As the reverse voltage is increased to a point called the voltage breakdown point and beyond, current conduction across the junction interface increases rapidly. The break from a low value of the reverse saturation current to hea;vy conductance is very sharp and well defined in most PN junctions. It is called the zener knee. When reverse voltages greater than the voltage breakdown point are applied to the PN junction, the voltage drop across the PN junction remains essentially constant at the value of the breakdown voltage for a relatively wide range of currents. This region beyond the voltage breakdown point is called the zener control region.

Zener Control Region: Voltage Breakdown Mechanisms

Figure 1-3 depicts the extension of reverse biasing to the point where voltage breakdown occurs. Although all PN junctions exhibit a voltage breakdown, it is important to know that there are two distinct voltage breakdown mechanisms, One is called *zener breakdown* and the other is called *avalanche breakdown*. In zener breakdown the value of breakdown voltage decreases as the PN junction temperature increases; while in avalanche breakdown the value of the breakdown voltage increases as the PN junction temperature increases. Typical diode breakdown characteristics of each category are shown in Figure 1-4. The factor determining which of the two breakdown mechanisms occurs is the relative concentrations of the impurities in the materials which comprise the junction. If two different resistivity P-type

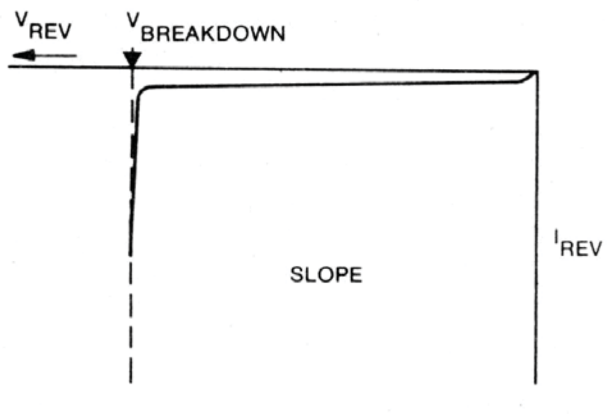

Figure 1-3 Reverse characteristic extended to show breakdown effect.

materials are placed against two separate but equally doped low-resistivity pieces of N-type materials, the depletion region spread in the low resistivity P-type material will be smaller than the depletion region spread in the high resistivity P-type material. Moreover, in both situations little of the resultant depletion width lies in the N material if its resistivity is low compared to the P-type material. In other words, the depletion region always spreads principally into the material having the highest resistivity. Also, the electric field (voltage per unit length) in the less resistive material is greater than the electric field in the material of greater resistivity due to the presence of more ions/unit volume in the less resistive material. A junction that results in a narrow depletion region will therefore develop a high field intensity and breakdown by the zener mechanism. A junction that results in a wider depletion region and, thus, a lower field intensity will break down by the avalanche mechanism before a zener breakdown condition can be reached.

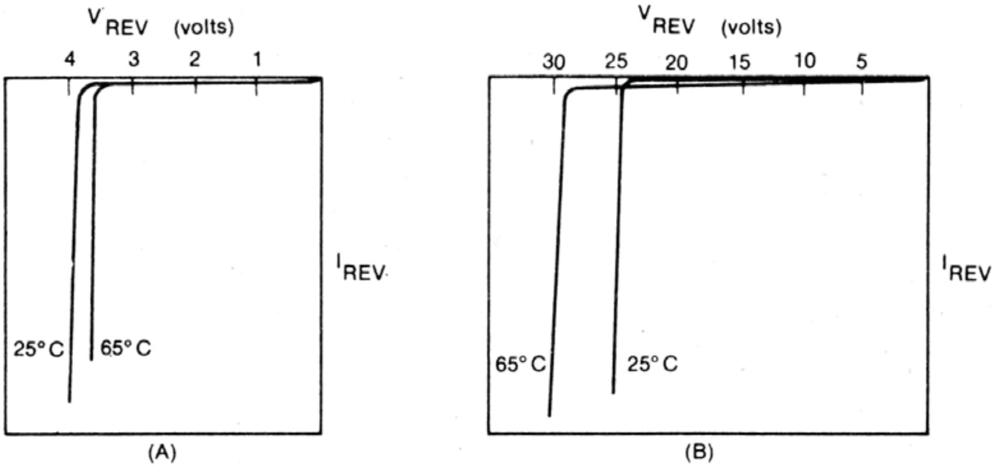

Figure 1-4 Typical breakdown diode characteristics. Note effects of temperature for each mechanism.

The zener mechanism can be described qualitatively as follows: because the depletion width is very small the application of low reverse bias (5 volts or less) will cause a field across the depletion region on the order of 3×10^5V/cm. A field of such high magnitude exerts a large force on the valence electrons of a silicon atom, tending to separate them from their respective nuclei. Actual rupture of the covalent bonds occurs when the field approaches 3×10^5V/cm. Thus, electron-hole pairs are generated in large numbers and a sudden increase of current is observed. Although we speak of a rupture of the atomic structure, it should be understood that this generation of electron-hole pairs may be carried on continuously as long as an external source supplies additional electrons. If a limiting resistance in the circuit external to the diode junction does not prevent the current from increasing to high values, the device may be destroyed due to overheating. The actual critical value of field causing zener breakdown is believed to be approximately 3×10^5V/cm. On most commercially available silicon diodes, the maximum value of voltage breakdown by the zener mechanism is 8 volts. In order to fabricate devices with higher voltage breakdown characteristics, materials with higher resistivity, and consequently, wider depletion regions are required. These wide depletion regions hold the field strength down below the zener breakdown valuel (3×10^5V/cm). Consequently, for devices with breakdown voltages lower than 5 volts the zener mechanism predominates, between 5 and 8 volts both zener and an avalanche mechanism are involved, while above 6 volts the avalanche mechanism alone takes over.

The decrease of zener breakdown voltage as junction temeperature increases can be explained in terms of the energies of the valence electrons. An