Atomistic Tight-binding Modeling of III-Nitride Materials and Field Effect Transistors

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**Ill-Nitride as a prospective TFET**

- **Advantage**: Possibility of subthreshold swing \(60\) mV/decade → lower power consumption
- **Drawback**: Tunneling based drive current → low I\textsubscript{on}

**Tunneling rate increase in Ill-Nitride TFETs**

- Large polarization field → small tunneling length
- Small effective masses (e.g., bulk In\textsubscript{0.5}Ga\textsubscript{0.5}As)
- Tunneling through low bandgap material → efficient tunneling

**Proposal & Experiments**: Jens, Fay, Seabaugh (Notre Dame)

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**Band Structure: TB model of GaN and InN**

- **GaN**: Valence bands
- **InN**: Low energy conduction bands
- **TB model**: spin-orbit model with nearest neighbor couplings
- **Bandgap and effective masses**: 

**Mechanical Structure: Strain and Band Edges**

- **Strain is significant inside the InN channel**
- **High strain values greatly affect the band structure around the channel**

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**L-shaped vs planar TFET: Gate control**

- **Gate field**: \(V\textsubscript{G}=10\) V, \(V\textsubscript{G}=6.5\) V
- **Gate current**: \(I\textsubscript{on}=10\) mA, \(I\textsubscript{on}=6.5\) mA

**Summary of I-V curve for III-Nitride TFETs**

- **L-shaped vs planar geometry**: 
  - **L-shaped provides better electrostatics**
  - **Design parameters** \(L\textsubscript{sh}, L\textsubscript{p}, \ldots\) are most important parameters
  - **Effect of strain**: Piezoelectric strain modifies band structure in the channel, hence possibility to control tunneling

**Future Work**

- **Model inhomogeneous/atomic polarization in the device.**
- **Study how strain modifies bandgap, effective mass etc.** and hence, contributes to tunneling
- **Role of InGa\textsubscript{N} alloy in TFET performance.**
- **Role of deep acceptor levels.**

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Theme 2383.002 : Quantum Engineered Steep Transistor

Task D.2.4: Atomistic Carrier Transport Modeling for Steep Devices