Sample preparation technique for the revelation of a semiconductor dopant using an FE-SEM

Takeshi Sunaoshi, Shuichi Takeuchi, Atsushi kamino, Masahiro Sasajima and Hiroyuki Ito
Hitachi High-Technologies Corporation

1. Introduction
For the evaluation of the dopant profiling of a semiconductor device, several kinds of techniques have been developed [1][2]. Especially, SEM is favored method because this method can obtain 2D dopant profile images quickly with minimal sample preparation. A typical sample preparation method of SEM is cleaving, but it is difficult to obtain a cross-section at a specific position of interest in semiconductor devices. To evaluate specific points of sub-micron sized patterns, FIB is generally used for sample processing. However, it is difficult to obtain the dopant profile in semiconductor devices with high contrast due to the damaged layer on its cross-section surface generated during FIB processing. In order to obtain the precise dopant profile, we optimized FIB processing conditions and Ar ion milling conditions using a standard sample with known resistance and dopant profile. We also applied an optimized preparation protocol to a commercial devices sample to demonstrate dopant profile visualization.

2. Experimental
2-1. Sample
- The sample used for this study was a p-type multilayer film prepared by epitaxial growth on an n-type silicon substrate.
- The p-type multilayers are distinguishable based on different contrast intensity levels.

2-2. Instruments
- (a) FIB processing
- (b) Ion milling

2-3. Method
1.FIB processing condition
- The relationship between thickness of the damaged layer and contrast of dopant layer was investigated.

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Sample condition</th>
<th>Fabrication volume (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-40</td>
<td></td>
<td>100-1240</td>
</tr>
</tbody>
</table>

*The milling period was derived from the milling rate of Si single crystal at each accelerating voltage.

2. Ion milling condition
- The FIB processed cross-section surface was further milled with the Ar ion milling to remove the damaged layer.
- Ion milling was performed at multiple accelerating voltage levels.

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Sample condition</th>
<th>Fabrication volume (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3-2</td>
<td></td>
<td>15 ~ 150</td>
</tr>
</tbody>
</table>

3. Result
3-1. FIB processing condition
1. Accelerating voltage
- The contrast intensity of each layer is lower than the cleaved sample.
- At below 30 kV, the interface position of p-type and n-type layer shifted slightly upwards.

2. Dose current
- Over 620 nA/µm² Ga ion dose, interface position of p-type and n-type layer was changed. The optimized FIB condition was at the accelerating voltage of 40 kV and below 210 nA/µm² dose current.

3-2. Ion milling condition
1. Accelerating voltage
- The highest contrast was confirmed at the accelerating voltage of 0.5 kV, indicating damaged layer was well removed.

2. Milling time
- As each milling period increases, the contrast intensity also increases.

4. Applications
1. SRAM (NMOS)
- The optimized condition of FIB processing was used.

2. SiC power device
- The optimized condition of Ar ion milling was used.

5. Conclusions
- The optimized condition of FIB processing and Ar ion milling was applied to the commercial devices sample to demonstrate dopant profile visualization clearly.

Reference

Copyright © 2016 Hitachi High-Technologies Corporation All Rights Reserved.