Oxidation induced stress in the SiO$_2$/SiC system

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Issues in SiC MOSFETS

- Interface states in SiO$_2$/SiC
- Strain at the SiO$_2$/SiC interface

High $D_{it}$ may be related to interface strain induced in oxidation.

No earlier experimental investigation of interface strain/stress.
To experimentally investigate the stress induced in thermal oxidation of SiC and to understand its effect on interface properties.
NEW method for stress measurement

Stoney equation

\[
\sigma = \left( \frac{E}{1-\nu} \right)_s \frac{t_s^2}{6t_f} \left( \frac{1}{R} - \frac{1}{R_0} \right)
\]

- \(\sigma\): Stress
- \(E\): Young’s modulus
- \(\nu\): Poisson's coefficient
- \(t_s\): Substrate thickness
- \(t_f\): Film thickness
- \(R\): Curvature radii of sample
- \(R_0\): Curvature radii of bare substrate

[Diagram showing the setup with laser, sample, and CCD camera sensor]
Experimental procedure

- RCA cleaning
- Thermal oxidation (1150°C)
- Backside oxide removing,
- Back to bare substrate

R measurement

SiC-C
SiO₂
SiC
SiO₂
SiO₂
SiC
RCA cleaning
Thermal oxidation (1150°C)
Backside oxide removing,
Back to bare substrate

R measurement

SiO₂
SiC
SiO₂
SiC
SiO₂
SiC

Shows that our method is highly accurate!!!

Measured room temperature stress in SiO$_2$/SiC

First demonstration of stress in SiO$_2$/SiC.
Possible origin of stress in SiO$_2$/SiC(Si)

Stress during oxidation ($\sigma_{ox}$)
- Lattice/density mismatch, chemical reaction...

Stress during cooling ($\sigma_{th}$)
- Difference of thermal expansion of each layer

<table>
<thead>
<tr>
<th>Material</th>
<th>Si density ($10^{22}$ atom/cm$^3$)</th>
<th>Thermal expansion coefficient ($\alpha$) ($10^{-6}$/°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>4.7</td>
<td>2.6</td>
</tr>
<tr>
<td>SiC</td>
<td>4.8</td>
<td>2.8-3.0</td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>2.2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

How do processes above 1000°C affect stress?

Need to do in-situ measurements!
Schematic of in-situ measurements

- Alumina tube
- Furnace
- Sample
- Quartz window
- Camera
- Mirror
- Mask
- PC & software
- Laser
Schematic and setup of in-situ measurement of stress
In-situ measurement of stress during Si oxidation

Curvature decreases after initial stage at higher temperature.
Stress in SiO$_2$ during Si oxidation

- **SiO$_2$ thickness**
- **Stress in SiO$_2$**

Oxidation induced stress is released after initial stage.
In-situ measurement of stress during SiC (C face) oxidation.

Phenomenon is similar to that during Si oxidation.
Stress in SiO$_2$ during SiC(C face) oxidation

- **SiO$_2$ thickness**
- **Stress in SiO$_2$$^\text{a}$

Stress may be released by viscous flow of SiO$_2$. 

**Stress in SiO$_2$**

- 1100°C
- 1000°C
- 900°C

**SiO$_2$ thickness**

- 1100°C
- 1000°C
- 900°C

- Stress (10$^8$Pa)
- Thickness (Å)

0 200 400 600 800
0 -2 -4 -6 -8
0 1000° 0 200° 400° 600° 800°
Conclusions

- Oxidation process induces a larger compressive stress in SiO$_2$/SiC, which is larger near the interface than in the bulk.

- Oxidation induced stress is substantially released by viscous flow of SiO$_2$ above 980°C.

- Stress relaxation may be less easy in case of dry oxidation of Si face SiC???