The Magnetic Filtering Vacuum Arc Film Deposition System and Its Applications

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Abstract: A cathodic arc with beam filter is employed for the deposition of metallic and hydrogen-free amorphous carbon films. A solenoid filter is used to prevent macroparticles and nonionized atoms from reaching the substrate. The detail transport characters of the filter are presented in the paper. With an optimum filter arrangement we are able to obtain a filter output of 18.4% of the total number of ions produced by the vacuum arc discharge. The deposited amorphous cabon thin film contains no hydrogen and a high fraction of sp^3 is determined by XPS. A dense Ti film deposited on H13 steel improves the corrosion resistance of the H13 steel and significant improvements of corrosion resistance were observed by implanting Ti, C in the film.

1 Introduction

Vacuum arc plasma deposition is a promising technique for the production of metallic[1,2], compound[3] and amorphous diamond[4,5] thin film. In comparision with other deposition methods, the vacuum arc plasma process is distinguished by its high degree of ionization and high deposition energy which allow the deposition of dense films with good adhere. In vacuum arc discharge, along with the plasma, macroparticles in the micrometre range are produced at the cathode spots, and the contamination of the film by macroparticles is a major obstacle to broad application of the vacuum arc plasma deposition. In order to form macroparticle-free films several techniques[6-8] have been developed, of which magnetic filtering has been the most successful[8]. In the magnetic filtering vacuum arc deposition technique, a bent magnetic field is employed to guide the vacuum arc plasma, in which the electrons are magnetized and follow the magnetic field lines whereas the ions are not magnetized but forced to follow the magnetic field lines by the plasma-interal electric fields.

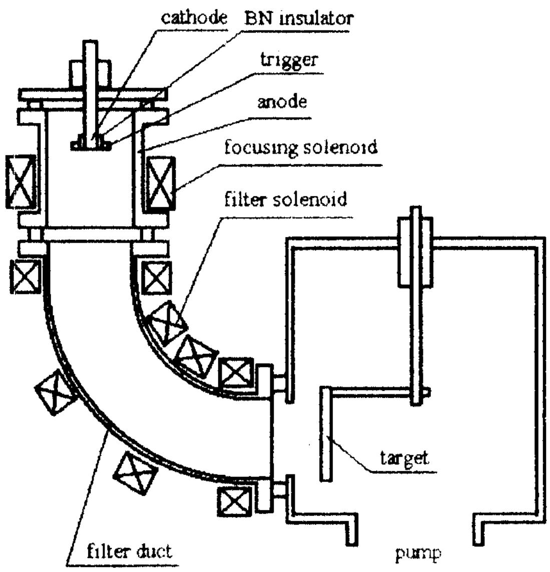

FIG 1 Schematic of the filtered vacuum arc deposition systetm

We have applied the technique of magnetic filtering to build a vacuum arc deposition facilities, see fig1, for the formation of macroparticle-free films. Here, the system and its applications are described

2 The filtered vacuum arc deposition system

The filtered vacuum arc film deposition system , showed in fig. 1, consists of a vacuum arc plasma source[9], a 90° bent duct with a solenoid macroparticle filter and a target chamber. The plasma source used for the production of the plasma uses a rod cathode (diameter 20mm) which is surrouned by a BN insulator, a trigger electrode and a cylindrical anode. The cathode is at ground potential, and the anode is biased positively. When a high-voltage pulse is applied to the trigger electrode, a flashover across the BN insulator surface creates a small plasma which triggers the main arc discharge between cathode and anode, then a plasma of the cathode material is ejected from the cathode spots with a characteristic velocity of $1\text{-}2\times10^4$m/s.

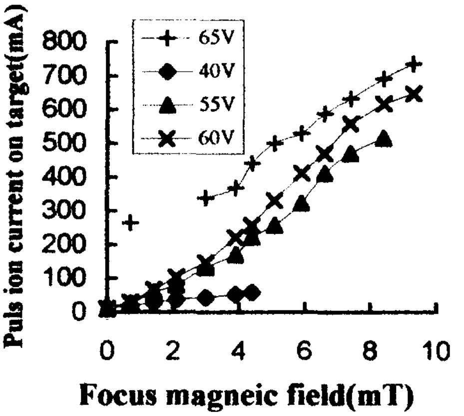

FIG 2 The pulsed current of Ti ions on target as a function of the focus magnetic field at different filter positive bias when the filter duct magnetic field is 15mT

In our experiments, the source works at plus mode with 2.5ms arc duration, and the trigger frequcy can be adjusted gradually from 0.5 to 25Hz. The arc current is in the range of 70~200A. To increase the output of the plasma source , an axial magnetic field up to 10mT is applied by employing a solenoid around the anode. The power for the solenoid is provided by a independent DC power supply. This field makes the plasma flow focus into a jet-like shape, so the plasma can be injected into the filter duct. Fig 2 gives out the influence of this focuus magnetic field to the filter efficiency at different filter guild magnetic fileld when trigging frequency is 10Hz and the filter duct positive bias is 40V.

The 90° bent duct of the filter made from stainless steel with a minor radius of 38mm,a major radius of 94mm. A DC power supply is employed by the solenoid which around the duct for the establish of a magnetic field with strength in the range of 0~15mT in the duct.

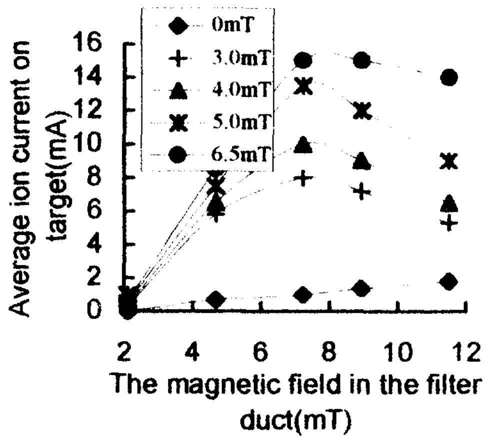

FIG 3 The target average current of Ti ions as a function of the filter duct magnetic field at different anode focus magnetic when the triggering freguency is 10Hz and the duct positive bias is 40V

When the plasma is ejected into the magnetic field of the bent filter, the electron Lamor radius is much smaller than the minor radius of the duct. So , in the collisionless case, electrons gyrate around and move along the magnetic field lines. The ions are bounded to the eletron motion by the electron force caused by a small charge separation. As a result of this, the plasma passes through the bent filter duct, and macroparticles and neutral atoms are filtered because they are not charged particles. Fig 3 gives out the influence of the duct magnetic filed to the filter efficiency .

To supress the ion flux toward the duct wall, a DC power supply is employed for applying a positive bias on the duct wall. Experiment results, see fig 2 , show that the filter transport efficiency increases with the duct positive bias, but when the positive bias exceeds 65V, the vacuum arc becomes unstable.

To apply negetive bias on the taget, two DC power supplies, one is 0~-300V and another is 0~-30kV, are used for plasma deposition and ion implantation. The high voltage power supply is also employed to clean the target by sputtering.

At focus magnetic field is 9.3mT,filter guide magnetic field is 10.5mT and the duct positive bias is 60V, we are able to obtain the optium filter output of 18.4% of the total number of Ti ions produced by the vacuum arc discharge.

3. Application of this facilities

3.1 Deposition of hydrogen-free amorphous carbon films

This filtered vacuum arc plasma deposition facilities are employed for the deposition of the amorphous carbon films. The deposition rate is about 0.2nm/s. High sp^3 fraction ,see fig4, of the films surface region is determined by the XPS C1s spectra. The spectrum has been fitted with three components, centered at 284.45, 285.41 and 287.36eV, which , according to S.T. Jacson[10] , correspond to sp^2 bonded carbon, sp^3 bonded carbon and an sp^2 carbon satellite peak due to energy loss processes. Table 1 gives out the sp^3 fraction and the critical load of the a-C films prepared by filtered vacuum arc at different deposition energy. The critical loads, at which the films begin crack, are mesured on a line-cutting equipment with a 120° diamond pin. From the experiment results, we can infer that below the 170eV the adhesive strength and the sp^3 fraction increase with the deposition energy.

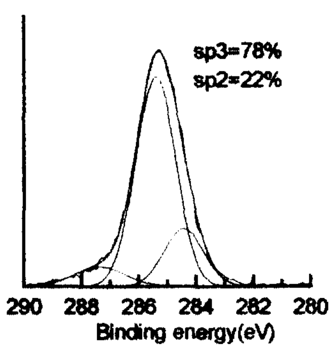

FIG 4 XPS C 1s region for a-C deposited by filtered vacuum arc method at 60eV ion energy

Table 1 The sp^3 fraction and the critical loads of the a-C films deposited by filtered cathodic arc at diferent ion energy

	20eV	60eV	120eV	170eV
sp^3 fraction	70%	78%	84%	88%
critical load(g)	177.9	220.4	234.2	269

3.2 Deposition of high-dense Ti films on H13 steel for metallic corrosin inhibition[11]

Dense Ti films on H13 steel were prepared at about 0.3nm/s by filtered vacuum arc for improving of the corrosion resistance. Experiment results, see table 2, show that the pitting

Table 2. Pitting corrosion potential(in 0.1N NaCl solution) of H13 steel treated by filtered vacuum arc deposition and MEVVA ion implantation technology

Sample	H13 steel	Ti film	TiC6	TiTi6	TiC6Ti6
Pitting corrosion potential(mV vs SCE)	-455	-355	-350	-325	-315

corrosion potential of H13 steel with a 400nm Ti film is 100mV higher than that of H13 steel. By implanting 95KeV $6\times10^{17}/cm^2$ Ti (sample TiTi6) ,and implanting 45KeV $6\times10^{17}/cm^2$ C before implantation of Ti (sample TiC6Ti6), the pitting corrosion potential of the H13 steel with 400nm Ti film is increased by 30mV and 40mV.

4 Acknowledgment

We gratefully thank Prof. Zhang Tonghe for his helpfull adivices, and Zhou Fensheng, Wu Xianying , and Li Qiang for their technical assistance . This work is supported by 863 National Advanced Materials Committee of China under Research Project 863-715-008-0040.

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