DC Plasma Ion Implantation in an Inductively Coupled RF Plasma

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ABSTRACT

Various modes of plasma ion implantation have been investigated in a small inductively coupled 13.6 MHz RF plasma source. Plasma ion implantation with HVDC(up to –10 kV bias) has been investigated in order to incorporate with the conventional implantation of Diamond Like Carbon. In this preliminary work, nitrogen ions are implanted into the stainless steel sample with a dose of $5.5x10^{-2}$ cm for a short implanting time of 7 minutes without target cooling. Surface properties such as microhardness, wear rate and the friction coefficient have been improved. X-RAY and SEM analyses show distinct structural changes on the surface. A combination of sheath assisted implantation and thermal diffusion may be responsible for improvement in surface properties.

Key words: Low Temperature Plasmas Applicaitons, Plasma Ion Implantation

INTRODUCTION

Various types of plasma sources may be used in conventional plasma ion implantation for surface modification of materials[1]. For ease in operation and low impurities, an inductively coupled 13.6 MHz RF plasma may be chosen. Our plasma is produced in a cylindrical stainless steel chamber of 31 cm in diameter and 42.5 cm in length[2]. The RF power at 50-250 W is applied to the two turns insulated helical antenna placed inside the chamber, an array of permanent magnet buttons is used to assist in plasma confinement. The strength of the cusp field inside the chamber is 670 gauss. Plasma parameters are characterized by a single Heiden RF compensated Langmuir probe and an Ocean Optics optical emission spectrometer. An optical pyrometer is also used to check target surface temperature. A water cooled target holder can place the sample along the line of sight directly opposite to the antenna.

Four modes of operations may be carried out, namely: (1) cw RF plasma-DC negatively biased target, (2)cw RF plasma-pulse negatively biased target[3], (3) pulse RF plasma-DC negatively bised target[4] , and (4) pulse RF plasma –pulse negatively biased target[5]. These modes of operation offer advantages and disadvantages as discussed by a number of authors shown, and they benefit material surface improvement with wide range of ion species and energy. In this paper, we present the work on HVDC bias technique. A combined PIII and deposition process will later be used to fabricate the diamond like carbon (DLC)coating. Stainless steel is used as a test specimen that has been prepared with standard procedures.

RESULTS

Stainless steel were implanted with nitrogen ions at –10 kV bias, RF power 250 W and gas pressure 0.5 mtorr, with or without cooling at different implanting times.

1.Tribological test results are summarized in the Tables 1 and 2

Table 1.Microhardness test of specimens before and after implantation

Specimen number	Implant time (minutes)	Dose (cm^{-2})	Unimplanted	Implanted	Change (%)
104	7.5+cooling	$5.9x10^{17}$	184.94+/-72	293.13+/-71	58.50
103	7.0	$5.5x10^{17}$	192.5+/-7.5	338.3+/-106	75.74
105	11.0	$8.2x10^{17}$	195.79+/-13.6	300+/-77	53.22

Table 2.Wear test

Specimen number	Friction coefficient	Wear Rate
unimplanted	0.71	$3.9x10^{-7}$
104	0.67	$8.29x10^{-8}$
103	0.39	$3.67x10^{-8}$
105	0.51	$1.09x10^{-7}$

2.Pin –on-disk wear test

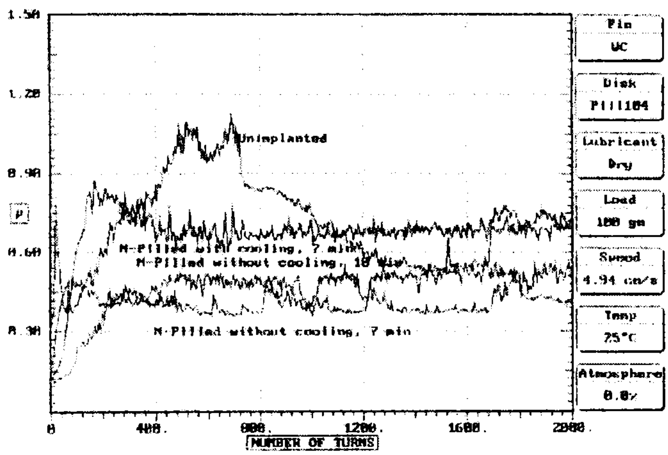

Fig.1.Graph of tribological analysis

2.Structural analysis results from X-RAY and SEM studies are shown in Figs.2 and 3

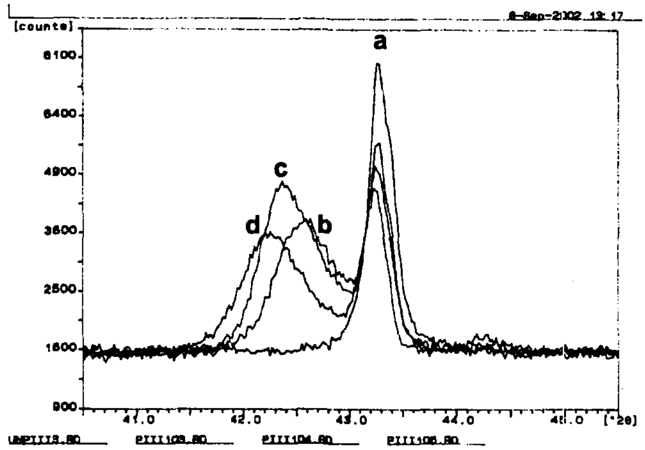

Fig. 2 X-ray diffraction profile in (111) plane a) unimplanted specimen, b) implanted specimen for 7 minutes without cooling (No.103), c) implanted specimen for 11 minutes without cooling (No.105) and d) implanted specimen for 7.5 minutes with cooling (No.104). Expanded Austenite is evident in sample b,c,d.

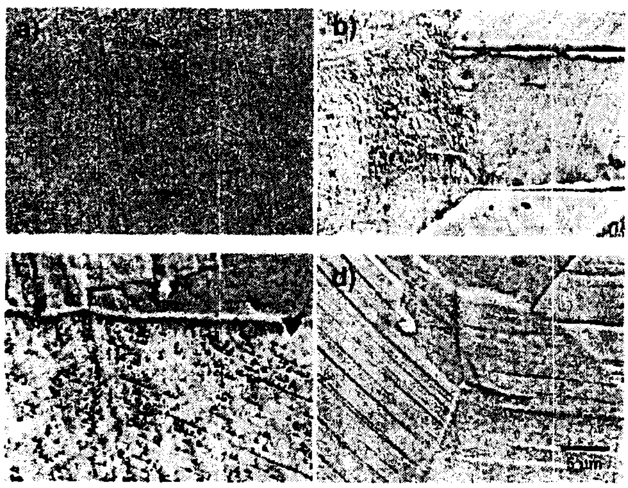

Fig.3 Scanning Electron Microscope images a) unimplanted specimen, b) implanted specimen for 7 minutes without cooling (No.103), c) implanted specimen for 11 minutes without cooling (No.105)

d)implanted specimen for 7.5 minutes with cooling (No.104). Implantation time and heating affect the grain edges and shear on the surfaces.

CONCLUSION

We have accomplished the ion implantation with HVDC (up to −10kV, limited by power supply available) in an RF discharge without the occurance of arcing. The test on stainless steel using nitrogen ions shows improvement in surface properties. The process renders some advantages over pulse ion implantation such as less stringent requirement on the HV pulse modulator. Furthermore, it can be incorporated in the so called PIII&D process which is suitable for fabrication of some material such as DLC.

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