STUDY OF PLASMA IMMERSION ION IMPLANTATION INSIDE CONDUCTING TUBES EMBEDDED IN AN EXTERNAL MAGNETIC FIELD AS A FUNCTION OF THEIR DIAMETER

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1. Introduction

Plasma immersion ion implantation (PIII) is an efficient technique used for the three-dimensional surface modification of materials [1]. However, the treatment of work-pieces as pipes, tubes, piston rings, etc, is difficult to be obtained inside them by conventional PIII. This is due to the lowering of the ion energy caused by the modification of the electric potential values depending on the produced plasma conditions. Recently, it has been shown that by inserting a grounded conductive auxiliary electrode along the axis of the tube, the average ion impact energy can be recovered [2]. Even so, other difficulties of implanting inside such convex surfaces still remain, becoming a challenge to date. On the other hand, applications of ExB fields in PIII proved to be suitable for increasing the implanted dose compared with the standard PIII [3]. Taking advantage of this result, PIII using ExB fields was tested in conducting tubes with different diameters.

2. Experimental

The experiment was carried out in a cylindrical vacuum vessel with 38-cm length and 26-cm diameter (See Fig. 1). For generation of the axial magnetic field, four magnetic coils were mounted on the PIII chamber. Tubes of stainless steel (SS) embedded in external magnetic field were used to study the effects of plasma immersion ion implantation (PIII) as a function of their diameter. Three tubes of 15 cm-length and diameters of 11 cm (larger), 4.0 cm (medium) and 1.5 cm (smaller) were prepared for the experiments. The study was complemented with and without a grounded auxiliary electrode (AE) placed on the axis of the tube. Nitrogen gas at $3x10^{-2}$ mbar was used to create the plasma. The pulse parameters were kept constant throughout the experiments in 6kV/20 μs/500 Hz. Intensities of magnetic field between 60G and 90G were used. The treatment time was 60 min.

3. Results and Discussions

During the discharge tests in tubes of larger diameter, with and without AE, nitrogen gas breakdown was established inside the tube at pressures near 2.0×10^{-2} mbar. Under the same operation conditions, stable plasmas with similar PIII current densities were obtained for both arrangements. Reducing the diameter of the tube to D = 1.5 cm turned the plasma unstable and made it inappropriate for ion implantation. This situation was solved by supplying gas at higher pressure or using higher magnetic field, without the presence of an AE. Under these conditions, nitrogen PIII treatments of these small diameter tubes were performed but gave not the best implantation result yet. Our results have also shown higher ion implantation current density (16 $mA.cm^{-2}$) in tube of intermediate diameter using AE, compared to largest diameter tube used. In this case, a thick nitrogen implanted layer of about 5 μm was obtained in the SS sample placed inside the tube, as is shown in Fig2.

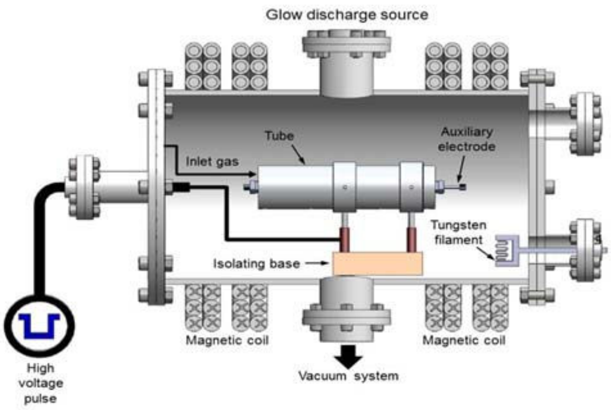

Fig 1. *Arrangement of system PIII with magnetic field*

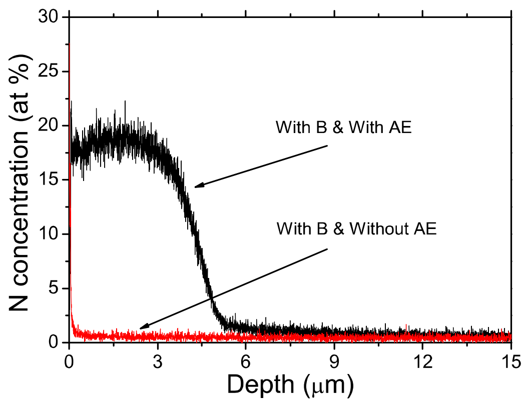

Fig. 2. *GDOES result for tube with D = 4.0 cm.*

These results are attributed to the thermal diffusion promoted by ions hitting the inner wall in a large number due to the presence of the AE and the magnetic field. Furthermore, samples of Si were placed together with SS samples inside the tube to study the effects of N ion bombardment. By GDOES analyzes, it was detected, besides N, high Fe concentration with large implantation depth. Here, it was noticed that N/Fe ratio depends

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