A Proposal for Design, Simulation and formation of a 0.45 μm thick Oxide on a Silicon Wafer

Mohammad Daraie¹, Elyar Pourali² and Ramin Asadi³

¹ Payame noor university of Tehran, Tehran, Iran
² Faculty of Electrical and Computer Engineering, Advanced Device Simulation Lab, Tarbiat Modares University, PO Box 14115-194, Tehran, 1411713116 Iran.
³ Azad university of Damavand, Damavand, Iran

Abstract- In this paper we propose a method for formation of a 0.45 μm thick oxide on a 4 inch silicon wafer. We show that the simulation results are in very good agreement with practical process. We have used Athena TCAD package, Centrotherm oxidation tubes and optical microscope and α-step thickness measuring devices to simulate, fabricate and testing of the oxide.

Keywords: Oxidation, silicon
A Proposal for Design, Simulation and formation of a 0.45 μm thick Oxide on a Silicon Wafer

Mohammad Daraie  Elyar Pourali  Ramin Asadi

Payame noor university of Tehran, Tehran, Iran  
Faculty of Electrical and Computer Engineering, 
Advanced Device Simulation Lab, Tarbiat Modares 
University, PO Box 14115-194, Tehran, 141173116 
Iran. 

Azad university of Damavand, Damavand, Iran

M_d_physics@yahoo.com  elyar.pourali@gmail.com  Asadi_24@yahoo.com

Abstract: In this paper we propose a method for formation of a 0.45 μm thick oxide on a 4 inch silicon wafer. We show that the simulation results are in very good agreement with practical process. We have used Athena TCAD package, Centrotherm oxidation tubes and optical microscope and α-step thickness measuring devices to simulate, fabricate and testing of the oxide.

Keywords: Oxidation, silicon

1 Introduction

Because of its great importance in planar silicon device technologies, the formation of silicon dioxide layers by thermal oxidation of silicon has been studied very extensively in the past several years [1-15]. So oxidation of silicon is an important step in silicon based devices and to develop a reliable process for oxidation is very important in fabrication of silicon based devices. Thick oxide is used for masking purposes. For example to prevent a diffusant from diffusing in on side of a wafer. In this work we wanted to design a reliable thick oxide process for masking purposes. To do this task we designed, simulated and did so many tests to have a reliable process of thick oxide on a silicon wafer. Simulation, practical and test results are included in the rest of this paper.

2 Simulation results

To simulate the oxidation process we have used the Athena TCAD package. We have shown that to have a 0.45 μm thick oxide we should use a dry-wet-dry process. The simulation steps are shown in table 1.

Table1: simulation steps of the 0.45 μm thick oxide

<table>
<thead>
<tr>
<th>Step Name</th>
<th>Temperature</th>
<th>Time (min)</th>
<th>Gas</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Up</td>
<td>1100°C, +10°C/min</td>
<td>30</td>
<td>N₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>Stabilization</td>
<td>1100°C</td>
<td>2</td>
<td>N₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>Dry Oxide</td>
<td>1100°C</td>
<td>10</td>
<td>O₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>Wet Oxide</td>
<td>1100°C</td>
<td>30</td>
<td>O₂</td>
<td>3.2 SLM</td>
</tr>
<tr>
<td>H₂</td>
<td></td>
<td></td>
<td></td>
<td>6 SLM</td>
</tr>
<tr>
<td>Dry Oxide</td>
<td>1100°C</td>
<td>5</td>
<td>O₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>Cooling Down</td>
<td>800°C, -10°C/min</td>
<td>30</td>
<td>N₂</td>
<td>5 SLM</td>
</tr>
</tbody>
</table>

Simulated structure and simulation result of the process of table 1 are depicted in figure 1.
As we can see the thickness of the oxide is ~0.45 μm.

3 Practical results

To perform the designed steps in section 2 we have used centrotalm oxidation tubes. Before to start the process we should clean the silicon wafers. So we have used the well-known RCA cleaning to perform this step. To have a good oxidation process we should clean the tubes too. To clean the tubes we did two steps. Organic solvents cleaning step with KOH and an etching step with HF.

After cleaning of the wafers and the tube, we cleaned the cassette of the silicon wafers with KOH and HF.

The process of oxidation is done as depicted in table 2.

First the wafers are loaded into the oxidation tube (steps 1, 2), and then the temperature rises to 1100 °C to perform the oxidation step (step3). Before the oxidation we have added a step to stabilize the temperature (step 4). After the stabilization is done the first step of oxidation begins (step 5) at the temperature of 1100 °C that is a dry oxide. Dry oxidation is done by a pure flow of O₂ gas with a flow of 5 SLM (Standard litter per minute). The second step of oxidation is a wet oxide that is done through combining of the O₂ (3.2 SLM) and H₂ (6 SLM) in a device called Hydrox in high temperature. The last step of oxidation is a dry oxide step that is done with a flow of 5 SLM of O₂ in the temperature of 1100 °C. After the oxidation process we should cool down the tube (step 8) and unload the wafers (10).

Table 2. Practical flow chart of the 0.45 μm thick oxide

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Step Name</th>
<th>Temperature</th>
<th>Time (min)</th>
<th>Gas</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Loading</td>
<td>800°C</td>
<td>2</td>
<td>N₂</td>
<td>10 SLM</td>
</tr>
<tr>
<td>02</td>
<td>Loading</td>
<td>800°C</td>
<td>2</td>
<td>N₂</td>
<td>10 SLM</td>
</tr>
<tr>
<td>03</td>
<td>Heating Up</td>
<td>1100°C, +10°C/min</td>
<td>30</td>
<td>N₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>04</td>
<td>Stabilization</td>
<td>1100°C</td>
<td>2</td>
<td>N₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>05</td>
<td>Dry Oxide</td>
<td>1100°C</td>
<td>10</td>
<td>O₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>06</td>
<td>Wet Oxide</td>
<td>1100°C</td>
<td>30</td>
<td>O₂</td>
<td>3.2 SLM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H₂</td>
<td>6 SLM</td>
</tr>
<tr>
<td>07</td>
<td>Dry Oxide</td>
<td>1100°C</td>
<td>5</td>
<td>O₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>08</td>
<td>Cooling Down</td>
<td>800°C, -10°C/min</td>
<td>30</td>
<td>N₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>09</td>
<td>Unloading</td>
<td>800°C</td>
<td>2</td>
<td>N₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>10</td>
<td>Unloading</td>
<td>800°C</td>
<td>2</td>
<td>N₂</td>
<td>5 SLM</td>
</tr>
<tr>
<td>11</td>
<td>End of Recipe</td>
<td>800°C</td>
<td></td>
<td>N₂</td>
<td>2 SLM</td>
</tr>
</tbody>
</table>

4 Testing results

After the oxidation process we should test our results. Two methods of testing are used to test the results of the oxidation process.

Method 1: Using an optical microscope we have measured thickness of the oxide at 10 different points (figure 2). But before this measurement we should etch a small portion of the oxide to reach the substrate, because we need both substrate and the oxide to measure the thickness of the oxide. After a lithography and an etching step the results were as table 3.

As we can see in the table 3 the thickness of the oxide in different places of the wafer is almost uniform and is in a good agreement with our simulation results. But to be sure we have done another test to measure this thickness.

Method 2: An α-step device is used to measure the thickness of the oxide. Before this test we have
etched and cleaned a portion of the wafer. The test results are shown in figure 3.

Table 3: Thickness of the oxide at different positions of the wafer.

<table>
<thead>
<tr>
<th>Position</th>
<th>Thickness (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>451.6</td>
</tr>
<tr>
<td>2</td>
<td>451.9</td>
</tr>
<tr>
<td>3</td>
<td>449.5</td>
</tr>
<tr>
<td>4</td>
<td>450.2</td>
</tr>
<tr>
<td>5</td>
<td>450.6</td>
</tr>
<tr>
<td>6</td>
<td>449.9</td>
</tr>
<tr>
<td>7</td>
<td>451.1</td>
</tr>
<tr>
<td>8</td>
<td>450.9</td>
</tr>
<tr>
<td>9</td>
<td>449.5</td>
</tr>
<tr>
<td>10</td>
<td>449.6</td>
</tr>
</tbody>
</table>

As we can the α-step results are in a good agreement with the simulation too.

5 Conclusion

An oxidation process is designed, simulated and performed on a silicon wafer. Simulation and practical results are in a good agreement and this proposal can be used in any thick oxide process in silicon based devices.

References