Discharge Characteristics For Molecular Gases In Rectangular Tube

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Abstract:

In this paper we report the result of investigation of the variation of discharge current in rectangular tube with discharge voltage for N_2 and CO_2 gases, these experiments are conducted for gas pressure from (0.75 Torr) to (7.5 Torr). Sparking voltages are measured for these gases over this range of pressure as well as the relations between electric field (E/P) with (P), variation of discharge resistance (R) with (P) and conductivity (σ)as a function of (P). These results show that the sparking potential vary with the product (pd) in accordance with paschen curve. The discharge characteristic is similar to the conventional discharge tube except the relation of (E/P) as a function of (P) .

خصائص التفريغ للغازات الجزيئية في الأنابيب المستطيلة

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ملخص البحث :

تم في هذا البحث دراسة تغير تيار التفريغَ في الإنبوبِ المستطيلِ مع فولتيةِ التفريغِ لغازي N_2 و CO_2. تم اجراء التجاربَ عند ضغطِ غازِ مِنْ (0.75Torr) إلى (7.5Torr). تم قياس فولتية الانهيار لهذه الغازات عند هذا المدى مِنْ الضغطِ بالإضافة إلى العلاقةِ بين المجال الكهربائي (E/P) مَع الضغط (P) واختلاف مقاومةِ التفريغ (R) مَع (P) والتوصيلية (σ)كدالة للضغط (P). تُظهر النَتائِجَ بأنّ تغير فولتيـة الانهيـار مـع (pd) طبقـاً لمنحنى Paschen. إنّ خصائص التفريغَ مشابهة لتلك التي لأنبوب التفريغ الاعتيادي ماعدا علاقةِ (E/P) كدالة للضغط (P).

Introduction :

Rectangular discharge tubes has become the subject of renewed experimental interest (1-4). The plasma density profiles of the positive column in rectangular discharge tube have been theoretically analyzed by Chang (1) by expanding the ambipolar diffusion theory originally proposed by Schottky (5). However, there have been few experimental studies concerning the rectangular discharge tube. Thus, it is important to experimentally investigate the discharge characteristic in rectangular tube using molecular gases.

Apparatus and experimental arrangement :

A schematic digram of the rectangular discharge tube structure is shown in Fig (1). Discharge tube has two electrodes, a rectangular plasma length of (45mm) and the positive column profile is 40 x 25 mm. The electrodes consist of two stainless steel discs of diameter (15mm). Discharge tube was evacuated to (0.75 torr) by a rotary pump. The absorbed gases on the wall and electrodes were removed by usual baking processes. The gases used in these measurements were N_2 and CO_2 . Purity of both gases was 95%. High stability [Leybold (52237)] power supply was used to cover the voltage range up to 6kV, during the course of this investigation. The discharge voltage was measured using high input impedance multimeter type (Tesla voltage BM289). In Fig.(2), (R) represents a (200 Ω) standard resistor were inserted in the circuit served as stabilization resistor of glow discharge .
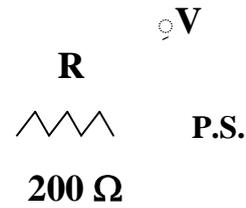
To vacume system

253

25 mm   40 mm
              45 mm

R   ⚬V

∿∿∿   P.S.

200 Ω
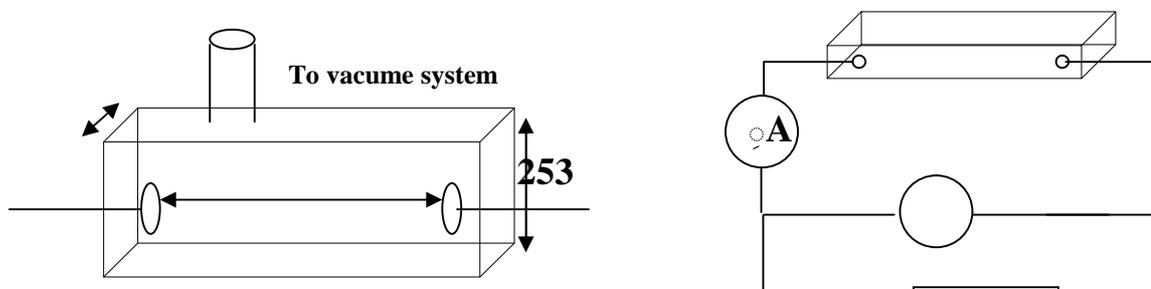
Fig (1) Discharge tube   **Fig (2) Experimental Setup**

Experimental Results:

The measurements were carried out by keeping pressure of the gas N_2 or CO_2, constant at particular value, the applied voltage was varied. The sparking potential was measured as the maximum critical voltage can be applied to the gap before the sudden increase in the current of the gap . Fig (3) shows the sparking potentials in N_2 and CO_2 gases as a function of (pd) where (p) is the gas pressure and (d) is the distance between electrodes . It has been shown that the sparking potential increase as the (pd) decreases. These results show the left side of paschen curve. The measurements could not be extended to higher (pd) value due to the limitation of the experimental apparatus.
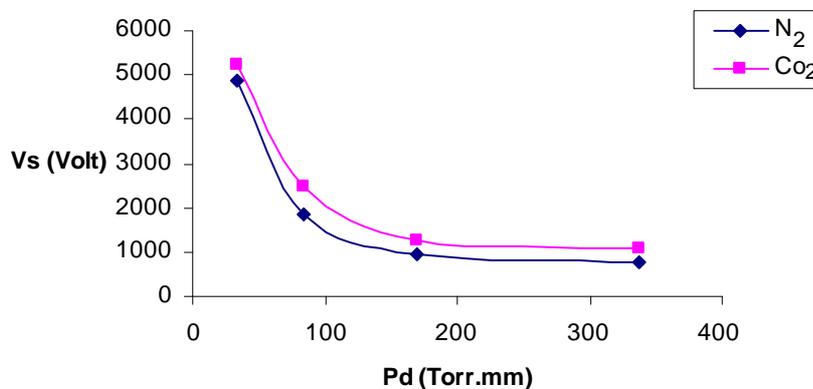
Fig (3) The sparking potentials in N_2 and CO_2 gases as a function of (pd)

A series of (V-I) measurements are carried out to investigate the behavior of electrical discharge in rectangular tube configuration over a

certain range of N_2 and CO_2 pressure extending from (0.75 Torr) up to (7.5 Torr). Figs (4,5)   shows that as the pressure increases the characteristic curve shift upward .

The discharge characteristic which show two different regions of self- sustained discharge. The first one where the voltage decrease as the discharge current is increased, which is the subnormal glow, the second where the voltage is almost constant with increasing the discharge current , which is the normal glow.
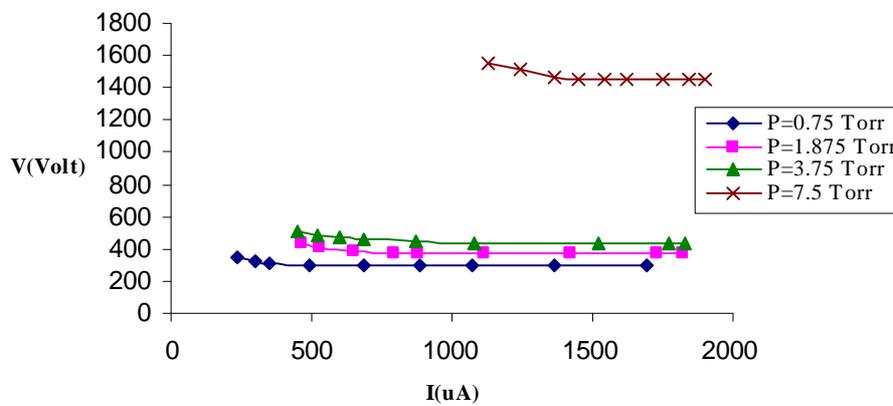

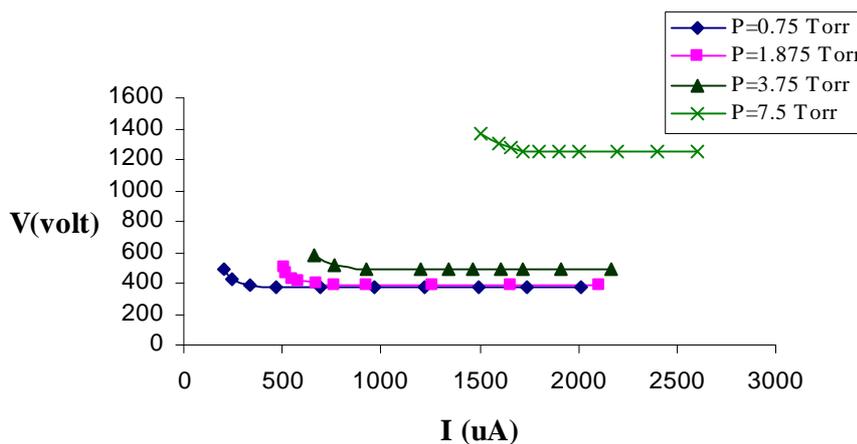**Fig (4) The (V-I) measurement at different Pressure for N_2**

Fig (5) The (V-I) measurement at different Pressure for CO_2

Fig (6) show the experimental relation of (E/P) with (P) for CO_2 and N_2 gases. It can be seen that the values of (E/P) decrease as (P) increase reaching a minimum value and it start to increase gradually.
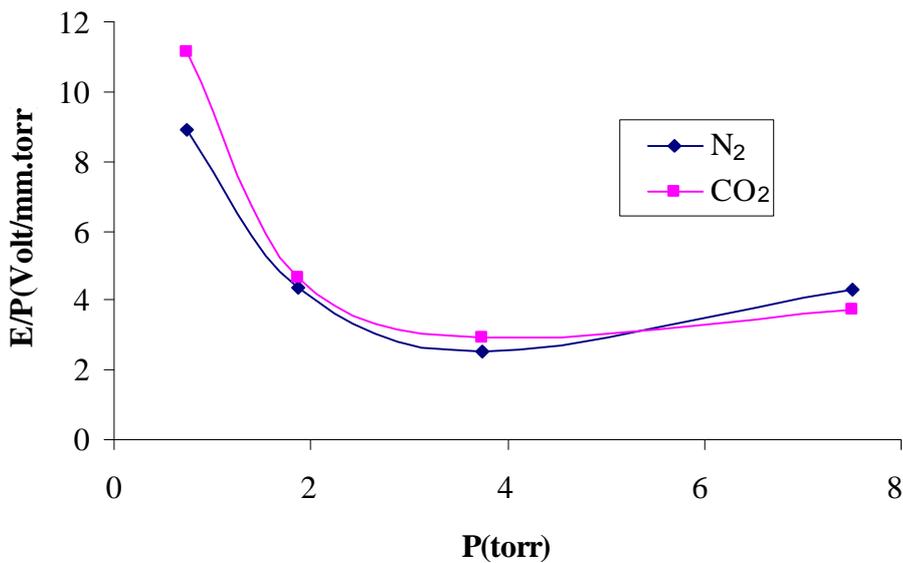
Fig (6) The relation of (E/P) with (P) for CO_2 and N_2 gases

Since the discharge conductivity was varied with pressure same as the electron temperature (6). Therefore Fig (7) show the effect of pressure increase on conductivity(σ). It can be seen that the conductivity decreases with increase (P).
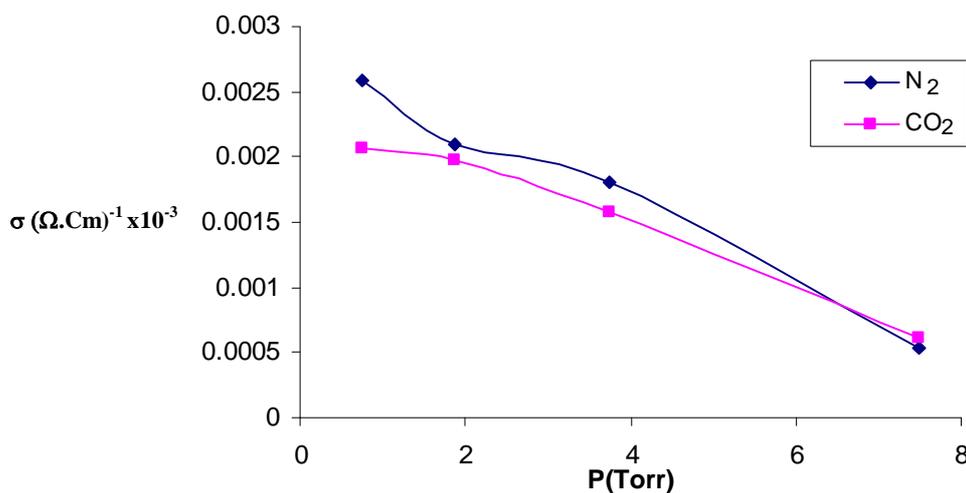

Fig (7) The relation between conductivity and pressure of N_2 and CO_2 gases

Fig (8) explains the variation of discharge resistance with gas pressure at constant value of discharge current [I_d (1.72 mA)].

Fig (8) The relation between resistance and pressure of N_2 and CO_2 gases

Discussion & Conclusion:

The sparking potential is proportional to the total number of the gas atoms which were limited the mean free path of electrons. The number of the excited gas atoms depends on the excitation process from the ground state gas atoms. The excitation occurs due to collisions between gas atoms and electrons of higher energy, which are proportional to the electron density. Therefore the gas pressure affect the sparking potential as well as the V-I characteristic curve. The increase of sparking potential with (pd) can be attributed to the mean free path of electrons at large (p). However, the mean free path is small and few electrons acquire sufficient energy over a mean free path to ionize. Hence most of the electrons produce electronic or molecular excitation. One can see that the sparking potential in CO_2 is greater than N_2 for the same value of (pd). This can be ascribe to the ionization potential for both gases (7). The change in gas discharge characteristic can be attributed to the transition from left of Paschen to the minimum as it is mentioned above.

The behaviour of (E/P) with (P) can be ascribed to the energy of electron which was lost in its motion within the electric field along the

positive column. (8) the gradually increase of (E/P) with increase (P) is attributed to the motion of electrons toward the walls(1,9).

The increase of discharge resistance, decrease of conductivity with gas pressure is due to increase of number of collision between gas atoms. So that, the electron loses most of its energy by unionized collisions (10).

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