Quadrant II – Transcript and Related Materials

Programme: Bachelor in Science (Third Year)

Subject: Physics

Paper Code: PYC 109

Paper Title: Solid State Devices and Instrumentation

Unit: 1

Module Name: Power diodes, Tunnel diodes

Name of the Presenter: Dr. Ramu Murthy

Notes

Power diodes:

Power diodes are similar to regular diodes but differ in their construction. In regular diodes, the doping level of both the P and N regions is the same and hence a PN junction results whereas in power diodes, the junction is formed between a heavily doped P region and a lightly doped N type region. This N-type region is the key feature in the power diode which makes it suitable for high power applications. The N- type layer being very lightly doped, almost intrinsic in nature and hence the power diode is also sometimes referred to as a PIN diode where I stands for Intrinsic. The symbol for a power diode is as shown in Fig.1 below.

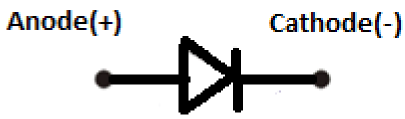

Fig.1: symbol of power diode.

The V-I characteristic for the power diode is as shown in Fig.2 below.

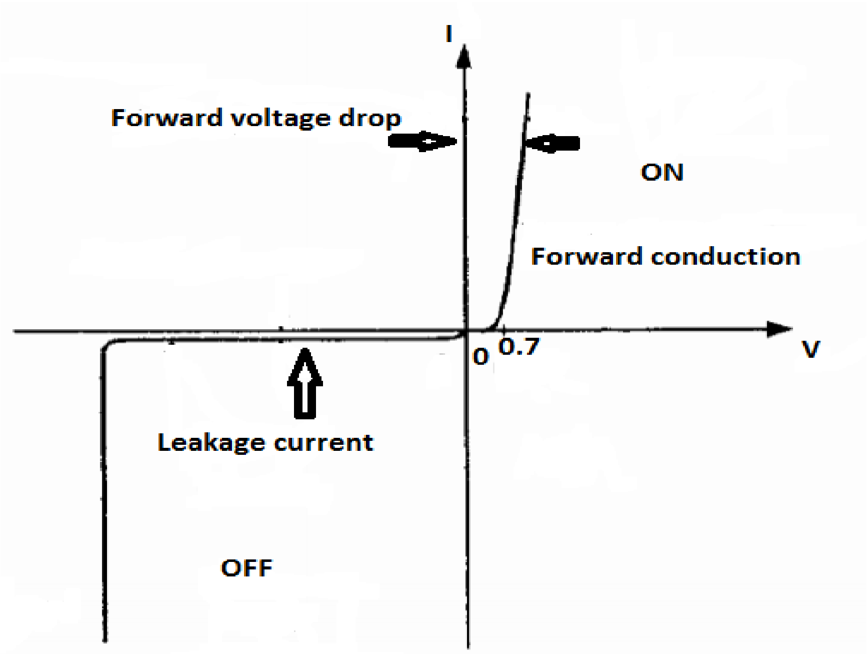

Fig.2: V-I characteristic for power diode.

The V-I characteristic of a power diode is almost similar to that of a regular PN junction diode. In regular diodes, in the forward biased region, the current increases exponentially with the forward biased voltage, however in power diodes, the high forward current leads to a high ohmic drop which dominates the exponential behaviour and the curve increases almost linearly. In reverse bias, small current flows through the diode called the leakage current. This current is negligible until a certain reverse voltage level called the breakdown voltage. Beyond this voltage, the current increases rapidly. The diode is characterized by a forward voltage V_F, breakdown voltage V_B and a reverse current I_R.

Tunnel diodes:

The tunnel diode was first introduced by Leo Esaki in 1958. The tunnel diode is different from other diodes in the sense that it has a negative-resistance region. In this region, an increase in the forward voltage results in a decrease in current. The fabrication of a tunnel diode results from the increase in doping concentration of the impurity atoms by about 1000 times resulting in a complete change in its characteristics. The characteristic is different with the existence of a negative-resistance region due to zener effect. The very high impurity concentration results in a very narrow depletion region that allows many carriers to tunnel through rather than having to surmount a barrier at a very low forward-bias potential that accounts for a peak in the characteristic curve. The reduced depletion region results in carriers punching through at velocities that far exceed those available with conventional diodes. The tunnel diode can hence be used in high speed applications such as in computers, where switching times in the order of nano seconds and sometimes pico seconds are desired. The negative resistance region is put to good use in the design of oscillators, switching circuits, pulse generators and amplifiers.

The symbol for the tunnel diode is as shown in Fig. 3 below.

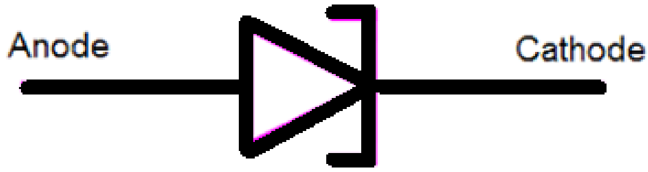

Fig.3: Symbol for tunnel diode.

V-I characteristic of Tunnel diode:

The tunnel diode's V-I characteristic is as seen in Fig. 4 below.

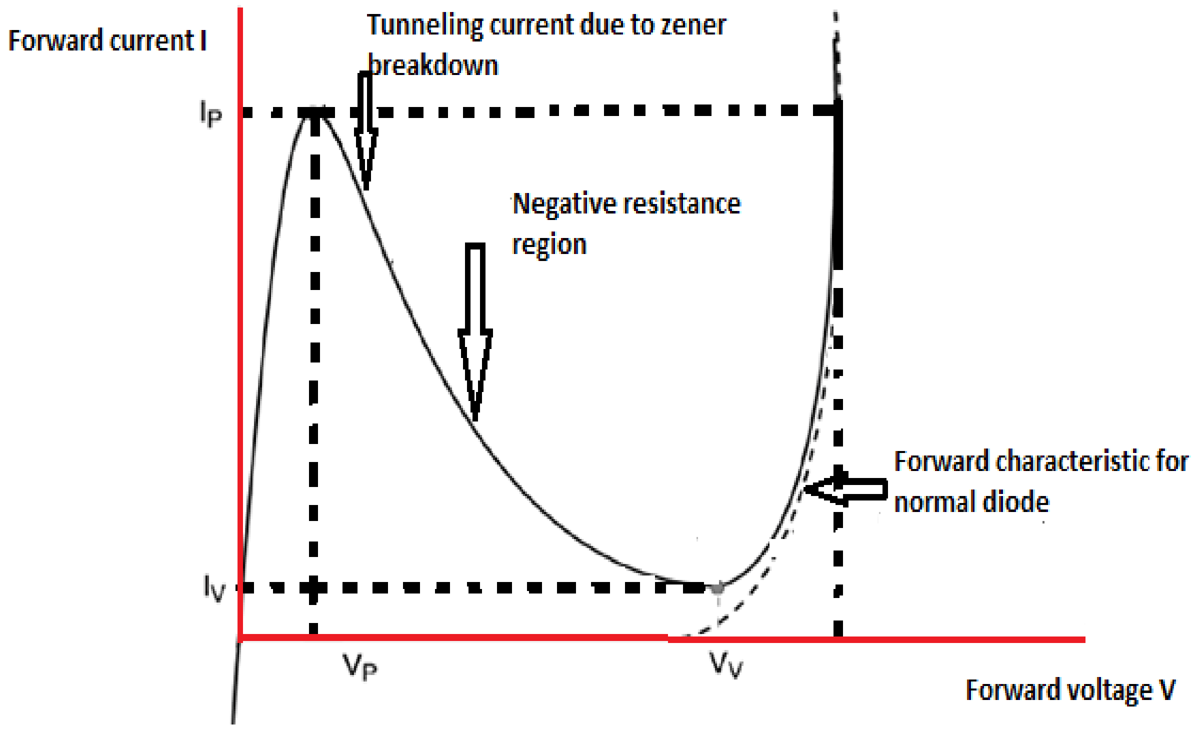

Fig.4: V-I characteristic of tunnel diode.

The V-I characteristic is the sum of two different components due to different mechanisms: (1) the application of a forward-bias voltage reducing the height of the barrier across the depletion region allowing current to flow due to majority carriers in the conduction band (dotted line) referred to as the Normal injection current (region 4) and (2) second component of current is due to Zener effect (region 1, 2 and 3).

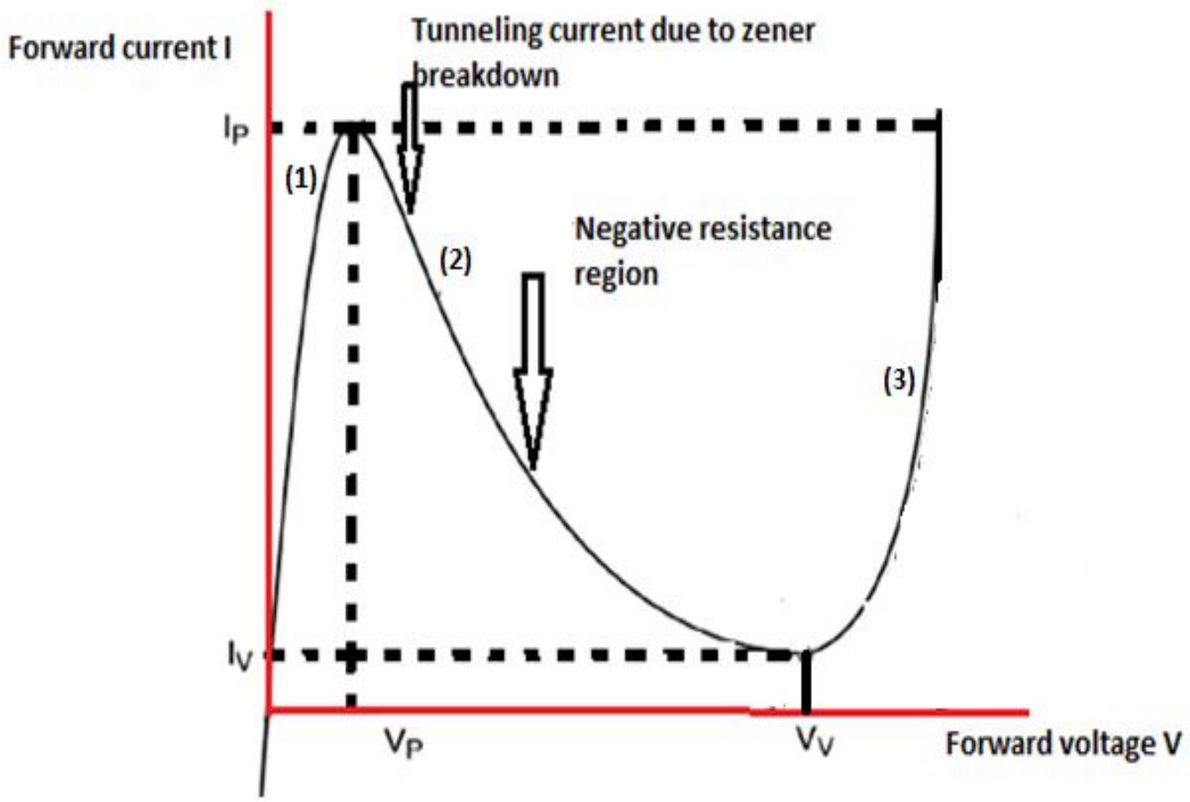

Fig.5: Regions 1, 2 and 3 due to Zener effect.

The narrow depletion region results in a very high electric field that causes carriers in the valence band to tunnel through to the conduction band on the other side(Fig.6) without having to overcome the barrier giving rise to I_P at some voltage V_P (region 1).

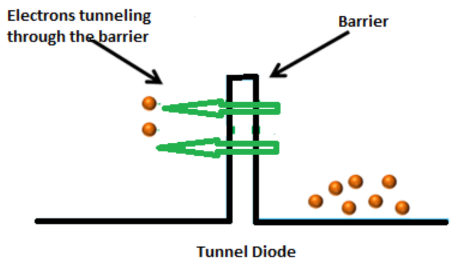

Fig.6: Carriers tunnelling through the junction.

Region (2): Negative resistance region due to a decrease in tunneling current with increase in voltage as the forward voltage reduces the electric field strength and the width of the depletion region becomes less well defined due to diffusion of carriers across the PN junction when the forward voltage exceeds V_P.

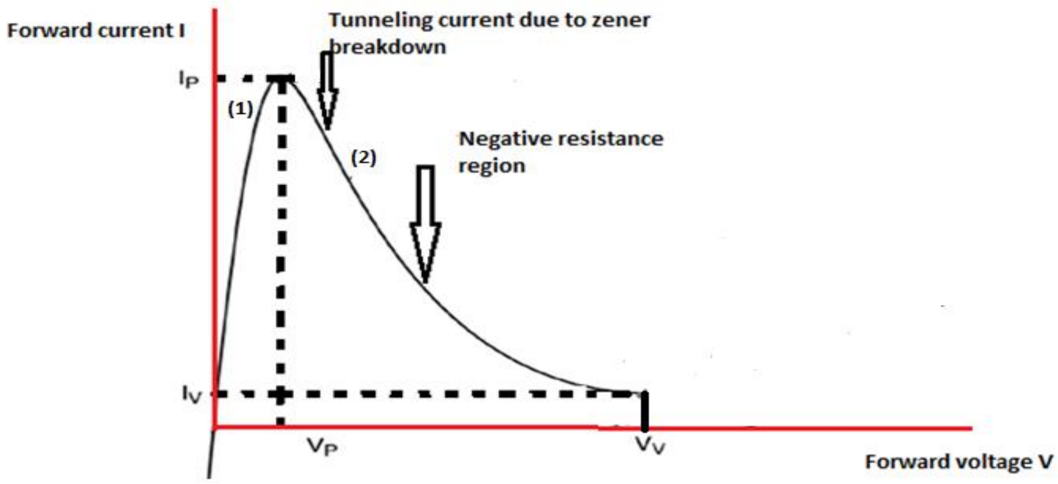

Fig.7: region 2 of the characteristic.

Region (3): Above the valley voltage V_V, the normal forward injection current predominates and the forward current increases in a usual manner with $I_F = I_P$ at a forward voltage of 0.5V for Ge tunnel diode and 0.9V for GaAS tunnel diode.

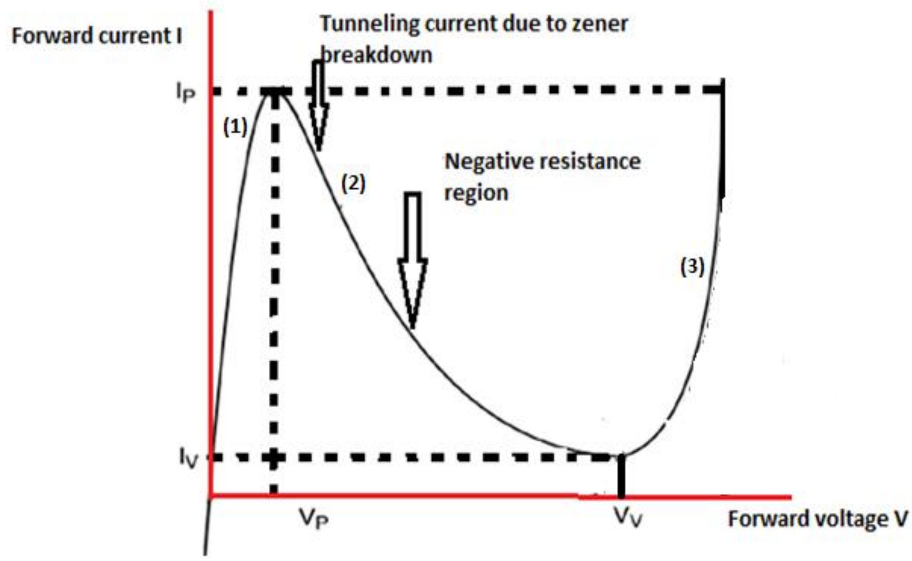

Fig. 8: region 3 of the characteristic.