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Studying the effect of addition (O_2/Ar) on the electrical properties of plasma glow discharge

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ABSTRACT

Containing oxygen plasma for many important applications in the semiconductor industry when adding a small amount of oxygen, can vary significantly properties of the plasma. In this work, the characteristics of the current-voltage characteristics and the failure potential in different percentages of O_2 in the gas composition (Ar / O_2) are measured. The result showed that the addition of oxygen leads to a decrease in the discharge current at the same discharge voltage and gas pressure. On the contrary, the low failure potential in percent less than O_2 of the minimum failure voltage (600, 650, 730, 750, 760, 780) and (5%, 10%, 15%, 20%, 30%, 50%) of O_2 percentage, respectively. Plasma detection using optical spectroscopy showed that two different plasma electron groups are characterized by different temperatures and densities, so increasing the electron temperature by adding O_2. While the electron density decreases with increase in the O_2 ratio.

Introduction

Glow discharge plasma can be defined as a region of relatively low temperaturegas that is sustained in an ionized state by energetic electrons [1].The most commonly used method of generating and sustaining a low-temperatureplasma for technical applications is by applying an electric field to aneutral gas [2]. Before application of the potential, any volume of a neutral gasis always electrically neutral and the gas at room temperature will contain a fewelectrons and ions. Occasionally, however, a free electron may be released froma molecule by the interaction of cosmic rays or other radioactive radiation or arandom high energy collision with another particle.

Theoretical part

Microwave discharges at atmospheric pressure have been studied intensively due to their many advantages. High electron density over 1014 cm^{-1} moderate neutral temperature a few thousand K, and relatively low electron temperature (1eV) are typical characteristics of the atmospheric pressure microwave plasmas.[3,4]From the application point of view, such characteristics are favorable to atomic spectrometry, decomposition of toxic gases like per fluorocarbon gas, and thermally resistible material processing.[4,5]In our previous report in which parameters of the plasma produced in a simple single dielectric tube were measured by optical emission methods,[6]the gas flow rate was one of the important conditions along with the microwave power. In this work, we investigated the temperature and density distribution as the flow rate and composition of the supply gas were varied. A modified discharge tube was used for efficient control of the plasma and for generation of more stable plasma using two different supply gases. The modified discharge tube consisted of two concentric dielectric tubes in which the inner dielectric tube supplied the vertically injected Ar gas and the outer dielectric tube provided a swirl flow of O2 gas for discharge assistance. This type has been widely used in the inductively coupled plasma torch for atomic spectrometry. Such a configuration assures the plasma stabilization through thermally isolating the plasma from the outer confinement tube or the ambient air [7]. The oxygen gas not only reduces plasma-wall interaction but also helps oxygen radical generation useful for particular applications. This paper reports experimental results of a parametric study of atmospheric plasma characteristics. Plasma

parameters were measured by optical emission spectroscopy OES by varying the operation conditions such as microwave power, gas flow rate, and gas composition ratio. In addition, the ambient air effects on the plasma volume and the rotational temperature were also studied. The results show that plasma parameter control is possible through the operation conditions[8].

$$\frac{I_1}{I_2} = \left(\frac{\lambda_{n,m,z}}{\lambda_{k,i,z}}\right)\left(\frac{A_{k,i,z}}{A_{n,m,z}}\right)\left(\frac{g_{k,z}}{g_{n,z}}\right) e^{\left(\frac{-E_{k,z}-E_{n,z}}{KTe}\right)} \text{.....(1)}$$

$$ne = \left(\frac{2\pi m_e K}{h^3}\right)^{3/2} \times \left(\frac{2A_{k,i,z}\ g_{k,i,z}\ \lambda_{N,M,Z}\ I_2}{A_{n,m,z}\ g_{n,m,z}\ \lambda_{k,i,,Z}\ I_1}\right) e^{\left(\frac{-E_{k,i}-E_{n,m}}{KT_{ex}}\right)} \times T_e^{3/2} \text{ ....(2)}$$

Reported by F.J. Vazquez et al. Increased electron density and reduced electron temperature by increasing gas pressure, while electron temperatures increased with increasing power. Although numerous studies have shown that the electrical properties of the plasma have been given little attention to the properties of the plasma spectrum [8].The purpose of this study is to investigate the behavior of the spectral lines intensity, electron temperature and electron density as the applied voltage and the work pressure in the discharge of argon plasma.It is necessary for the manufacturer to discharge himself. This equation is known as the Punchin's law, where V_B is the failure effort. P is the pressure and d is the distance. The fixed A, B and γ (secondary electron coefficients) are constant (dependent on the gas composition). Depending on the gas composition [9]. This equation appears the relation between V and Pd, which indicates that the breakdown voltage changes in such a way that the Pd product is different. The relationship between V and Pd is not linear and has a minimum value for each gas. Minimum sparking. The potential for a low Pd value before the minimum Panchen takes average length of electron path longer ionization less frequency. Required a higher voltage to keep the number of ions with the energy needed for the reconstruction of the continuous flow of electrons first. In short, a higher voltage requires the start of a forced discharge. For higher pd values, the average free path of the electrons is shorter and the collision is greater. However, the increase in the electron energy between the collisions is less. The excitement is competing against ionization and is required to generate higher voltage ions. In addition, at higher pressures, the free ionic ion path is lower and the ions lose energy in the gas with displacement collisions of tensile expansion and resonance. High voltage is required to maintain sufficient ion energies [10].

Experimental Setup

The discharge was performed in DC mode, the external RL resistance was used to reduce the drainage flow to ensure that discharge to the drainage area is abnormal. A digital millimeter flow was used for drainage and voltage. The plasma chamber is a cylindrical vacuum made of stainless steel 40 cm and a length of 30 cm. Essentially, the chamber contains two electrodes, which consist of a stunning radiation evacuation, and one removable and fixed electrode (called a cathode). Each of them had a diameter of 10 cm, and the cathode was separated by 5 cm. The drainage chamber was drained using a two-stage pump (Edward 12 m 3 / hr) and an alkaline aperture pump of 380 liters/sec, a flowmeter. The flow of gas-gas mixing and gas pressure was measured by Perini with Edward's 1105 control. The spraying method begins with the evaluation of the enclosure at a pressure of less than $8.6x10^{-2}$ mbar. Is a noble gas that can not respond to the target or sample of the mother. The Ar / O_2 gas mixer (10%, 20%, 30% .50%) enters the room at a specified pressure. The surface finish and the nature of the substrate used for sedimentation are very important, as the properties of the films affect tremendously. Vanadium oxide films are covered on glass substrates and then ultrasonically removed in acetone and dried in the air before loading into the sediment compartment. These infrastructures were dispersed in an Ar / O_2 plasma (10%, 20%, 30% .50%) at a 660-watt bias voltage. And 40mA current for 2 hours. Purpose of vanadium 99.99% purity and 60.5mm diameter with a thickness of 2 mm .

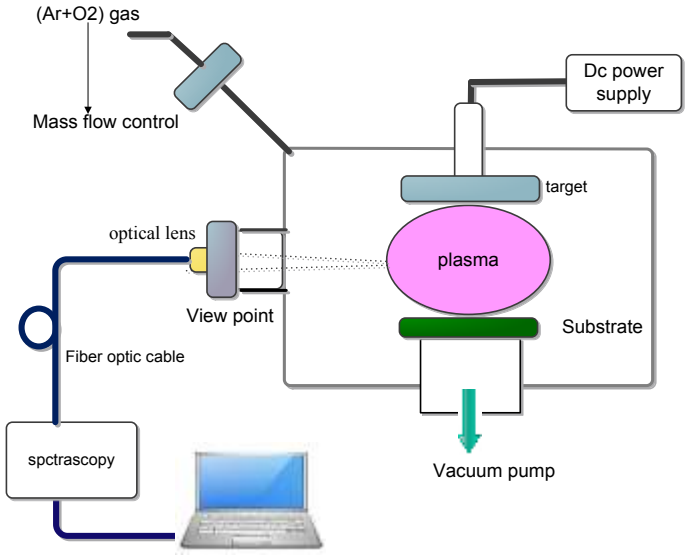

Figure. (1): The main experimental set-up used in this work.

Results

The current –volt characteristic, at different O_2 percentage in (Ar/O_2) gas mixture shown in figure (2). Where gaspressure is kept constant at 0.14 mbar. From this figure, We can show that the discharge current increase at the applied voltage increase that means the electrical discharge are operation in the abnormal glow discharge region. It is clearly seen that, at the same applied voltage and gas pressure, the discharge current decreases by increasing the O_2 percentage in(Ar/O_2) gas mixture. The decrease in the discharge current with increased O_2 percentage can be explained as follows: the ionization cross –section of O_2 is smaller than that of Ar[11]. In addition, Since the electron affinity of oxygen, discharges in oxygen contain negative ions, which result in the increase of plasma resistance due to reduction of electron density and thus the discharge current decreases. In addition, since the electron-oxygen is associated with oxygen depletion contains negative ions, resulting in increased plasma resistance due to low electron density, and as a result, the discharge stream decreases.

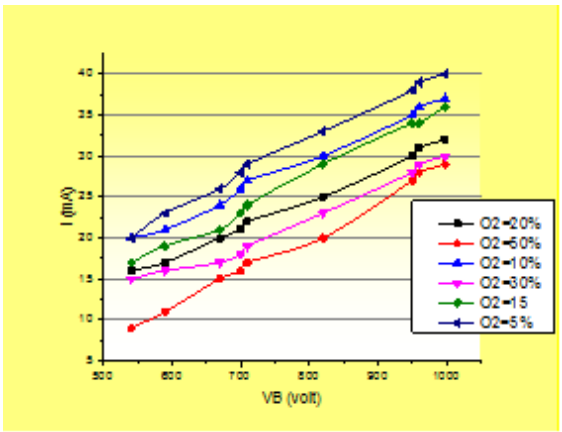

Figure2. The I-V dischargecurve is distinguished at a different O_2ratio at working pressure of 0.08mbar.

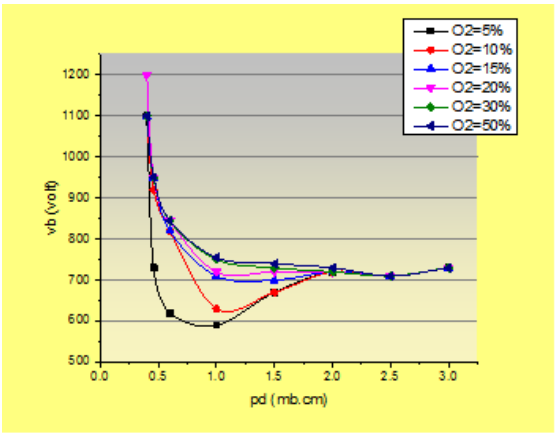

Figure 3. Panchen's curves at a different O_2 percentage with distance 5cm between cathode and anode

The values of breakdown voltage for various percentages of O_2 in gas combinations (Ar / O_2) are From this figure(3), we can show that the breakdown voltage increase by an additional increase in O_2 percentage of the gas mixture this can be related to, the additional energy loss channel oxygen gas such as vibration, rotational and molecular dissociation, VB abruptly was increased when the small amount of oxygen was added. In addition, since plasma resistance was increased due to high electron affinity of oxygen, discharge sustained voltage was also increased. Furthermore, the oxygen is electronegative gas and the loss of electrons due to diffusion and attachment to oxygen molecules in (O_2 /Ar) plasma requires the electric field strength in the plasma to be higher than in argon plasma so as to produce enough electrons to maintain the plasma discharge as shown in the table(1). As the number of additional oxygen molecules increases, a progressively higher electrical field is required. J.K. Rhee et al [12] shown the same results.

Table (1): Breakdown voltage as a function of the *pd*parameter for (O_2/Ar) gas.

Break down voltage (V_B) V	O_2%
600	5%
650	10%
730	15%
750	25%
760	30%
780	50%

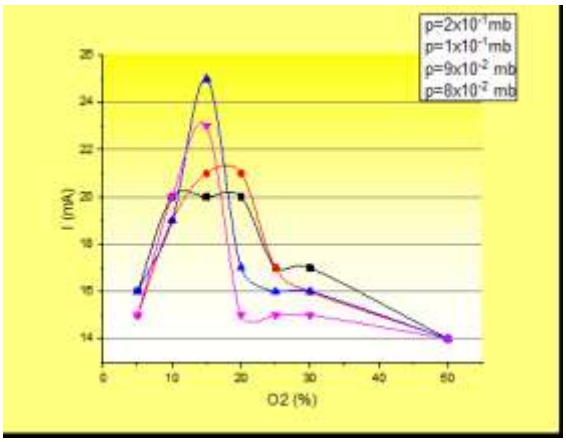

Figure 4: Different discharge current by mixing O_2 at different working pressures

Note that from the above figure(4), with a maximum discharge value of 10% oxygen at a pressure of $9x10^{-2}$ mbar, it begins to decrease gradually with an increase in the oxygen ratio and pressure, because an increase in theratio leads of oxygen to a decrease in the velocity of electrons and in The result is a reduction in electron density, which increases plasma resistance and decreases current. Lowest amount in the highest percentage of O_2 gas[13].

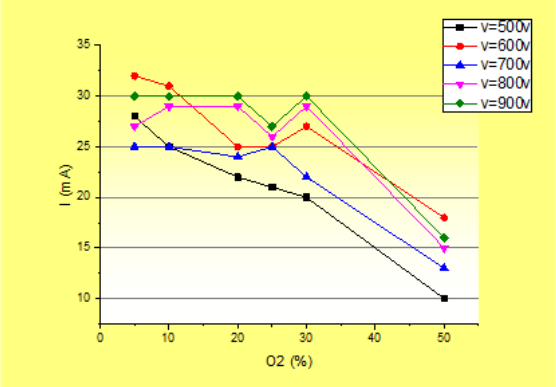

Figure 5: The discharge current varies with the different mixing O_2 percentage at different applied voltage

Note that the spark current decreases with increasing oxygen gas ratio. The shape of these values shows the discharge current for different dc voltages. The highest current in oxygen is 10% and at 600V [14].

Conclutions

The I-V specification for a different ratio of O_2 in a mixture of Ar/O_2 demonstrates that O_2 is added as well. Pour and reduce discharge flow at the same discharge and gas pressure . the increase in O_2 discharge to Ar increase the voltage failure value . in addition the temperature of the electron increase with the addition of O_2. increase, the density of the electrons decrease with the addition of O_2.

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دراسة تأثير إضافة (O2 / Ar) على الخواص الكهربائية لبلازما التفريغ التوهجي

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الملخص

تحتويبلازما الأوكسجين على العديد من التطبيقات الهامة في صناعة أشباه الموصلات فعند إضافة كمية صغيرة من الأوكسجين ، يمكن أن تختلف خصائص البلازما بشكل كبير. في هذا البحث تم قياس فولطية الانهيار بنسب مختلفة من غاز O_2 وأظهرت النتائج أن إضافة الأوكسجين يؤدي إلى انخفاض في تيار التفريغ عند نفس جهد التفريغ وضغط الغاز. على العكس من ذلك، انخفاض الجهد عند اقل نسبة من O_2 (600 ، 650 ، 730 ، 750 ، 760 ، 780 فولط) عند نسب (5٪ ، 10٪ ، 15٪ ، 20٪ ، 30٪ ، 50٪) من نسبة O_2 ، على التوالي. وأظهر النتائج طيف البلازما باستخدام جهاز التحليل الطيفي البصري زيادة في درجة حرارة الإلكترون بزيادة في نسبة O_2. بينما تنخفض كثافة الإلكترون بزيادة في نسبة O_2.