Bias Temperature Stress (BTS) and $D_2O$

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Bias Temperature Stress (BTS)

• Holding the device at high temp and high voltage for some time and then re-exam characteristics.
• Standard test used in the MOS community.
• Although not understood in detail, the combination of high voltage and high temperature allows defects/traps to be populated.
• Most importantly it is a standard device reliability test.
Bias and temperature-induced instability (BTI) of threshold voltage ($V_{th}$)

Nitridation leads to electron immunity and increases hole trapping

- Electron Spin Resonance (ESR) shows
- NO annealing reduces the number of $E'$ centers (oxygen vacancy) in oxides
- Maybe interface SiO$_x$N$_y$

Rozen et al. JAP 105, 124506 (2009);
• In order to obtain more insights into the BTS mechanisms, we have employed BTS on various MOSCAPs, varying crystal face and interface treatments.
• All NO annealed.
• D$_2$O exposure.
On Si-face, D reduces holes traps and increases electron traps.

SiO2 200nm, 15V 150°C BTS  
CV 40V to -40V 25°C
Electron Traps

<table>
<thead>
<tr>
<th>Crystal Face</th>
<th>Electron-Trapping density ( \times 10^{10} \text{ [cm}^{-2}\text{]} )</th>
<th>Nit ( \times 10^{10} \text{ [cm}^{-2}\text{]} ) 0.2~0.6eV below ( E_c )</th>
<th>interface D content ( \times 10^{12} \text{ [cm}^{-2}\text{]} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si-f</td>
<td>18.3</td>
<td>6.8</td>
<td>0</td>
</tr>
<tr>
<td>Si-f w/ D</td>
<td>21.6</td>
<td>6.8</td>
<td>1.0</td>
</tr>
<tr>
<td>a-f</td>
<td>59.9</td>
<td>7.9</td>
<td>0</td>
</tr>
<tr>
<td>a-f w/ D</td>
<td>62.9</td>
<td>7.9</td>
<td>2.2</td>
</tr>
<tr>
<td>C-f</td>
<td>&gt;70.1</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>C-f w/ D</td>
<td>&gt;70.1</td>
<td>?</td>
<td>16</td>
</tr>
</tbody>
</table>

During PBTS, Electron trappings in the near interface oxide,
- Increases with \( D_2O \) exposure.
- Increases with near conduction band \( D_{it} \).

All NO annealed
In darkness, \( E=+0.75\text{MV/cm}, 150^\circ\text{C BTS} \)
### Hole Traps

<table>
<thead>
<tr>
<th>Crystal Face</th>
<th>Hole-Trapping density $\times 10^{10}$ [cm$^{-2}$]</th>
<th>interface D content $\times 10^{12}$ [cm$^{-2}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si-f</td>
<td>21.6</td>
<td>0</td>
</tr>
<tr>
<td>Si-f w/ D</td>
<td>12.9</td>
<td>1.0</td>
</tr>
<tr>
<td>a-f</td>
<td>&lt;0.1</td>
<td>0</td>
</tr>
<tr>
<td>a-f w/ D</td>
<td>&lt;0.1</td>
<td>2.2</td>
</tr>
<tr>
<td>C-f</td>
<td>5.4</td>
<td>0</td>
</tr>
<tr>
<td>C-f w/ D</td>
<td>3.2</td>
<td>16</td>
</tr>
</tbody>
</table>

During PBTS, Hole trappings in the near interface oxide,
- Decreases with D$_{2}$O exposure.

All NO annealed
E=-0.75MV/cm, 150°C BTS, no shift in Darkness,
1min light exposure during BTS was used to generate holes for trapping.
Conclusions

• D reduces holes traps and increases electron traps
  – Possibly OH alters N related hole trap to electron traps
• $D_{it}$ near $E_c$ increases Electron trapping in BTS
  – Interface defect levels aligned to oxide defect levels
  – Enhance e tunneling
• a-face with NO intrinsically has very low hole trappings, but very large electron trappings.