A 6 CM DIAMETER ION SOURCE FOR ASSISTANT DEPOSITION

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Abstract

Various kinds of broad beam ion sources have been developed for space applications. Recently, they are also used for ground base application. In this paper a 6 cm diameter cusp field ion source which is specially designed for assistant deposition is described. The design and the results of performance tests are presented. It is shown that by means of matching the parameters a good performance can be obtained with this source. In the range of low energy the beam energy could be as low as 50 ev with 20 mA extracting current and 0.91 beam profile flatness parameter. It is very siutable for assistant deposition. In the range of extracted voltage from 1000 to 1300 v a focusing-like beam with beam current density as high as 4.2 mA/cm^2 can be created and it can be used for sputtering deposition.

1. Introduction

Since the ion sources used for ground base applications a great progress has been made in the ranges of material modification, optical assistant deposition, biological application etc. Optical deposition requires good film adhesion, high transmission and uniform deposited film. It is neccessry to have a ion source which has uniform beam current density profile with higher beam current at low energy. Such ion source can make a good film without damaging the substrate. This paper introduces a high performance 6 cm diameter ion source, its design and performance. The factors effecting the flatness of beam profile have been also investigated. It is shown that the flatness of exhaust beam profile can be varied in a wide range due to changing the beam current and extracted voltage. So this ion source can be a versatile ion source —— at lower energy and beam current it is very suitable for assistant deposition and at high energy and beam current it also can be used for sputtering deposition without special focusing-grid.

2. Construction and apparatus

Schematic of ion source is shown in Fig. 1. The outer diameter of cylindric discharge chamber is 94 mm. It is made of stainless steel and consists of two parts, the front and the rear cylinders. A middle annular plate seperates them. 6 mm diameter AlNiCo permanent magnet bars are set uniformly on the outer periphery of the discharge chamber. The magnetic circuit consists of rear cathode support, rear pole piece, middle plate and grid support. They are all made of mild iron. Both screen-grid and accelerator are made of molybdenum and have 0.4 mm in thickness. The diameter of exhaust ion beam is 60 mm. There are 1908 holes on both grids. The diameter of screen-grid holes and accelerator holes are 1 mm and 0.8 mm, respectively. The holes are arranged in equilateral triangle. The center distance between two holes is 1.3 mm. The spacing between two grids is 1 mm. The anode consists of two parts, the front and the rear anodes. The front one is a thin cylinder and the rear one is an annular plate with a lot of small holes through which agron gas is introduced into chamber axially and uniformly. The flow rate is controlled by a needle valve. The cathode and neu-

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tralizer are all made of tungsten wires. There are two cathode filaments. When one of them is broken the another one can be reset on in working condition for extending the continuous lifetime of the ion source. The cathode assemble can be inserted into the discharge chamber from rear end of the ion source.So it is very convenient for changing the cathode filament. The whole ion source is put into a cylinder which is 11o mm in length and 94 mm in diameter. This ion source can work without water-cooling.

The vaccum chamber used for experiments is 4oo mm in diameter and 46o mm in height. The pressure was $2x1o^{-4}$ torr during operation. The density and flatness of exhaust ion beam were measured with a movable Faraday probe which located at 195 mm downstream of the accelerator. The magnetic field strength and its distribution in the discharge chamber are measured by Gaussmeter and ion filings maps.

3. The performance tests of ion source

Due to the larger anode areas and improved magnetic field distribution this ion source has wide ranges of energy and ion beam current and has good performance at low energy. The results of performance tests show : (1) The energy of extracted ions ranges in 5o-13oo ev, (2) Quite high beam current can be obtained at low energy with stable operation and high beam profile flatness. Figure 2 shows the ion beam profile obtained at low energy. 24 mA of beam current was obtained at screen-grid potential of 2o v, discharge voltage of 3o v and accelerator potential of 365 v. The beam current flatness parameter (F) which calculated according to equation(1)[1] is o.91.

$$F = \frac{\int_0^R 2\pi r J(r) dr}{2\pi R^2 J_{max}} \qquad (1)$$

where $J(r)$ is the current density at the radial coordinate r, J_{max} is the maximun current density in the beam and R is the beam radius.

The date for calculating the beam flatness parameter was measured in the beam spot of 1oo mm diameter at a distance of 195 mm downstream of the accelerator grid. (3) A focusing-like beam can be created at high extracted voltage and beam current at same location. Figure 3 shows the beam profile at extracted voltage of 1ooo v,beam current of 13o mA, discharge voltage of 43 v and accelerator voltage of 2oo v. Its highest beam density is 4.2 mA/cm^2. Therefore it can be used for sputtering coating. (4)The discharge losses are different at different operation parameters. The lowest one is 545 ev/ion. At lower energy the discharge losses are more than 1ooo ev/ion, but for ground base application it is not a very important factor.

For optimizing the ion source design the experiments to determine the effects of magnetic field on ion source performance were conducted. The magnet bars which are set on the outer periphery of the discharge chamber consist of two groups, the front and the rear. The magnatic field strength of each bar was not the same, but each bar had the field strength of about 1ooo gauss. By means of changing the numbers of the magnet bars, from 3 to 6 bars it is shown that the ion source performance was improved with increasing the numbers of bars,e.t. the discharge loss decreased. The ion source performance changed with the numbers of bars is shown in Fig.4. Simultaneously, the beam flatness also increased a little with increasing the numbers of bars as it is shown in the Fig. 5.The ion filings maps for 3 and 5 bars are shown in the Fig 6 (a)and 6 (b), respectively. But when the six bars were used the discharge voltage must be increased for maintaining the arc discharge.At the grid potential of 3oov for the ion source with 6 bars the discharge voltage must be higher than 3o v. From that it is obvious that magnetic field strength shouldn't be too high for a given ion source and there must be a optimum value which is such a compromise between the value desi-

red for primary electron containment and that desired for Maxwellian electron escape to the anode.[2]

4. Factors effecting on the uniformity of beam profile

In order to obtain more uniform beam profile the factors which effect the beam profile platness were determinated experimentally. The results showed: (1) The beam profile flatness increased with increasing the accelerator grid potential (V_a) (see Fig. 7) But the density of beam current decreased. It is due to increase of divergent angle. (2) The beam current profile flatness decreased with increasing the beam (I_b), screen-grid potential (V_b) and discharge voltage (V_d) (see Fig. 8,9,1o). It is, maybe, due to a increase in the double ion component of the beam current, because the double ion density profile is much more nonuniform than the single ion density profile.[3]

It is indicated in ref. 1 that the discharge chamber length to diameter ratio is shown to be an important optimization parameter. So the tests with two ion source having same magnetic field strength, but different length to diameter ratio were done. The results are shown in Fig. 11. The beam profile flatness increased slightly with decreasing the length to diameter ratio (L/D) from o.66 to o.55. The reason is ,maybe, that small amount of double ions is not influenced the beam profile strongly.

5. Conclutions

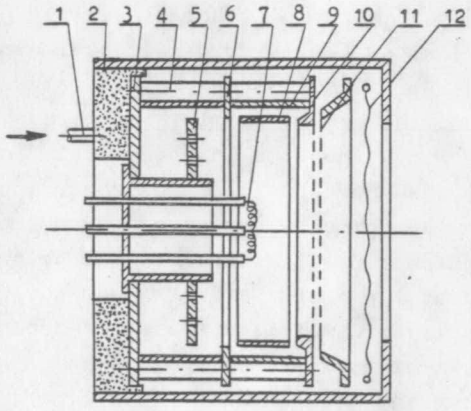
A 6 cm diameter ion source for assistant deposition was designed and tested. Its experimental results showed that the performance of this ion source is improved with increasing the applied magnetic field. But when the applied magnetic field is too strong the arc discharge becomes unstable.It is indicated that the beam profile flatness increased with increasing the accelerator grid potential and applied magnetic field and decreased with increasing the beam current, screen grid potential and discharge voltage. The effect of the ratio of diameter on the beam profile flatness is not very obvious. The experimental results have demonstrated that the design of this ion source was successful. By means of matching the performance parameters the high beam current profile flatness can be obtained at low energy and low beam current. It is very siutable for assistant deposition. At high extracted voltage and high beam current focusing-like beam can be created and can be used for sputtering. So this ion source is a versatile source with good performance and simple configuration. Recently, this source has been used in optical assistant deposition and satisfactory results have been obtained.

References

1. J.R.Beattie and P.J.Wilbur,"15 cm Cusped Magnetic Field Mercury Ion Thruster Research" ,AIAA Paper 75-429.

2. H.R.Kaufman and R.S.Robinson,"Ion Source Design for Industrial Applications",AIAA Paper 81-o668.

3. J.R. Beattie and P.J.Wilbur,"Cusped Magnetic Field Mercury Ion Thruster", AIAA Paper 76-1o11.



1. Gas inlet.
2. Cylinder.
3. Rear pole piece.
4. Magnetic bar.
5. Rear anode.
6. Middle pole piece.
7. Cathode.
8. Front anode.
9. Discharge chamber.
10. Screen grid.
11. Accelerator grid.
12. Neutralizer.

Fig.1 Schematic of ion source

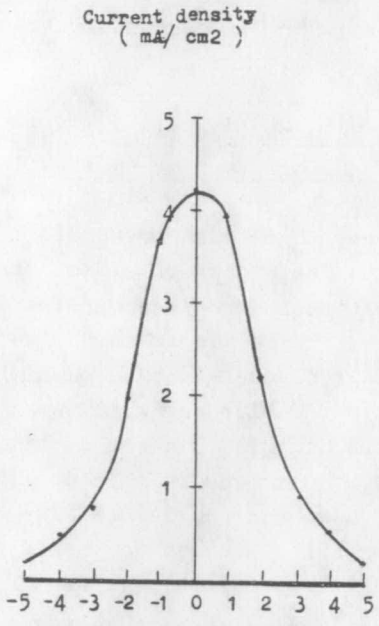


Fig. 3 Beam current density profile at high energy (V_b= 1000 v, I_b=130 mA, V_a=-200 v, V_d= 43 v)

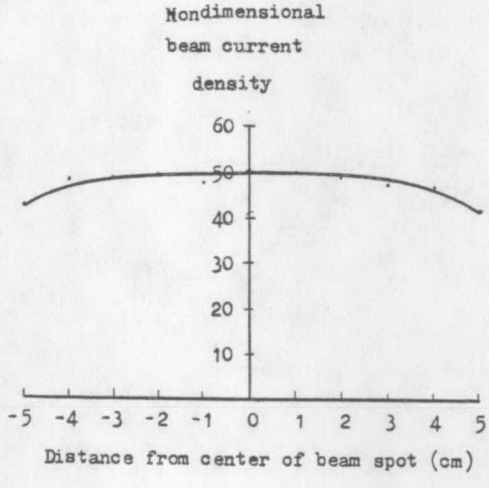
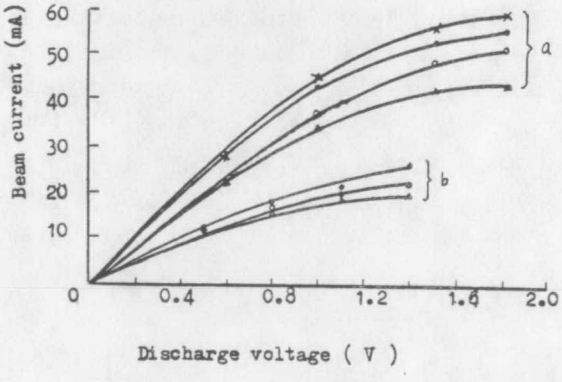
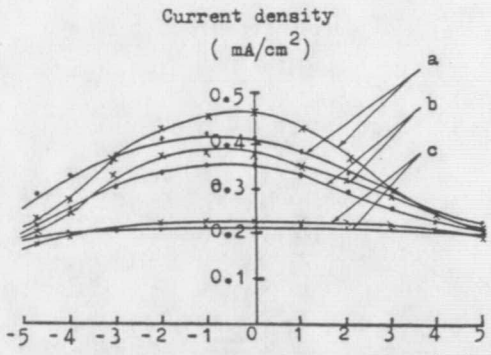


Fig. 2 Beam current density profile at low energy (I_b=24 mA, V_a=-365 v, V_d= 30 v, V_b= 20 v.)



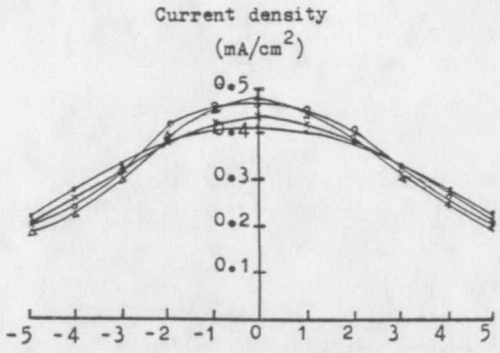
a —— V_b=500 v, V_a=-500 v, V_d=40 v
b —— V_b=300 v, V_a=-60 v, V_d=30 v
x —— 6 bars, • —— 5 bars,
o —— 4 bars, ▲ —— 3 bars.

Fig. 4 Ion source performance with different number of magnetic bars



x —— 3 bars , • —— 5 bars.
a —— V_b=500 v , I_b=30mA, V_a=-500 v.
b —— V_b=300 v , I_b=29 mA , V_a= -480 v.
c —— V_b=100 v, I_b=26 mA , V_a= -480 v.

Fig. 5 Beam current density profile with different numbers of magnet bars



△ —— V_a=-200 v, ○ —— V_a=-300 v,
× —— V_a=-400 v, • —— V_a=-500 v.

Fig. 7 Beam current density profile with different accelerator potential at V_b= 500 v, I_b= 30 mA, V_d= 30 v.

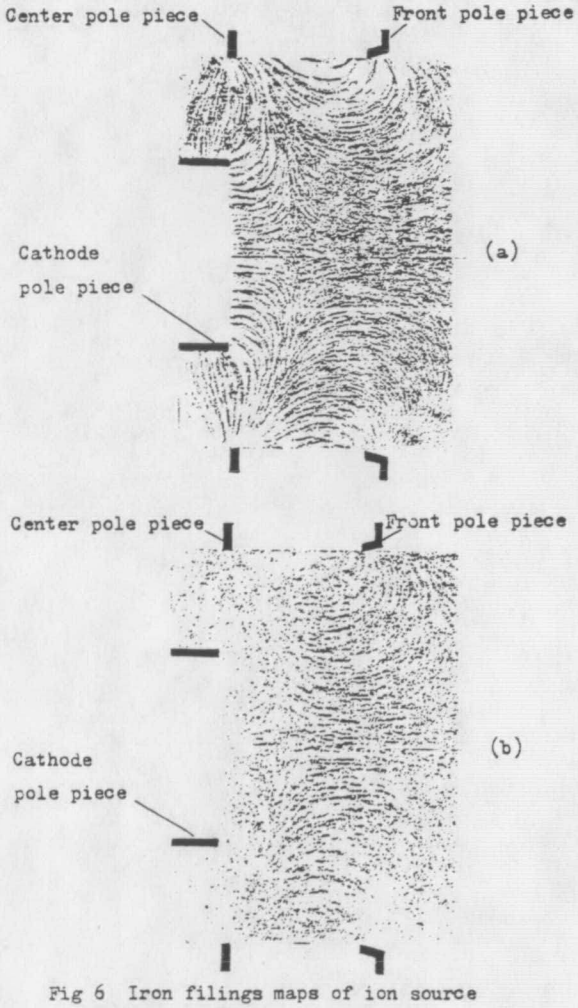
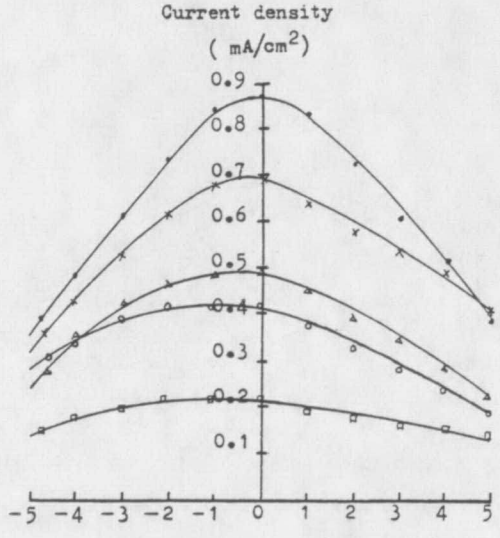
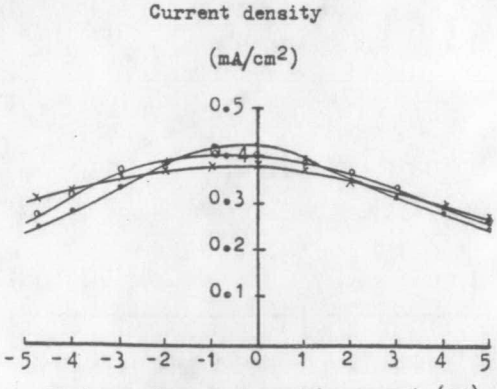


Fig 6 Iron filings maps of ion source
(a) 3 bars, (b) 5 bars.



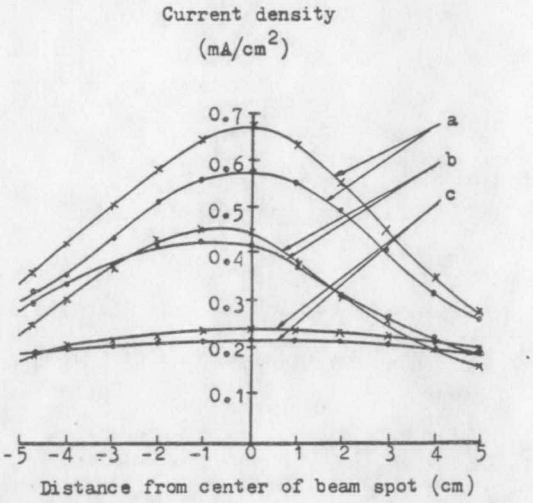
□ —— I_b=20 mA, ○ —— I_b=30 mA,
△ —— I_b=40 mA, × —— I_b=50 mA,
• —— I_b=60 mA.

Fig. 8 Beam current density profile with different beam current at V_b=500 v, V_a=-500 v, V_d=30 v.



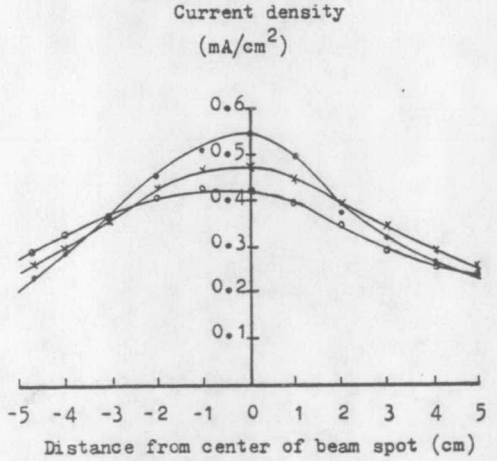
• —— V_b=600 v, ○ —— V_b=400 v ,
× —— V_b=300 v.

Fig. 9 Beam current density profile with different screen grid potential at V_a=-500 v, V_d=30 v, I_b=30 mA



• —— L/D= 0.5 , × —— L/D =0.66
a —— V_b= 1000 v, I_b= 50 mA, V_a= -500 v.
b —— V_b= 500 v, I_b= 30 mA, V_a= -500 v .
c —— V_b= 100 v, I_b= 26 mA, V_a= -480 v .

Fig. 11 Beam current density profile with different ratio of L/D



• —— V_d=60 v, × —— V_d=40 v ,
○ —— V_d=30 v.

Fig. 10 Beam current density profile with different discharge voltage at V_b= 500 v, I_b= 30 mA, V_a= -500 v