History of solid disk improvement for rotating charge stripper

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Charge strippers for U beam acceleration
2 stripping sections

Between fRC and IRC
14-16mg/cm² 64+→86+
Rotating-Disk stripper

Between RRC and fRC
35+→64+
He gas Stripper
Rotating-Disk stripper

To extend lifetimes by rotation of large C-foil.

Development began in 2005.

C-disk with a diameter of 120 mm was installed and tested in 2007.

C-disk could not be used as a stripper because of non-uniformity of thickness.

No large C-disk has met our requirements.

→ Improvement was necessary as soon as possible.

Small pieces of Arizona Company’s Polycrystalline graphite foils were used to manage U beam time until 2011.

Foil was replaced every 9 hours for the increased beam intensity. (U71+ 2-3eμA)

Beam study of C, Be and Ti disk

October 2012

Parameters:
Outside diameter: 120mm
$^{64}\text{U}^+ (50 \text{ MeV/u})$
Rotation speed: 300-1000 rpm
Measurement: Charge distribution, Beam quality, Long durability

C: Arizona
19mg/cm$^2 +0\ -10\%$

Be: GoodFellow
0.1mm $\pm 10\%$
19mg/cm$^2$

Ti: GoodFellow
0.04mm $\pm 10\%$
19mg/cm$^2$
Charge distributions of Be and Ti disk

C-disk can not be measured because of non-uniformity of thickness

Be disk (before use)

**Disk 1**
- t = 0.1mm not polish

**Disk 2**
- t = 0.085 Diamond polish

**Disk 3**
- t = 0.085 Diamond polish

**Disk 4**
- t = 0.085 Diamond polish
- Special process
Be disk (after use)

Disk 1
November-December 2012
1.18×10^{18}

Disk 2
April-May 2013
March-April 2014
1.68×10^{18}

Disk 3
April-May 2014
8.83×10^{17}

Disk 4
October-November 2014
9×10^{17}
# Results of Be disk

<table>
<thead>
<tr>
<th></th>
<th>Irradiation current</th>
<th>Days</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be Disk 1</td>
<td></td>
<td></td>
<td>Many cracks</td>
</tr>
<tr>
<td>Not polish</td>
<td>4 - 5 eµA</td>
<td>37</td>
<td>Still usable</td>
</tr>
<tr>
<td>0.1-mm thick</td>
<td>1.18x10^{18}</td>
<td></td>
<td>Slight beam fluctuation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Be Disk 2</td>
<td></td>
<td></td>
<td>Distortion and Many cracks</td>
</tr>
<tr>
<td>Diamond polish</td>
<td>4 - 12 eµA</td>
<td>51</td>
<td>Not usable</td>
</tr>
<tr>
<td>0.085-mm thick</td>
<td>1.68x10^{18}</td>
<td>(30+21)</td>
<td>Slight beam fluctuation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Be Disk 3</td>
<td></td>
<td></td>
<td>Distortion, Slightly cracked</td>
</tr>
<tr>
<td>Diamond polish</td>
<td>12 eµA</td>
<td>17</td>
<td>Still usable</td>
</tr>
<tr>
<td>0.085-mm thick</td>
<td>8.83x10^{17}</td>
<td></td>
<td>No beam fluctuation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Be Disk 4</td>
<td></td>
<td></td>
<td>Slightly Distorted</td>
</tr>
<tr>
<td>Diamond polish</td>
<td>8 eµA</td>
<td>20</td>
<td>No crack</td>
</tr>
<tr>
<td>0.085-mm thick</td>
<td>9x10^{17}</td>
<td></td>
<td>Still usable</td>
</tr>
<tr>
<td>Special processing</td>
<td></td>
<td></td>
<td>No beam fluctuation</td>
</tr>
</tbody>
</table>

* Static C-foil 7.12x10^{15} (71+)
Polishing the glassy carbon by the technique for Be disk

Material: glassy carbon
Manufacturer: TANKEN SEAL SEIKO Co., LTD.
Model: F22
Thickness: 0.085mm (from 1-mm thick)
Company: Crystal Optics Inc.

Outer diameter: 110mm
Thickness: 0.085mm ± 0.005
Thickness distribution: within ±2% at 12 positions
High Orientation Graphite sheet
(KANEKA CORPORATION)

0.035mm × 2 = 7.1mg/cm² x 2 = 14.2mg/cm²
<table>
<thead>
<tr>
<th>Property</th>
<th>Units</th>
<th>Test methods</th>
<th>Typical values</th>
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</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>µm</td>
<td>Micrometer</td>
<td>25  40</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In plane (XY axis)</td>
<td>W/mK</td>
<td>AC calorimeter method</td>
<td>1500 1500</td>
</tr>
<tr>
<td>Thru plane (Z axis)</td>
<td></td>
<td>Laser flash method</td>
<td>5  5</td>
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<tr>
<td>Thermal diffusivity</td>
<td>cm²/s</td>
<td>AC calorimeter method</td>
<td>9.0  9.0</td>
</tr>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td>Kaneka method</td>
<td>2.0  2.0</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>MPa</td>
<td>ASTM-D-882</td>
<td>40  40</td>
</tr>
<tr>
<td>Bending</td>
<td>Cycles</td>
<td>JIS-C5016, R=2mm,135°</td>
<td>&gt;10000 &gt;10000</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>S/cm</td>
<td>JIS K 7194</td>
<td>13000 13000</td>
</tr>
<tr>
<td>Heat resistance</td>
<td>°C</td>
<td>TG-DTA</td>
<td>500  500</td>
</tr>
<tr>
<td>Water absorption</td>
<td>%</td>
<td>JIS K 7209</td>
<td>&lt;0.1 &lt;0.1</td>
</tr>
</tbody>
</table>

These data are not guaranteed values but the measurement values at our company.
Charge distributions Be, C disk and GS

Average charge
Be 86.1
C-Disk 86.4
GS 86.4
Profile monitor image after the charge stripper

↑ Be disk

↓ C disk

← GS
GS in beam time

March-May 2015

Beam intensity: 15 e\(\mu\)A
Thermal load: 205W
Uranium particles: 1.41\(\times\)10\(^{18}\)
ANSYS: Approximately 600K
### History

<table>
<thead>
<tr>
<th></th>
<th>Arizona</th>
<th>Be disk</th>
<th>C disk</th>
<th>KANEKA GS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum beam intensity</strong></td>
<td>2-3eµA</td>
<td>12eµA</td>
<td>12eµA</td>
<td>15eµA</td>
</tr>
<tr>
<td><strong>Lifetime</strong></td>
<td>$7.12 \times 10^{15}$ (71+) 9 hour</td>
<td>$1 \times 10^{18}$ (64+) 20 days</td>
<td>Not measured</td>
<td>$&gt;1.41 \times 10^{18}$ (64+) Measuring</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>$1000$ (1 Day)  $30000$ (1 Mon)</td>
<td>$12000$ 1 piece</td>
<td>$3200$ 1 piece</td>
<td>$500$ 1 pair</td>
</tr>
</tbody>
</table>

### Summary

KANEKA GS has shown an excellent performance and longest lifetime.

The second stripper problem was solved.

Strippers with thickness variation can be prepared easily.

GS is very strong and flexible (we can treat it with scissors or cutter knife).

GS can be used to provide other ion beams with better quality.
Thank you for your attention!