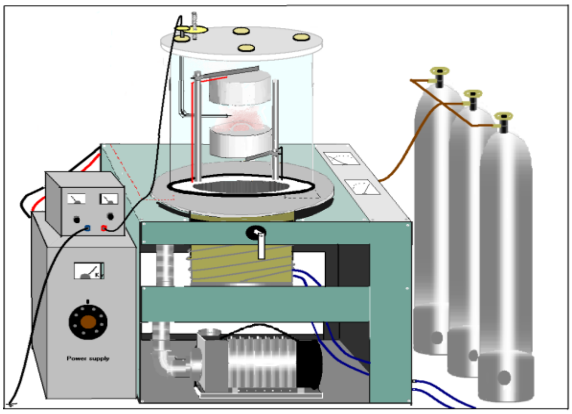
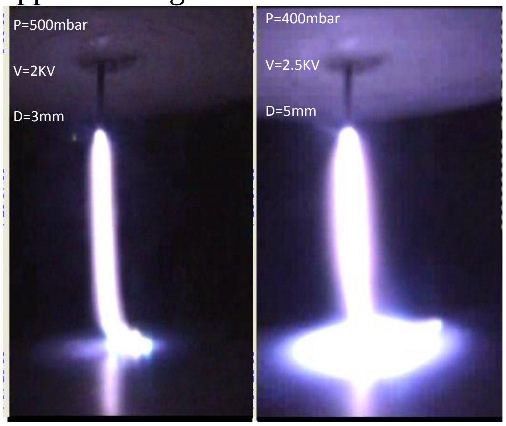


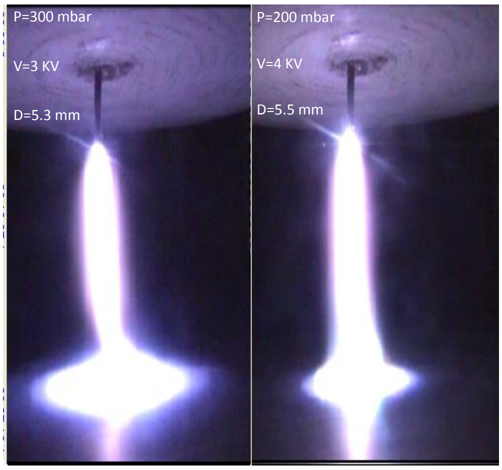
Fig. (1): Experimental set-up which is produced the streamer.

Results and Discussion:

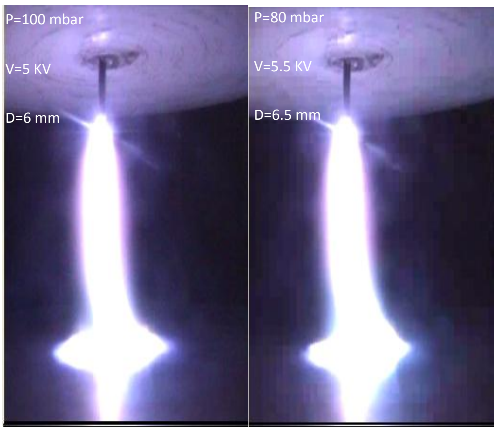
The essential aim of this work is to test the similarity laws on streamers at different pressures p, or more precisely, for streamers at different densities n, where n=p/(k_B/T) according to the ideal gas law. For the streamer diameter, we have to analyze its reduced value p · d/T. However, even at fixed pressure, the streamer diameter can vary by more than an order of magnitude, depending on applied voltage.



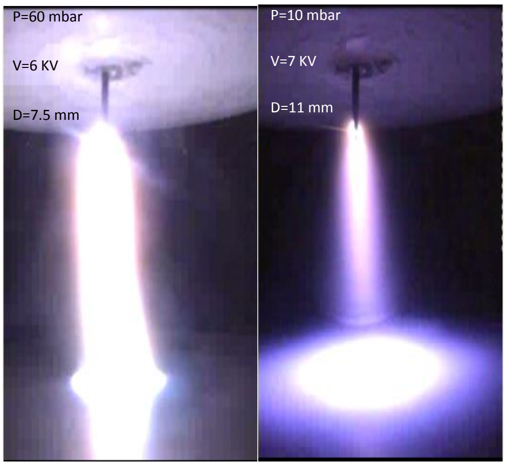
(a) (b)



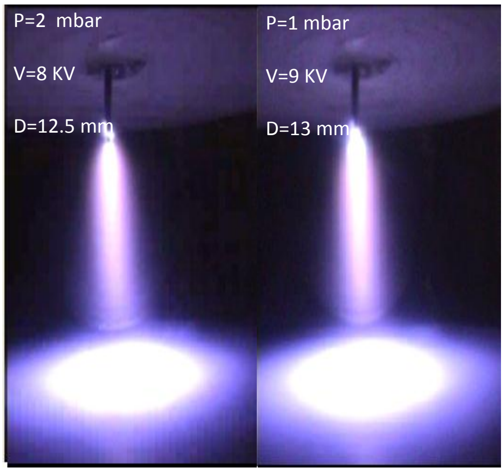
(c) (d)



(e) (f)



(g) (h)



(i) (j)

Fig.(2) Images of glow discharge in mixture(90%He+10%CO)

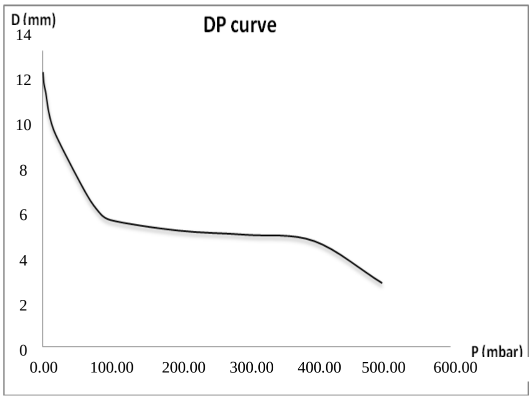


Fig.(3):Diameter–Pressure characteristic for discharge in mixture (90%He+10%CO)

(a)

(b)

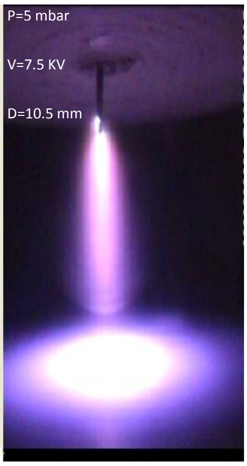
(c)

(d)

(e)

(f)

(g)



(h)

(i)

(j)

Fig.(4): Images of glow discharge in mixture (80%He+20%CO)

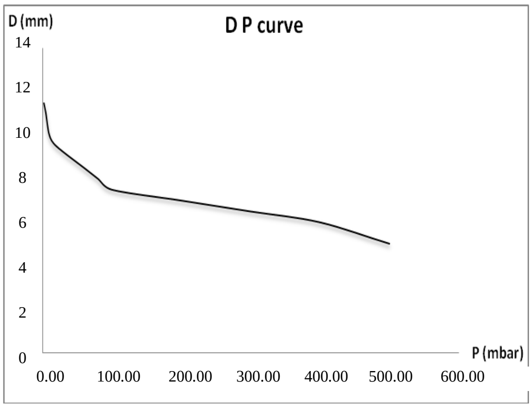
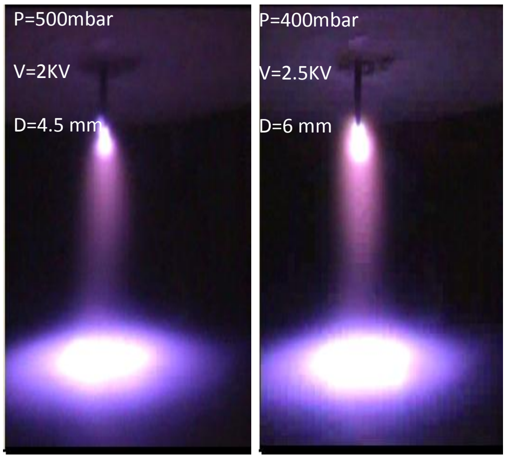
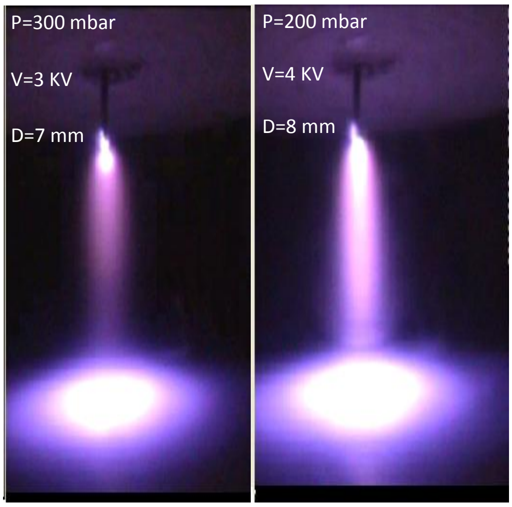


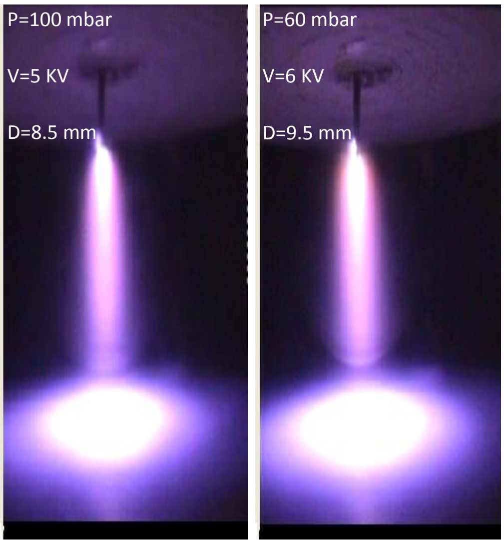
Fig.(5):Diameter–Pressure characteristic for discharge in mixture (80%He+20%CO)



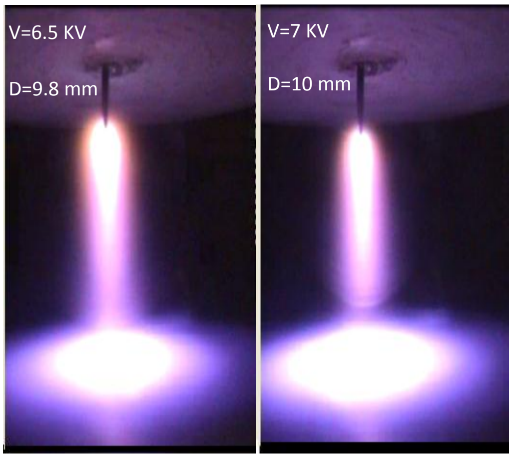
(a) (b)



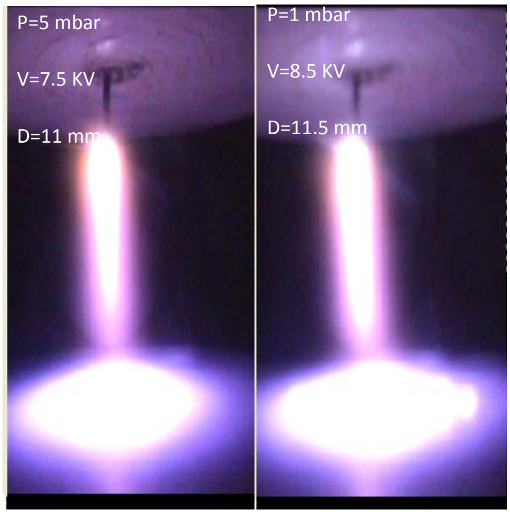
(c) (d)



(e) (f)



(g) (h)



(i) (j)

Fig.(6): Images of glow discharge in mixture (70%He+30%CO)

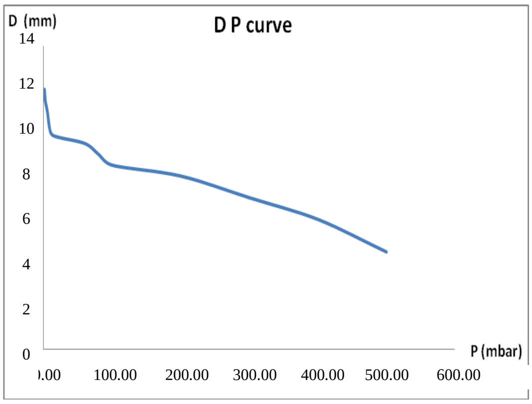


Fig.(7):Diameter–Pressure characteristic for discharge in mixture (70%He+30%CO)

Figures (2,4,6) shows a series of images of the glow discharge in mixture (90%He+10%CO) at fix electrode spacing., and varies applied voltages and different pressure. The cathode is the wire coming from the top of the image and the anode is the surface along the bottom edge of the image. Breakdown voltages begin at 2kV to 10kV and increase with decreased pressure. From the images in figure(2) the sizes of the initiation cloud and glowing shell scale inversely with pressure and the diameter of the glow stream is determined because the number of the charged particles increased when the pressure decrease and draw the figures (3,5,7) which is illustrated the relation between the voltage breakdown and pressure This is a result of the electron mean free path which determines the streamer scales. Theoretically, it scales inversely proportional with the gas particle density. The gas particle density can be substituted by pressure via the ideal-gas equation provided that the temperature is constant.

From the compare between all figures (2-7), we are noticed that when the ratio of gas mixture are changed (90%He+10%CO), (80% He+20%CO) and (70%He+30%CO) for same pressure (500 mbar to 2mbar) and Voltage breakdown (2KV to 10 KV) the stream diameters are increased, that means the effect of CO gas on He gas by increase the mean free path of charged particles.

Refrences:

[1] Tanja M. P. Briels, Eddie M. van Veldhuizen, and Ute Ebert, "Branching of Positive Discharge Streamers in Air at Varying Pressures", IEEE Transactions on Plasma Science, Vol. 33, No. 2, April 2005.

[2] S. Nijdam, F. Van de Wetering, R. Blanc, E. M. van Veldhuizen and U. Ebert, "Probing photo-ionization: experiments

[3] on positive streamers in pure gases and Mixtures", J. Phys. D: Appl. Phys. 43 (2010) 145204 (16pp)

[4] Milan S. imek , Martin C. lupek, Václav Babicky, and Pavel Sunka, "Production of reactive species by atmospheric pressure streamers in N_2–O_2 mixtures", *Pure Appl. Chem.*, Vol. 78, No. 6, pp. 1213–1225, 2006.

[5] Proefschrift, "Exploring streamer variability in experiments", 2007 T.M.P. Briels.

[6] Alejandro Luque, Valeria Ratushnaya and Ute Ebert, "Positive and negative streamers in ambient air: modeling evolution and velocities", *J. Phys. D: Appl. Phys, 22 April 2008..*

[7] T. Briels, E. Van Veldhuizen and U. Ebert, "Positive streamers in air and nitrogen of varying density: experiments on similarity laws", *J. Phys. D: Appl. Phys, 2 Spt. 2008.*

[8] T. Briels, J. Kos, G. Winands, E M van Veldhuizen and U. Ebert, "Positive and negative streamers in ambient air: measuring diameter, velocity and dissipated energy", *J. Phys. D: Appl. Phys, 1 Spt. 2008.*

[9] David Staack, Bakhtier Farouk, Alexander Gutsol and Alexander Fridman, "Characterization of a dc atmospheric pressure normal glow discharge", Plasma Sources Sci. Technol. 14 (2005) 700–711.