Electronic-Circuit II
Chap 3 Power Electronics
Special Purpose Diodes

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Course Homepage
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Outline

- Varactor Diode
- Schottky Barrier Diode
- PIN Diode
- Tunnel Diode

Varactor Diode

- A varactor diode is voltage dependent variable capacitor semiconductor
- Also Known as varicap, voltcap, epicap, VVC (voltage variable capacitance)
- In a reverse biased diode the P and N regions act as the plates of the capacitor
- The depletion region acts as an insulating dielectric
- The value of the junction capacitance is given as

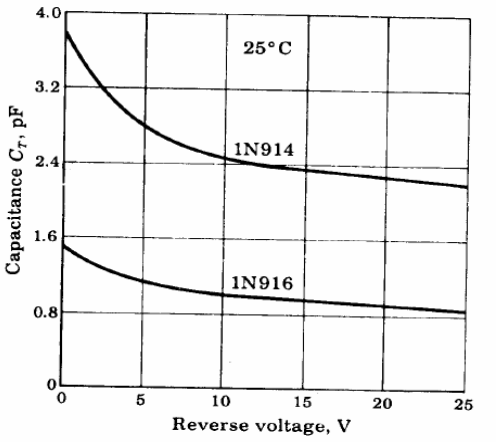
$$C = \epsilon A / W$$

Where, ϵ = permittivity of the semiconductor material

A = area of the P-N junction

W = width of the space charge region

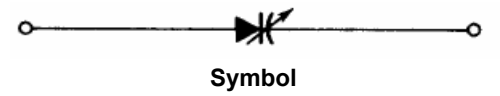
Varactor Diode contd…



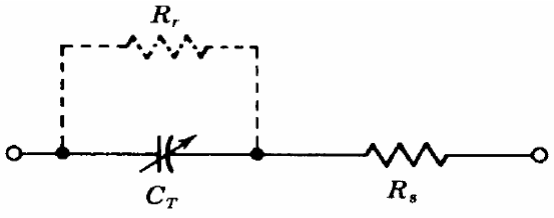
- The increment in reverse bias voltage increases the width of the space charge region (W)
- This reduces the junction capacitance as $C = \epsilon A/W$

Fig. Typical barrier capacitance variation with reverse voltage of silicon diodes 1N914 and 1N916

Symbol and Equivalent Circuit



Symbol



Equivalent Circuit

- In the eq. circuit, R_s represents the body (ohmic) series resistance of the diode
- C_T represents capacitance
- R_r represents the reverse diode resistance shunting C_T

Applications of Varactor Diode

- Varactor diodes replaced the mechanically tuned capacitors in applications such as television receivers and automobile radios
- FM Modulator (e.g. reactance modulator)
- Automatic frequency control devices
- Adjustable bandpass filters

Numerical

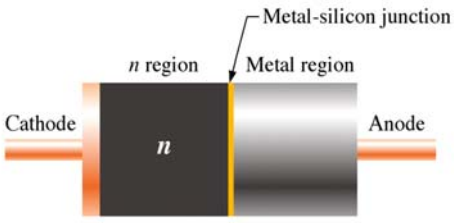
- A varactor diode with a linearly graded doping profile has a capacitance of 50pF when no bias is applied to the diode. Determine the junction capacitance for the silicon diode when the reverse bias applied to the diode is of 8V.

  [Ans: 21.59 pF]

Schottky Barrier Diode Intro.

- At low frequencies, an ordinary diode can easily turn off when the bias changes from forward to reverse
- With the increase in frequency, the diode reaches a point where it can't turn off fast
- This effect is called *charge storage*
- This restricts the diode to operate at high frequencies
- The solution to this problem is provided by Schottky Barrier diode

Schottky Barrier Diode Construction & Symbol

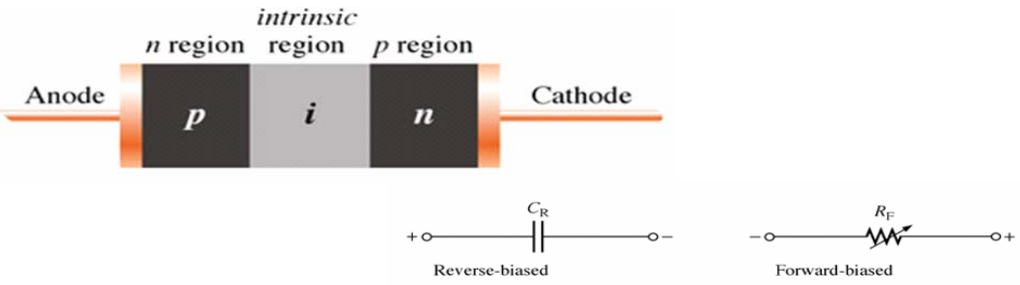


- Formed by bringing metal into contact with a moderately doped n-type semiconductor material
- The current is conducted only by the majority carriers (electrons) so it doesn't exhibit minority-carrier charge storage effects found in ordinary diodes

V-I Characteristics of Schottky-Barrier Diode

- V-I characteristics of SBD is remarkably similar to that of a p-n junction diode with two important exceptions
  - The forward voltage drop of a conducting SBD is lower than that of a p-n junction diode. For eg. SBD made up of Si exhibits a forward voltage drop of 0.3 V to 0.5 V, compared to the 0.6 to 0.8 V in ordinary Si diodes
  - Since, it doesn't exhibit the minority carrier charge storage effects, they can be switched on to off and vice versa much faster than is possible with p-n junction diodes

PIN Diodes



- Used mostly in Microwave frequency applications
- It's variable forward series resistanc characteristic is used for attenuation, modulation, and switching
- In reverse bias it exhibits a nearly constant capacitance.

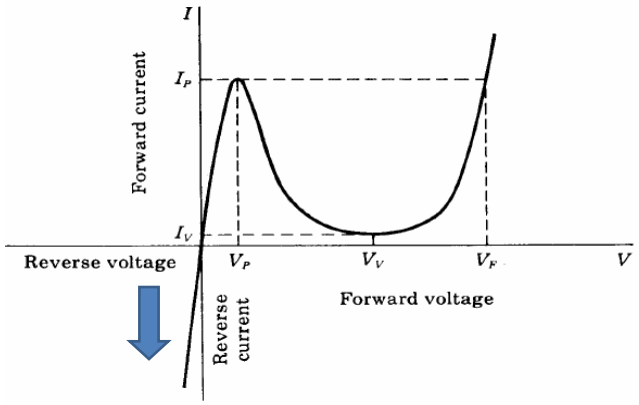
Tunnel Diode Introduction

- An ordinary p-n junction diode has an impurity concentration of about 1 part in 10^8
- In those diodes the potential barrier restrains the flow of carriers from the side of the majority charge carriers to that of the minority charge carriers
- When the impurity concentration is increased, 1 in 10the device characteristics are completely changed due to tunneling
- These diodes are known as tunnel diodes or Esaki diodes

The tunneling Phenomenon

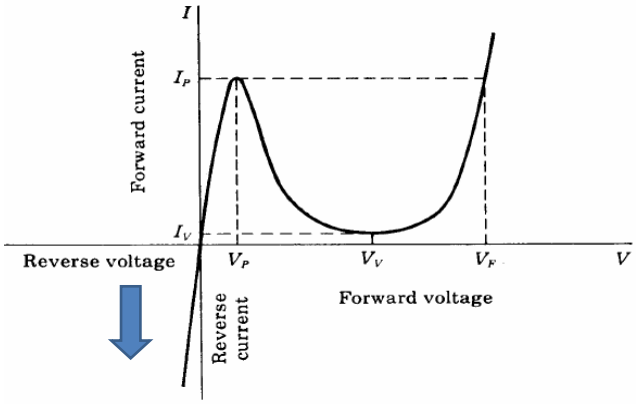
- According to classical mechanics, a particle must have an energy equal to the height of a potential energy barrier if it is to move from one side of the barrier to the other
- However for barriers as thin as tunnel diode, the Schrodinger's equation indicates that there is a large probability than an electron will penetrate through the barrier
- This quantum mechanical behavior is called tunneling and hence these high-impurity density p-n junction devices are called tunnel diodes

V-I Characteristics of Tunnel Diode



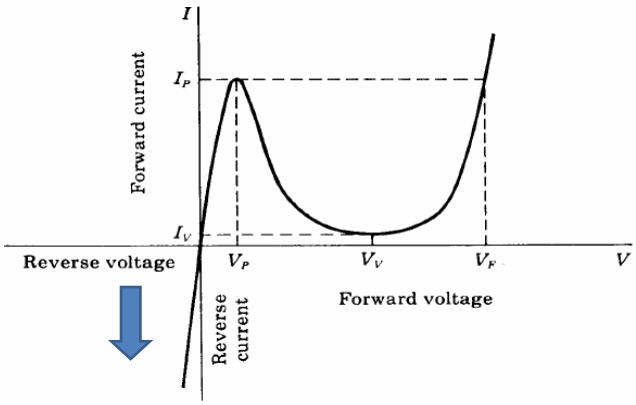
- Excellent conductor is reverse direction
- For small forward voltages (up to 50 mV for Ge), the resistance remains small (of the order of 5 ohm)
- At peak current (I_P), corresponding to V_P slope dI/dV =0

V-I Characteristics of Tunnel Diode



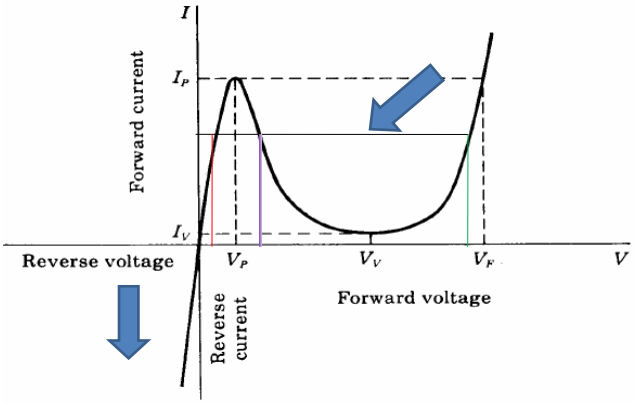
- If V is increased beyond V_P, the current decreases
- Consequently, the dynamic conductance g = dI/dV is negative

V-I Characteristics of Tunnel Diode



- Exhibits a negative-resistance characteristic bet^n peak current IP and minimum value IV
- After that point, the tunnel diode acts as a normal diode

V-I Characteristics of Tunnel Diode



- For currents whose values are between I_V and I_P , the characteristics curve is triple valued, i.e. each value of current can be obtained at three different voltage levels

Advantages, Disadvantages & Applications of Tunnel Diodes

- Advantages
  - Low cost
  - Low noise
  - Simplicity
  - High Speed
- Disadvantages
  - Low Output Voltage Swing
- Applications
  - Oscillators for microwave systems, high speed switching

Behavior of Tunnel Diode (in terms of Energy band Diagram)

- Refer this to the handout provided