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NONEQUILIBRIUM STRONGLY NONUNIFORM MICROWAVE DISCHARGE IN THE MIXTURE OF NITROGEN WITH ARGON

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Abstract. The influence of small concentrations of Ar atoms on the properties of nitrogen microwave discharge at pressure 1 Torr was studied. It was shown that even the small Ar admixtures change the plasma absorbed power, the size of the discharge and intensities of emission of nitrogen.

1. INTRODUCTION

Gas additions to the basic plasma gas enable to change the plasma parameters and can be used for plasma diagnostics (e.g., actinometric method). It is known that even the small quantities of admixtures can drastically change the plasma properties. This gives the possibility of purposeful monitor the processes of ionization and excitation of plasma particles causing the change of the power consumption, neutral and ion composition of plasma, and plasma chemical activity. A large body of data illustrates such influences. For example, addition of small concentration of methane to microwave hydrogen plasma leads to considerable increase of the line intensity of H_α (Gomes-Alexandre et al. 1993, Bardos et al. 1997). Large series of investigations were fulfilled in a quasi homogeneous DC discharges in the mixtures of nitrogen with hydrogen which are often used as plasma gases (Golubovsky et al. 1984, Popa et al. 1997). Electric discharges including the microwave discharges are non-uniform in general. Non-uniformity can lead to different influence of admixtures in different parts of discharges. Thus the method of gas-admixtures is also the method of study and demonstration of the role of discharge non-uniformity in the plasma physical and chemical processes.

Electrode microwave discharge (EMD) is a representative of non-uniform discharges (Lebedev et al. 2006, 2008, 2010). EMD was earlier studied in the mixture of hydrogen with Ar and in the mixture of nitrogen with hydrogen (Lebedev et al. 2003, 2010). Some results of study of influence of small argon additions on the plasma emission of nitrogen EMD are presented in this paper.

2. THE EXPERIMENTAL SET-UP

Experimental set-up was described in detail in (Lebedev et al. 2006, 2008, 2010) and its last variant is presented in Fig. 1. Briefly the setup consists of the stainless steel cylindrical discharge chamber with diameter of R_1=7 cm, the microwave powered (up to 180 W, 2,45 GHz) electrode/antenna with outer diameter of 5 mm, system of gas feeding, and diagnostic devices for study of microwaves and discharge visible emission. Plasma gases were N_2 and Ar with flow rates 10 sccm for N_2 and 0-10 sccm for Ar, the gas pressure in the chamber was 1 Torr. Gases were introduced in the chamber through the upper cover of the discharge vessel. Discharge light emission through the lateral quartz window is focused by the quartz lens, collected by the optical fiber, and recorded with spectrographs AvaSpec-2048 and AvaSpec-2048-4-RM. The optical fiber can be moved both in longitudinal and radial directions by means of two-coordinate micrometric table with the spatial resolution 150 μm to measure the total emission intensity along the line of view. Discharge spectra were measured in two points along the discharge axis: in the bright near electrode region and in the middle point of the radius of the discharge sphere. Discharge visualization is made with video camera, digital photo camera, and electron-optic high time resolution digital camera K-008. EMD was initiated by spark-gap placed in the channel in the electrode. The incident microwave power in this set of experiments was 50-70 W.

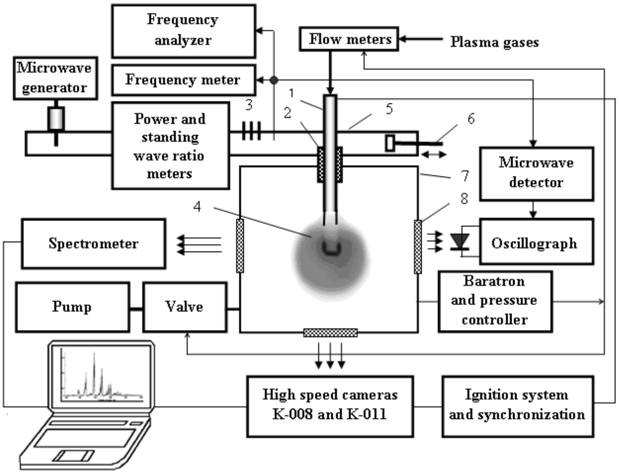


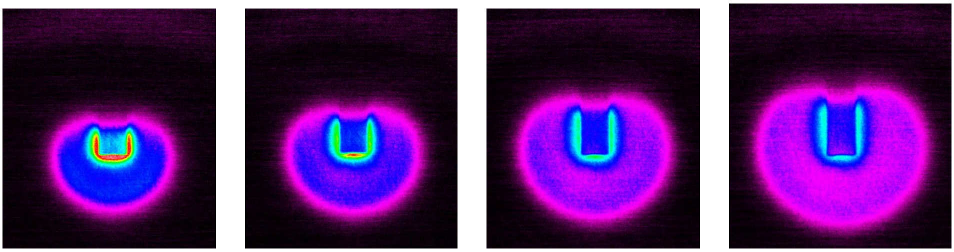
Figure 1: Experimental set-up. 1- electrode/antenna, 2 – isolator, 3 – impedance transformer, 4 – plasma, 5 – coaxial-to-waveguide converter, 6 – shorting plunger, 7 – discharge chamber, 8 – optical windows.

2. RESULTS AND DISCUSSION

Results of experimental study show that even the small concentrations of Ar (< 2%) change the EMD properties. Plasma absorbed power increases at small Ar

Table 1. Influence of Ar content on the plasma absorbed power in EMD in N_2.

Ar flow rate,sccm	0	0,16	0,4	0,6	1,0	2,0	4,0	6,0	8,0	10,0
Absorbed power,W	21,8	26,3	24,1	22,8	21,1	18,5	15,3	8,6	7,7	6,1



0 0,16 0,4 0,8

Argon flow rate, sccm

Figure 2: Influence of the Ar content on the N_2 EMD image (N_2 flow rate 10 sccm).

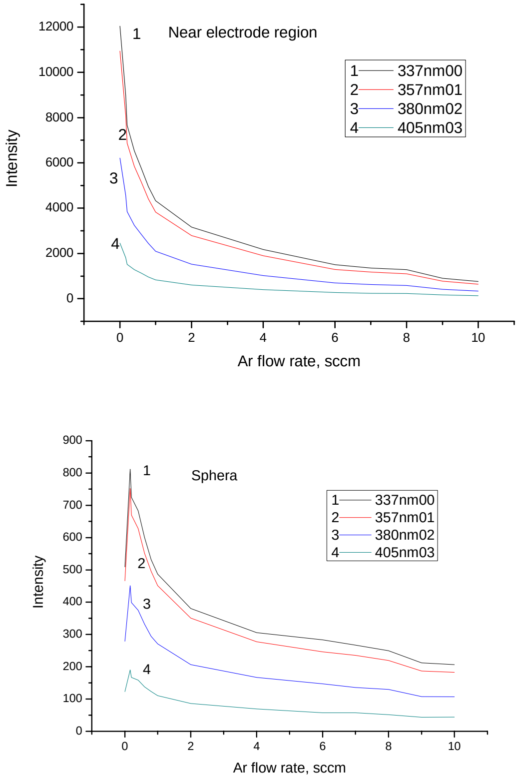


Figure 3: Influence of Ar content on the intensities of bands of the second positive system of N_2 in the near electrode region (upper picture) and in the spherical part (lower picture) of nitrogen EMD.

concentrations and decreases at higher Ar concentrations (Table 1). The luminous part of EMD is a steady increased function of Ar concentration (Fig. 2). The emission intensities of 1^+ and 2^+ bands are decreased with addition of Ar in the near electrode layer whereas the curves with maximum were observed in the spherical part of EMD at low hydrogen concentrations. These results show that physical and chemical processes are different in different parts of non-uniform discharge.

Analysis of experimental results on the base of self-consistent quasi-static model of EMD (Lebedev et al. 2009) and basic kinetic processes in N_2 and Ar+N_2 mixture (Lebedev et al. 2009, Eslami et al. 2008, Henriques et al. 2002) showed that known reactions between excited and ionized Ar and N_2 can not explain the observed change of EMD properties at small concentrations of Ar. The fact of changes of plasma properties at small Ar admixtures should be taking into consideration if Ar is used for plasma diagnostics.

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