Development of sputter ion pump with strong magnetic field for obtaining of ultra-high vacuum

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INTRODUCTION

The new synchrotron source SRS SKIF (Novosibirsk) requires ultra-high vacuum condition for obtaining of long lifetime stable 3 GeV electron beam with external low emittance at level 75 pm.rad. In recent years, combined pumps consist of non-evaporable getters and sputter ion pumps in one vessel start to be more and more popular. At this combination a mass-dimension characteristics are improved and ultimate pressure decreases considerably.

Usually pumping speed of conventional sputter ion pumps reaches its maximum value at pressure range from 1E-7 Torr to 1E-6 Torr. The paper describes a developing of compact sputter ion pump optimized for application in combination with non-evaporable getter pump at ultra-high vacuum condition. The main idea is an increasing of magnetic field and a decreasing of Penning cell size to increase pumping speed and shift its maximum to low pressure range.

The modified mode type of the sputter ion pump is planned to be used in SRS SKIF because its pumping speed for noble gases is higher than for diode type.

THEORETICAL CALCULATION

The pumping speed of one cell can be determined as:

\begin{align}
 S &= 1.56 \times 10^{-5} \left( 1 - \frac{1.5 \cdot 10^{-6} \cdot P}{1 + 4 \cdot 10^{-6} \cdot P} \right)^{0.5} \cdot h \cdot d \cdot Bz \cdot \left( B - Bz \right) \\
 S &= 3.9 \times 10^{-6} \left( 1 - \frac{1.5 \cdot 10^{-6} \cdot P}{1 + 4 \cdot 10^{-6} \cdot P} \right)^{0.5} \cdot h \cdot d \cdot Bz \cdot \left( B - Bz \right)
\end{align}

where \( Bz \) – sputter magnetic field [T] corresponding to discharge switching on: \( Bz = 6 \times 10^{-4} \)

\begin{align}
 S_{\text{total}} &= \frac{15.26 \times 10^{-6} \cdot V_{\text{gas}}}{d \cdot P_{\text{max}}} \\
 S_{\text{total}} &= 9.1 \times 10^{-6} \cdot \left( 1 - \frac{1.05 \times 10^{-1} \cdot (B - B_{\text{max}}) \cdot d \cdot P}{U_{\text{a}}} \right)^{0.5}
\end{align}

The total pumping speed of whole pump can be found as:

\begin{align}
 S_n &= \frac{S_{\text{cell}} \cdot d \cdot C_{\text{cell}}}{C_{\text{capillary}}}
\end{align}

where \( C_{\text{cell}} \) – effective pumping speed of pump for nitrogen [l/s]; \( C_{\text{capillary}} \) – effective pumping speed of pump for nitrogen [l/s]; \( C_{\text{capillary}} \) – molecular conductivity of both gaps between anode and cathodes [l/s].

EXPERIMENTAL METHOD

The method is based on the measurement of pressure drop on a vacuum element with known conductivity (Dynamic Flow Method).

\begin{align}
 S_{\text{eff}} &= \frac{C_{\text{source}}}{R_{\text{source}} - R_{\text{after}}}
\end{align}

Where \( S_{\text{eff}} \) – effective pumping speed of pump at pressure \( P_{\text{source}} \);

- \( C_{\text{source}} \) – total source conductivity [l/s];
- \( R_{\text{source}} \) – pressure before gas flow by IG2 [Torr];
- \( R_{\text{after}} \) – pressure after gas flow by IG2 [Torr];
- \( P_{\text{source}} \) – pressure measured by Baratron [Torr];
- \( K \) – sensitivity coefficient

CONCLUSION

- The several sputter ion pumps with the different magnetic fields and height and diameter of cells were tested in pressure range from 1E-9 to 1E-4 Torr.
- It presents the theoretical calculations and the experimental results of pumping speed which agree between themselves very well.
- The pump with cells diameter 8 mm and the magnetic field 0.28 T looks very perspective.
- It is expected that specific pumping speed 1.6 l/s/cm\(^3\)/Torr for nitrogen can be obtained by choice of cell geometrical sizes and gap between anode and cathodes.

DESCRIPTION OF SPINNER ION PUMPS

The main parameters of pumps are presented in Table 1. The pump body and the anode cells is made of stainless steel. The cathodes are made of titanium. All tested pumps are diode type.

<table>
<thead>
<tr>
<th>Name of manufacture</th>
<th>Diameter, mm</th>
<th>Height, mm</th>
<th>Gap between anode and cathode, mm</th>
<th>Cell quantity, pcs</th>
<th>Magnetic field, T</th>
<th>High voltage, kV</th>
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<tbody>
<tr>
<td>BINP #1</td>
<td>12</td>
<td>14</td>
<td>4</td>
<td>36</td>
<td>0.12</td>
<td>5.0</td>
</tr>
<tr>
<td>BINP #2</td>
<td>12</td>
<td>14</td>
<td>4</td>
<td>36</td>
<td>0.28</td>
<td>5.0</td>
</tr>
<tr>
<td>Karox</td>
<td>16</td>
<td>20</td>
<td>???</td>
<td>32</td>
<td>0.11</td>
<td>5.0</td>
</tr>
<tr>
<td>BINP #3</td>
<td>7.6</td>
<td>4</td>
<td>4</td>
<td>95</td>
<td>0.12</td>
<td>3.0 / 5.0 / 7.0</td>
</tr>
<tr>
<td>BINP #4</td>
<td>7.6</td>
<td>14</td>
<td>4</td>
<td>95</td>
<td>0.28</td>
<td>3.0 / 5.0 / 7.0</td>
</tr>
</tbody>
</table>

THE EXPERIMENTAL RESULTS

The measurements were carried out at high voltage of 5 kV and pressure range from 1E-9 Torr to 1E-4 Torr. The most perspective pump with cells diameter 8mm was measured at voltages 3 kV and 7 kV also.

The pumping speed and discharge current versus pressure for tested vacuum pumps with cells diameter more than 10 mm are shown on Figures 1 and 2.

The pumping speed and the discharge current versus pressure in tested vacuum pump with cells diameter 8 mm are presented on Figures 3 and 4.

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