Use of Oxynitride Dielectric to Maximise the Growth Rate of Selective Epitaxial Base Layer in a Self-Aligned Double-Polysilicon SiGe Bipolar Transistors

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Outline

• Introduction
• Process flow
• The development, properties and use of the oxynitride interpoly layer
  ◆ Selectivity of epitaxial deposition
  ◆ Stress
  ◆ Etchrate
• Process window definition
• Performance and yield of the bipolar
• Conclusion
Introduction: SiGe Heterojunction Bipolar Transistor

Base  Emitter  Collector

SiGe base layer
Inter poly SiON

Metal 1
W plug
Ti-silicide
Polybase
Polymirror
SiGe base
Nitride sidewall
L-shaped spacer
Introduction:
Selective SiGe epitaxial deposition

- Advantage vs. non selective SiGe deposition
  - Self aligned structure
  - reduced collector-base parasitics
  - improved $f_{\text{MAX}}$ over $f_T$ ratio

- Disadvantage vs. non selective SiGe deposition
  - Very low SiGe deposition rate
  - Sensitive to micro- and macro loading
The development, properties and use of the oxynitride interpoly layer

Process flow:

a. Si
b. Si
c. Si
d. Si
e. Si
f. Si

- Oxide
- Polysilicon
- SiON
- Nitride
- Si/SiGe layer
The development, properties and use of the oxynitride interpoly layer

• Requirements

- Improved selective behaviour towards SiGe deposition.
- Etchrate during the opening of the intrinsic base should be as low as possible for reasons of defect reduction, process stability and electrical performance.
- The film needs to have a low stress to avoid delamination.
- Good thickness uniformity over the wafer to ensure low range of the electrical characteristics.
The development, properties and use of the oxynitride interpoly layer

- Selectivity of epitaxial deposition

  - Typical LPCVD Nitride has a poor selectivity
    The deposition rate of SiGe must be low: only 9 nm/min.

  - PECVD Oxynitride shows a high selectivity
    The deposition rate of SiGe can be increased until the SiGe process control becomes the limiting factor: the final deposition rate is increased by a factor 4 to 5.
The development, properties and use of the oxynitride interpoly layer

Stress:

<table>
<thead>
<tr>
<th>Recipe</th>
<th>SiON35-95</th>
<th>SiON50-80</th>
<th>SiON65-65</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃ (sccm)</td>
<td>35</td>
<td>50</td>
<td>65</td>
</tr>
<tr>
<td>N₂O (sccm)</td>
<td>95</td>
<td>80</td>
<td>65</td>
</tr>
<tr>
<td>SiH₄ (sccm)</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>RF power (W)</td>
<td>350</td>
<td>350</td>
<td>350</td>
</tr>
</tbody>
</table>

SEM X-section of the delayering of a high stress interpoly layer
The development, properties and use of the oxynitride interpoly layer

Etchrate vs. TEOS oxide:

<table>
<thead>
<tr>
<th>Oxide etch rate (A/min)</th>
<th>Sion 35-95</th>
<th>Sion 80-50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% HF</td>
<td>0.532</td>
<td>0.336</td>
</tr>
<tr>
<td>BHF</td>
<td>0.191</td>
<td>0.080</td>
</tr>
<tr>
<td>14% HF</td>
<td>0.673</td>
<td>0.308</td>
</tr>
</tbody>
</table>

Selectivity vs. TEOS oxide etch
The development, properties and use of the oxynitride interpoly layer

Process window definition:

- Etch rate ratio between SiON and TEOS in BHF
- % N in SiON
- Stress [GPa]
The development, properties and use of the oxynitride interpoly layer

Performance and yield of the bipolar:

- Current gain: 110
- $BV_{ceo}$: 4.1 V
- Early voltage: $-125$ V
- $f_T$: 40 GHz
- $f_{MAX}$: 85 GHz
- $f_{MAX}/f_T$ ratio: $> 2$
The development, properties and use of the oxynitride interpoly layer

Conclusions :

• The manufacturability of the selective SiGe processing is significantly improved by replacing LPCVD nitride as interpoly dielectric by a single layer PECVD oxynitride layer.

• The composition of the oxynitride layer was chosen as a function of selectivity, etchrate ratio, and stress. This layer allows a significant improvement of growth rate of the selective epitaxial deposition by a factor 4 to 5.

• The oxynitride interpoly dielectric is implemented in an industrial 0.35 µm SiGe BiCMOS technology. Good electrical performance and yield have been proven.