DESIGN AND CONSTRUCTION OF A PROTOTYPE SPUTTER ION PUMP IN ILSF

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Abstract

Design and construction process of special kind of the sputter ion pump is described briefly in this paper. By optimizing some parameters such as dimension and shape of the penning cells, anode voltage, magnetic field and internal structure of pump, it is possible to significantly decrease cost of construction and operation of synchrotron vacuum system. The effect of parameters like anode voltage, magnetic field etc. on pumping speed and final pressure are described.

INTRODUCTION

Sputter ion pump (SIP) is one of the most common capture pumps, which are widely used in ultra-high and high vacuum region of the accelerator systems. Sputter ion pumps, which trap gas molecules in their body, provide a clean, simple operation, relatively inexpensive, low power consuming and low maintenance alternative for producing and maintaining ultra-high vacuum. One the most important advantages of SIPs, which make them suitable for the accelerators particularly storage rings is that they do not have any moving parts and therefore no vibration are transmitted to vacuum chambers, magnet lattice, RF system etc. In addition, they have long lifetime and more resistant against sudden increase in pressure or improper operation than other pumps.

In sputter ion pumps, ionized gas molecules removed from the system by chemisorption, burying and implementation into a getter material. Titanium is commonly used in SIPs as a getter material because it is chemically reactive with most gas molecules when it is deposited as a pure metallic film on a surface. Fresh titanium film is produced by sputtering of titanium cathode which occurs when cathode surface bombarded by positive gas ions.

Penning reported cathode sputtering in ion gauges as "cathode disintegration" in 1936. He noted "Cathode disintegration may also be used for the purpose of reducing the pressure of a gas in a closed chamber. The cathode particles disintegrated combine with gas molecules and thus bring about a reduction in pressure." [1, 2]

After that, several types of the sputter ion pumps have been invented and lots of attempts have been made to improve the performance of them. [3-18]

Most of the commercial sputter ion pumps optimized to reduce pressure between 10^{-5} to 10^{-9} Torr. Therefore, using the pumps that optimized for this purpose in vacuum system, the cost of providing and maintenance would be reduced.

DESIGN OF PENNING CELLS

Performance and speed of the sputter ion pump depends on parameters such as size and geometry of penning cells, anode voltage, magnetic field etc. To optimize the penning cells, a model based on numerical calculation was used. Finite element analysis was used for penning discharge in low magnetic field (LMF) mode. Density of the trapped electrons in cell and ion current have been calculated for different cell radius, height, anode voltage and magnetic field. Finally, the pumping speed was estimated by ion current together with sputtering gain and probability of the gas molecules absorption.

The pumping speed estimation process is involved with three steps. In the first step, the electric potential and magnetic field distribution inside the cell must be calculated. Then the electron density is estimated from the balance between electron and ion currents. Finally, the pumping speed will be estimated from the ion current, sputtering gain and the probability of gas absorption. Fig. 1 shows the potential distribution of penning cell by using FEMM software [19].

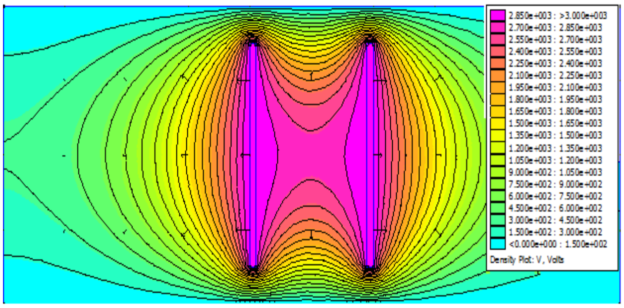

Figure 1: The electric potential of a penning cell.

CONSTRUCTION OF SPUTTERING ION PUMP

Besides the above information, other parameters such as magnetic field shape, the amount of heat due to electrical discharge which reach to the electrodes, thermal expansion of the electrodes, reducing the insulation resistance, pressure distribution inside the pump, etc must be determined for design of the sputter ion pump. Magnetic field distribution in the pump body is depicted in Fig. 2. The magnetic field inside the pump chamber is

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relatively uniform and is about 0.1 Tesla which has been approved with Hall probe measurements at the ILSF.

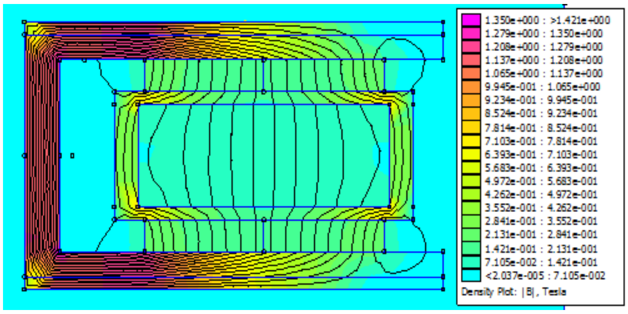

Figure 2: Magnetic field distribution in pump body.

The thermal power which receive by the electrodes due to discharge at 10^{-7} Torr is less than 0.03 W/cm^2. Therefore, the cooling system does not require for the pressure less than it.

Insulation material used to separate the high voltage electrode to the ground electrode is made of alumina. Two points need to be considered in the design of this part:

- Surface resistance of the insulator should not decrease over the pump lifetime. If the resistance is less than $10^{-10}\Omega$ than measuring the pump current is difficult. If the resistance of insulation is less than $10^{-8}\Omega$ than it will be warm and breakdown.
- Thermal expansion must be compensated in the electrodes so that no stress reaches to insulator at work or during baking.

The pump has been designed in such a way that the thermal expansion of the electrodes is less than 0.2mm at 300°C. According to mentioned specifications, the sputtering ion pump was constructed by 51 penning cells (Fig. 3A, 3B) and Fig. 3C shows the model of this pump. All parts of the pump was carefully cleaned and assembled in clean conditions after construction. The pump was baked at 300°C and pressures of 10^{-6} Torr.

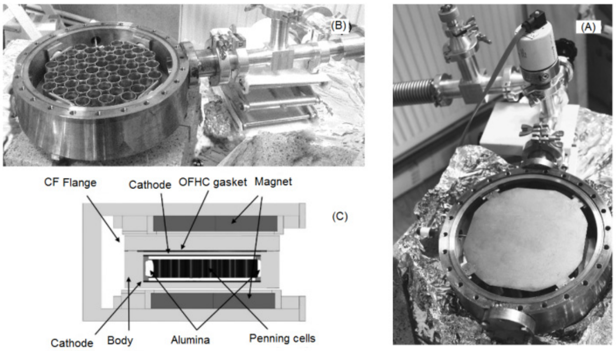

Figure 3: (A, B) Constructed sputter ion pump, (C) the model of constructed pump.

MEASURMENT RESULTS

The pump was tested after fabrication and preparation in different configurations. The overall rate of outgassing in the presence of gauge and valve, is measured about 10^{-10} Torr.litter/sec, which indicate good fabrication quality, cleaning and baking procedures. Pressure-time curves for 700, 2000 and 3500 volt anode voltages are shown in Fig. 4. As seen, increase of the anode voltage results to increase of pumping speed and to decrease of ultimate pressure.

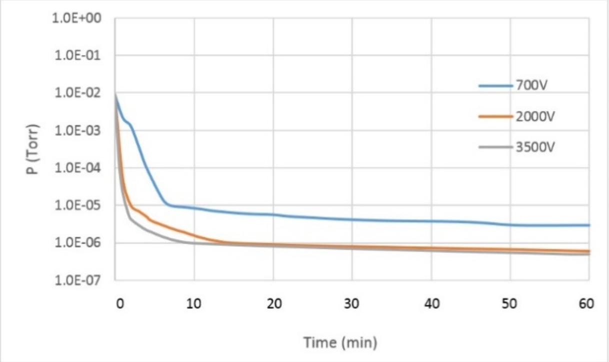

Figure 4: Pressure versus Time for 700, 2000 and 3500 volt anode voltages.

Penning discharge current dependency on the pressure for the fabricated prototype is shown in Fig. 5 which shows a linear behavior between them.

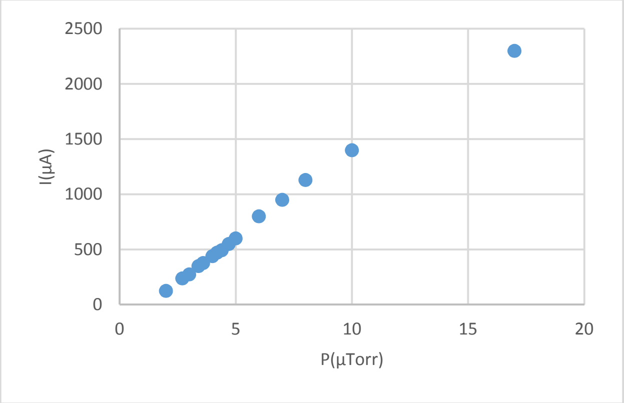

Figure 5: Penning discharge current dependency versus pressure.

We found that the ultimate pressure0.03 nTorr can be obtainable after 72 hours.

CONCLUSION

This paper briefly describes the design and construction procedure of the special type of sputtering ion pump in order to evaluate and optimize the effective parameters in selection and design of the sputter ion pumps used in Iranian light source facility. Further study on the efficiency of the fabricated pump with different parameters and changing elements will be performed. Study on initial titanium and sputtered titanium can provide useful information for optimizing the pump.

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