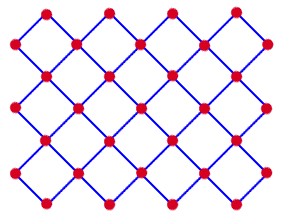
Intrinsic (i) or pure semiconductor  
Returning now to silicon; it has been noted that it is an insulator at 0K. This is because there is insufficient energy available from the lattice to cause a covalent bond to *break*, so there are no free charges. However, as the temperature of the crystal is raised, there is a finite probability that a small concentration of bonds will gain enough energy to break, releasing an electron to become a free, conduction band electron, while at the same time leaving behind an unfilled covalent bond (empty state in the *valence band*) which in turn can meander around the lattice. This unfilled bonded is called a hole and mathematically is treated as a *positive charge* (see figure 6).



**Figure 6 : Schematic diagram to show the presence of equal concentrations of electrons and holes in an intrinsic semiconductor as its temperature is raised and covalent bonds are broken by thermal energy. Both the electron and the hole move randomly through the lattice.**

The process of free carrier *generation* is balanced by *recombination* under thermal equilibrium conditions so that the electron and hole concentrations reach steady state values. The concentrations of electrons and holes in an *intrinsic* (*i*) (i.e. pure) semiconductor, ni and pi, are equal, and may be calculated from the expression;

Equation 1

Eg is the forbidden energy gap, or bond strength, of the semiconductor, which on an energy band diagram is the energy separation between the conduction and valence bands; *k*B is Boltzmann's constant. NC and NV are the "effective densities of states" and arise from rigorous derivations which take account of the quantum mechanical or wave-like nature of the electrons;

|  |  |  |
| --- | --- | --- |
| Equation 2 | and | Equation 3 |

Both NC and NV are slowly varying functions of absolute temperature, T. *m*\*n and *m*\*p are the effective masses of the electrons and holes respectively, and *h* is Planck's constant. The values of *n*i for Si and GaAs at 300 K are 1.45x1016 and 1.8x1012 m-3 respectively, reflecting the strong dependence of ni on Eg;

Equation 4

Equation 1.1 also indicates that ni increases exponentially with temperature. We will see later that this can be a major problem if a device becomes too warm under operation, so that the concentration of intrinsic carriers exceeds the concentration deliberately introduced by doping the semiconductor with specific impurities.

The bond strength (*E*g) is a prime factor determining the physical properties of the solid. A relatively large amount of energy is required to break the covalent bonds of diamond (carbon); it is therefore mechanically hard, optically transparent (clear) and an excellent insulator at all practical temperatures. The bonds in Si, Ge and Sn are progressively weaker so that Si and Ge are archetypal semiconductors while Sn is more like a metal than semiconductor (often called a semimetal) with a very high concentration of broken bonds (i.e. electrons and holes) at 300 K.

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