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DYNAMICS OF DISCHARGE CHAMBER WALL ABLATION IN PULSED NITROGEN OR CARBON DIOXIDE PLASMA

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Abstract. The intracavity laser spectroscopy method was used for plasma diagnostics of high-current pulsed discharge in moderate pressure nitrogen or carbon dioxide. The main attention was payed to the dynamics of quartz wall ablation during a discharge pulse and to the influence of evaporated species on a gas plasma parameters.

1. INTRODUCTION

Often attempts on rising pulsed plasma temperature by higher currents can result in undesirable as a rule phenomenon - discharge chamber wall ablation. Nevertheless a lot of papers the dynamics of ablation as well as the influence of evaporated species during a discharge pulse on the evolution of basic plasma parameters are practically unstudied and require for detailed investigation the application of laser techniques with high temporal and spectral resolution. The most sensitive absorption method –

the intracavity laser spectroscopy differs favourably from other laser spectral methods due to the possibility of simultaneous recording of a lot of spectral line profiles for a single laser pulse.

2. EXPERIMENT

Close to rectangular electric pulse with duration of 1.4 ms was applied to a tungsten electrodes in the quartz tubular chamber (1 cm inner diameter and 16 cm length) filled with high-purity nitrogen or carbon dioxide at intermediate pressures: 5-20 Torr. The discharge energy was varied from 0.5 to 1.5 kJ. The chamber with quartz windows was located along the axis in a non-selective cavity of a dye laser. The laser radiates a smooth broadband spectrum in the visible range with pulse duration of 3 μs. The maximal laser spectrum width was about 15 nm. Dye laser spectra with absorption lines were recorded by a 0.001 nm resolution echelle spectrograph. The effective path length of laser radiation through plasma reached 350 m.

3. RESULTS AND DISCUSSION

The absolute values of densities and the evolution of Si species ablated from a transparent wall of the chamber were determined and the influence of Si atoms and ions appeared in gas plasma on excited energetic states populations of N and C atoms and ions, electron density and temperature was examined.

For both nitrogen and carbon dioxide the pure gas plasma with electron temperature of 9-11 kK is observed only at minimal energy, i.e. Si absorption lines are absent in laser spectra. The time dependence of excited N or C ions density is similar to the electric pulse shape. The minimal measured species densities mainly depend on laser pulse duration and oscillator strength of absorption line recorded and were about 10^8 cm^{-3} for N^+ and C^+, 10^9 for N, Si, Si^+ and Si^{++}, and 10^{10} for C.

With discharge energy increase a strong plasma-wall and radiation-wall interactions and as a result quartz erosion and ablation occur after 0.4-0.5 ms from electric pulse onset (see the Fig.). The maximum of Si species absorption is observed in 0.7-0.9 ms time interval. Simultaneously with growing of Si density the absorption from gas excited states sharply decreases right up to the absence of gas lines in several cases. The most drastical variation of gas plasma parameters occurs at minimal initial gas pressure - 5 Torr.

The main peculiarities of plasma evolution are kept with increase of initial gas pressure up to 20 Torr. Together with Si lines an intensive molecular spectral structure (intendingly SiO) is recorded in dye laser spectra. The electron density was measured from the Stark broadening and shift of absorption lines. The electron density dynamics has usually three peaks and it follows the main stages of a discharge. Plasma temperature was calculated from Sacha and Boltzmann relations. The absolute mass of an ablated material was found from spectral data.

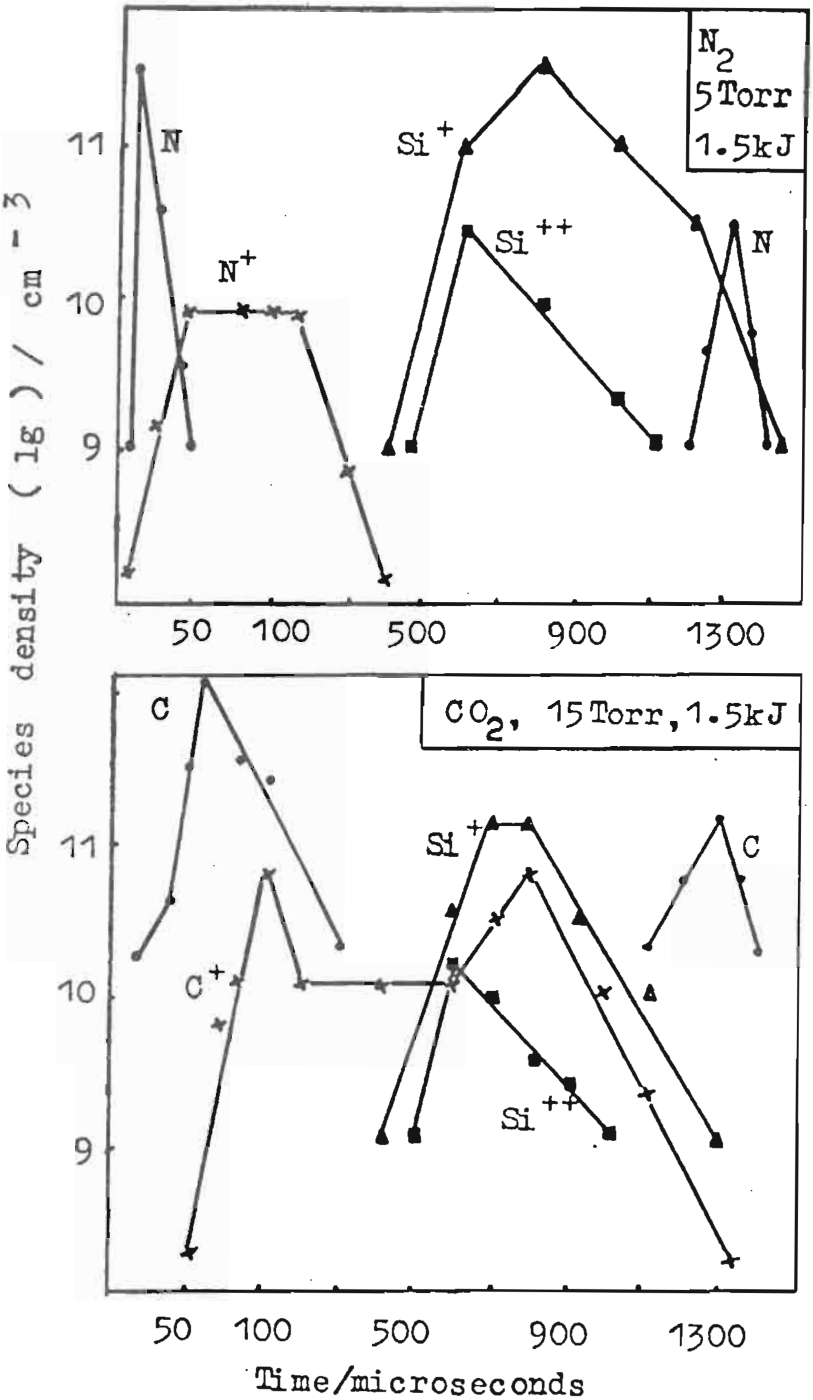

Fig. Dynamics of species densities in a plasma of pulsed discharge