AN IMPLANTATION FACILITY
FOR SURFACE MODIFICATION OF METALS

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Abstract

A 280 KeV ion implantation facility has been developed for research of surface modification of metals by ion beams and their applications. The machine consists of an ion implanter and a surface treatment equipment by ion beam. The energy of 60-280 KeV and typical N^+ and Ar^+ ion beam current of 3 mA have been obtained for the implanter, respectively. The sputtering ion source mounted on the surface treatment equipment has produced N^+, Ar^+ and Xe^+ beam current of more than 10 mA at extraction voltage of 2 KeV. The machine has three functions of direction implantation, ion beam sputtering deposition and dynamic ion bean mixing when two parts were combined. The main component and feature of the machine are described in this paper. The results of the tested samples have been given.

1. INTRODUCTION

Ion implantation is a powerful method for modifying the near surface properties of material. To cater for diverse research and application the implanting facilities must be flexible. For example, ion beams of elements are desirable, dose can cover the range from 10^9 ions cm^{-2} to 10^{18} ions cm^{-2}, sample sizes are variable, energy is adjustable, etc. A 280 KeV ion implantation facility has been developed to meet mentioned above at Institute of Nuclear Science and Technology of Sichuan University. This paper describes some main assembly construction and features of the machine.

2. MACHINE CONFIGURATION AND FEATURE

The 280 KeV ion implantation facility consists of two parts. One part is a 280 KeV ion implanter with mass analyzer and another is a surface treatment installation by ion beam. The schematic diagram of the machine is shown in Fig.1. This implanter utilizes the post acceleration mode [1]. Ion beam is extracted from Freeman source at voltage of 30 KeV, then enters a 90° analyzing magnet. The analyzed ion beam is accelerated up to 250 KV and finally scanned over the sample in the target chamber.

2.1 Ion source

The ion source is a critical component of the ion implantation system. Freeman source is used in this implanter because it can provide ion beams of all species in the periodic table. Ion beams are extracted from the slit of 15×20 mm at the voltage of 30 KeV. A lot of modifications were made to increase the performance and lifetime of the Freeman source. Typical analyzed beam currents of 1 mA for B^+ and of 3 mA for N^+, Ar^+ have been obtained.

2.2 Analyzing magnet

The divergent beam extracted from Freeman source enters the analyzing magnet with a pair of rotation pole tips. Not only this magnet can select beam species required, but also enable the beam to be focused into the variable resolving slit where is incorporated into the acceleration tube . The deflection angle of the magnet is 90°, the deflection radius is 35 cm, the gap of magnetic pole is 5 cm, the magnetic field is 1.04 T. Such an arrangement can provide analyzed beam up to 209 amu at energy of 30 KeV[3].

2.3 Acceleration column

It is well known that acceleration column is an important component for the implanter because it enables ion beam to obtain energy required and occurs focusing action. In the design of the machine, the maximum ion energy and current of the implanter are 280 KeV and 3 mA, respectively. Therefore, a higher gradient acceleration column with double gap is adopted [4]. The column 78cm long is made of porcelain rings glued with adhesive to stainless steel rings. The column is divided two sections, each of the sections has 3 units, and two sections are linked with O ring and many screws. Within the column the acceleration lens comprised three plate diaphragm electrodes are placed at the position where near the center of total length of the column. The external diameter of the diaphragm electrode is 20 cm, the internal aperture is 9 cm, and the

distance between electrodes is 6 cm. Thus, when the voltage of 250 KV is applied to the electrodes, the average gradient of gap is 20.8 KV/cm. According to calculations of taking account of space-charge effect, the optical properties of ion beam transport in column are better for different energy (60-280 KeV), mass number (11-209) and ion beam current(0.5-5 mA)[5]. The tests have proved that the column has no breakdown and flash over phenomena when the tested voltage is up to 300 KV.

2.4 Surface treatment installation by ion beam

Surface treatment installation by ion beam is a stainless steel cylinder of ϕ 520×240 mm. It can provide sputtering deposition for material surface modification. It is also a target chamber with mechanical scanning system for the 280 KeV implanter. A sputtering ion source is mounted on perimeter of the cylinder, which produces many ions such as N^+, Ar^+ and Xe^+ etc. beam current of more than 10 mA at extraction voltage of 2 KV. It incorporates a sample holder that rotates about an axis and translates up and down. Many samples or substrates are loaded at the one time for individual sputter or implantation. The rotational speed of the holder can be varied from 0.5 to 30 rpm. The dose's non-uniformity produced by the mechanical scanning system is about 15%. The position of the holder can be altered with a rotation rod, so the sample surface would be faced the ion beam in the optimum condition for sputtering and ion beam mixing. There are some provisions of diagnostic within the target chamber, such as Faraday cup, the measuring probes of temperature and film thickness [6].

2.5. Machine feature

(i). Short beam transfer line The ion beam extracted from Freeman source directly enters 90° analyzing magnet. The natural position of beam waist is at the variable resolution slit within the column by adjusting rotational pole tips without any electrostatic lens [7], which makes possible a short beam line. The distance between the slit and first accelerating electrode is 10 cm. In order to control the beam current reaching the slit and reduce load of entrance lens the beam limiter is placed into the flight tube between magnet and the resolution slit. Behind the earth electrode of the accelerating lens, the suppresser electrode is placed to protect secondary electron from back-acceleration and enable the beam to be stabilized.

(ii). Versatile It is an important feature that this facility is versatile. The metal films are deposited on the samples by ion beam sputtering installation; the analyzed ion beam from the implanter can directly implant into the surface of materials. Thus, there are three processing methods when sample or substrate is treated by this machine, i.e. direct ion implantation, ion beam sputtering deposition and dynamic ion beam mixing.

3. SOME IMPLANTATION

The machine has been used for exploratory research for a variety of different substrates. Here is the example. Ta-rich surface alloys have been prepared directly on GCr15 bearing steel substrates by dynamic ion beam mixing technique in the machine. All samples were given preliminary implantation with N^+ at a dose of 2 $\times10^{17}$ cm^{-2} and an energy of 100 keV, respectively. Then, the Ta film was deposited on the samples when Ta target is bombarded by Ar^+ beam (current of 10 mA). Simultaneously, the substrate was implanted at energy of 120 KeV and at dose of 8 $\times10^{16}cm^{-2}$ and 15 $\times10^{16}$ cm^{-2} of Xe^+ beam, respectively.

The test results have show that the samples surface properties have been improved. For example, the surface hardness of the sample has been enhanced by 35%, the friction co-efficient has been decreased from 0.4 to 0.27, wear resistance can be enhanced by 5-6 time.

4. CONCLUSION

The 280 keV ion implantation facility equipped with an ion implanter and a surface treatment installation by ion beam. The results obtained in the performance test are as follows:

(1) A wide of energy range of 60-280 keV and Ar^+. N^+ beam currents of more than 3 mA have been obtained, respectively.

(2) For the surface treatment equipment by ion beam Ar^+, Xe^+ and N^+ etc beam currents of more than 10 mA at extraction voltage of 2 kV have been achieved. A lot of metal films (Cr. Mo etc.) can be deposited on the sample by the sputtering ion beam.

(3)The results of the performance test and sample treatment proved that this machine is versatile for surface modification of metals and preparation of solid films.

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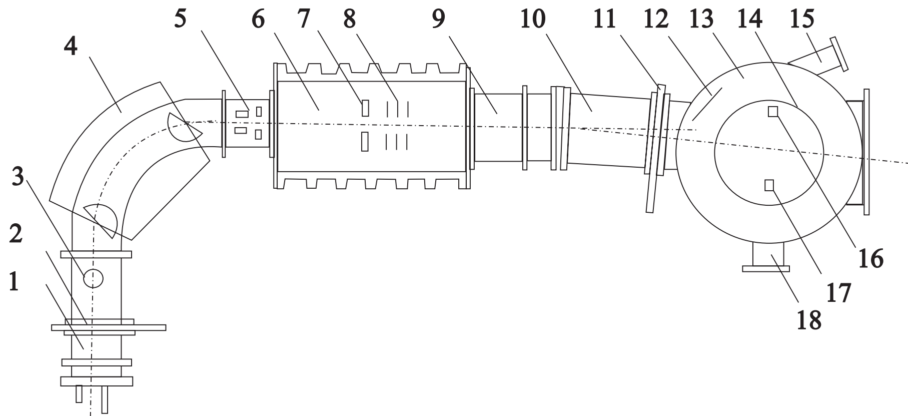

Fig.1. Schematic drawing of the 280keV ion implantation facility

1. Freeman source 2,11. insertion value 3. beam measuring aperture 4. analyzing magnet 5. beam limiter 6. acceleration column 7. adjustable resolution slit 8. accelerating lens 9. quadrupole triplet 10. electrostatic scanning system 12. sputtering target 13. surface treatment installation 14. holder 15. sputtering ion source 16. measuring head of film thickness 17. temperature measure 18. cleaning ion source