Mid-pressure $Ar/N_2/H_2$ RF discharge characterisation

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Low-temperature nitrogen containing plasmas are used in numerous applications e.g. for surface functionalization, nitriding etc. Often argon is used as the buffer gas as excited states of argon can actively participate in the production of nitrogen reactive species while quenching of these species by Ar is orders of magnitudes smaller. It has been found that addition of hydrogen to Ar / N_2 mixture increases the concentration of both excited nitrogen and hydrogen atoms in the plasma, prevents target surface oxidation and thus enhances nitritation efficiency [1].

The aim of present work was electrical and spectroscopic characterisation of Ar /0-5% N_2/ 1% H_2 RF mid-pressure discharge. The discharge was ignited in quartz tube at 20 Torr pressure and at a total gas flow rate of 60 SCCM with the help of a 40 MHz generator. The electrical characteristics were recorded with oscilloscope TDS-540B. Time averaged spectra belonging to the discharge region between electrodes were recorded with spectrometers Ocean Optics 4000, MDR-23 and Andor Michelle from lateral direction of the tube.

On the basis of registered current, i, voltage, u, and phase shift between them, φ, the voltage on the plasma, $u_{PL}=u\cdot\cos(\varphi)$ and input power, $P=i\cdot u\cdot \cos(\varphi)$ were calculated. At used currents (0.01-0.1 A) the current growth caused only a small decrease of the plasma voltage. The plasma voltage was lowest for pure Ar (30-40 V), and highest for Ar / 5% N_2 / 1% H_2 (160-180 V). Input power increased with the current and N_2, H_2 concentration in the mixture. For pure Ar it remained in the range 0.2-2 W while for Ar / 5% N_2 / 1% H_2 it was 2-10 W. Electric field strength in the plasma column, E_{PC} , was found for Ar and Ar/5% N_2 mixture as slope of the dependence u_{PL} = f(L), where L is the distance between powered and grounded electrode. At current i=0.06 A in the case of pure Ar E_{PC}= 3.1 V/cm while in the mixture of Ar / 5 % N_2 E_{PC}= 15.6 V/cm.

The gas temperature was determined on the basis of N_2(C-B,4-2) rotational spectra at 295 nm. In our experimental conditions the temperature increased from 430 K (pure Ar) up to 600 K (Ar / 5 % N_2 / 1% H_2). N_2(C) vibrational temperatures were determined on the basis of Boltzman plot of N_2(C) vibrational transitions 3-5, 4-2. At constant input power, P=2 W the vibrational temperature changed from 5000 K (Ar / 0.5% N_2) up to 6500 K (Ar / 5 % N_2 / 1% H_2). Density of Ar atoms in 1s states was determined by method which utilizes the reabsorption of photons in plasma [2]. In Ar plasma at P=3W the densities were [Ar(1s_5)]$\approx 5\cdot10^{12}$ cm^{-3}, [Ar(1$s_{2,4}$)]$\approx 1\cdot10^{12}$ cm^{-3} and [Ar(1s_3)] $\approx 7\cdot10^{11}$ cm^{-3}. In Ar/N_2 plasma, the bands of N_2 FPS interfered with Ar lines and did not allow reliable determination of [Ar(1s)].

References

[1] Avni R 1984 *NASA Technical Memorandum* 83803 1-28

[2] Schulze M, Yanguas-Gil A, Keudell A and Awakowicz P 2008 *J. Phys. D: Appl. Phys.* **41** 065206