# Electrical and optical characterization of $CO_2$/He glow discharge

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**Abstract.** Glow discharge studies are produced in a atmosphere of $CO_2$/He mixture at a pressure of 1.5 Torr. The experiment was conducted to observe the optical emission spectroscopy of the plasma, and determined the electron temperature and ion density by the use of a double Langmuir probe. The electron temperature of the mixture was found in the range of 4.54 to 5.37 eV, and the ion density values between 2.15 and 12.00 x $10^9$ particles/cm$^3$. The principal species observed were: $CO_2^+$, $CO^+$, CO, $C_2$, $O_2^+$, O*, and He*.

## 1. Introduction

Cold plasmas studies produced at low pressures (few Torr) are of great importance due to their applications in various scientific and technological fields, for example, the characterization of the glow discharge parameters as voltage, current, electron temperature and density, which are essential for their uses in the creation or modification of materials, used in industry; for the simulation of planetary atmospheres[1, 2] and understanding of atomic and molecular processes that occur in such systems. $CO_2$ is one of the gases that make up our atmosphere, its density is 379 ppm (particles per million) but slight increases in his percentage is one of the responsible of the greenhouse effect [3]. Greenhouse Gas Inventory Report has stated that $CO_2$ emissions account for 85% of all greenhouse gas emissions with the majority of these emissions created as the result of fossil fuel combustion and the increase in the concentration of $CO_2$ in the air [3, 4]. Several solutions have been proposed to mitigate the environmental effects of rising $CO_2$ emissions through both government policy and scientific innovation [5]; direct conversion processes remain the main option for thin films disposition or treatment of materials, with plasma assisted methods, RF plasmas[5, 6], corona discharge [7], dielectric barrier discharge [8] and glow discharges [9]. Due to the damaging effect on the environment than fossil fuels leads, it has been looking for alternative sources of energy waiting for the damage decrease in the near future [10]; why searching for a solution to this problem, so it is important to find physical mechanisms leading to dissociate the main element resulting from the combustion process. This paper presents the electrical and optical characterization of a $CO_2$/He glow discharge.


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## 2. Experimental details

The schematic diagram of the experimental setup is described in previous work [11, 12]. The discharge cell consists of two movable parallel electrodes enclosed in a stainless steel vacuum chamber. The two electrodes were made of copper disc of 2.5 cm in diameter. The electrodes are positioned at the center of the reaction chamber with 20 mm gap spacing. The plasma chamber had a volume of $1.16\times10^4$ cm$^3$ and it was pumped down by a vacuum system (Turbomolecular pump Alcatel ATP80 and mechanical pump Varian DS302) to a base pressure of $10^{-6}$ Torr. A continuous dynamic flow of $CO_2$–He gas mixture (ultra-pure gases, Praxair 99.99%) was let in the system through needle valves at the desired pressures. A DC glow discharge was produced between the two electrodes. While keeping the total pressure at 1.5 Torr, the concentration of $CO_2$ gas in the mixture was done by changing the He partial pressure. To keep a current constant of 10 mA (measured by a digital Fluke multimeter model 8846A), independent of the gas mixture, a ballast resistance (R = 5kΩ) was used, it was done by changing the power supply voltage (Spellman SA4) between 300V (for 100% of He) to 500V (for 100% of $CO_2$). The discharge voltage in the gas mixture is lower than that in pure carbon dioxide. In a lateral flange, a quartz window was used to monitor the active species generated in the glow discharge by optical emission spectroscopy; the spectrum (200–1100 nm) was measured using a spectrometer Ocean Optics HR4000CG-UV-NIR. The spectrometer has a resolution of 0.15 nm. For the electron temperature and density measurements, the voltage difference applied to the probe was performed by computer control scanning to -30 V to +30 V by a regulated DC power supply. The scanning time for one *I-V* curve was 5-10 minutes. Owing to sputtering or contamination of the probe tips, the total measurement time for one probe was restricted to approximately 5-6 h. The final *I-V* curves obtained were the results of an average of 15 data scans at each probe voltage.

## 3. Results

From the measured experimental current-voltage characteristic curve (Figure 1) of 33.3%C0$_2$/66.6%He glow discharge plasma obtained by double Langmuir probe at a pressure of 1.5 Torr, it is possible to get electron temperature ($T_e$) and ion density ($n_i$) [13].

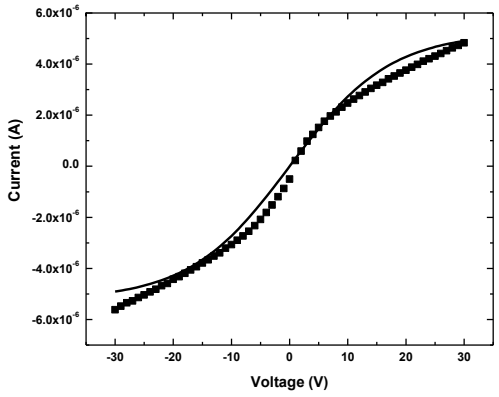



**Figure 1.** Curve fit of double Langmuir curve of V vs. I.

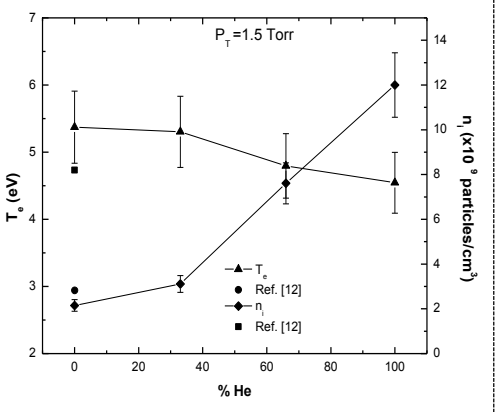



**Figure 2.** $T_e$ and $n_i$ in a mixture of $CO_2$/He at different concentrations of He.

Figure 1 shows that the theoretical curve (solid line) fits well to the measured data, with a correlation coefficient of 0.988. That procedure gives an electron temperature ($T_e$) of the mixture in the range of 4.54 to 5.37 eV, and ion density ($n_i$) values between 2.15 x $10^9$ and 12.00 x $10^9$ particles/cm$^3$, these values are observed in figure 2. Errors in the $T_e$ and $n_i$ were discussed in reference [12] and the overall variations in $T_e$ and $n_i$ were found to be 10% and 12%, respectively.

Figure 2 shows the electron temperature ($T_e$) and ion density ($n_i$) in a $CO_2$/He glow discharge mixture

at different concentration of He gas. The measurement was conducted at concentration of 0 %, 33%, 66% and 100% of He gas. It can see that the presence of $CO_2$ in the mixture significantly modifies the ion density and electron temperature. The admission of helium to the discharge decreases the value of the electron temperature, while the ion density increases. That could be explained, due that an increase in helium percentage in the mixture can be expected to reduce the electron collision frequency, thereby providing more time for electrons to gain energy from the electric field and thereby accelerating further.

The present result at pure $CO_2$ discharge is 3.8 more lower than the values obtained recently by Mendez-Martínez et al [12] for ion density, while for electron temperature is 1.8 more higher than the results obtained by Mendez-Martinez et al [12] (see Figure 2).

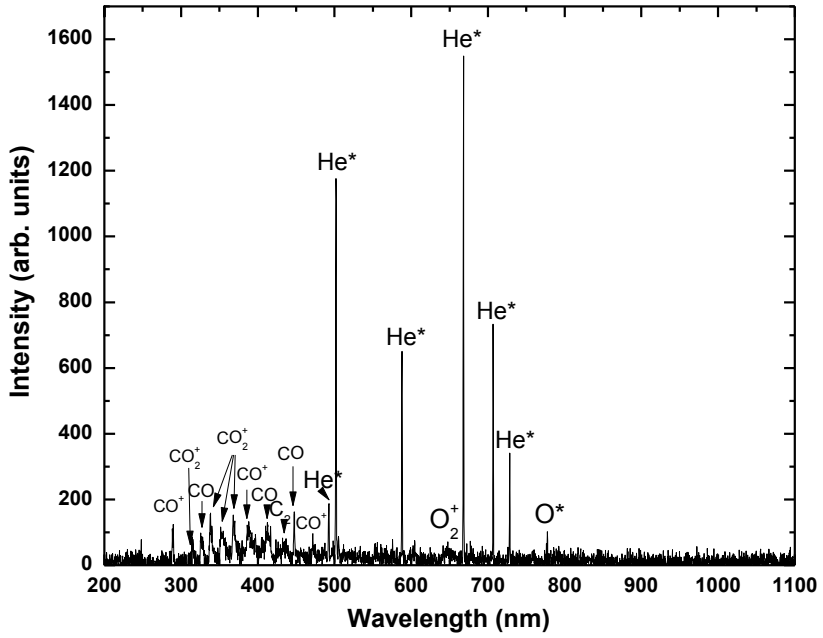



**Figure 3.** Optical emission spectrum of a mixture $CO_2$/He.

Figure 3 shows the optical emission spectroscopy of the binary mixture $CO_2$/He obtained at a total pressure of 1.5 Torr and a concentration of 33.3%$C0_2$/66.6%He. It observed that the more intense emission band correspond to carbon dioxide in the range of 285 to 410 nm; for CO and $CO^+$ bands between 285 and 475 nm and for helium lines in the range of 490 to 730 nm. It was also possible to identify bands of $O_2^+$ and lines of O*.

A detailed analysis of emission spectra shows the formation of the following elements: $CO_2^+$ (288.65, 315.48, 388.27, 354.12, 367.58 and 407.02), $CO^+$ (289.98, 315.48, 338.37 and 471.53 nm), CO (325.82, 368.11, 412.52 and 447.04 nm), $C_2$ (435.03 nm), $O_2^+$ (641.53 nm), O* (777.23 nm), and He* (492.57, 501.90, 587.94, 668.17, 706.82 and 728.44 nm).

The main atomic and molecular processes in the glow discharge produced by the binary mixture of carbon dioxide and helium are mainly due to processes of excitation and ionization by electron impact. So, the formation of these elements can be described as: $CO_2 + e^- \rightarrow CO_2^+ + 2e^-$, ionization; $CO_2 + e^- \rightarrow CO + O^+ + 2e^-$, dissociation; $CO_2 + e^- \rightarrow CO^+ + O^* + 2e^-$, dissociation and excitation; $CO_2 + e^- \rightarrow$

$C + O^+ + O+ 2e^-$, dissociative ionization; $C + C \rightarrow C_2$, recombination, and $He + e^- \rightarrow He^* + e^-$, excitation.

## 4. Conclusions

The species identified by optical emission spectroscopy of $CO_2$/He glow discharge are: $CO^+$, $CO_2^+$, CO, $C_2$, $O_2^+$, O* and He*. The electron temperature was found are in the range of 4.54 to 5.37 eV and the ion density between 2.15 x $10^9$ and 12.00 x $10^9$ particles/$cm^3$. It observed that the presence of $CO_2$ in the mixture significantly modifies the ion density and electron temperature. The admission of helium to the discharge decreases the value of the electron temperature, while the ion density increases. That could be explained, due that an increase in helium percentage in the mixture can be expected to reduce the electron collision frequency, thereby providing more time for electrons to gain energy from the electric field and thereby accelerating further.

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