Investigation of a capacitively coupled atmospheric pressure RF excited glow discharge in He-water mixtures by molecular beam mass spectroscopy

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Investigation of a capacitively coupled atmospheric pressure RF excited glow discharge in He-water mixtures by molecular beam mass spectrometry

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Atmospheric pressure glow discharges (APGDs) have been extensively studied over the last decade by means of electrical and optical measurements or modeling (e.g. [1]). Mass spectrometry measurements of ionic species in capacitively coupled discharges are well known at low pressures. A few mass spectrometric studies have been carried out in atmospheric pressure plasmas, mainly focusing on afterglows (plasma jets) and corona discharges (low thermal ion energies) and not in the sheath region of an ionizing plasma.

An RF excited APGD between two parallel bare metal plate electrodes in He-H_2O mixtures has been investigated by molecular beam mass spectrometry. The first results from mass spectroscopy studies of positive and negative ions in active plasmas at atmospheric pressures are reported in this experiment. The ion sample is created in the sheath formed at the mass spectrometer sampling orifice plate, which acts as grounded electrode in the parallel plate electrode geometry, and not in the afterglow of jets (and corona) where the ions measured are typically thermalized due to the large number of collisions with neutrals before reaching the sampling orifice. The mean ion energies measured in these atmospheric pressure sheaths are also close to thermal which is expected as the mean free path at atmospheric pressure is less than 1 μm. Nonetheless, it is expected that there are different ionic species from the active/ionizing plasma zone compared with the ones produced in the afterglow that are completely determined by charge exchange reactions. The choice of water is motivated by the important presence of OH in atmospheric plasmas with liquid interaction and its growing interest [3]. A better knowledge of the ion chemistry in water containing plasmas will assist in a better understanding of water chemistry in atmospheric plasmas and plasmas in contact with liquids and its numerous (potential) applications.

The RF APGD (13.56MHz) is excited in parallel plate geometry between two bare metal electrodes. The electrode system consist of a water cooled circular copper electrode with a diameter of 20.5 mm interfaced to the inlet plate of the HPR-60 molecular beam mass spectrometer (MBMS) (Hiden Analytical Ltd., Warrington, UK) [4] with a fixed inter-electrode distance of 0.5 mm. The power was kept constant at 20W for experiments conducted with different water concentrations. Two mass flow controllers for introducing the helium-water mixture in the reactor were used. One flow is going through a bubbling vessel to introduce water in the helium flow, whereas the other flow contains pure helium. The concentration of water in the

reactor is adjusted by changing the ratio of helium flow through the water compared to the total helium flow and measured by residual gas analysis.

The dependence of the water concentration at constant power of the ionic species for both positive and negative ions is investigated. For all the investigated concentrations of He-H_2O mixtures the dominant positive ions are H_3O^+, OH^+, O^+, He_2^+, HeH^+, O_2^+ and H_3^+. Hydration of the ions increases with increasing water vapour concentration and decreases with increasing discharge power. For concentrations of 900 ppm water in He and above negative ions can be detected [5]. It was observed that the detected negative ion flux increases with increasing water concentration. The dominant ion is OH^- and its clusters. With the emergence of the negative ions, there is a drop in positive ion flux to the mass spectrometer together with a significant increase in applied voltage indicating increasing electron loss by attachment and ion loss by mutual positive and negative ion recombination. In view of the low concentration of water at which negative ions start to influence the plasma properties, the effect of negative ions in atmospheric pressure plasmas with small amounts of water vapour or O_2 will be important. Positive and negative ion cluster formation increases with decreasing discharge power and increasing concentration of water vapour at constant power.

Reference

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