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# NON-LINEARITY OF $N_2$ – Ar – H2 PLASMA MONITORED BY OES

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## ABSTRACT

*New and efficient monitoring strategies are necessary to obtain interesting answers of the plasma. In order to comprehend the dynamic involved in such an ambient when interactions occur between solids and free particles, it has been utilized the plasma diagnostic by Optical Emission Spectroscopy – OES. Due to the large publication of studies related to plasma combinations of $N_2$, $H_2$ and Ar, the atmosphere of $N_2$ – Ar – $H_2$ plasma was analysed by OES technique. The species $N_2^+$, $N_2$, and H$\alpha$ were identified and monitored observing the relative intensities increasing of those three species versus flow of $H_2$ gas; it has been observed a non-linear comportment.*

## 1. INTRODUCTION

Nitrogen plasma or plasma mixture in which nitrogen is an actuating gas is commonly used in coating techniques in order to improve superficial properties such as microhardness, corrosion resistance and others [1,2,3]. The substitution of pieces superficially insufficient for desirable ones must be done with lesser monetary and temporal costs in order to get the interest of the industries. Because of that, several experiments have been achieved and one of the many parameters which can be monitored is the plasma mixture. Researchers have published which the addiction of two or three gases becomes the plasma more efficient than pure plasma in the processes of superficial modification [2,3]. In the present work is shown the gradual addiction of hydrogen gas in $N_2$ – Ar plasma in order to observe the change of all glow discharge properties and so to study the changes of the kinetic of particles presents in treatment ambient. The study is based on results of plasma diagnostic by *Optical Emission Spectroscopy* – OES which makes possible to identify, relatively quantify [1] and establish relations among species of plasma, mainly $N_2^+$, $N_2$ and H$\alpha$, modifying controls parameter such as work pressure, electrical current and applied voltage. In this work the power is kept constant. Moreover it is also justified the physical comportment of those active species and their action on material surface. Finally, it is determined under evaluated conditions which proportion becomes the plasma more energetic and efficient to optimize the processes.

## 2. EXPERIMENTAL

The vacuum system is a cylindrical chamber (40 cm in diameter and height. It is made of stainless steel). In order to active the plasma it was utilized a high voltage DC source. The OES system is composed by a monochromator with 500 mm focal length and triple grating turret. In order to study the glow discharge it was accomplish the proportions 1 $N_2$ – 1 Ar – x $H_2$ and 2 $N_2$ – 1 Ar – x $H_2$, where x varies from 0 to 4 SCCM. So, 10 proportions were studied keeping constant the power. The species analyzed were $N_2^+$, $N_2$, H$\alpha$ The intensity of Ar (811.5 nm) species acquired in plasma with the same flow of argon was equaled. All the system is depicted in the Figure 1.

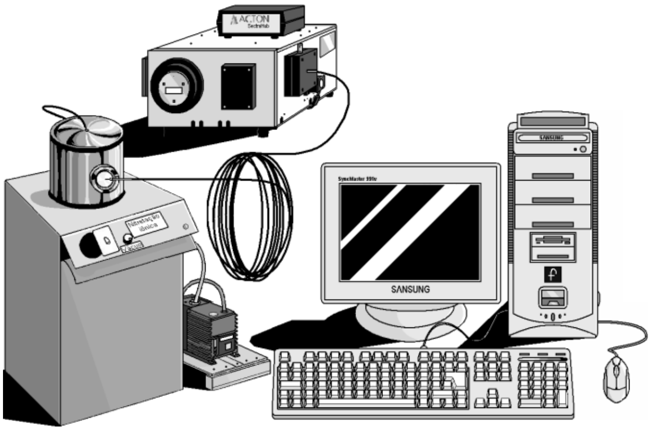


**Figure 1 – Experimental system which includes a vacuum chamber and the OES apparatus**

## 3. RESULTS AND DISCUSSION

According to the figure 2 the intensity of specie H$\alpha$ does not increase linearly. In the same point, intensity of neutral and ionic molecular species of nitrogen is higher. So, it is possible to attribute the uncommon comportment in the proportion 1 $N_2$ – 1 Ar – 2 $H_2$ to the excitation Penning promoted by argon species [1]. The figure 2 shows a light decreasing of $N_2$ species because there are more combinations between H and N when the flow of $H_2$ increases [2], except when the first introduction of the second gas occurs. The introduction of few quantities of a gas with lesser ionization potential leads to the increasing of the electrical current and the power too. When the quantity

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of hydrogen overtakes that value its function becomes to absorb the energy as much as nitrogen and argon do.

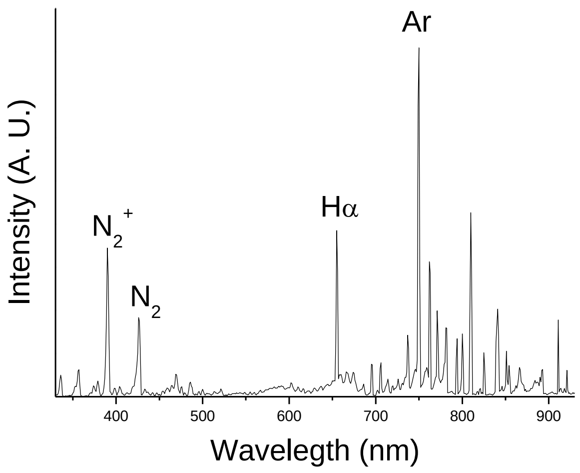


**Figure 2 –** ***Relative luminous intensities associated to $N_2^+$ (391,4 nm) blue, $N_2$ (427,1 nm) red and Hα (656,3 nm) green versus $H_2$ flow (0 – 4 SCCM). The Ar and $N_2$ flows are 1 SCCM and the power is 75 W***

But, something else happens when the proportion of nitrogen gas is increased. Accord to the Figure 3, the highest luminous intensity associated to particles of nitrogen does not appear in the same proportion of the first case. Since molecules of nitrogen are lighter then atoms of argon, the number of particles which acquire more kinetic energy is relatively larger. In this case, the addiction of nitrogen favors the chemical interactions between nitrogen and hydrogen particles resulting in radicals such as NH [4]. Those connections impede the emissions of excited nitrogen ions. However, the impacts of fast electrons break those NH radicals allowing the creation of new nitrogen molecules. Because of that equilibrium, the number of photons emitted by nitrogen does not vary until the total pressure becomes high enough in order to decrease significantly the speed of electrons.

That effect can be viewed better in the Figure 4 in which the evolution of $N_2^+$ excited particle is monitored in 4 proportions.

The Figure 5 presents the emission aspect of $N_2$ - Ar - $H_2$ plasma mixture.

## 4. CONCLUSIONS

Creation of NH radicals decrease the kinetic energy of electrons in $N_2$ - Ar - $H_2$ plasma mixture.

If the quantity of $N_2$ gas is similar to Ar gas, the maximum energy of plasma is in the point of 2 SCCM of hydrogen flow, when there are enough Ar particles in order to promote excitation of $N_2$ species. That effect is known as Penning excitation..

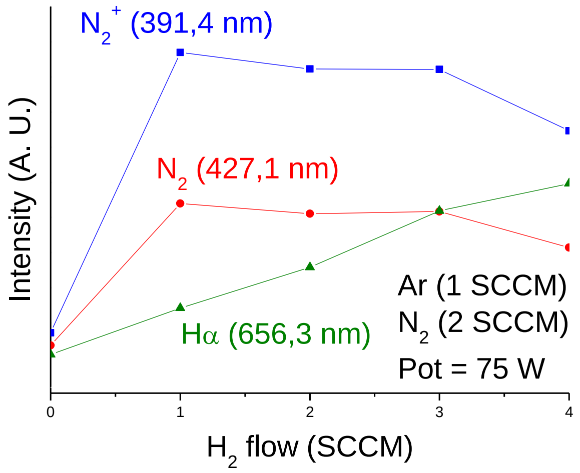


**Figure 3 –** ***Relative luminous intensities associated to $N_2^+$ (391,4 nm) purple, $N_2$ (427,1 nm) red and Hα (656,3 nm) green versus $H_2$ flow (0 – 4 SCCM). The Ar flow is1 SCCM, $N_2$ flow is 2 SCCM and the power is 75 W***

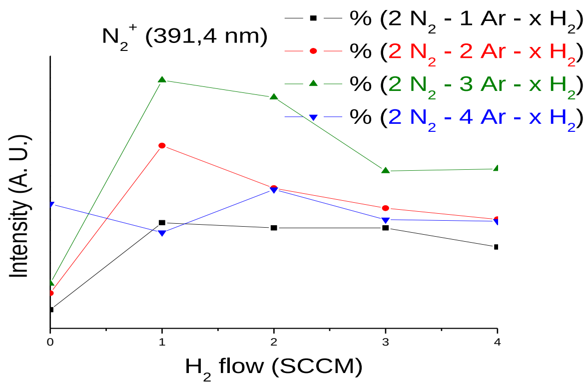


**Figure 4 –** ***Relative luminous intensities associated to $N_2^+$ (391,4 nm) versus $H_2$ flow (0 – 4 SCCM). The Ar proportion is varied too. The power is 75 W***

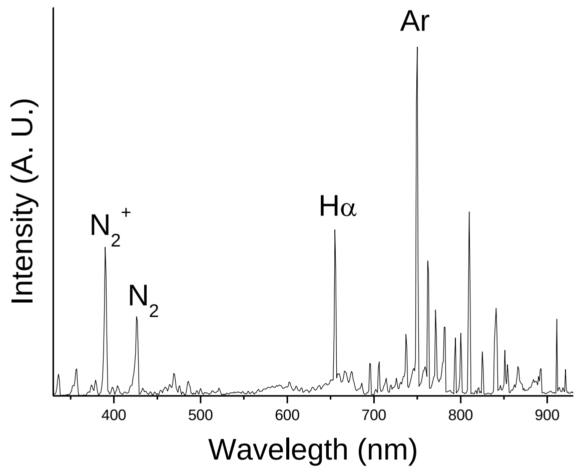


**Figure 5 –** *Emission aspect of $N_2$ - Ar - $H_2$ plasma mixture. The flow of all gases is 4 SCCM. The power is 75 W*

## 5. ACKNOWLEDGEMENTS

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