ENHANCEMENT OF MECHANICAL PROPERTIES OF HIGH CHROMIUM STEEL BY NITROGEN ION IMPLANTATION

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Abstract

This article reports the study of mechanical properties of high chromium steel after N-ion implantation. The samples are implanted with 120keV N-ion at doses ranging from $1x10^{18}$ions/cm^2 to $4x10^{18}$ions/cm^2. Mechanical properties of implanted samples are compared with those of Cr-plated samples. The compositions of the N-ion implanted layer were measured by Auger electrons spectroscopy(AES). Their mechanical properties as a function of N-ion doses were characterized by nano-indentation, sliding and impact wear tests.

INTRODUCTION

Ion implantation is a surface modification technology in which atoms or molecules are ionized, accelerated to tens or hundreds keV of energies, and then implanted to the target materials. Ion implantation method is world-widely used for high quality semiconductor production, and development for new materials to have special properties [1,2]. Comparing with conventional surface modification technologies, it does not generate toxic wastes, which can threaten the environment. It provides precise control of surface thickness and strong adherence of surface material. Some research works have been conducted to improve the mechanical and chemical properties of metals using ion implantation[3~6].

This study is Enhancement of Mechanical Properties of High Chromium Steel by Nitrogen Ion Implantation.

GAS ION IMPLANTER

The detail specifications of implanter components are as followings:

- DuoPIGatron Ion Source:
  - Thermal cathode : W Filaments
  - Intermediate Electrode : Mild Steel, Cone Angle of 30 degree
  - Beam current : 20mA
  - Energy : 50 keV

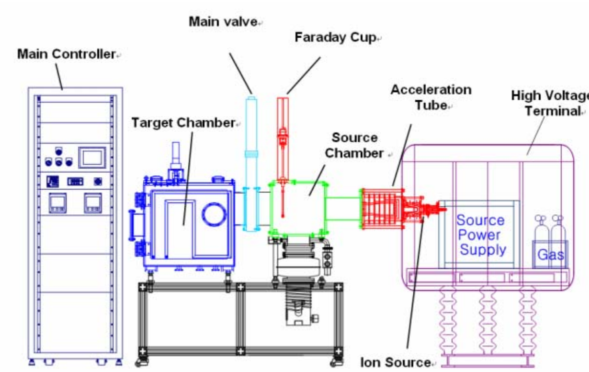

Figure 1: A gas ion implanter for the nitrogen ion implantation.

- Vacuum System:
  - Pump : Oil Diffusion
  - Ultimate Pressure : 4 x 10^{-6} Torr

- Ion Diagnostics:
  - Scanning Faraday Cup : Th-W, 5mm dia

The simple gas implanter can be utilized for developing various types of ion sources through function tests of ion sources as well as for developing sophisticated surface treatment technologies to be used in mass production of small piece products.

EXPERIMENT

The nitrogen ions are generated using by duopigatron ion sources up to 10mA, 40 keV and accelerated up to 120 keV. The high chromium samples are implanted with 120keV nitrogen ion at doses ranging from $1x10^{18}$ions/cm^2 to $4x10^{18}$ions/cm^2. The chemical composition of nitrogen ion implanted layer was determined from the elemental depth profiles measured by Auger Electron Spectroscopy(AES:PHI 670). To obtain the hardness (H) of nitrogen ion implanted layer, not including the surface influence, a nanoindenter(Nano indenter XP developed by MTS) was used. The wear property of nitrogen ion implanted layer was evaluated using a ball-on-disk type tribometer with a 9.525mm diameter Cr-steel ball as a counterpart material. The test was performed in the room atmosphere temperature without lubrication under an applied normal load of 0.1kgf. The sliding velocity was 0.37m/s and total the total sliding distance was 1000m. To evaluate the impact property of nitrogen ion implanted layer, the impact test using a high Cr-steel ball was carried out by impressing a normal load of 0.03kgf to them 100times.

DISCUSSION

The hardness depth profiles of nitrogen ion implanted high chromium steel for various ion implantation conditions are shown in Figure 2. The hardness of the nitrogen ion implanted sample with 120keV $4x10^{18}$ions/cm^2 was measured to be approximately 10GPa, which is approximately 2.6 times higher than that of un-implanted sample (H=3.8 GPa). And the hardness of nitrogen ion implanted sample with 120keV $4x10^{18}$ions/cm^2 is higher than the Cr-plated sample from surface to about 50nm depth.

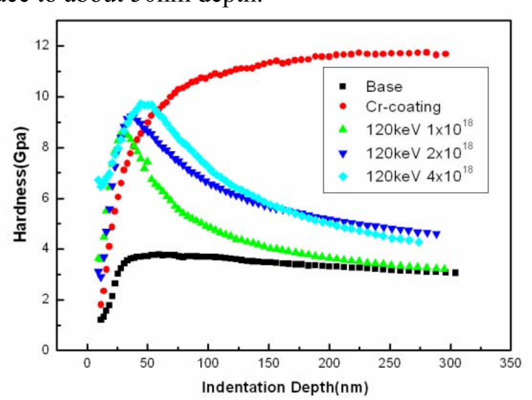

Figure 2: Hardness depth profiles obtained with nanoindentation.

The depth profile of chemical compositions was measured by AES, and its result is illustrated in Figure 2. The concentration of nitrogen is about 35% (500~2500 Å), and a considerable amount of the nitrogen is still detected up to a depth of 4000 Å from the surface.

Figure 4. shows the friction coefficient as a function of sliding distance. As the dose increases, the friction coefficient lowers. The lowest friction coefficient was 0.3 at the 120keV $4x10^{18}$ions/cm^2. Wear properties of nitrogen ion implanted samples with 120keV $4x10^{18}$ions /cm^2 were largely improved. Compared to the Cr-plated samples, the width of wear track and friction coefficient developed on the nitrogen ion implanted samples are about 60% and 25% smaller, respectively.

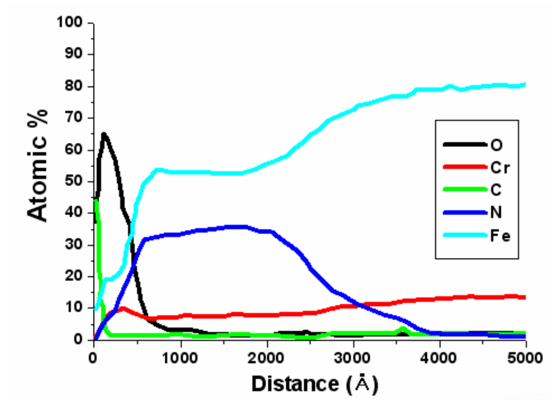

Figure 3: Auger depth-profiling results of nitrogen implanted high chromium steel.

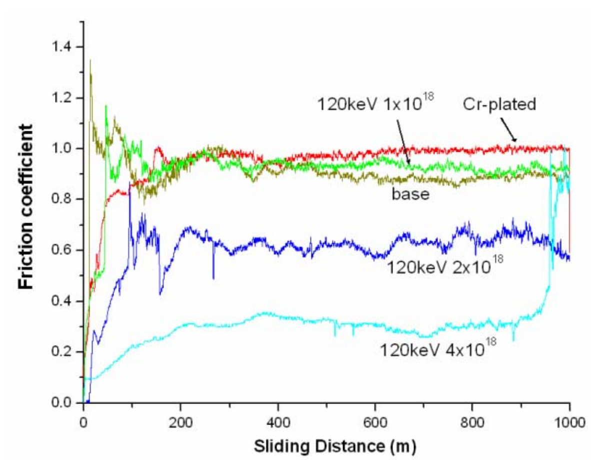

Figure 4: Friction coefficient as a function of sliding distance.

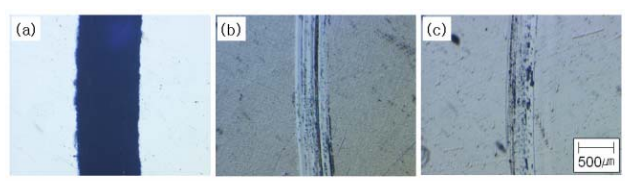

Figure 5: The morphologies of sliding wear formed. (a) base, (b) Cr-plated, (c) implanted(120keV $4x10^{18}$ions /cm^2).

The results obtained in the impact test are given in the Figure 6. After impact of 100times, the impact cavity size of Cr-plated sample was most small but the micro-cracks were observed around the impact cavity.

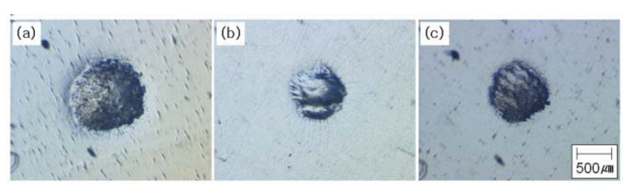

Figure 6: The morphologies of impact wear formed. (a) base, (b) Cr-plated, (c) implanted(120keV $4x10^{18}$ions /cm^2).

CONCLUSION

The results reveal that the hardness and mechanical properties of ion implanted samples were found to depend strongly on the ion doses. The hardness of the N-ion implanted sample with $4x10^{18}$ions/cm^2 was measured to be approximately 10GPa, which is approximately 2.6 times higher than that of un-implanted sample (H=3.8 GPa). Also Wear properties of nitrogen ion implanted samples with 120keV $4x10^{18}$ions/cm^2 were largely improved. Compared to the Cr-plated samples, the width of wear track and friction coefficient developed on the nitrogen ion implanted samples are about 60% and 25% smaller, respectively.

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