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13.56MHz RF Implanter Vacuum System

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1. Introduction

In these days, Ion implantation is widely used in many fields such as enhancing the chemical and physical properties of materials, anti-corrosion, wear resistance and electrical conductivity. So an rf implanter which uses a cavity operating at the frequency of 13.56MHz has been considered and developed at Proton Engineering Frontier Project (PEFP) [1]. The implanter consists of an ion source, a focusing magnet, an rf cavity, a bending magnet and a diagnostic chamber. Beam energy is up to 120keV. For high quality beam measurement, we need the high vacuum state. Therefore, we used a scroll pump and two TMPs(Turbo molecular pumps; ion source and cavity). In this paper, we present the test results of the 13.56MHz implanter's vacuum system.

2. RF Implanter

In this section, we introduce the overall system and design specifications of 13.56MHz implanter.

2.1 13.56MHz RF Implanter System

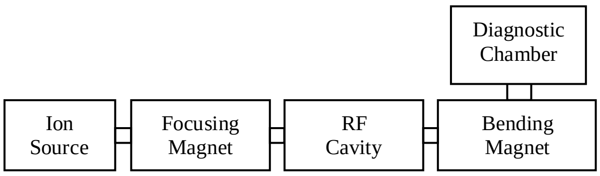

Fig. 1. 13.56MHz rf implanter system

Fig. 1 shows that 13.56MHz rf implanter system. This system consists of an ion source, a focusing magnet, an rf cavity, a bending magnet, and a diagnostic chamber.

2.2 Ion Source

An ion source is an electro-magnetic device that is used to create charged particles. The ion sources are used primarily to form ions for particle accelerators, ion implanters and ion engines.

The design specifications of the ion source for the implanter are shown in Table I.

Table I: Operating parameters of the ion Source

Ion type	He^+
Beam energy	27 keV
Arc current	0.46 A
Operation mode	CW

2.3 Focusing Magnet

Main purpose of focusing magnet is to focus Helium ion beams which are moving to beam line from ion source and rf cavity. Table II shows the focusing magnet's optimal operation conditions. The focusing magnet is a compact magnetic quadrupole triplet.

Table II: Magnet Operating Conditions

Voltage	60 V
Current	20 A
Magnetic Field	0.26 Tesla

2.4 RF Cavity

In this experiment, we used an rf cavity to accelerate particles. The peak surface electric field and magnetic field are important constraints in cavity design. Table Ⅲ shows the rf cavity design specifications.

Table III: Design parameters of the cavity

Total length of cavity	294 mm
Gap length	6 mm
Cavity diameter	400 mm
Operation frequency	13.56 MHz
Ion species	He^+
Accelerating voltage	120 kV
Quality factor	2500
RF power	1.2 kW
Beam aperture	20 mm
Inductance	43.83 uH
Capacitance	3 pF

2.5 Bending Magnet

Energy of the beam could be determined by changing the excitation current of the bending magnet. The bending radius and angle were 0.37 m and 90 degrees, respectively. Magnetic rigidity ($B\rho$) of the beam is about 0.1T-m for 120 keV helium beam.

2.6 Diagnostic Chamber

The diagnostic chamber including wire scanner was placed behind bending magnet and was mounted 80 cm away from it. To detect the beam size, the wire scanner is installed in diagnostic chamber.

2.7 Vacuum System

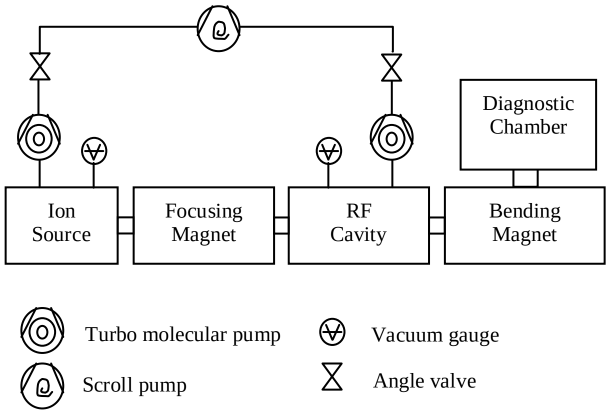

Fig. 2. 13.56MHz rf implanter Vacuum system

Fig. 2 shows the implanter vacuum system. In this experiment, we used three vacuum pumps: one is a low vacuum pump and the others are two high vacuum pumps. A low vacuum pump is dry scroll VARIAN Triscroll 300. One of the high vacuum pumps is Osaka vacuum, Ltd. TG1300M, used for an ion source. The other was TURBOVAC 361, used for an rf cavity.

3. Vacuum Test

3.1 Evacuation Time Calculation

One basic consideration in designing high-vacuum systems is the time required to evacuate a vessel to a given pressure. This usually ranges from a few minutes to a few hours. Our purpose is to compare gas evacuation time between calculation and experiment.
Referring to implanter, the evacuation process can be represented by the relationship

$$-V\frac{dP}{dt} = SP \qquad (1)$$

, where V is the volume of the vessel, *dp/dt* the rate of change of pressure with respect to time, P the pressure, and S the pumping speed [2]. The evacuation time from Eq. (1) for constant volume and system pumping speed is

$$t = \frac{V}{S}\left(\ln\frac{P_0}{P_f}\right) \qquad (2)$$

,where P_0 is the initial pressure and P_f is the final pressure. In our implanter system t is about 4minutes.

Table IV: Calculation specifications

Volume	93 *l*
Pumping speed(scroll)	4.16 l/s
Pumping speed(TMP-ion)	1300 l/s
Pumping speed(TMP-cavity)	380 l/s

3.2 Evacuation Time Test Result

Fig. 3 shows the evacuation process as a function of time. TMPs were started about two hours later after turn-on of the scroll pump. Note that the pressures of an ion source and a cavity are different mainly due to the pumping speed difference. The ultimate pressure of the ion source was 4.4x10^{-7} torr.

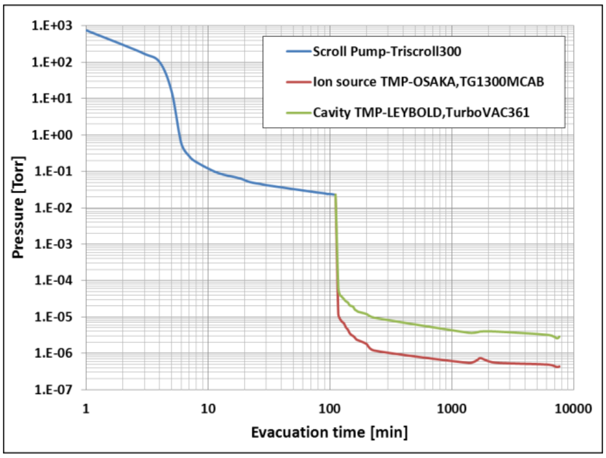

Fig. 3. Implanter vacuum test result

4. Conclusions

We have checked the performance of the 13.56MHz rf implanter vacuum system. The ultimate vacuum pressure was about 4.4x10^{-7} torr. The measured pumping down time was much longer than the calculated time. The main reason for this discrepancy is that the calculation is based on simple volume pumping condition with assumption of no leakage and constant pumping speed. In addition, the conductance effect of the vacuum pipes was ignored, which means the pumping speed was overestimated.

ACKNOWLEDGEMENTS

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