HIGH TIME-RESOLUTION IMAGES OF HOLLOW CATHODE PLASMAS INSIDE METALLIC TUBES OBTAINED BY FAST CAMERA

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1. Introduction

Plasma Immersion Ion Implantation (PIII) and Deposition (PIII&D) inside tubes has been tried successfully in recent years, especially for deposition of DLC in metallic tubes of different diameters for applications in Petroleum, Chemical, Pharmaceutical and Space industries. In our laboratory at INPE, we have been implanting nitrogen inside SS304 tubes of different diameters and also depositing DLC films in such tubes. Discharges inside the tubes are known to be of the hollow cathode or high voltage glow discharge types, depending on the voltage/current characteristics. Behavior of the plasma here is important in terms of achievable ion implantation, sputtering and film deposition. So, the images of the plasma inside tubes are important for these final results of surface treatments. Hence, an optical camera with high time resolution was used for imaging the plasma under different pulsing conditions of a metallic tube.

2. Experimental

Hollow cathode plasma was generated inside metallic SS304 tube of 11cm diameter and 20 cm length, using high voltage pulses of 1.5 to 6 kV, 0.5 to 4 kHz frequency and 20 to 70 μs pulselength, under working nitrogen pressures of 2 to 4×10^{-2} mbar. In some cases, heated tungsten filament was additionally used, to improve the discharges inside the tube. In this work, highly time-resolved photo images of plasmas produced inside the tubes were attained using a fast camera by Photron.

3. Results and Discussions

Initially, time integrated frontally illuminated tube images for each pulse were taken, showing good match of the H.V. pulses with them. For pulses with 1 to 4 kHz, there was a perfect match, considering the time spent in each frame and the camera opening. For the lowest frequency of 500 Hz set in the pulser, images were seen with 660 Hz repetition, without matching. Resolving such frames further, images of the plasmas during the pulse was obtained, showing the plasma turning-on period, the total brightness period, followed by the plasma turning-off period. Plasmas in the turning-on period of less than 50 μs were strong blue, followed by a very bright pink during another 50 μs. This light emitting period continued after the H.V. pulse ending, in dark yellow, sustaining for another 100 μs or more, depending on the pulser conditions. These different colors reflect different plasma conditions of higher to lower temperatures. Furthermore, images of the plasmas tell that they are quite homogeneous in radius direction with very bright region at the center of the tube. When filament was used, light emission became stronger and persisted for longer period. Other information are being pursued with this camera: trying to time resolve the images further, and obtain side way images of the plasma, both inside the tube as well as outside it. This last step could make it clear the reasons of the axial non-uniformity of ion implantation inside the tubes when Plasma Ion Implantation method is applied to them.

Fig. 1. *Metallic SS304 tube inside which a plasma is formed for nitrogen PIII or DLC PIII&D deposition.*

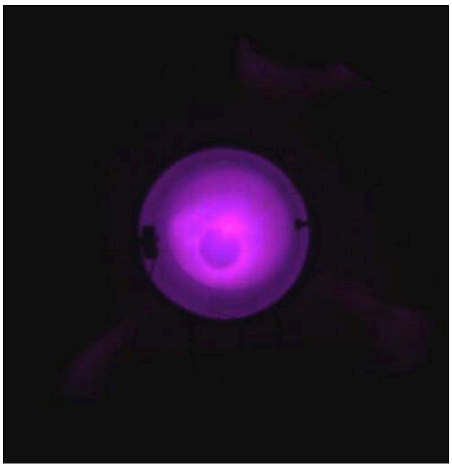

Fig. 2. *Nitrogen plasma captured as a single pulse by a fast camera.*

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