Schottky-Barrier Diode Modeling Using VBIC

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Outline

• Schottky-Barrier Diode (SBD) cross-section
• Model Feature and Problem
• Model Network
• Simplified VBIC model for SBD
• DC Results
• CV Results
• Summary
**Schottky-Barrier Diode Cross Section**

- Fabricated in CMOS 0.35 um process
- Making a Ti-Silicide contact in Nwell for Schottky Barrier junction
- Different geometry (variable length but fixed width)
## Model Feature and Problem

<table>
<thead>
<tr>
<th>Physical Effects</th>
<th>Diode</th>
<th>1st Diode for SBD + 2nd Diode for substrate</th>
<th>PNP Bipolar SGP model</th>
<th>NPN Bipolar VBIC model</th>
<th>NPN Bipolar VBIC model + Diode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward SBD current</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Substrate current</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Substrate current including injection</td>
<td></td>
<td></td>
<td></td>
<td>Less accurate</td>
<td>✓</td>
</tr>
<tr>
<td>Bias dependent reverse leakage current</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Capacitance for SBD only</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Capacitance for SBD and substrate</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Model Network

- NPN Bipolar VBIC model (Anode = Base, Cathode=Collector, Substrate = Sub)
- Added extra Diode (Anode – Cathode) for bias dependent leakage current
- Emitter is shorted to collector terminal
Simplified VBIC Model for SBD

- Used parasitic PNP of main NPN VBIC model
- Very small value of some model parameters has been set in order to make no significant impact in the SBD-diode behavior
Forward Characteristic

Characteristics
- Anode Current: IBCI, RCI, RCX
- Substrate Current: ISP, NFP, IBEIP, IKP, IBCNP

Parameter Diagram
- Anode Current: Iанode
- Substrate Current: Isubstrate
- Cathode Current: Icathode

Graph: vanode vs Vsub = 0, -10 V

Icathode, lanode, Isubstrate
Substrate Bias Dependent

Vanode = 0, -1 V

Characteristics | VBIC Parameter
--- | ---
Cathode Current | IBCIP
               | NCIP
Bias Dependent Leakage Current

**Characteristics**

| Anode/Cathode Current | IS | N | RS |

**Diode Parameter**

**Graph**

LENGTH=20um

![Graph showing the characteristics of anode/cathode current with a log scale for voltage and current. The graph includes a curve representing the leakage current, with parameters IS, N, and RS listed in a table.]
Temperature Dependent Characteristics

VBIC model parameters can predict temperature dependent forward current. While temperature dependent reverse leakage current can be modeled with Diode parameter.
Capacitance Model

Simulation result shows negative capacitance value in forward bias.
Used base-emitter capacitance together with base-collector capacitance in order to avoid negative capacitance.
Summary

• Proposed a SPICE sub-circuit including VBIC bipolar transistor and a diode for accurate modeling of the Schottky barrier diode

• In particular,
  – forward current
  – substrate current
  – bias dependent leakage current
  – junction capacitance

Has been modeled more accurately.