Resonant Tunneling Diodes

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6.772 Final Presentation
Outline

• Resonant tunneling
• Example structure
• Benefits of resonant tunneling devices
• Potential applications
• Obstacles to commercialization
• References
Resonant Tunneling

- Wave function of tunneling electron in two barriers overlap
- Produces one or more energy levels at which both barriers are transparent to electron flow
Resonant Tunneling

- Zero bias: no current
- Fermi level in emitter reaches resonant energy level in well: current starts to flow
- Resonant energy level in well is halfway between Fermi level and conduction band in emitter: current is maximum
- Resonant energy level in well reaches conduction band in emitter: current stops
Several resonant energy levels inside the well, create several current peaks.
Example Structure

• Most successful combination is GaAs-AlGaAs or GaAs-AlAs
• Well layer is undoped GaAs
• Barrier layers are undoped AlGaAs or AlAs
• The bulk layers are heavily doped GaAs
• Often have thin spacers between bulk layers and barrier layers to prevent dopant diffusion
## Example Structure

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-GaAs ($N_D=10^{18}$ cm$^{-3}$)</td>
<td>20.0</td>
</tr>
<tr>
<td>undoped – GaAs</td>
<td>5.0</td>
</tr>
<tr>
<td>undoped – AlAs</td>
<td>1.5</td>
</tr>
<tr>
<td>undoped – GaAs</td>
<td>4.5</td>
</tr>
<tr>
<td>undoped - AlAs</td>
<td>1.5</td>
</tr>
<tr>
<td>undoped - GaAs</td>
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![Graph showing current density vs voltage with two curves labeled T = 77K and T = 300K.](image)
Benefits of RTDs

• High switching speeds because not transit time limited
• Dwell time depends exponentially on barrier thickness
• Also depends on temperature, but not well modeled yet
Benefits of RTDs

• Low current density yields low power
• Maximum currents reported in a device at room temperature are on the order of $10^5$ A/cm$^2$
• Maximum peak to valley current ratios reported are 4:1 or 5:1. This is especially important in logic applications.
• Similar performance across wide temperature range
Potential Applications

- Digital logic circuits, oscillators, varactors
- Extreme temperature applications
- LEDs and lasers
- Bipolar transistors
Obstacles to Commercialization

- Requires very low defect levels in the materials. Can often tell by current peak distortion.
- Integration of hetero-structures on silicon-based chips
- Tunneling speed and current density are exponentially dependent on width of barriers
References

4. Liou Wan-Rone, Jia-Chuan Lin and Mei-Ling Yeh. Simulation and Analysis of a High-Frequency Resonant Tunneling Diode Oscillator. 1996.