RESONANT TUNNELING DIODES

Jonathan Gorlin

ECE 3080 – Semiconductor Devices

Overview

- Introduction
- Device Operation
- Performance
- Applications
- Conclusion

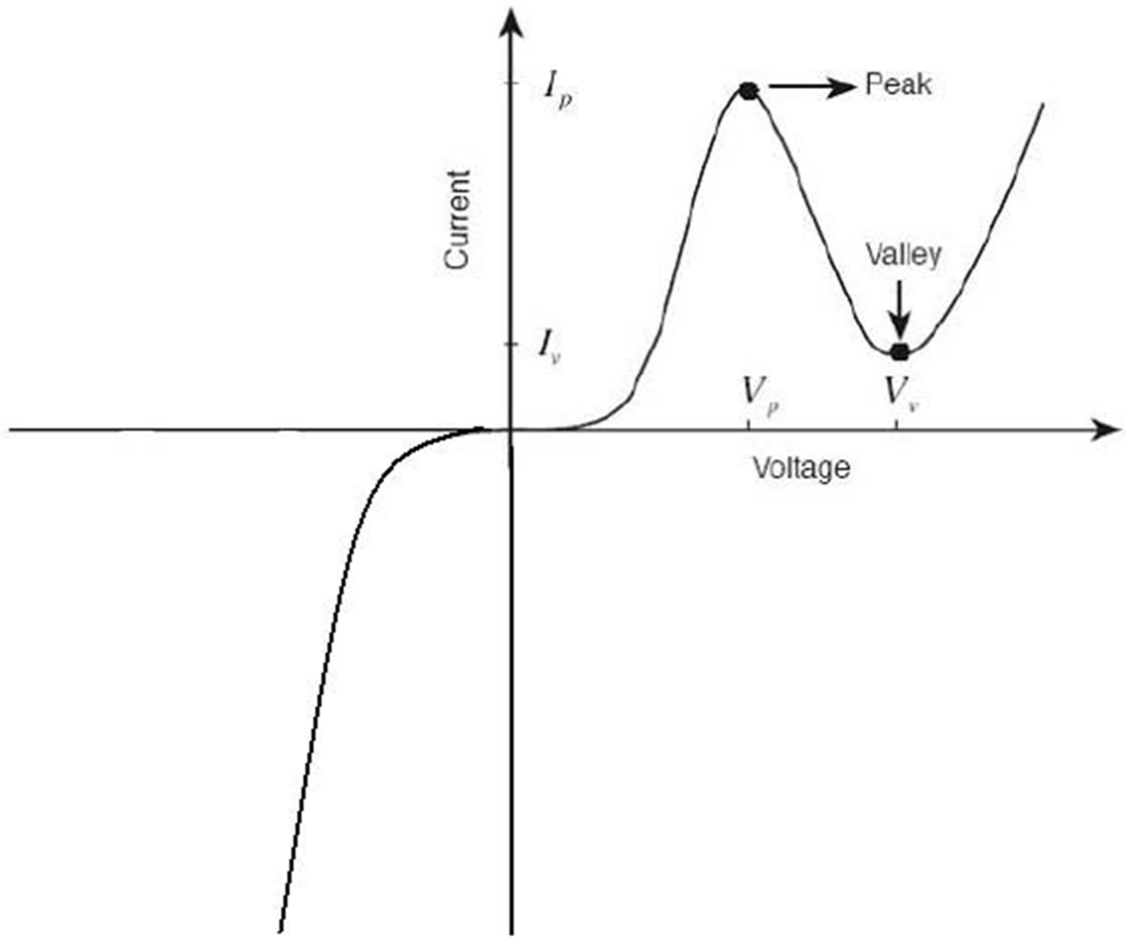
Introduction

- Tunnel Diodes
  - Very fast switching for low power, high frequency applications
- Numerous Variations
  - Esaki Diodes
  - Resonant Tunnel Diodes
  - Si/Si-Ge Resonant Interband Tunnel Diodes
  - Planar Tunnel Diodes
  - Vertical Silicon Tunnel Diodes
  - ACP Tunnel Diodes

Tunnel Diode Operation

- Based on the QM principle of tunneling
- In forward bias, electrons tunnel through narrow barrier
- Further biasing leads to negative resistance region
- Traditional TD have a very high leakage current in reverse bias
- Thin depletion region causes high capacitance

Tunnel Diode IV Characteristics

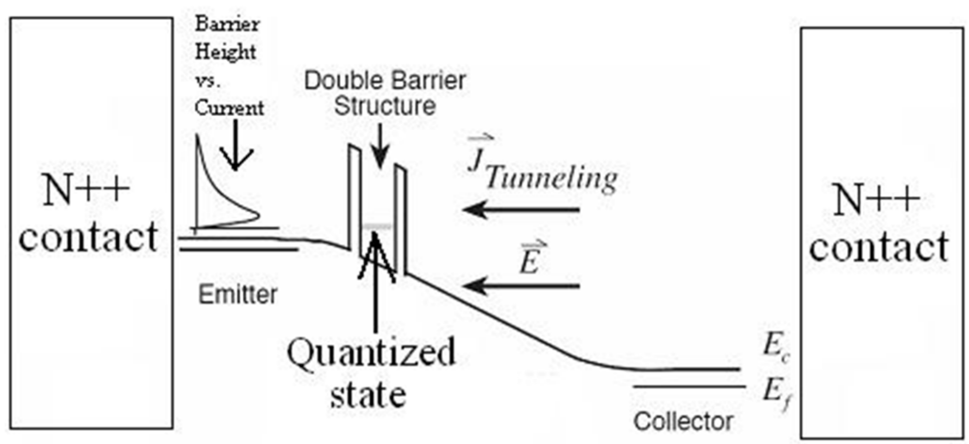


Resonant Tunneling

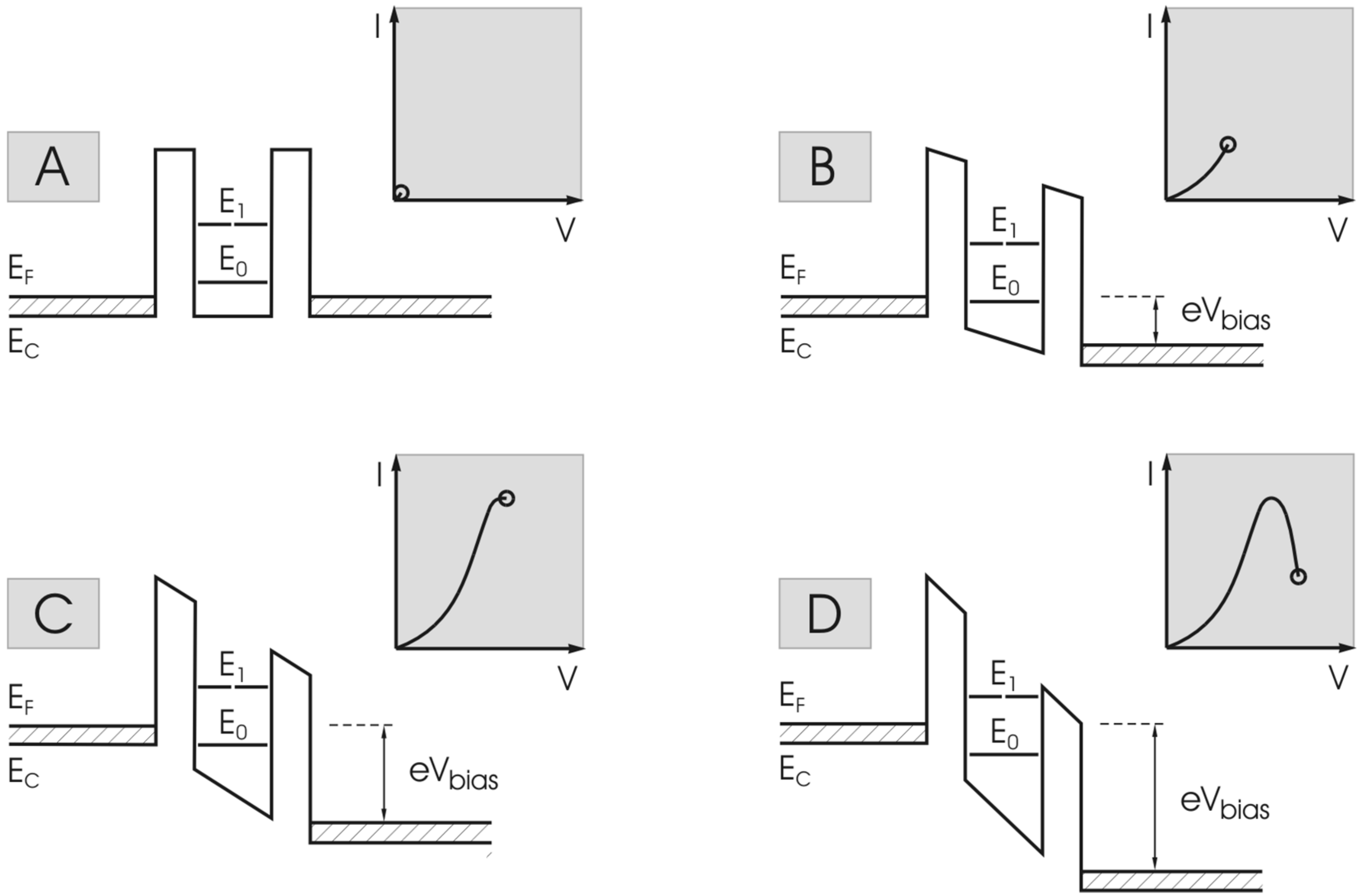
- At certain energies, the transmission coefficient is 1 as if no barriers present
- Transparency only due to resonance at certain quasi states
- The bias allows alignment of emitter with resonant states

Resonant Tunneling Diode

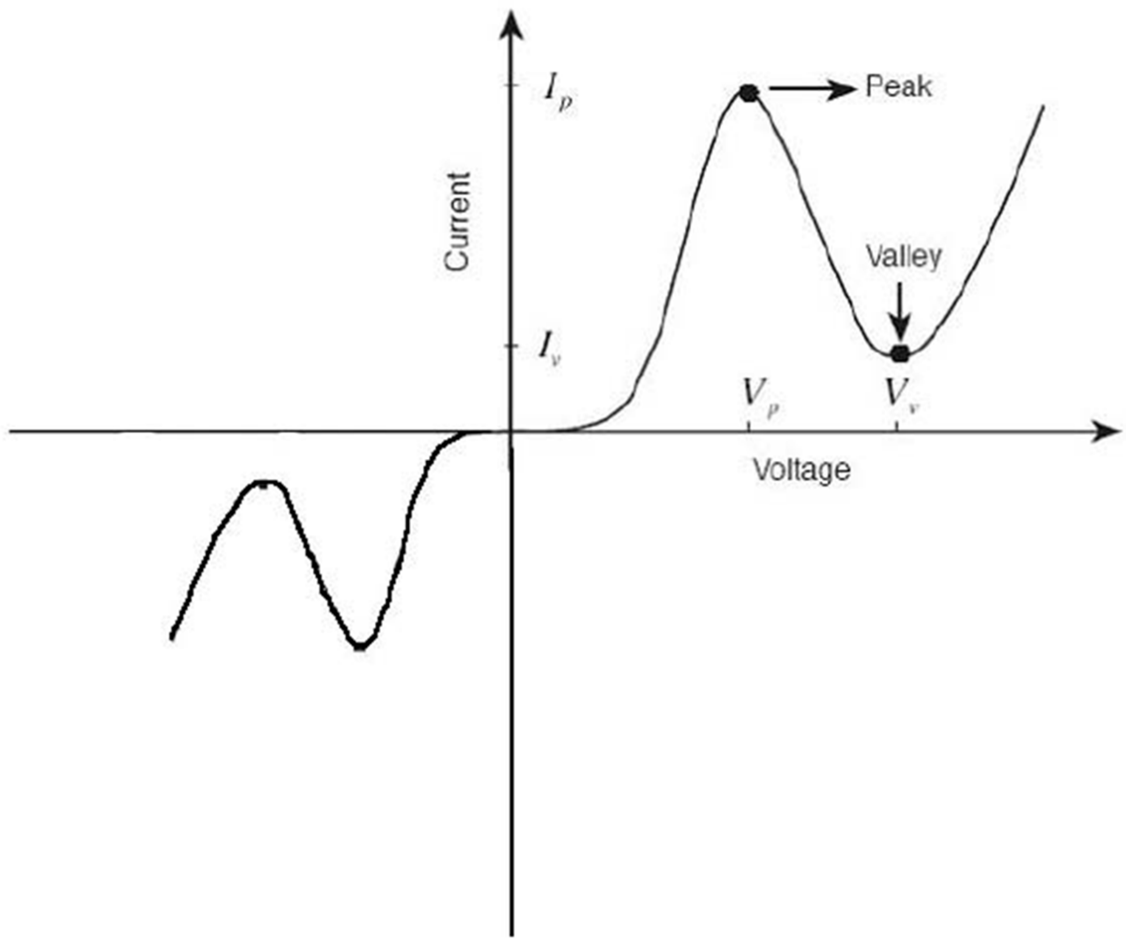
- RTDs use a double barrier quantum well
- The well is surrounded by heavily doped narrow band gap elements
- Well thickness ~5nm, barrier layers ~1.5-5nm



RTD Under Bias



RTD IV Characteristics



Comparison

- RTDs have a symmetrical I-V response for both forward and reverse biasing
- High leakage current is eliminated
  - Good rectifier
- Lower capacitance due to insulating region between wells

Performance

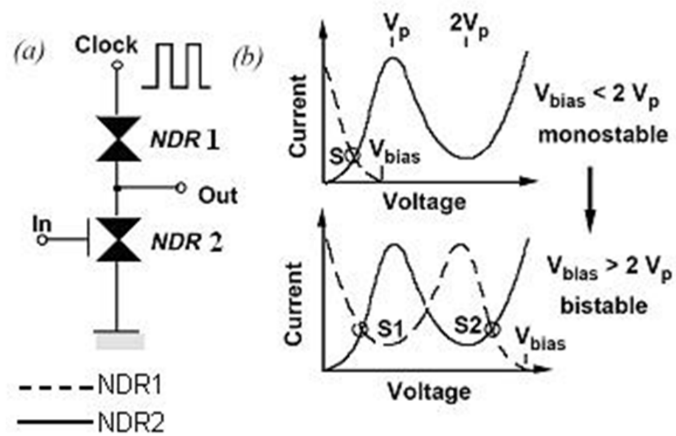
- Output power of RTD is limited
- Can reach frequencies upwards of 2 THz
- 1.2 ps switching speed vs 12ps for Esaki tunnel diode
- A 650 GHz oscillator has been achieved using Schottky Collector RTDs

Fabrication

- Usually III-V compound for heterojunctions
- Grown using molecular beam heteroepitaxy
  - GaAs/AlAs
  - AlAs/InGaAs or InAlAs/InGaAs
- MOCVD fabrication starting to gain momentum

Applications

- Monostable-bistable transition logic element
  - Used in high sampling rate applications – imaging/communications
- Oscillators – the negative resistance can be used to compensate for ohmic losses in oscillator circuits
- AtoD converters



Conclusion

- Better fabrications techniques required
  - Precise barrier thickness control is essential as the device characteristics are dependence on thickness
- Need to improve output power without amplifier
- Researchers still exploring areas of application
- Even after 30 years, still expensive on large scale

References

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