Investigation of Various GeF₄ Gas Mixtures for Improvement of Germanium Ion Implantation

Ying Tang*, Sharad Yadave, Oleg Byl, Chee-Weng Leong, Eric Tien, Joseph Despres — Entegris, Inc.

OBJECTIVE
Evaluate various GeF₄ gas mixture compositions for improving germanium ion implantation performance.

BACKGROUND
Germanium implant is commonly used in advanced semiconductor device manufacturing as one of the major material modification steps. Germanium Tetrafluoride (GeF₄) is almost exclusively used as the primary source gas and its impact on ion source performance (poor source lifetime due to fluorine-induced halogen cycle) is well known.

TOOL / EXPERIMENTAL SETUP
All of the experiments presented in this paper were performed on an ion source test stand (STS) which is located at Entegris. In this test, an Indirectly Heated Cathode (IHC) source with tungsten (W) arc chamber and liners were used as this represents the most typical ion source configuration used in the field. During the beam current performance test, the beam current was normally run under the fixed source beam at 20 mA. Additional tests were run for certain conditions in which the arc current was fixed at 2 A, and these results are also presented in this paper. Other major beam parameters were set up as shown below unless noted otherwise:

- Arc voltage 90 V
- Extraction voltage 20 kV
- Suppression electrode voltage 3 kV
- Source magnet and electrode positions were optimized for each beam condition

*Tests were run on different dates and times. A standard Ge implant using pure GeF₄ was run every day to recast the baseline condition. Beam currents were then normalized to that condition for comparison.

SOURCE CONDITIONS — 11 HOURS SHORT SOURCE LIFE TEST

GeF₄/H₂ and GeF₄/CH₃F Co-flow (fixed ratios)

<table>
<thead>
<tr>
<th>Beam Current (mA)</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>GeF₄ 1 sccm, ArcV 90V, Source Beam fixed at 20 mA</td>
</tr>
<tr>
<td>1.5</td>
<td>GeF₄+GeH₄ (Low)</td>
</tr>
<tr>
<td>1.0</td>
<td>GeF₄+GeH₄ (High)</td>
</tr>
<tr>
<td>0.5</td>
<td>GeF₄+H₂</td>
</tr>
<tr>
<td>0.25</td>
<td>GeF₄+CH₃F (Low)</td>
</tr>
<tr>
<td>0.25</td>
<td>GeF₄+CH₃F (High)</td>
</tr>
</tbody>
</table>

CONCLUSIONS

- The test results presented in this paper comparing various GeF₄ gas mixtures with a pure GeF₄ baseline show the following:
  - Co-flow with inert gases, such as N₂ or Xe, generally reduces Ge⁺ beam current.
  - GeH₄ co-flow enables improvement in beam current, as does co-flow with hydrogen. However, during our test, significant Ge⁺ residue inside the source area was observed after running GeH₄ co-flow.
  - Co-flow with CH₃F results in higher Ge⁺ beam current than pure GeF₄. But the gain is less than GeF₄/H₂ mixtures.
  - Beam spectra show that CH₃F can also reduce the W⁺ beam similar to co-flowing with hydrogen. However, the addition of CH₃F results in C⁺ and CH⁺ peaks being observed.
  - Due to the carbon content in CH₃F, significant carbon residues are observed. Flakes or residues can be formed and accumulate in the arc chamber which can impact performance and/or source life. EDS confirmed those flakes/residues are mainly carbon.
  - After testing the different co-gases of N₂, Xe, GeH₄, CH₃F and comparing to the baseline of GeF₄, it still clearly shows that the GeF₄/H₂ mixture provides the highest beam current and longest source life performance.