SOLID ION SOURCE BASED ON HOLLOW-CYLINDRICAL MAGNETRON SPUTTERING DISCHARGE

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A new solid ion source is described. The ion source based on hollow-cylindrical magnetron sputtering discharge produces the beam of various solid ions (*B*, *C*, *Si*, *Ti*, *V*, *Fe*, *Ni*, *Ta*, *W*) which are then extracted by an ion optical accelerating system. In this ion source DC discharge is used for generation of the ions of different metals and capacitively coupled RF discharge with a frequency 13.56 *MHz* is used for generation of the ions of other solid materials.
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1. INTRODUCTION

The sources of ions of solid materials are used for implantation of impurities and dopants, thin-film deposition, material modification. Designs of metal ion sources can be divided into several types depending on boiling-point and ionization potential of required metals. If metal has low boiling temperature than metal vapor can be obtained by moderate metal heating and can be feed into ion source having more or less typical design [1, 2]. Ions of metals, which have relatively low ionization potential, can be obtained due to surface ionization directly on the hot metal surface [3, 4]. But these methods applied for metals with high melting temperature provide only little beam current. In this case vacuum arc ion source is convenient [5]. In this source metal vapor vacuum arc discharge is used for plasma production. In this type of the ion source pulse duration reaches 100 μs, pulse reiteration frequency is about 1 pulse per second and beam current is about 10 *mA*.

Ions of different metals may be also obtained by sputtering from an electrode in a discharge. It is clearly that only sputtered-based sources have simple construction and can operate under room temperature. Owing to configuration of the electrical and magnetic fields being orthogonal, stable glow discharges and intense sputtering of cathode material can be obtained in a magnetron at low pressures.

In this paper the design and performance of the solid ion source based on hollow-cylindrical magnetron sputtering discharge is described.

2. DESIGN

The sketch of the ion source with accelerating electrode is given in Fig. 1. The basic elements of the construction of the hollow-cylindrical magnetron sputtering ion source are the following: anode (1), cathode block (2) and magnetic system (3).

The water-cooled end anode is made of non-magnetic stainless steel and is electrically isolated from the cathode block. The anode is powered and cooled through the isolated vacuum feedthroughs in the bottom of the cathode block. The shape of the anode provides reduced redeposition of sputtered target material on surface of the isolators.

The water-cooled cathode block of the ion source is used as a cathode of the discharge gap and provides cooling of sputtered target. The cathode block consists of the water-cooled hollow-cylindrical cathode made of stainless steel (4), which also is used as a holder of sputtered target (5). The target is fixed in the cathode block by electrode-extractor (6).

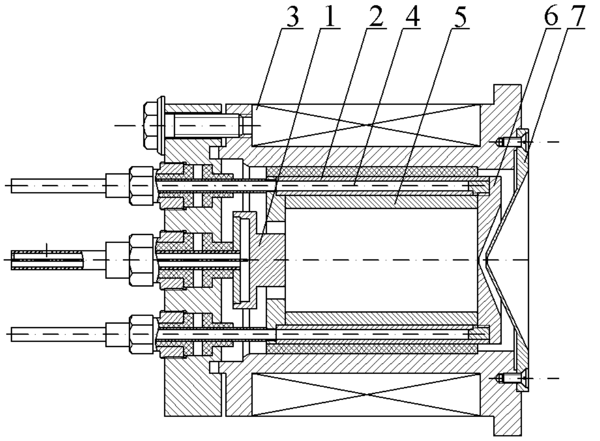

Fig. 1. 1 – anode, 2 – cathode block, 3 – magnetic system, 4 – water-cooled hollow-cylindrical cathode, 5 – sputtered target, 6 – electrode-extractor, 7 – accelerating electrode

The magnetic system produces arch magnetic field with a peak intensity of 500 *Oe* near the interior surface of the sputtered target.

The working gas (Ar, H_2, CH_4) is fed through the channels of the rear side of the ion source (not viewed on Fig. 1) into the cathode-anode discharge gap. The working gas pressure in the discharge volume of the source can be adjusted in a range of 10^{-2} - 10^{-4} *Torr*.

The cathode can be capacitively coupled to a 13.56 *MHz* RF power supply with power up to 2.5 *kW* or can be connected to DC power supply with negative potential up to 1000 *V* with respect to the anode. The magnetic field, in conjunction with the electric field applied to the sputtered target (5), create intense plasma in the near target region. From this region working gas ions are extracted and accelerated by the cathode potential to cause sputtering, mainly in the region of the magnetic field arch.

The accelerating electrode (7) produces electric field which extracts ions from the magnetron discharge plasma and forms them into a beam. The accelerating electrode shape approaches to Pierce geometry.

The advantage of such a construction of the ion source is fairly small losses of sputtered material owing to isolation of the gas discharge volume. The non-extracted atoms are deposited on the target surface and can be sputtered again. This fact and absence of hot cathodes in the source construction provide much enlarged operational life of the sputtered target and opportunity to operate with chemically active working substances.

The extraction of ions is carried out by the electrode-extractor (6).

3. THE ION SOURCE OPERATION

During experiments the discharge voltage (U_{dis}), discharge current (I_{dis}), pressure (p) were measured.

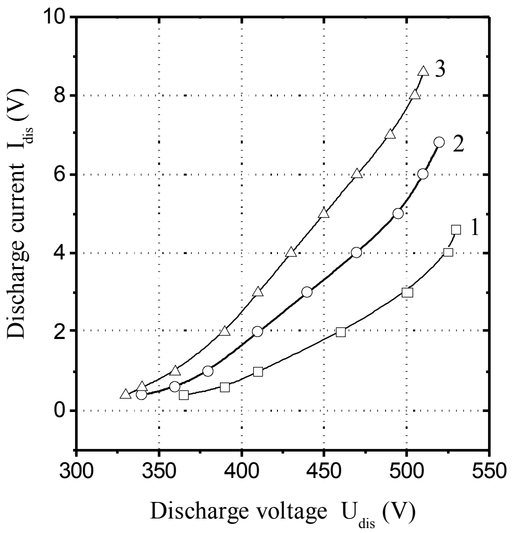

Fig 2. Voltage-current plots under different pressures: 1 – $p=3\cdot10^{-4}$ Torr, 2 – $p=8\cdot10^{-4}$ Torr, 3 – $p=3\cdot10^{-3}$ Torr

The discharge was initiated in the area of sputtered target under such conditions: voltage was in range of U_{dis}=325÷530 *V* and the discharge current changed in range of I_{dis}=0.3÷8 *A*, pressure was in range of $p = 5\cdot10^{-4} \div 5\cdot10^{-3}$ *Torr*. Figure 2 shows typical voltage-current plots under different pressures.

The electron current density distribution along radius of hollow cylindrical sputtered cathode under different discharge parameters was also measured (Figure 3). It can be seen that the electron current reaches a value of discharge current at the system axis, i.e. the stream of electrons from the discharge region travels across a magnetic field in radial direction toward the system axis. The stream of sputtered atoms is formed and travels also toward the cathode axis where the sputtered atom density peaks. Thus, in the given discharge configuration, both the density of the sputtered atoms and density of electrons peak at the system axis. This provides effective ionization of sputtered target atoms and enhanced current density of extracted solid ions.

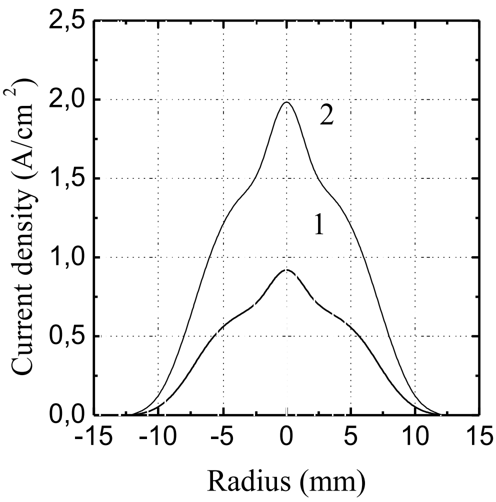

Fig. 3. The current density distribution along the beam radius: 1 – I_{dis}=5 A, 2 – I_{dis}=8 A. The pressure was $p=3\cdot10^{-3}$ Torr

4. CONCLUDING REMARKS

A new solid ion source is described. The ion source based on hollow-cylindrical magnetron sputtering discharge produces the beam of various solid ions (*B*, *C*, *Si*, *Ti*, *V*, *Fe*, *Ni*, *Ta*, *W*) which are then extracted by an ion optical accelerating system. In this ion source DC discharge is used for generation of the ions of different metals and capacitively coupled RF discharge with a frequency 13.56 *MHz* is used for generation of the ions of other solid materials.

5. ACKNOWLEDGEMENT

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ДЖЕРЕЛО ТВЕРДОТІЛЬНИХ ІОНІВ НА БАЗІ ПОРОЖНЬОГО ЦИЛІНДРИЧНОГО РОЗПИЛЮВАЛЬНОГО МАГНЕТРОННОГО РОЗРЯДУ

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Описано нове джерело твердотільних іонів. Джерело іонів на базі порожнього циліндричного розпилюючого магнетронного розряду генерує пучок різних твердотільних іонів (B, C, Si, Ti, V, Fe, Ni, Ta, W), які потім витягаються іонно-оптичною прискорюючою системою. У цьому іонному джерелі для генерації іонів різних металів використовується розряд постійного струму, а для генерації іонів інших твердих матеріалів використовується ємнісний ВЧ-розряд з частотою 13,56 Мгц.

ИСТОЧНИК ТВЕРДОТЕЛЬНЫХ ИОНОВ НА БАЗЕ ПОЛОГО ЦИЛИНДРИЧЕСКОГО РАСПЫЛИТЕЛЬНОГО МАГНЕТРОННОГО РАЗРЯДА

Н.А. Азаренков, А.А. Бизюков, И.А. Бизюков, В.В. Бобков, А.Е. Кашаба, К. Кригер, К.Н. Середа, И.К. Тарасов

Описан новый источник твердотельных ионов. Источник ионов на базе полого цилиндрического распылительного магнетронного разряда производит пучок различных твердотельных ионов (B, C, Si, Ti, V, Fe, Ni, Ta, W), которые затем извлекаются ионно-оптической ускорительной системой. В этом ионном источнике для генерации ионов различных металлов используется разряд постоянного тока, а для генерации ионов других твердых материалов используется емкостной ВЧ-разряд с частотой 13,56 МГц.