increase of temperature increases the energies of the valence electrons. This weakens the bonds holding the electrons and consequently, less applied voltage is necessary to pull the valence electrons from their position around the nuclei. Thus, the breakdown voltage decreases as the temperature increases.

The dependence on temperature of the avalanche breakdown mechanism is quite different. Here the depletion region is of sufficient width that the carriers (electrons or holes) can suffer collisions before traveling the region completely i.e., the depletion region is wider than one mean-free path (the average distance a carrier can travel before combining with a carrier of opposite conductivity). Therefore when temperature is increased the increased lattice vibration shortens the distance a carrier travels before colliding and thus requires a higher voltage to get it across the depletion region.

As established earlier, the applied reverse bias causes a small movement of intrinsic electrons from the P material to the potentially positive N material, and intrinsic holes from the N material to the potentially negative P material (leakage current). As the applied voltage becomes larger, these electrons and holes increasingly accelerate. There are also collisions between these intrinsic particles and bound electrons as the intrinsic particles move through the depletion region. If the applied voltage is such that the intrinsic electrons do not have high velocity, then the collisions take some energy from the intrinsic particles, altering their velocity. If the applied voltage is increased, collision with a valence electron will give considerable energy to the electron and it will break free of its covalent bond. Thus, one electron by collision, has created an electron-hole pair. These secondary particles will also be accelerated and participate in collisions which generate new electron-hole pairs. This phenomenon is called carrier multiplication. Electron-hole pairs are generated so quickly and in such large numbers that there is an apparent avalanche or self-sustained multiplication process (depicted graphically in Figure 1-5). The junction is said to be in breakdown and the current is limited only by resistance external to the junction. Zener Diodes above 7 to 8 volts exhibit avalanche breakdown.

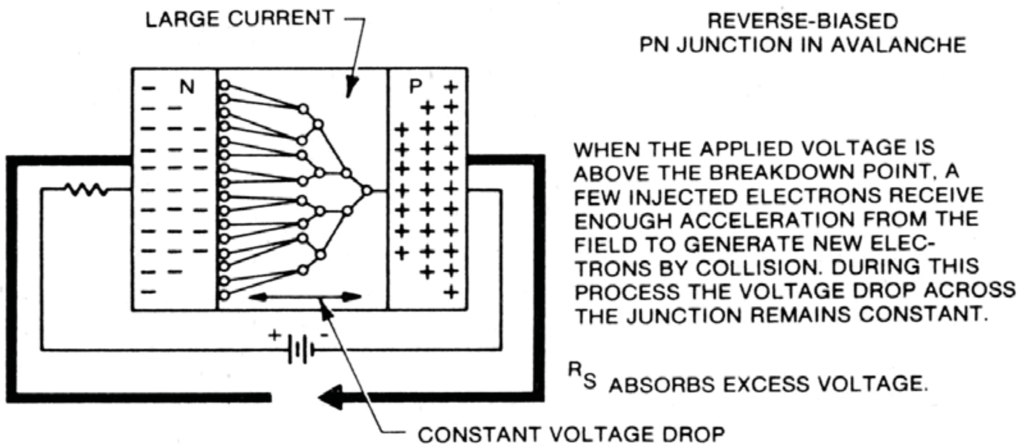

Figure 1-5 PN Junction in Avalanche Breakdown.

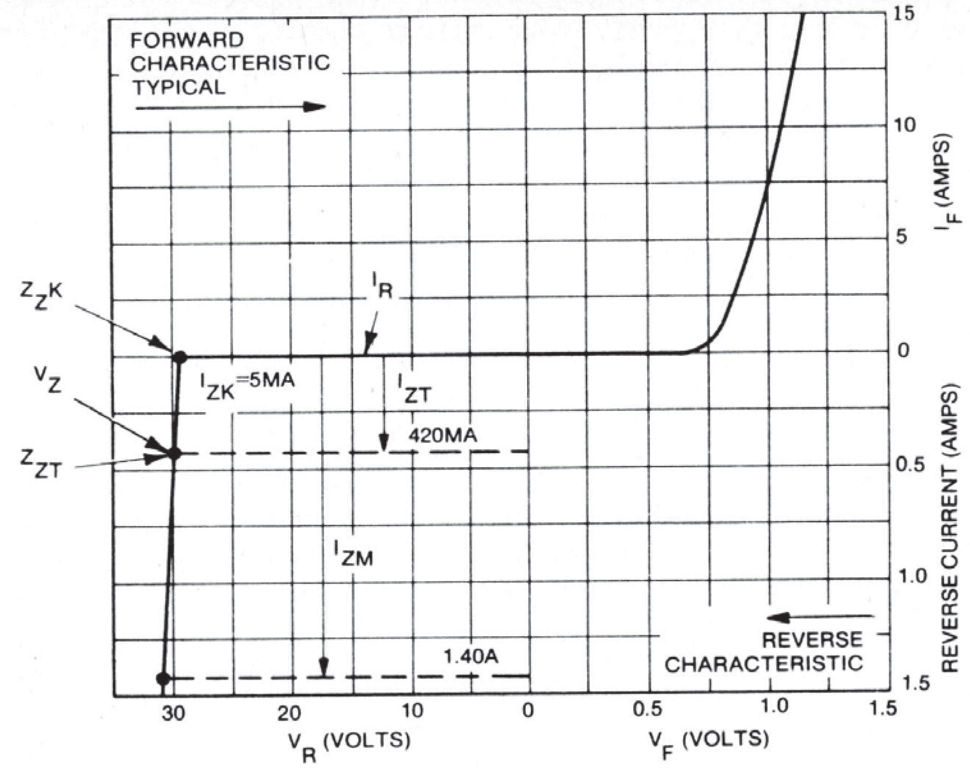

Figure 1-6 Zener Diode Characteristics.

As junction temperature increases, the voltage breakdown point for the avalanche mechanism increases. This effect can be explained by considering the vibration displacement of atoms in their lattice increases, and this increased displacement corresponds to an increase in the probability that intrinsic particles in the depletion region will collide with the lattice atoms. If the probability of an intrinisc particle-atom collision increases, then the probability that a given intrinsic particle will obtain high momentum decreases, and it follows that the low momentum intrinsic particles are less likely to ionize the lattice atoms. Naturally, increased voltage increases the acceleration of the intrinsic particles, providing higher mean momentum and more electron-hole pairs production. If the voltage is raised sufficiently, the mean momentum becomes great enough to create electron-hole pairs and carrier multiplication results. Hence, for increasing temperature the value of the avalanche breakdown voltage increases.

Volt-Ampere Characteristics

The zener volt-ampere characteristics for a typical 50 volt zener diode is illustrated in Figure 1-6. It shows that the zener diode conducts current in both directions; the forward current I_F being a function of forward voltage V_F. Note that I_F is small until $V_F \approx 0.65$ V; then I_F increases very rapidly. For $V_F > 0.65$ V I_F is limited primarily by the circuit resistance external to the diode.