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メタンを含んだ低温水素/重水素プラズマ中における炭素膜生成に窒素が及ぼす影響

Effect of Nitrogen on Carbon Film Growth in Low Temperature Hydrogen or Deuterium Plasmas with Methane

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Introduction

The serious problem of tritium retention in the carbon tiles and carbon deposited film on the first wall prohibits their use in ITER DT burning phase. The control of tritium retention and its removal from the first wall are one of the most important issues in the future fusion reactor development.

Nitrogen injection has been considered and tested as one of the methods for suppression of carbon dust growth and reduction of tritium inventory. We have investigated effects of nitrogen injection into H_2/CH_4 or D_2/CH_4 plasmas using a small helical device, Heliotron-DR, which generates low density and low temperature hydrogen or deuterium plasma in steady state condition (T_e = 5-10 eV, n_e = (0.4-1.6)$\times 10^{16}$ m^{-3}). These conditions are useful to study the suppression mechanisms of carbon film formation and tritium inventory by nitrogen injection in the remote plasmas of fusion devices.

Experiments

Low temperature RF plasmas with H-C-N or D-C-N reactive species are generated in hydrogen or deuterium plasmas with small amount of CH_4 and N_2 injection. In the experiments that the nitrogen was injected into H_2/CH_4 plasmas as C/H scavengers, the deposition of hydrogenated carbon films strongly depends on the surface temperature of the Si samples [1]. In that case the carbon film deposition and dust particles growth dramatically suppressed by nitrogen addition when the surface temperature was higher than ~400 K. It was found from XPS measurements that the carbon film exposed by $H_2/CH_4/N_2$ plasmas contains C-N bond in the film when T_s~320 K. From optical emission spectroscopy, volatile CN band spectra were observed in $H_2/CH_4/N_2$ mixture plasmas (Fig. 1.). The volatile molecules like HCN, NH_x were also observed by QMA in $H_2/CH_4/N_2$ mixture plasmas (Fig. 2.). It is likely that the generation of CN radicals on the carbon film surface would have an important role for suppression of hydrogenated carbon film growth from the results that the suppression effect strongly depends on the surface temperature. The gas phase reaction of nitrogen with H (D) and C may lead to exhaust of carbonized molecules from the volume, since the formation of volatile HCN molecules prevents carbon agglomeration in the gas phase and on the material surface. It should be also mentioned that the formation of NH_x and ND_x may contribute to reduce the hydrogen isotope retention in the deposited hydrogenated carbon film.

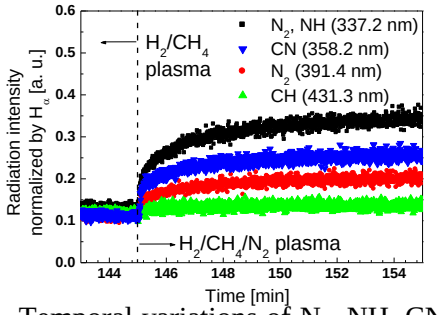

Fig. 1. Temporal variations of N_2, NH, CN and CH radiation intensities after nitrogen injection into H_2/CH_4 plasmas.

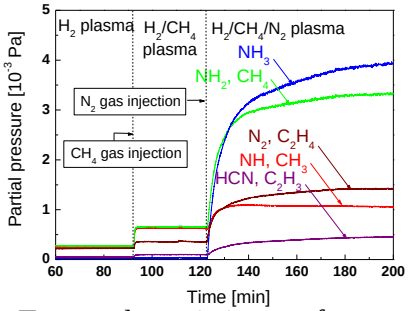

Fig. 2. Temporal variations of some partial pressures of H-C-N reactive species after CH_4 or N_2 injection.

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