EXPERIMENTS ON PLASMA IMMERSION ION IMPLANTATION INSIDE A CONDUCTING TUBE

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Experiments on plasma immersion ion implantation (PIII) inside a conducting tube are investigated. This work is accomplished with a grounded auxiliary electrode (AE) placed inside the tube. In order to evaluate this process, samples made of stainless steel were placed inside the tube to be treated at 3kV voltage and pressure of $2x10^{-2}$ mbar. Our results have shown that a stable plasma discharge is formed inside the tube using AE. Furthermore, measurements performed by X-ray diffraction showed presence of a new phase (γ_N phase), indicating structural changes of SS304 sample. It has caused a substantial reduction in the value of the friction coefficient compared to that untreated sample.

Keywords: Plasma immersion ion implantation; PIII inside tube; Auxiliary electrode; Stainless steel;

Introduction

Plasma immersion ion implantation (PIII) is a well-known technique used for the three-dimensional surface modification of materials [1]. However, the treatment of workpieces with concave geometry is difficult, not allowing a good ion implantation inside them due to the modification of the electric field distribution there [2]. Hence, the treatment of PIII in the inner walls of metallic tubes is a challenge to date. Theoretical studies have shown that the behavior of the potential inside a tube is associated with the characteristic length scale, called ion-matrix overlap length [3]. Recent work has shown that the incorporation of a grounded Auxiliary Electrode (AE) inside the tube maximizes the potential drop, thereby improving the implantation energy [4]. Based on these results, the effects of PIII inside the tube with and without AE was studied in a high power PIII. To evaluate these processes, samples of stainless steel and silicon were placed inner the tube walls to be treated.

Experimental part

Nitrogen PIII inside the tube at working pressure of $2x10^{-2}$ mbar was performed. Tubes with 11-cm diameter and 15-cm length were placed in a large chamber of 600 liters in order to carry out the PIII test. The pulser parameters were kept constant throughout the experiments with voltage of 3 kV, pulse width of 30 µs and repetition frequency of 1 kHz. To monitor the temperature, an infrared thermometer Mikron model M90 with nominal range between 250 and 2000 ^{o}C was used. Stainless steel 304 disks with dimensions of 15 mm-diameter and 3 mm-thickness were treated for 60 min. After treatment, the structural changes were investigated by X-ray diffraction (XRD). Atomic force microscopy (AFM) measurements were carried out to analyze surface topography and roughness. Tribological measurements were accomplished in a CSM-instruments Pin-on-disk tribometer.

Results and discussion

Results of electric discharge tests showed a better performance of the plasma discharge, as well as, a higher current when the AE is used.

In order to perform the PIII treatment, SS304 samples were placed inside the tube to study the effect of PIII with and without an auxiliary electrode (AE). AFM images results are shown in Fig. 1 for reference and treated sample using tube without AE. Changes on surface morphology are observed after ion implantation in relation to the reference sample. The roughness has increased from Rq ~ 5 nm to Rq ~ 10 nm. This result can be attributed to an intense ion bombardment. As a consequence, a substantial rise of the temperature was achieved (350 ^{o}C) before the end of treatment. The high temperature achieved is favorable for greater diffusion of the implanted ions which results in a nitrogen rich thick layer. The presence of implanted ions has changed the crystalline structure of SS304, as can be noticed in the diffraction patterns depicted in Fig. 2. Here, a high intensity broad peak located next to γ_{111} peak is recognized. This result indicates the formation of a metastable expanded austenite phase, rich in nitrogen, called γ_N phase. The effect of this nitrogen layer on sample surface can also be seen in the change of the value of friction coefficient (μ). Our measurements in treated samples have shown a slight fall of μ, from 0.8 to 0.6 in relation to the reference sample. Treatments using AE are being carried out.

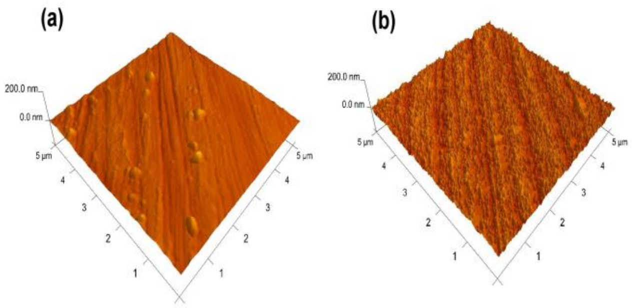

Fig. 1 - *Surface morphology observed by AFM (a) reference sample and (b) treated sample for 60 min.*

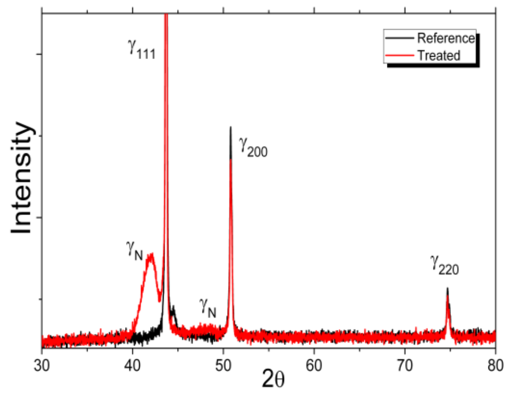

Fig. 2 - X-ray diffraction patterns of stainless steel 304 for reference and treated samples after 60 min of treatment.

Conclusions

Our results showed a more stable plasma discharge inside the tube when AE was used (compared to the case without it). On the other hand, samples used for test in tube without AE revealed substantial structural and morphological changes on the surface. This result points out to the high flux of ion hitting the inner wall.

References

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