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MASS SPECTROMETRY OF A PLASMA NEEDLE WITH AN EXTERNAL GROUNDED COPPER RING

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Abstract. Plasma needle is 13.56MHz RF discharge that operates in a mixture of ambient air and helium. This type of plasma source is used in treatment of plant tissue, microsurgery, disinfection of dental cavities and wounds. In this paper we used the configuration with an additional, grounded copper ring placed near the tip of the needle. Larger volume of plasma and lower plasma ignition powers are provided by adding the ring. Hiden HPR60 mass analyzer was used to obtain the mass spectra and determine the yields of N,O and NO radicals in the plasma.

1. INTRODUCTION

Advantage of atmospheric non-equilibrium plasmas is that it is possible to treat samples that are sensitive to low pressures and plasma can easily be put in contact with samples that need to be treated. A variety of applications have already been demonstrated, e.g., in semiconductor technology, art restoration and treatment of living plant tissue (Puač at.al., 2006). Because of its mild plasma and geometry, plasma needle is especially convenient for medical applications. Non contact disinfection of dental cavities and wounds and minimum-destructive precise treatment and removal of diseased tissue can be done by the plasma needle (Stoffels et.al., 2006). Treatment can be done with better than 0.1 mm accuracy (resolution).

Plasma parameters such as power given to the plasma, helium flow rate, distance between the tip of the needle and the treated sample have to be optimized so that necrosis of cells would be avoided. The exact mechanisms of plasma-cell interactions have not been fully understood yet. Radicals generated by plasma itself may play a very important role in such interactions. Measurements of the concentration of nitric oxide provided by plasma is also very important because it plays major role in many processes in the organism. Mass spectrometry was done to provide better insight into plasma-cell interactions. While similar work of Stoffels et.al (Stoffels et.al, 2006). has been done on the seemingly identical system in their papers they had to use somewhat larger dimensions and flow because pumping of the mass analyzer perturbed and even turned off the discharge.

Our measurements were performed on a standard size plasma needle that we originally used for the treatment of plant cells. After some efforts we were able to make plasma needle operate in conditions similar to the ones used during the treatments of biological samples. Power transmitted to the plasma was less then 1 % of the power given by RF power supply. However, we had to increase the gas flow from several 100 sccm to more than 1000 sccm. Our goal was to make the mass analyzer work under conditions similar to those one used in plasma treatments which would not greatly affect the discharge itself. Application of a higher flow rate would only reduce the density of detected radicals.

2. EXPERIMENTAL SET UP

The needle consist of a central tungsten wire (0.5 mm in diameter) placed inside a ceramic tube with slightly larger diameter and both placed inside the glass tube 6 mm in diameter. Helium flows between ceramic and glass tube with typical flow rate of few hundred standard cubic centimeters per minute. In our configuration, additional grounded copper ring is added around the glass tube and close to the tip of the needle. This kind of configuration provides a larger volume of plasma and lower plasma ignition powers in addition to operation less dependent on the exact position of the target. The central wire represents the powered electrode and the grounded electrode is the treated sample. Experiments were performed using the ambient air at atmospheric pressure and room temperature. The flow rate of helium was varied from 1 slm to 3 slm.

Hiden HPR 60 MBMS system which incorporates a Hiden EQP mass/energy analyzer is used. Hiden EQP consists of two parts: pumping part that has three different pumping stages and which makes it possible to work on atmospheric pressures and the detector part witch itself works on low pressures. Plasma needle is placed in such a way that the tip of the wire electrode is positioned against the orifice of the analyzer system at the variable distance of several millimeters. Species created in the discharge are sampled using a triple stage differentially pumped molecular beam inlet system which consists of three orifices of different diameter. The sampling orifices are carefully aligned to produce a molecular beam which minimizes the collisions of the sampled particles with each other and with surfaces.

3. RESULTS AND DISCUSSION

Our measurements were done in Residual Gas Analysis mode. Stable plasmas could be obtained in air-helium atmospheres containing down to 10 % of helium. Data were collected for different values of plasma parameters such as power, various distances between the needle and the spectrometer and flow rate. When presenting the results we have used yields of specific masses instead of counts per second obtained directly from the detector. Yield was calculated as percentage of a certain signal in the total signal in order to cancel out the fluctuations:

$$Y = \frac{Y^i_{mass}}{\Sigma_i Y^i_{mass}} [\%] \quad (1)$$

where Y^i_{mass} is specific positive ion (like N^+, O^+, etc.) and this was divided by sum of all recorded masses (1-100 amu). Besides the expected helium peak we can see intense peaks of numerous molecules. It is impossible to distinguish N_2O^+ from CO_2^+ as both

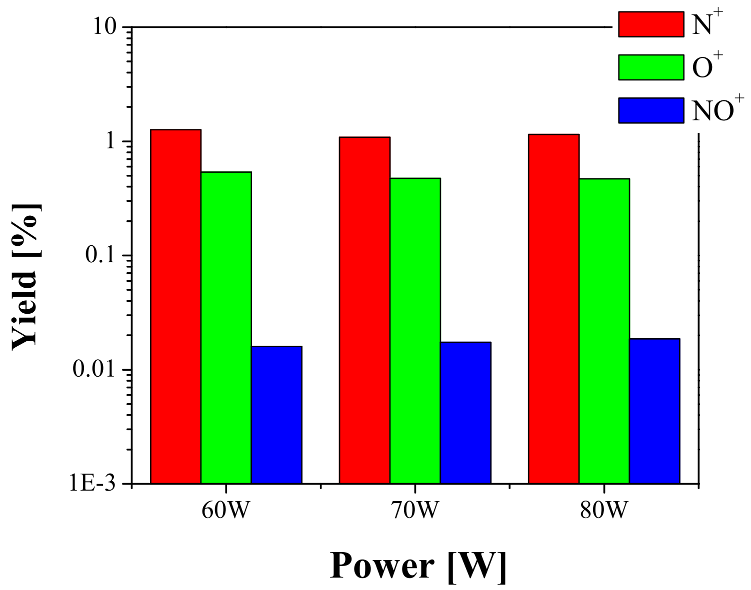

Figure 1: Yields for N, O and NO radicals as a function of power given by the RF source for distance of 1mm and helium flow of 1 slm.

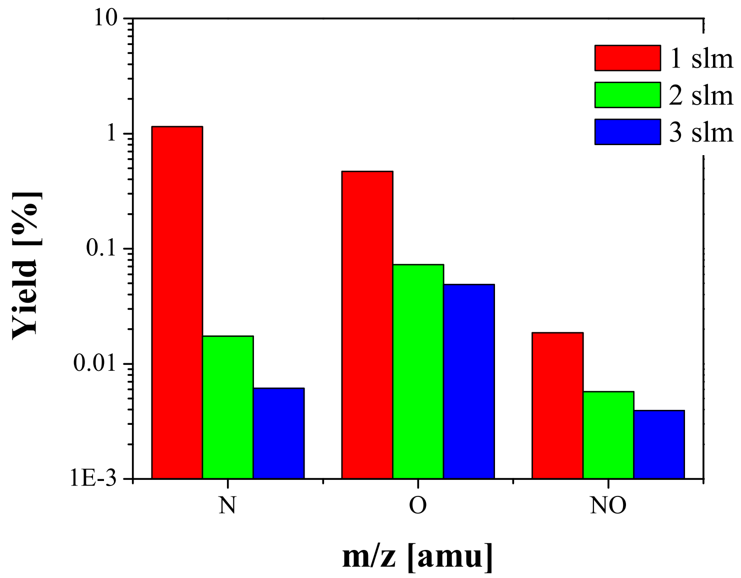

Figure 2: Yields for N, O and NO radicals as a function of helium flow rate for the distance of 1mm and power of 80W.

have the mass of 44 amu. Another problem is that pumping speed of different species such as He and N_2 may be quite different so relative intensities may be unreliable and a more thorough callibration is required.

The yields for N^+, O^+ and NO^+ ions for three different powers can be seen in Fig 1. Signal of NO^+ increases with the increase of the power while signals of the atomic ions decrease. With the increase of the flow rate of the feeding gas (He) from 1 standard liter per minute to 3 slm one can observe a decrease in yields for all three ions (Fig 2). This may be explained by dilution of the atmospheric gases by the buffer gas which is supported by the increased yield of helium. Thus we have to use smaller flow rates of helium in order to gain more active species. During our previous work on the treatments of plant cells the flow rate of helium was around 100 sccm so we can assume that even a larger amount of active species was created as long as the electron temperatures are not reduced by molecular species.

4. CONCLUSION

Mass spectrometry of plasma generated by plasma needle with additional grounded copper ring was done using Hiden HPR 60 mass spectrum analyzer. Concentrations of N, O, NO were determined as well as their dependence from RF power and helium flow rate. Plasma mode transition was observed for higher values of power transmitted to plasma. Concentrations of NO_2 and O_3 were also measured. Plasma needle was operated in such configuration and conditions that are convenient for both spectrometry and treatment of samples.

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