Hydrogen production from water by using an argon microwave plasma at atmospheric pressure: preliminary study

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In this work the capability of an argon microwave plasma (MIP) generated by a surface wave (SWD) at atmospheric pressure as an effective source to obtain hydrogen from water molecules has been tested. In this way, molecular bonds are broken inside the discharge by collisions with the plasma particles, liberating the hydrogen contained in them. The water samples are driven into the discharge using a method called bubbling. It has been verified that the hydrogen line intensities increase when the water quantity introduced in the plasma does. This process is very clean due to the absence of other reaction products. The analysis has been carried out by studying the radiation emitted by the plasma (Atomic and Molecular Emission Spectroscopy).

1. Introduction

Hydrogen could constitute an important source of energy in the future since this gas can be easily used to obtain electric energy by means of fuel cells. Its combustion liberates a large amount of energy per unit weight and does not involve CO_2 gas emission. The relative shortage of H_2 free in the atmosphere forces to obtain this compound from other molecules containing hydrogen in their composition [1,2]. Among several compounds such as hydrocarbon alcohols [3,4], water could be an important source of hydrogen. The energy required to break the bonds of the water molecule can effectively be provided by a plasma discharge. The plasma characteristics, such as high temperature, energy density and degree of ionization, fast response time and minimal cost has led several researchers to use them as a reactive media for H_2 production [5,6].

The aim of this work is to study the capability of an argon microwave plasma (MIP) generated by a surface wave (SWD) at atmospheric pressure as an effective source of energy to liberate the hydrogen of the water molecules introduced in it. They are very stable and have a great reproducibility, and to be sustained very low microwave power is required.

2. Experimental procedure

The argon discharge was created in a 1.5 and 4 mm inner and outer diameters quartz tube. The tube had one of its ends opened so a plasma column at atmospheric pressure could be obtained. The plasma gas was argon with a purity of 99.999% and its flow (245 slm) could be controlled by a HI-TEC system (IB 31). The microwave power for the creation and maintenance of the discharge (100 W) was provided in a continuous mode at a frequency of 2.45 GHz by a Sairem Generator (GMP12kT/t). This power was supplied to the plasma by a *surfatron* [7] as an exciter device.

The analysis was carried out by studying the radiation emitted by the plasma in the shape of spectrums (Atomic and Molecular Emission Spectroscopy). This radiation was collected by an optical fiber and driven to the entrance slit of a Jobin-Yvon Horiba monochromator. In Figure 1 the schematic diagram with the plasma source and the optical configuration to register the spectra is shown.

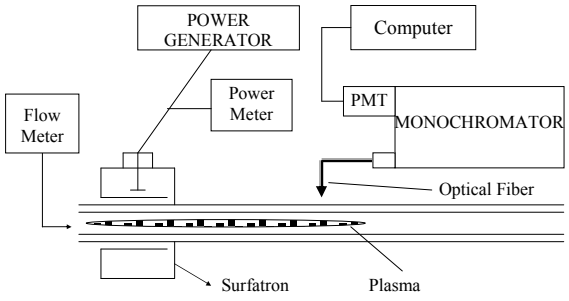

Figure 1. Experimental setup.

The method used to introduce the water samples in the discharge is called bubbling. It takes place at room temperature and does not involve an additional energetic significant consumption. Part of the argon gas flow (14, 21 and 28 slm) was bubbled in a recipient with water, dragging molecules of sample towards the gas flow. This mixture constituted by the gas flow and the sample of water, was mixed with the rest of the argon flow and injected into the discharge. In this way the reaction time between H_2O molecules and the argon atoms was increased

before being introduced in the plasma. When water is inside the discharge its molecules interact with the plasma particles which efficiently transfer, by means of collisions, the necessary energy to break the bonds of the introduced molecules.

3. Results

The water molecules are dissociated inside the plasma. The production of hydrogen in it could be verified analyzing the Balmer Series lines of this element (H_α, H_β and H_γ), which experienced an increment of their intensities when the argon flow bubbling water grows up (Figure 2). In this figure the intensities are normalized to energies over the case of no argon flow bubbling the water. The hydrogen already present in the discharge is due to both the water impurities in the argon gas or the water vapour in the ambient air.

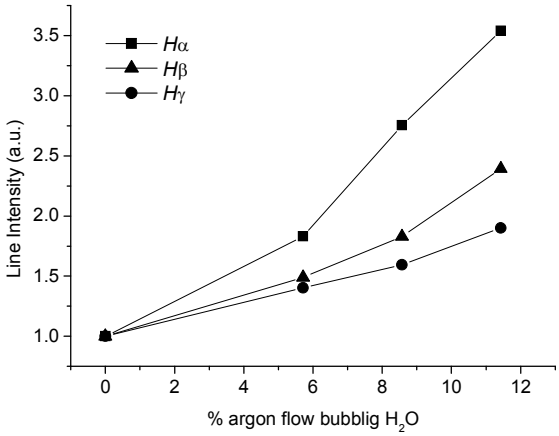

Figure 2. Intensities of the hydrogen lines

Particularly Figure 3 shows the increment of the H_α line intensity.

The electrons are the species that transfer the energy from the microwave power to the rest of the plasma particles, exciting and ionizing the argon atoms. In this type of discharges the electron energies are in the range 2-4 eV. The O-H molecular bond has an average energy of 4.7 eV. This indicates that only the electrons in the tail of the energy distribution function could break these bonds. The metastable argon atoms, with energies over 11 eV, could also contribute to the dissociation of the water molecules.

The intensity emitted by the OH specie also grew up with the increment of water introduction, which reflect that this molecules are produced by recombination of the O and H atoms produced in the plasma by the broken water molecules [8].

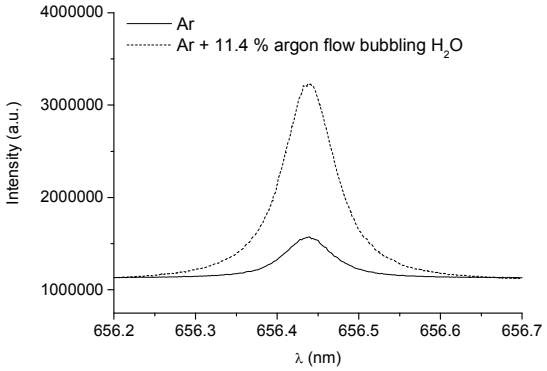

Figure 3. H_α line intensity in an argon and an argon-water plasma column.

The lesser hydrogen production using water instead of other substances like hydrocarbon alcohols is compensated by the lack of other species emission, so this process is very clean due to the absence of other reaction products.

4. References

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Acknowledgments

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