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Dynamics of carbon plasma induced by an excimer laser in nitrogen environment

S. Messaoud-Aberkane, T. Kerdja, S. Abdelli, S. Nait-Amor,
S. Iafane, S. Malek and K. yahiaoui.
Centre de Développement des Technologies Avancées
Lot.20 Aout 1956,BP17. Baba Hassen, Alger, Algeria.
Email: aberkane_sabrina@yahoo.fr

Abstract. The dynamics of laser-ablated carbon plume propagation through different background Nitrogen pressure have been investigated with time and space-resolved emission spectroscopy. Results of temporal and spatial evolution of CI and CII emissions lines at4267A° and 2478A°4267A° respectively under different nitrogen pressure show that there are two stages of expansion in accordance with shock wave and drag force model propagation model

1. Introduction

Reactive pulsed laser ablation deposition (RPLAD) consisting on the laser ablation of target in reactive gas has become an attractive technique for a wide variety of compound thin films synthesis. In order to produce high quality films with desired properties, the well understanding of the temporal behaviour of ejected species in the ablated plume is necessary. In this work, we report on emission spectroscopic diagnostic of carbon plasma in nitrogen environment at different pressures.

2. Experimental set-up

Carbon plasma is induced by KrF excimer laser radiation (ë=248 nm, ô =25 ns, f =10 Hz) at a fixed fluence of 12 J/cm². The laser beam is focused under an angle of 45°, onto a rotating graphite target surface. The chamber is evacuated at 10^{-6} mbar and then filled with N_2 at pressures in the range of 0.5 to 2 mbar.
In order to identify the emitting species and to analyse the plasma propagation, the plasma plume is imaged on the entrance slit of 0.8m spectrometer (Spex, 1200tr/mm) with a spatial resolution of 100 µm and a spectral resolution of 0.8Å. The light emission is collected by a fast photo-multiplier tube (Hamamatsu R928) connected to a fast digital oscilloscope (Tektronix TDS3032).

3. Experimental results

3.1. Temporal evolution

we have studied the spatio-temporal evolution of CI and CII lines at 247.8 and 426.7nm respectively, starting from d =3mm to avoid the continuum emission in the vicinity of the target.
The fig.1 a,b shows the time of flight of the transient maximum emission intensity of the CI and CII lines for different observation distances, at different pressures.

We show that as the gas pressure is increased, the propagation of the carbon species is more affected. We can see two stages of expansion. The first is well fitted using drag force model according to the following formula:

$$d = d_f [1 - exp (-\beta t_{max})] + d_0 \qquad (1)$$

Where $d_f = v_0/\beta$ is the stopping distance, v_0 the initial velocity, β the damping coefficient and d_0 a boundary condition [1].

The second stage is well fitted by the shock wave model according to the expression [2]:

$$d = a.t^{(0.4)} + d_0 \qquad (2)$$
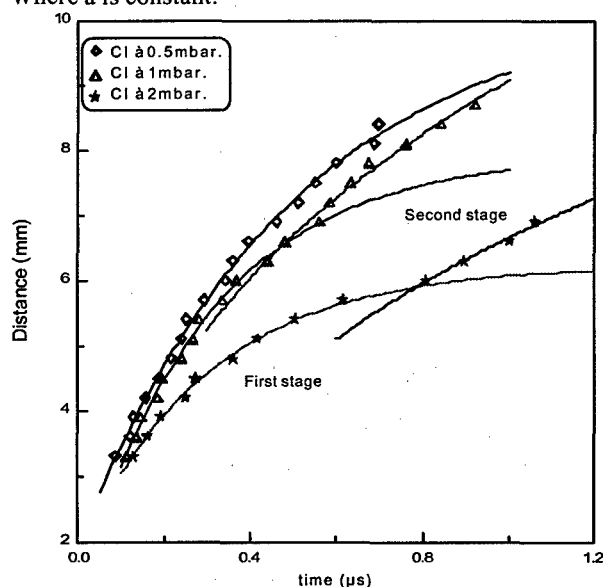
Where a is constant.

Fig (1.a): (t_{max}, d) plots of the C I emission line (247.8 nm) at different nitrogen pressures.

The drag model fit parameters and the initial velocity v_o, are reported in table1, showing that the stopping distance d_f decreases with increasing pressure in agreement with the expected confinement effect. The coefficient β increases with increasing gas pressure. Initial velocity v_0 remains the same independently from the used pressure.
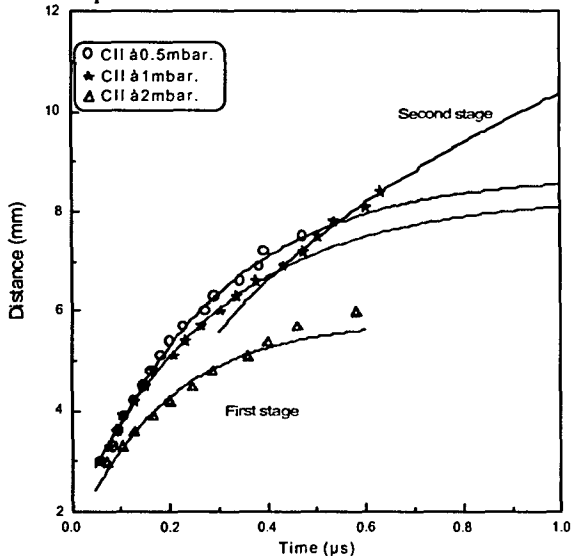

Fig (1.b): (t_{max}, d) plots of the C II emission line (427.6 nm) at different nitrogen pressures.

C II (λ= 427.6 nm)			
	$d_f(mm)$	$\beta(\mu s^{-1})$	v_o (m/s)
0.5mb	7.27	3.74	2.7×10^4
1mb	6.03	4.75	2.8×10^4
2mb	4.36	5.18	2.3×10^4
C I (λ= 247.86 nm)			
	$d_f(mm)$	$\beta(\mu s^{-1})$	v_o (m/s)
0.5mb	8.07	2.15	1.7×10^4
1mb	7.44	2.12	1.6×10^4
2mb	4.51	3.02	1.4×10^4

Table1: d_f, β values inferred from the simulation of the experimental data for the emission lines of C I and of CII by using the drag model and the corresponding calculated initial velocity.

3.2. Spatial distribution

Figures (2.a) and (2.b), show the spatial evolution of maximum emission intensities of CI and CII respectively, at different nitrogen pressures.

The curves are characterised by a strong continuum emission up to 3mm from the target surface, which masks the transitions lines emission. At larger distances, the one can see a structure with maximum moving to the target surface as the pressure is increasing.

This effect is due to the plasma confinement by N_2 gas molecules as it was previously observed with an inert gas [3]
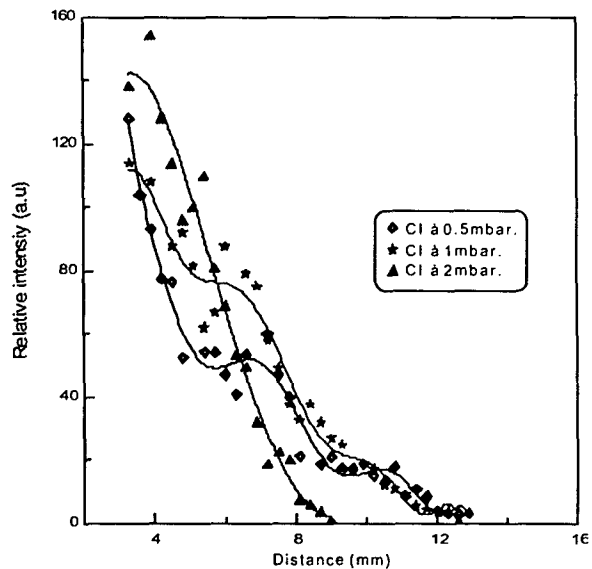

Figure (2.a): The maximum emission intensity of the CI* transition at 247.8nm as a function of the distance at different nitrogen pressures.
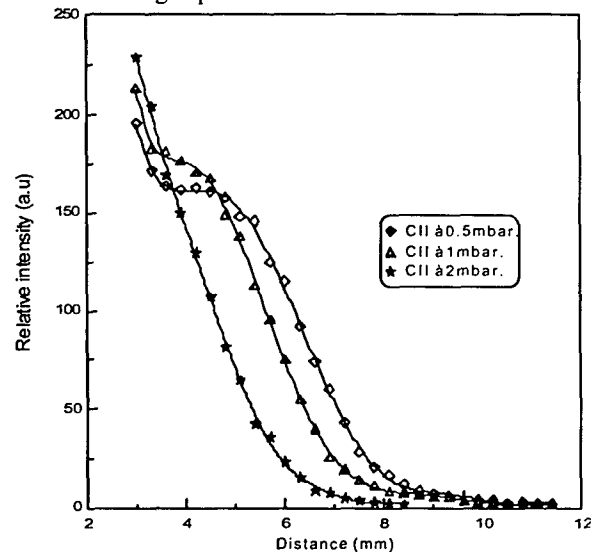

Figure (2.b): The maximum emission intensity of the CII* transition at 426.7nm as a function of the distance at different nitrogen pressures.

4. References

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