Surface Modification of UNCD Films by Nitrogen PIII inside Conductive Tubes

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1. Introduction

Plasma immersion ion implantation (PIII) is a widely used technique for the surface modification of materials, aiming mainly for improvements of mechanical, electric or magnetic properties of complex-shaped three-dimensional objects [1,2]. Ultra-Nano Crystalline Diamond (UNCD) films have been subject of large interest in the scientific community, motived by their exceptional properties for tribological, mechanical, biomedical and electronic applications. To discuss the role of nitrogen in surface reactions and its effects on grain boundary cohesion, information on the binding mode of nitrogen are of great interest, which can be obtained by studies on diamond surface covered with adsorbed nitrogen. Nitrogen incorporation in the UNCD structure recognized to affect most of the film properties, including a changes the tribological behavior, molecular structure and chemical bonds. The effect of nitrogen resulted in the enhanced adhesion strength of UNCD films by increasing sp^2 bonds and subsequently relaxing residual stress in the films [3]. In addition, the tribological performance of UNCD films can be improved by nitrogen incorporation because promotes the graphitization of the films and could be used in protective and coating technology. Therefore, the effect of Nitrogen PIII inside conductive tubes on UNCD films grown on titanium substrate by HFCVD process was studied.

2. Experimental

Stainless steel metallic tubes with different diameters, 40 mm (T40) and 110 mm (T110), with 150 mm of length were placed in a large vacuum chamber of 600 liters to carry out the nitrogen PIII treatment. Nitrogen gas at 3 Pa was used to create the plasma while the pulse parameters were kept at 3 kV/3 A/30 µs/1 kHz for the T110 and 2.7 kV/1 A/30 µs/3 kHz for the T40. In order to study the effects of the treatment, several samples of UNCD films were placed inside the tube to be treated for 120 min. An infrared thermometer Mikron model M90 was used with nominal range between 250 and 2000 ºC was used to monitor the temperature of the tube during the treatment by nitrogen PIII. The morphology and structures of the UNCD films were investigated before and after the NPIII treatment, using Field Emission Gun Scanning Electron Microscopy (FEG-SEM) with auxiliary Energy Dispersive Spectroscopy (EDS) – Hitachi microscope model SU-70. X-Ray Diffraction (XRD) performed the analysis of crystallinity in a Philips PW-1840 diffractometer. Raman Scattering Spectroscopy (RSS) – Labram HR evolution – Horiba Scientific evaluated the quality of UNCD films.

3. Results and Discussions

NPIII on the UNCD films changed the surface morphologies and characteristics of the RSS peaks of the samples treated by NPIII inside tubes. EDS results revealed the presence of nitrogen adsorbed in samples and new elements such as Fe and Cr that were sputtered from metallic tubes. UNCD film depth profiling revealed the presence of carbon diamond and small amounts of Ti, Fe, Cr, Ni and Mn in the subsurface region, after NPIII in T110. Therefore, N and O were not demonstrated to be present in this subsurface region. The iron in both cases is characterized by a transfer of electron charge from metallic tube used for the treatment NPIII, which was more pronounced in the case of the T40. This is a consequence of high concentration of nitrogen implanted into samples and of the increase in temperature due to the high ion flux bombardment on the surface, which was favorable to sputtering. The results have also demonstrated a substantial dependence of nitrogen PIII performance with the tube diameter.

4. References

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