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Analysis of the Glow Discharge in a CW - CO2 Laser Based on the Similarity Variable

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ABSTRACT

This paper addresses the way lead to be voltage- current diagrams of the carbon dioxide lasers with different combinations ratio of CO2: N2: He. The laser system with inner diameter of discharge tube, ~ 10 mm and the distance between the electrodes 1m and the operational gas mixture pressure, variable from 10-2 up to 3×10-2 bar. The analysis of the glow discharge was studied in terms of similarity variable (Pd).

Keywords: *CO2 laser, Glow discharge, similarity variable diagrams.*

INTRODUCTION

Although, the establishment of physical basis and primary experiment of electrical discharge have been done on the early of last century [1, 2], this subject has importance in many applications such as; spectrometry [3], in theoretical simulations [4] and experimental utilizations [5]. Among of the different plasma medium with weakly ionization, the electric discharge was been as an operative for ionization. In addition, the low pressure glow discharge medium had been as an active medium for many of gaseous lasers [6] and so in order to getting to know better result and providing an optimum discharge medium for high performance and better efficiency, this study is still attractive and important [7,8].

The CO_2 laser is one of the capable an efficient lasers in industrial applications. The pulse or continues wave emission of the laser beam is depend on pumping way [9]. In this type of laser, it is used from the gas mixture of He, N_2, and CO_2 gases and the laser radiation is takes places at the vibrational levels of CO_2 molecule. The simulation of glow discharge of medium is more complicated when using gas mixture of different types. In the CO2 lasers, the ratio of gases is generally depend on the laser application but basically, it is proposed that the ratio N_2 and CO_2 gases would be almost equal and the ratio of He is more than the two others. The adding of the He and N_2 gases causes that the laser efficiency to be extremely increases. Indeed, the role of He gas is in order to reduce the discharge medium temperature since it has a large thermal conductivity and transfers the thermal energy into the wall tube of the laser [10]. In the electrical pumping process, N_2 atomic level at the energy of 0.3 eV basically plays the role of excited level due to electrical pumping and after the relaxation; its energy transfer into the upper level of CO_2 gas (i.e. population inversion level) through spontaneous emission and the lasing action takes places through radiation from the populated vibrational state in to the ground state of CO_2 molecule [11].

The main goal in this study is to characterize the current – voltage diagnostics of glow discharge in terms of gas pressure, similarity variable characteristic (pd). Furthermore, the characteristics of the gas mixture have been investigated at different gas ratio. In addition, in order to prevent from opto-galvanic effects [8], the electrical measurements have been done without optical resonator of laser system [12].

EXPERIMENTAL SETUP

The schematic diagram of the power supply, cooling system laser tube and measurement devices are shown in the Figure1. The material of laser tube is Pyrex glass with inner radius of 10 mm and electrode material is from Steel-Chrome with 1 m distances. The purity of N2

was 99.999% and for He and CO2 were 99.995%. The gas mixture system includes three needle valves for three gas spices and a vacuum gage which is made by Edwards Ltd. The linear power supply made by Hypotonic 875-33 Ltd, probe voltage P6013 by Tektronix Ltd, and oscilloscope by Tektronix 4045 for registration of discharge voltage and current signal.

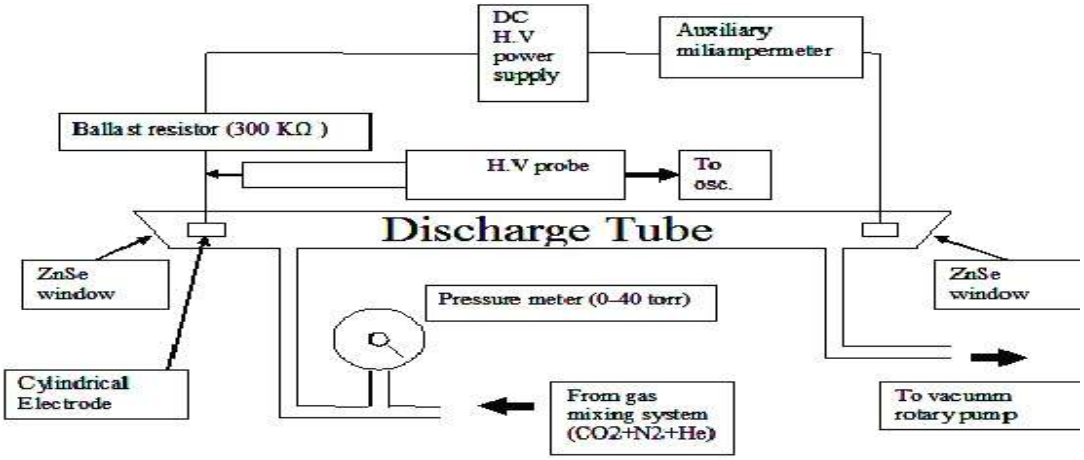

Figure1. *The schematic diagram of the experimental setup*

RESULTS AND DISCUSSIONS

The experimental conditions were obtained based on the glow discharge similarity variable (pd). The dependence of discharge voltage on the pd for given gas mixture is shown in the Figurre2

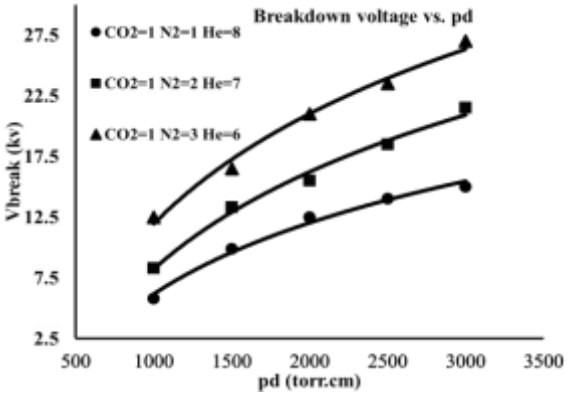

Figure2. *The variation of discharge voltage in terms of pd*

The ratio of CO2/N2 at the gas mixture of 20% is 1, for 30% is 1/2 and for 40% is 1/3. For instance in the mixture of 20% the ratio of CO2 is 10%, N2 is 10% and He is 80%. It is worth mentioning the condition is as that in the right hand side of Pashan curve and considering to the theoretical models introduced for gas discharge at low pressure [13] and the behavior of discharge voltage is approximately assumed to be linear. Other point is that the discharge voltage is decreased when the ratio of He is increased relative to the two another molecular gas.

The variation of electrodes potential in terms of discharge current at the total pressure in the range of 10 to 30 torr are shown in the Figures3-7.

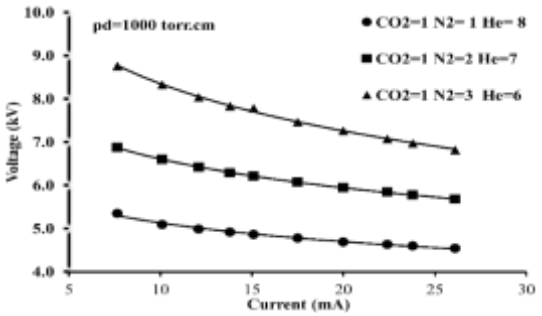

Figure3. *The behavior of glow discharge voltage vs current at pressure 10-2 bar.*

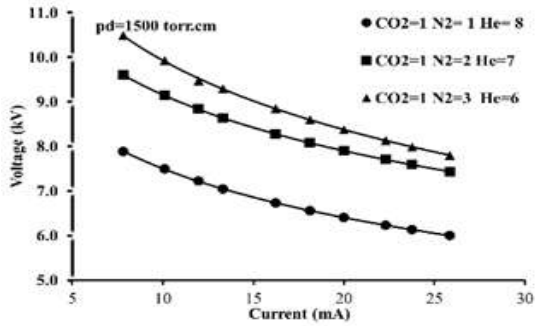

Figure4. *The behavior of glow discharge voltage vs current at pressure 1.5× 10-2 bar*

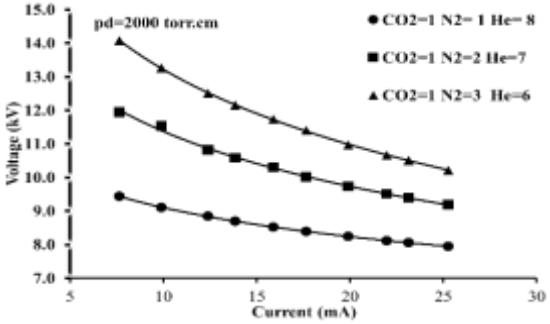

Figure5. *The behavior of glow discharge voltage vs current at pressure 2× 10-2 bar*

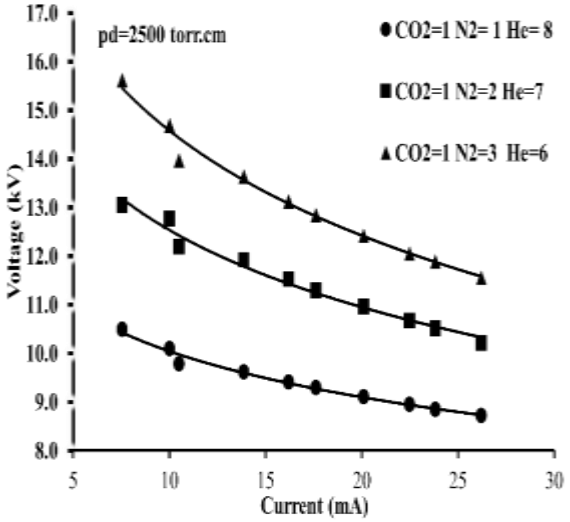

Figure6. *The behavior of glow discharge voltage vs current at pressure 2.5×10-2 bar*

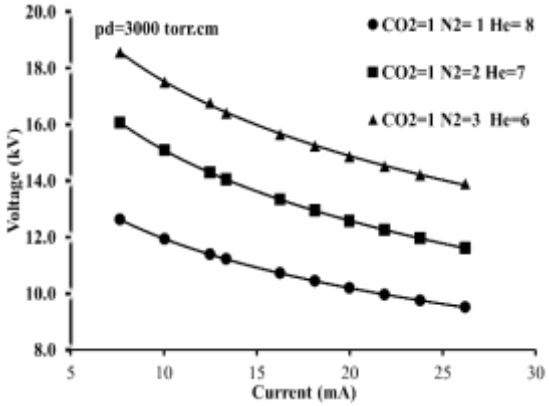

Figure7. *The behavior of glow discharge voltage vs current at pressure 3× 10-2 bar.*

The experimental data and the approximated discharge voltage are given in the Table1 at different total pressure and gas mixture.

Table1. *The experimental data and discharge voltage at different pressure and gas mixture.*

	10 torr		15 torr		20 torr		25 torr		30 torr	
	Exp	**Theo**	**Exp**	**Theo**	**Exp**	**Theo**	**Exp**	**Theo**	**Exp**	**Theo**
20%	5.8	6.4	9.9	11.1	12.5	12	14	13.8	15	17.8
30%	8.3	8.8	13.3	13.3	15.5	16.6	18.5	18.8	21.5	23.5
40%	12.5	12	16.5	15.1	21	20.6	23.5	22.2	27	26.4
Tot. Rel. Dev (%)		5.9		6.6		4.1		3.3		8.0

As it can be seen with increasing of the total ratio of gas mixture and constant pd the discharge voltage is increased and also is increased versus pd at the constant gas ratio.

CONCLUSION

It is resulted that in cw CO2 (gas mixture CO2, N2, He) lasers at low pressure (10-30 mm Hg), the Pashan law was governed and the discharge similarity variable (Pd) depended on the ratio of total molecular gas relative to the He ratio in gas mixture. Thus, it showed the effect of collisional ionization between He atoms at the quasi-stable levels and ground state molecular levels of CO2 and N2. In addition, the effect of molecular gas percentage in the glow discharge voltage-current behavior was specified and it was established that when the gas mixture has more molecular species percentage, the electrical resistive of discharge had more variation with current increasing.

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