Electron-hole pairs

As we mentioned, the reason the resistivity of pure Si is so high relative to a metal is that the density of holes and electrons in Si is so small compared to a metal (in fact, holes do not exist in metals since metal atoms don't bind via a valence bond). In Si n_i is about one trillionth the density of Si atoms: $n_i = 10^{10}$ (holes or electrons) cm^{-3} compared to 5×10^{22} atoms cm^{-3}. This is to be compared to a metal where the electron density is ~ atomic density because free electrons are created when the metal atoms bond together (there are no holes in metals). The reason for this is that the amount of energy required to break a bond and free an electron, creating thereby an *electron-hole pair* in Si, is about 1.1 electron-volts, or 1.1 eV. (1 electron volt is the energy acquired by an electron dropping through an electric potential of one volt which isn't much energy: 1 eV = 1.6×10^{-19} C x 1 V = 1.6×10^{-19} joules. An angry fly stamping its foot on the floor probably uses up 10^{-8} joules or around 10^{11} eV). The average energy U of an electron or a hole in Si due to thermal jostling is U = kT, where k is Boltzmann's constant = 1.38×10^{-23} joule deg^{-1} and T is the temperature (K). At room temperature (293 K) U = 4×10^{-21} joules, or 0.025 eV. Thus the average thermal energy is more than forty times smaller than the energy needed to break a bond, and, since the probability for a bond breaking is proportional to $e^{-\frac{\mathrm{BondEnergy}}{kT}}$, relatively few are broken. The factor $e^{-\frac{\mathrm{BondEnergy}}{kT}}$ is the Boltzmann factor which comes from classical statistical mechanics **(Maxwell-Boltzmann Distribution)**

Si conducts because there are so many (5×10^{22}) atoms per cm^{-3} that a reasonable number (10^{10}) of electron-hole pairs are in existence at any given time. As the temperature decreases the number of pairs also decreases and at absolute zero (0 K) Si is an insulator. Metals conduct at 0 K.