DOI:10.24996/ijs.2018.59.1C.6

ISSN: 0067-2904

Spectroscopic study of AL nitrogen plasma produced by DC glow discharge

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Abstract

The work done in this paper to study properties for nitrogen plasma generated by method electrical discharge when the aluminum was a target. Experimental study on the effect electrodes material, applied voltages on spectroscopic parameter for DC discharge plasma in Nitrogen gas using planner electrodes were done.

The electron temperature, increase with increasing applied voltage from (700 to 1100) V. While the plasma density, calculate by Stark broadening effect, which increase with it.

The peaks intensities for N2 transition (λ= 336.6 nm and 391.4 nm) increase with increasing applied voltage. The vibrational energy (TVib) for N2 molecular increase from 0.165 to 0.185 eV with increasing applied voltage from (700 to 1100) V, which less than the calculated electron temperature.

Keywords: Nitrogen plasma, Glow discharge, Spectroscopy, Temperature electron, Density electron.

دراسة طيفية للبلازما النيتروجين المنتجة بواسطة التيار المستمر

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الخلاصة

العمل المنجز في هذا البحث هو لدراسة خصائص بلازما النيتروجين المنتجة بطريقة التفريغ الكهربائي عندما يكون الالمنيوم هو الهدف. تم أجراء دراسة تجريبية على تأثير مواد الأقطاب، الفولتية المطبقة على المعلمات الطيفية بلازما التفريغ الكهربائي للتيار المستمر في غاز النيتروجين باستخدام أقطاب متوازية.

ظهرت العديد من القمم الجزيئية لل N_2 في المدى 300-440 mm وبعض القمم الإضافية المقابلة للخطوط الذرية والأيونية للنيتروجين مادة الهدف والهيدروجين، في جميع العينات.ازدادت درجة حرارة الإلكترون، المحسوبة حسب طريقة النسبة، مع زيادة الجهد المطبق من 700-1100 v في حين أن كثافة البلازما، والمحسوبة من تأثير ستارك لتوسيع القمة ازدادت معها. تزداد شدة القمم لخط N_2 (336.6 nm و 391.4 nm) مع زيادة الجهد المطبق.

الطاقة الاهتزازية للالكترون الالكترونات T_{vib} لجزيئة N_2 من 0.165 إلى 0.185 فولت مع زيادة الجهد المطبق من 700 إلى 1100 V، والتي هي أقل من درجة حرارة الإلكترون المحسوبة.

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Introduction

Matter can exist in a variety of stable forms which are governed by the physical environment. The conventional classification of stable states is that of the solid, liquid and gas. However, it has been recognized that a fourth state can be distinguished, this is the plasma state. Plasma is characterized by a collection of charged particle (ions and electrons) [1]. The plasma generated by several method [2]; **Electrical**: Discharge tubes, tokomak, stellarator. **Thermal**: Q-machine, shock-waves, stellar atmosphere. **EM waves**: laser fusion. **Particles**: high energy neutral beam injection.

Glow discharge plasma can be defined as a region of relatively low- temperature gas that is sustained in an ionized state by energetic electrons. The most commonly used method of generating and sustaining a low-temperature plasma for technical applications is applying an electric field to a neutral gas [3].

Any volume of a neutral gas always contains a few electrons and ions that are formed, as a result of the interaction of cosmic rays or radioactive radiation with the gas through.

The Nitrogen plasma was diagnosed by using optical emission spectroscopy (OES), Optical emission spectroscopy is a popular technique to investigate glow discharges for identification of plasma species used in surface treatment [4].

Consider two electrodes inside a chamber containing gas, the glow that will be formed in low-temperature gas with a high-impedance dc. Power supply is illustrated in Figure-1, [5]. The plasma produced in the abnormal glow discharge [5] [6]

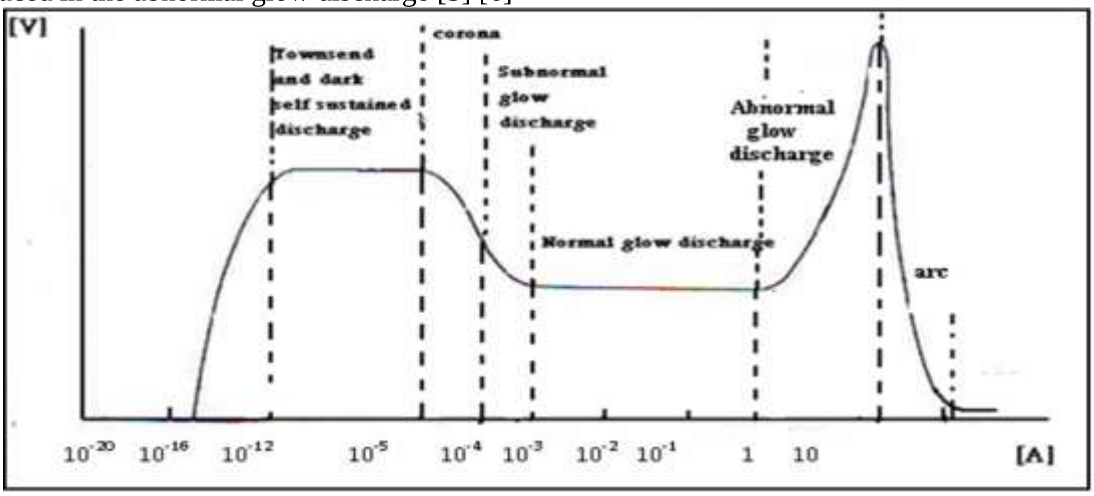

Figure 1-The formation of a dc glow discharge regions [6].

In this study, aluminum was used as a pole and the properties of the nitrogen plasma produced by electrostatic discharge were studied. In nitrogen molecule, the 1s electrons are localized, so their orbitals do not overlap effectively. In turn, the remaining 10 valence electrons occupy molecular orbitals resulting from mixing the atomic orbitals 2s and 2p, including s–p interactions due to their proximity, as shown in Figure-2 [7].

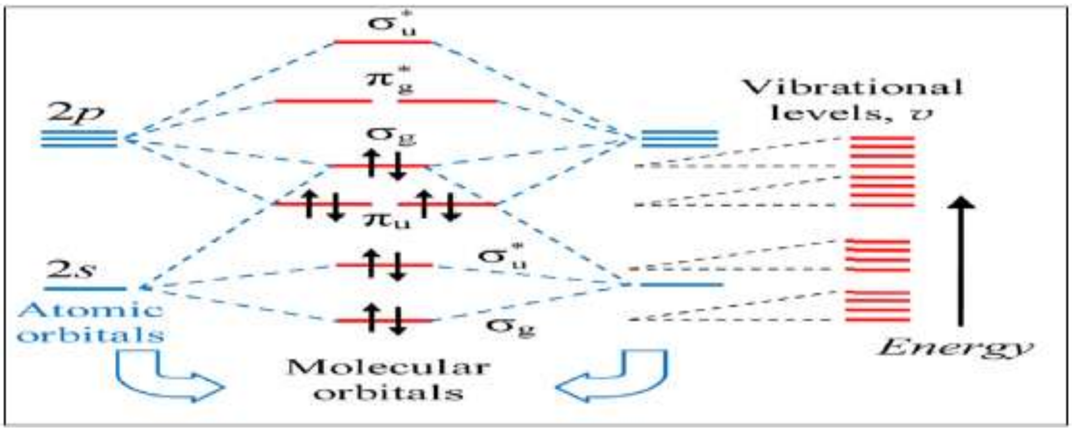

Figure 2- The molecules of nitrogen perform vibrations as fashioned by the particular electron occupancy of bonding versus anti-bonding (*) molecular orbitals [7]

Experimental Part

Figure-3 shows a photograph of the main experimental setup of DC discharge plasma system used in this work, which consist of: double stage rotary pumps, a glass chamber, Perini head and reader, H.V DC-power supply, multi-meters for discharging current measurements, high voltage voltmeter and gas source. The gas source – flow controller system which used for delivering the feed to the plasma chamber at desired flow rate and gas pressure. It consists of the nitrogen gas storage cylinders, regulators, tubing and needle valve.

Figure 3-The image of DC discharge system with.

Where the system consists of the:

Chamber was evacuated by two stages rotary pump, CIT-ALCATEL Annacy, (made in France) to a base pressure 5×10^{-3} mbar. Pirani gauge type Edward, (made in England) was used to measure the pressure of the chamber from atmospheric to the base pressure of the vacuum system, of about 10^{-3} mbar. A home - made variable power supply constructed for delivering 4 kV. The voltage transformer (220V/2kV), high voltage diodes (6 kV), 10 kΩ current limiting resistor and capacitor (5kV) 1μf. In addition, there is Ammeter and Voltmeter annexed to the system to control the delivered electrical current and voltage respectively. Spectrometer used to Spectral diagnostics during the process by monitoring of the plasma. As shown in Figure-4.

Figure 4-The image of spectroscopy measurement setup

After the configuration of the system and the measuring instruments attached to it, started the experiment which includes several steps. The atmospheric gases physic-chemisorbed on the interior surfaces, arises from the exposure of these surfaces to ambient atmosphere.

So, the first step in this procedure is to make degassing of rotary pump (backing) to reduce the pressure inside this pump, and to get rid of the heavy molecules that prevent increased vacuum, and this process will continue for a period of 60 minutes. After that, the chamber was vacuumed down to 5×10-3 Torr. At the finish this procedures we begin to deliver the nitrogen gas inside the chamber with purity 99.9% until reach to the atmosphere pressure to ensure the presence of only the nitrogen gas molecules inside the chamber, and then vacuum the chamber to selected pressure values chamber.

Result and Discussion:

Figure-5 displays the spectroscopic patterns produced by DC discharge in nitrogen gas with 3 cm inter electrode distance at different applied voltages (700 to 1100) V using aluminum target. There are many N2 molecular peaks in the range from 300 to 480 nm and some peaks corresponding to atomic and ionic lines for Aluminum, and nitrogen. The peaks intensities increase with increasing applied voltage from 700 to 1100 V, as a result of increasing the electrons energy by electric field. This increment excited more atoms (or molecular) due to increasing the excitation cross section which mainly depend on electrons energy [8]. Two of hydrogen lines were appeared at 656.28 nm and 486.13 nm in all samples.

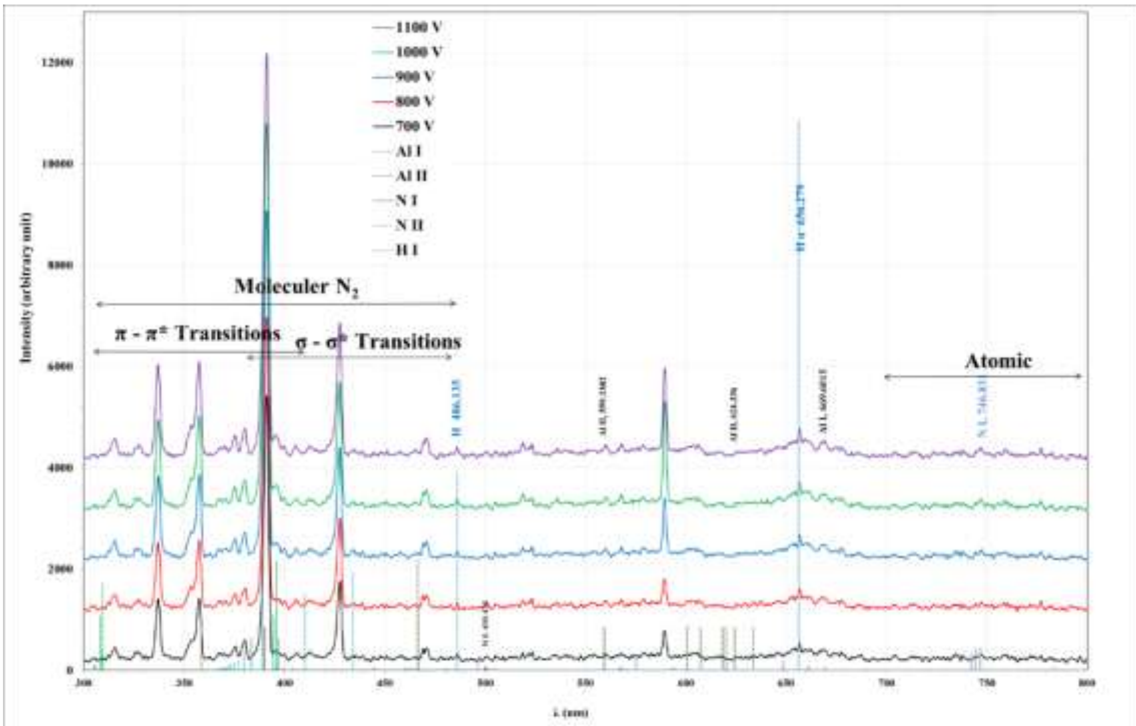

Figure 5- Plasma emission pattern produced by dc discharge in nitrogen using Aluminum target with different applied voltage

The electron temperature was calculated employing the ratio method between the intensities of the two hydrogen lines for different applied voltages.

Figure-6 shows the Hα peaks fitted with standard Gaussian curve to find there full width at half maximum (Δλ). The Stark effect method was used to determine the electron density with different applied voltage. It's clear that the full width increase with increasing applied voltage.

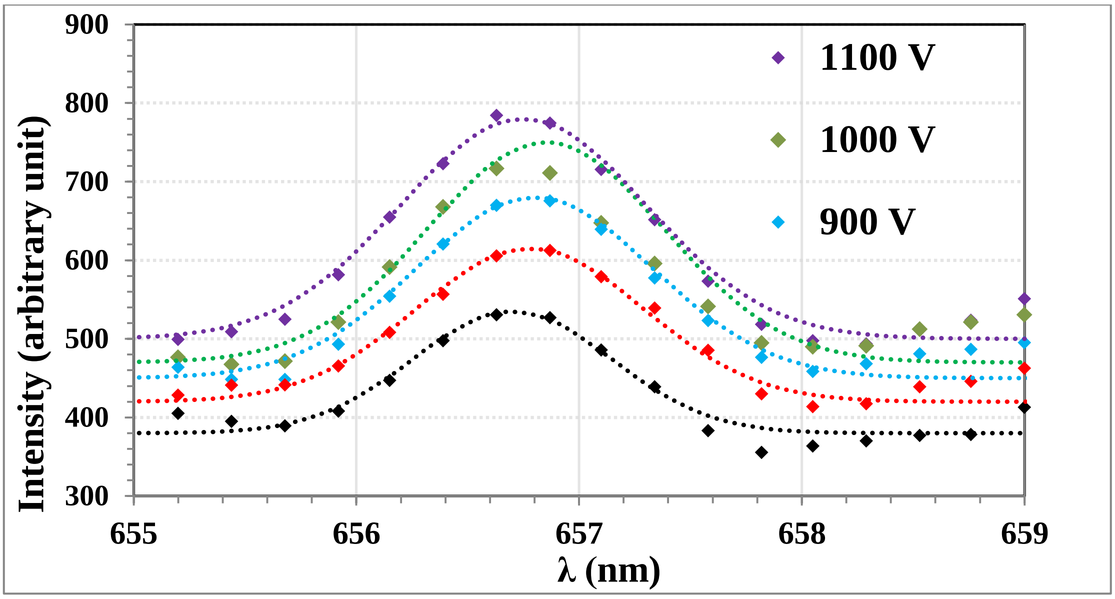

Figure 6- Hα (656.28 nm) peaks broadening and Gaussian fitting at different applied voltage using Al target in nitrogen gas.

Figure-7 illustrates the variation of electron temperature and electron density with applied voltage. The electron temperature increase from 0.592 to 1.116 eV, while the electron density increase from 5.25×1016 to 7.0×1016 cm-3 with increasing applied voltage from 700 to 1100 V as a result of increasing energy gain to electrons from increasing electric field.

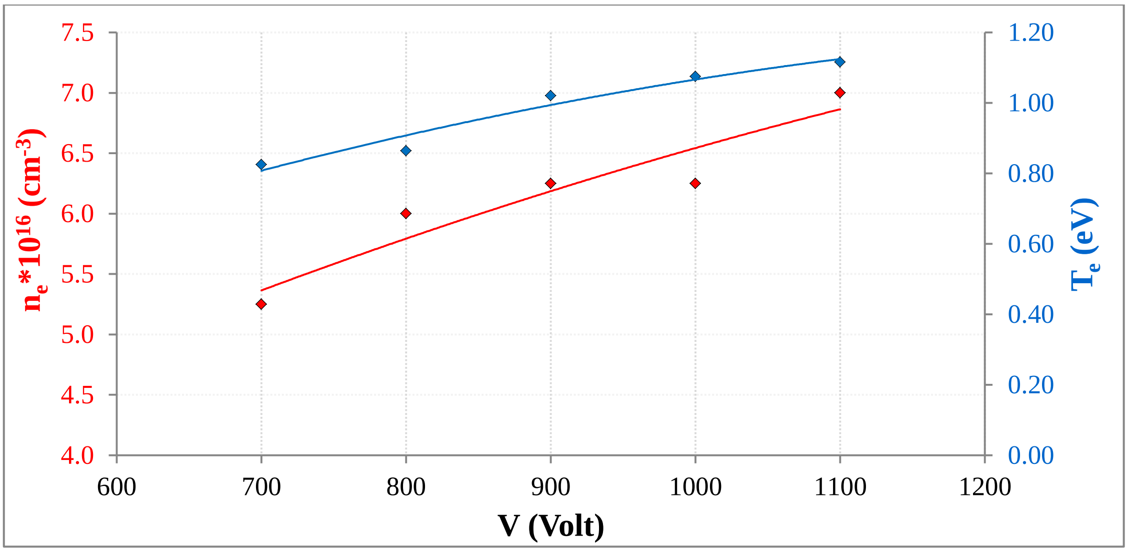

Figure 7- The variation of Te and n_e for DC plasma in N_2 with different applied voltage using Al target at constant working pressure (0.2 mbar) with 3 cm inter electrode distance.

Table-1 illustrates the calculated values of (Te, λD, ωp and ND) for DC discharge in N2 gas with different applied voltage using Al target at constant This pressure for abnormal glow discharge with 3 cm inter electrode distance

Table 4 -plasma parameters DC plasma in N_2 with different applied voltage using Al target

V(v)	Te(ve)	ne×1016 (cm-3)	ωp ×1012 (rad/s)	λD *10-6(cm)
700	0.592	5.250	12.922	2.496
800	0.620	6.000	13.814	2.388
900	0732	6.250	14.099	2.543
1000	0.772	6.520	14.099	2.611
1100	1.116	7.000	14.921	2.966

Figure-8 shows the spectroscopic patterns for dc discharge in nitrogen at wavelength range from 320 to 480 nm, these region shows many clear peaks corresponding to the N2 molecular transition, at different applied voltages (700 To 1100) V, using aluminum target.

There are many peaks corresponding to π-π^* transitions and others to σ-σ^* transitions for nitrogen molecular, with energy comes from coupling of electronic, vibrational and rotational energy difference. There are two peaks with pure electronic transitions indicated with (ν=0 and ν' = 0) for π-π^* and σ-σ^*. These levels split into many sub levels due to coupling with vibrational and rotational energy levels.

Also, the intensity of emission peaks increase with increasing the applied voltage, due to increasing the means of electron energy causes more exited molecules and atoms.

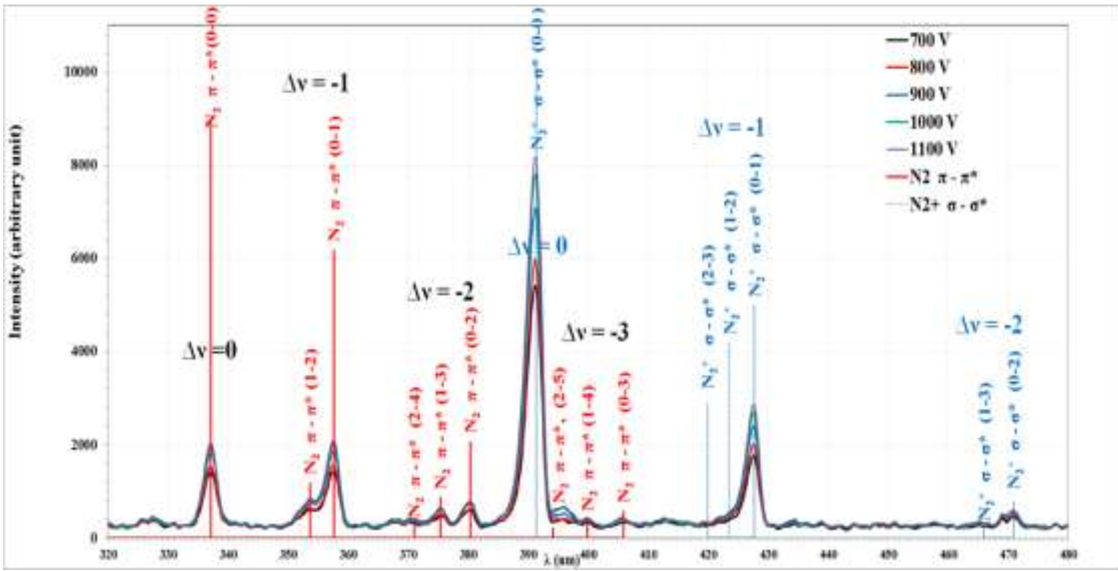

Figure 8-Matching the emission patterns, for different applied voltage using Al target, with N_2 molecular lines.

Figure-9 shows the variation of peaks intensities for the two transitions with (ν=0 and ν' = 0) located at λ= 336.6 nm and 391.4 nm. The intensity for the two lines increase with increasing applied voltage.

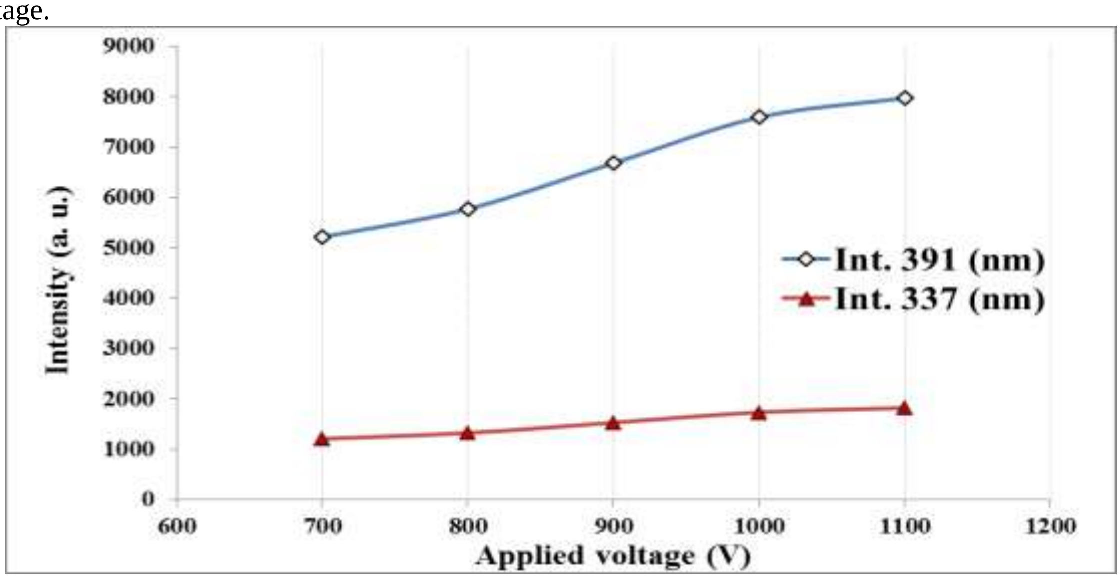

Figure 9-Variation of line intensities for pure electronic transition with applied voltage using Aluminum target.

Figure-10 shows the intensity for the two lines versus the used DC voltage using aluminum target. It is clear that the intensity ratio increase with applied voltage with values.

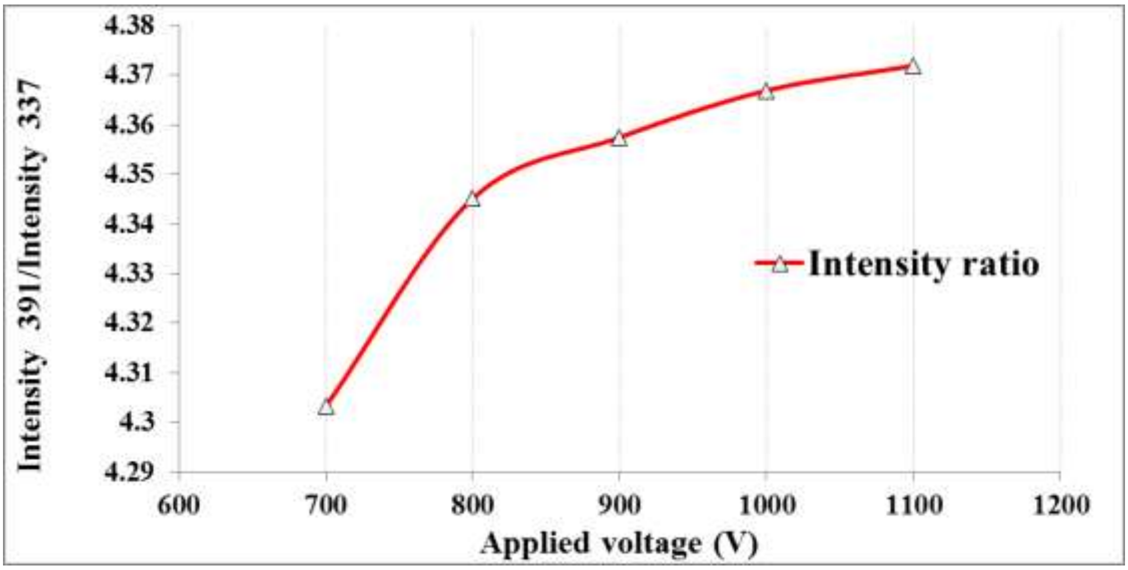

Figure 10-Variation intensity ratio between the two lines ($I_{391.4}$:$I_{336.6}$) with applied voltage using Aluminum target.

The vibrational temperature for N2 molecular for emission produced by DC discharge at different applied voltages, using aluminum target, were calculated using (Spectrum Analyzer 1.7) software, depending on the probability of transitions and energy levels which included in this program.

The variation of vibrational temperature of nitrogen molecular (TVib.) with applied voltage was shown in Figure-11. The (TVib) increase from 0.244 to 0.348 eV with increasing applied voltage from 700 to 1100 V.

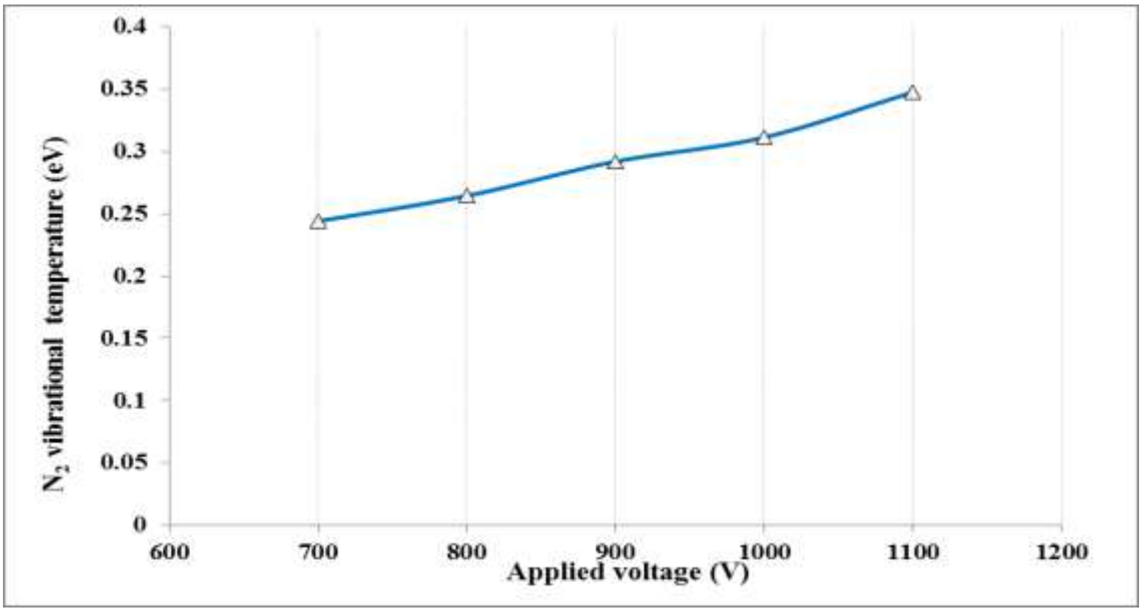

Figure 11- variation of vibrational temperature with applied voltage using Al target.

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