Impact of He admixture on the ammonia formation in N_2 seeded D_2 plasmas in the GyM facility

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Abstract

In this contribution we present the results obtained during nitrogen seeding experiments performed in GyM. The aim of the experiments was to evaluate the variation of ammonia (ND_3) formation in the presence of helium (He). Control of experimental conditions was performed by means Langmuir probe (LP) measurements. By Optical Emission Spectroscopy (OES), have been acquired spectra centred at about 336 nm, in this region falls the emission band of the ND radical, used as indicator of the ND_3 production. ND_3 formation during experiments has been followed by measures of the Residual Gas Analysis (RGA). ND_3 quantification was achieved by operations involving the collection of the exhaust in LN_2 trap and liquid ion chromatography (LIC) analysis. Results showed that increasing amounts of He added to a nitrogen seeding plasmas produces a proportional decrease in ND_3 while the plasma parameters are not modified.

1. Introduction

Impurity seeding with nitrogen is routinely used to reduce the power load to divertor by radiation in front of the target plates as demonstrate in JET-ILW and AUG [1]. As a side product of the use of nitrogen at metallic plasma-facing surface, ammonia in significant amounts can develop. The ND_3 formation is a critical issue because ND_3 might cause damage to pumps, valves and other materials and could have a significant implication on the operation of the ITER tritium plant, which is prepared to process titrated ND_3 in small amounts. In this context it is important to try and identify means to reduce/prevent ND_3 formation during experiments with nitrogen seeding in present day devices. The effects on the ND_3 formation of the helium admixture to N_2 seeded D_2 plasmas were evaluated in GyM linear device [2].

2. Experiment

Experiments as a function of the partial pressures ratio N_2/He, from 3% to 20%, were carried out at T_e= 5.7 eV, n_e= 4.5x10^{16} m^{-3} (similar to ITER first wall plasma parameters) keeping constant the total pressure at 1.7x10^{-2} Pa and the partial pressure ratio N_2/D_2=10%. OES measurements allowed the identification of molecular spectra related to the deuterium/nitrogen interaction. Molecular spectra were calculated on the basis of molecular constants, theoretical line strengths and apparatus profile. Bands of the second positive system of N_2, and of the first negative system of N_2^+ were used for determination of the T_e [3]. OES was also used to determine helium ion fluxes by S/XB theory [4].

The evolution of the neutral chemical species introduced in the vessel and consumed/produced during the plasma phase were performed by RGA measurements. To quantify ND_3 produced during the experiments, a technique has been developed to collect exhaust in a liquid nitrogen trap. After regeneration at room temperature, exhaust is bubbled in distilled water at 5°C by argon flow. The chemical composition of the solutions obtained is performed by LIC analysis [5, 6].

3. Results

The effects of the He addition on the density of the excited species (ions, radicals and molecules) and on the plasma parameters were evaluated by analysis of the OES spectra.

In the spectra acquired during experiments are shown ND (0,0) and (1,1) bands at 335.7 nm and 336.4 nm respectively belonging to the 3360 (system $A^3\Pi$-$X^3\Sigma$) and N_2 (0,0) band at 337.13 nm belonging to the second positive system $C^3\Pi u$ - $B^3\Pi g$. Each vibrational transition of these bands consists of line-like Q rotational branch and a much more distributed P and R branches. Estimation of the total band emission (proportional to density of excited molecules) is made by integrating all lines of the band (R + Q + P+ satellites). Results obtained from calculations show that density of excited ND radicals drop whit He contents as reported in figure 2. Calculations of the He^+ flux from HeI lines - 667.82 nm (2p ^{1}P - 3d ^{1}D), 706.57 nm (2p ^{3}P-3s ^{3}S) and 728.13 nm (2p ^{1}P - 3s ^{1}S) - reveal an increase of the He^+ flux as He increases on the mixture of the plasma feed. Analysis the ratio of N_2^+ B-X 0-0 to N_2 C-B 0-1 for each spectrum acquired as a function of the He addition show that ratio remains constant and corresponds to T_e=5.1 eV. The average value obtained from LP measurements is T_e=5.7 eV.

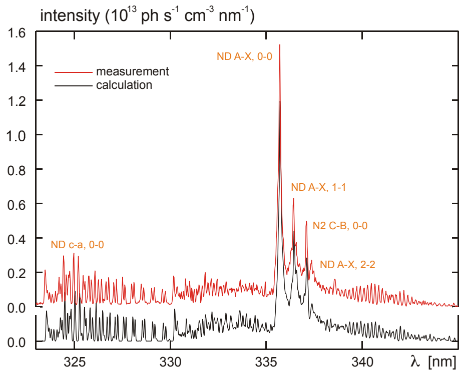

Figure 1. Experimental spectrum obtained from discharge whit 3% of He and fitting ones obtained by using data source for diatomic molecules.

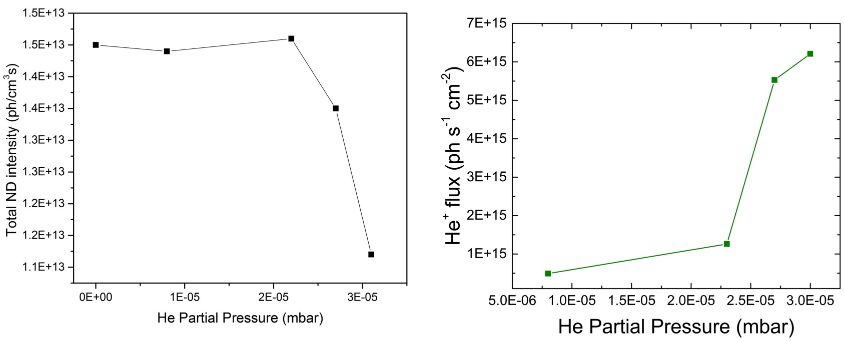

Figure 2. Left - Calculated total ND intensity as a function of the He partial pressure, right- He^+ flux calculated by S/XB theory as a function of the He partial pressure on the feed plasma mixture.

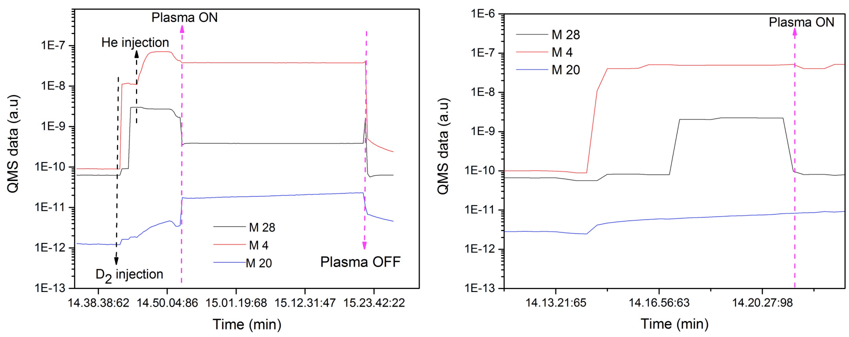

Figure 3. Time evolution of the M=4 (D_2+He), M=28 (N_2) and M=20 (ND_3). Left – experiment with 1.3 sccm of He, right-3 sccm of He.

Results from RGA analysis are reported on the figure 3. As plasma starts an increase of the current for M=20 is observed. Comparing the two plots reported, it is evident that an increase of the He amount produces a decrease of the current at M=20, and a consequent decrease of the ND_3 formation. This evidence was confirmed by LIC results that show a decrease in ND_3 formation, proportional to the increase of the He ion flux, up to 40% in experiments carried out with 20% of helium in the N_2/D_2 mixture.

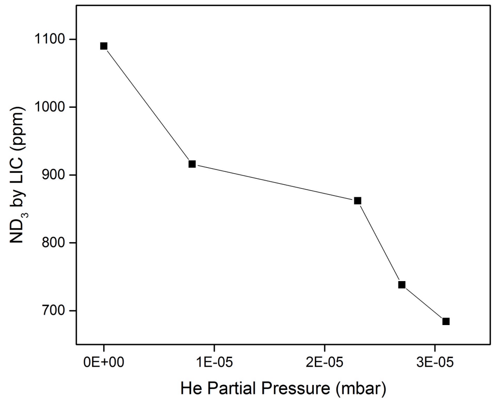

Figure 4. ND_3 concentration in ppm counted by LIC for solutions obtained from bubbler of the exhaust collected during experiments whit different He contents.

4. Conclusion

ND_3 formation from N seeded D plasmas in presence of the different amounts of the He was quantified by LIC. Results show a decrease of the ND_3 as He increases. This behaviour is confirmed by MS analysis. OES analysis showed a drop of the intensity ND band with He content, as other measurements do. So that ND radical may be used as an indicator of ammonia production during nitrogen seeding experiments.

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