LASER PRODUCED CARBON PLASMA IN AN AMBIENT GAS

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Observation of carbon plasma expansion in an ambient gas showed that beyond some pressure, the plasma and the gas are separated in two distinguish volumes. Molecular band emission occurs behind the shock front and helium as an ambient gas gives the highest Swan band emission.

Introduction.

Laser ablation at low irradiance (10^8-10^9Wcm^{-2}) is mostly used for the deposition of thin films such as high critical temperature supraconductors [1], diamond like carbon [2] polymeric films synthesis [3] and is commonly used in microelectronic fabrications [4], studies of molecular species [5] and production of large clusters.

Recently a particular interest goes to the production of carbon clusters particularly for the fullerene synthesis.

We are interested in this paper by the spatial extension of the molecular Swan band emission of C_2 which must be considered as a fullerene precursor. The molecular emission studies are helpful to optimize the parameters for diamond like carbon film deposition and to correlate carbon clusters with the plasma dynamics [6].

Experimental arrangment.

A Q-switched Nd-Yag laser delivering 200 mj energy in a pulse of 30 nsec, was focused on to a rotating carbon target to generate a carbon plasma. Experiments were done in vacuum and for different ambient pressures of helium and argon in the range 0.1 to 100 mbar.

The plasma plume was imaged at the entrance slit of a 1 m Czerny-Turner spectrometer with a magnification of 1. The spectrometer entrance slit was set to 100µm giving a spatial resolution of 100µm, and it was masked so that the detector views only 1 mm of the available height slit. The spectrometer was calibrated using a mercury arc lamp and He-Ne laser, the spectral resolution is 0.8 Å. The signal was monitored using a fast photomultiplier coupled to a fast oscilloscope.

Plasma expansion in vacuum.

The emission spectrum of the plasma is recorded in the wavelength range 300-600 nm at various distances from the target surface. Spatial variation of electron temperature estimated using the relative intensities of two spectral lines of C II at 426.7 nm and at 392 nm is 3-5 ev at the target surface.

Temporal profile of CII transition at 426.7 nm and CIII at 451.6 nm were recorded to estimate the plasma front velocity. The plasma front velocity of CII and CIII transitions were found to be 4.10^6 cm/sec and 7.10^6 cm/sec respectively in concordance with the self regulated model [7].

The electron density was estimated using carbon lines for which the Stark broadening coefficients have been measured (426.7nm, 392.0nm). Using our measured temperature, the broadening coefficients are interpollated from values in ref [8]. The two lines showed approximatively a Lorentzian line profile, the correction for the instrumental line broadening was accounted for. The electron density varies in the range 10^{16}-10^{17}cm^{-3} from the target surface up to 1cm.

The temporal profiles of CI at 493.2nm, CII at 426.7nm and CIII at 451.6nm shows that the plasma consiste in essentielly CII and CIII ions followed by a large amount of neutrals carbon with a lower velocity.

Expansion in the ambient gas

When a rarefied gas surrounds the solid carbon target, and at some pressure, it appears a luminous sheet ahead of the carbon plasma which remains visible a long time after the laser pulse [9]. This can be modeled by considering two gases like volumes, the carbon plasma and the background neutral gas which are separated by a shock wave representing a barrier between the two gases. Complete diffusion of the carbon plasma occurs after the shock front velocity vanishes to sound velocity of the surrounding gas [10].

Before that occurs a gas layer of thichness depending on the mean free path of energetic particles of the plasma in the background gas, is created between the plasma cloud and the surrounding gas.

The energy distribution of the particles was determined by detecting the optical radiation emitted by the plasma. By this measurement one can rather reliably judge the qualitative nature of the plasma debris.

Fig. 1. shows the radius attained by the C^+ ions determined from the temporal profile of CII transition at 426.7nm, and the continum curve showing the theoretical calculations [9] for the shock front velocity at differents pressure of Helium, for comparison. The initial expansion velocity always remains in accordance with the vacuum velocity as the pressure is increased, however, the velocity of the plasma front rapidly decreases and the volume attained in the fixed time is strongly pressure dependent [10].

Fig. 2. shows radius attained by CII and CIII transitions in vacuum and in Helium as an ambient gas at 1 mbar. At this pressure of Helium, the temporal profile of CII transition shows a double structure which becomes well resolved two pulses as the distance from the target increases. At the same distance, CIII transition emissivity goes to an undetectable level. The peak velocity of the first pulse follows exactly the peak velocity of CIII transition in vacuum as shown in Fig. 2 , so , the double pulse structure appearing at some distance from the target is due to a recombination process occuring in the luminous sheet.

Band Swan observation.

Fig. 3. and Fig. 4. shows the spatial extension of molecular band emission of C2 at 516.1nm for various pressures of argon and helium respectively. The spatial profile of emissivity becomes sharp and increases as the pressure of the ambient gas increases. Helium as an ambient gas gives the highest emitted spectrum.The comparison of the temporal profiles of CII, CIII transitions and Swan band emission shows that the molecular emission occurs behind the interface between the ambient gas and the plasma. The pickup of the ambient gas as seen in Fig. 1 will slow the leading edge of the plasma producing a pile up of density [11] behind the shock front giving a condensing carbon vapor.

Conclusion.

A simple shock model agrees with the observation of sheet propagation for the carbon plasma interaction with an ambient gas. The double structure profile appearing at some distance from the target is due to the strong recombination of high ionisation levels. Strong molecular emission occurs behind the shock front. The molecular band emission is maximum at 100mbar of helium and 5mbar of argon. The presence of helium as an ambient gas gives the highest molecular emission.

References.

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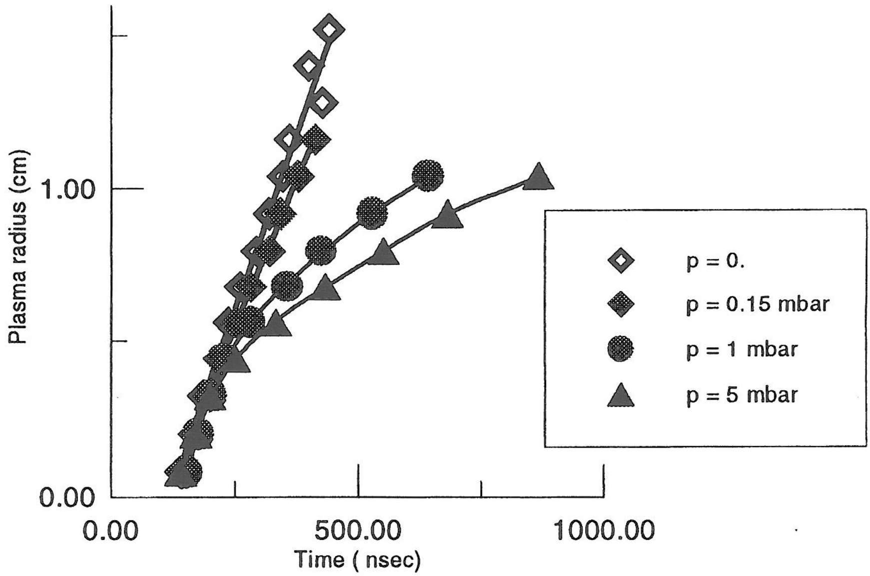

Fig. 1. Plasma radius for different pressures of helium.

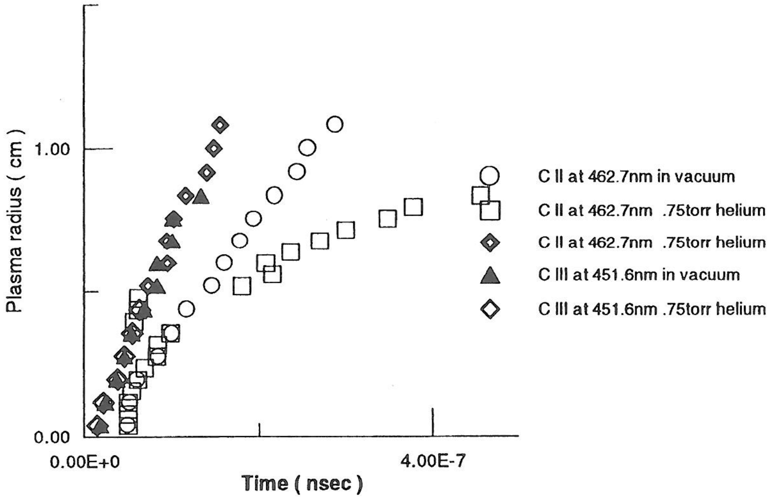

Fig. 2. Radius attained by CII and CIII transitions versus time.

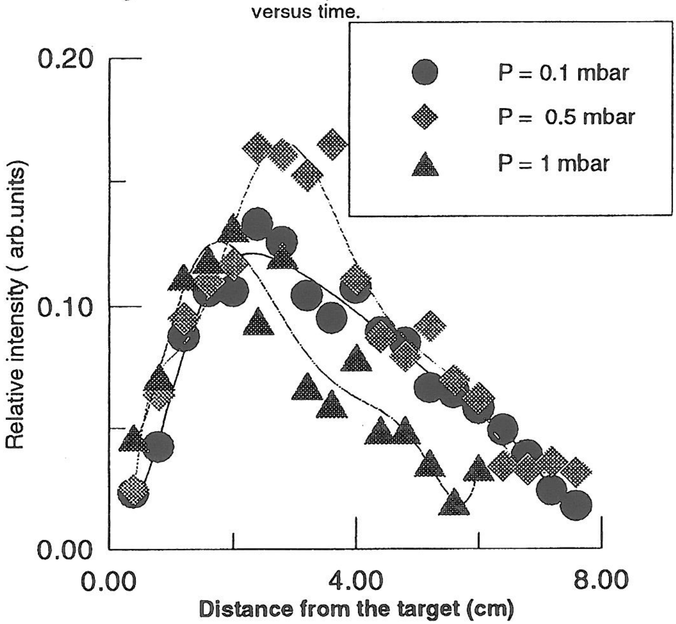

Fig. 3. Spatial extension of molecular Swan band emissivity in argon.

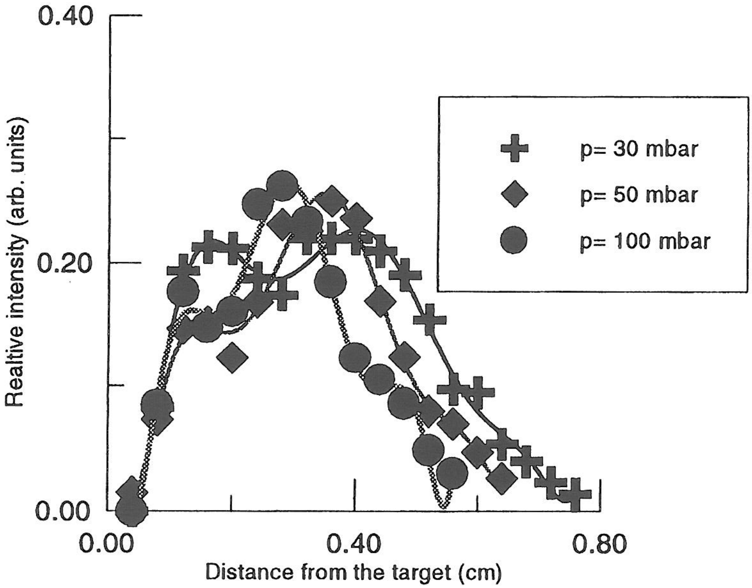

Fig. 4. Spatial extension of molecular Swan band emissivity in helium.