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CHARACTERISATION OF A NITROGEN CCP AT LOW PRESSURE

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Introduction

The present work is part of an endeavour to perform laboratory simulations of the chemistry of Titan, satellite of Saturn. In the atmosphere of Titan, composed of N_2 and CH_4, solid particles are produced by photochemistry and charged particles from Saturn's magnetosphere. We mimic this chemistry using a low-pressure capacitively coupled plasma (CCP), produced in a gas mixture representative of Titan's atmosphere [1]. The production of solid particles in these discharges has already been observed [2], together with the delay in their formation and their effect upon the electron density. Here, we present a first contribution to this global task, by characterizing pure nitrogen CCPs (with a simpler chemistry) RF discharges. The study involves both modelling and diagnostics of the discharge plasma, aiming to compare simulations and measurements.

Experimental set up and diagnostics

The CCP discharge is described in detail in [1]. The plasma is produced at 13.56MHz within a cylindrical parallel plate reactor (13.7cm in diameter and 4-5cm in height), surrounded by a grounded metallic grid. Nitrogen is injected continuously through the polarised electrode by a mass flow controller. A few amount of argon is added at constant Ar/N_2 ratio. The applied RF potential is measured with a high voltage probe and the effective RF power, coupled to the plasma, is measured taking into account circuit losses. Here, measurements are done as a function of pressure, from 0.2 to 2mbar, at 20 and 30W coupled powers. With the cylindrical metallic grid the system acts as a microwave cavity, which allows deducing the electron density from the shift of the cavity's resonance frequency in the presence of plasma [2]. The results presented in [2] are corrected here, by further considering the heating of the cavity and by improving the resolution of the frequency shift measurement. For the chosen TM_{210} mode, the resolution of frequency shift detection is 0.1MHz, corresponding to a lower limit of 10^{13} m^{-3} for the electron density. Optical Emission Spectroscopy is done through the grid, using a UV - visible - near IR monochromator, to measure band-intensities with the nitrogen SPS and FNS, and the 881.5nm line-intensity with argon. Further, with the purpose of obtaining gas temperatures similar to those of Titan (~150K), we have coupled a circulating system of liquid nitrogen to the outer wall of the grid, thus cooling the driven electrode from its working temperature of 340K down to a minimum temperature of 170K.

Modelling

Plasma modelling involves the solution to a hybrid code, given the working values of the pressure and the RF potential. The code couples: (i) a 2D (*r*,*z*), time-dependent fluid module [3], describing the charged particle dynamics within the reactor (including the continuity and momentum transfer equations for electrons and positive ions N_2^+ and N_4^+, the electron mean energy transport equations, and Poisson's equation for the RF electric potential); (ii) a 0D kinetic module, describing the production and destruction of nitrogen (atomic and molecular) neutral species (including the two-term electron Boltzmann equation, and the rate balance equations of 45 vibrationally excited states of the ground-state molecule $N_2(X^1\Sigma_g^+$, v=0–45) and 10 electronically excited states of N_2 and N). These modules are strongly coupled, as the kinetic module provides the source terms and the electron macroscopic parameters required by the fluid module, and uses the charged particle densities calculated by the fluid module. Simulations yield the self-consistent DC-bias potential, the effective power coupled to the plasma, and the two-dimensional spatial distributions of (i) the densities and fluxes with the charged particles and the electron mean energy; and (ii) the RF plasma potential. The model gives also predictions for the densities of the most relevant excited states of nitrogen, together with information about the measured line-intensity transitions.

Results

There is an agreement between simulations and experiment, for the evolution of the electron density and the DC-bias potential, as a function of the RF potential and pressure. Figure 1 shows preliminary measurements of high-lying rotational lines, whose relative intensity decreases when the electrode is cooled.

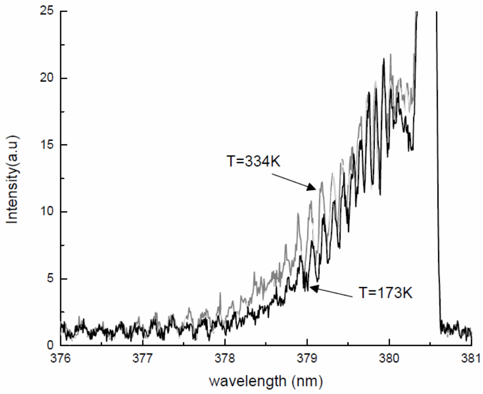

Fig 1. Rotational spectra of the (0-2) SPS band, obtained at 1mbar pressure and 55sccm N_2 flow

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