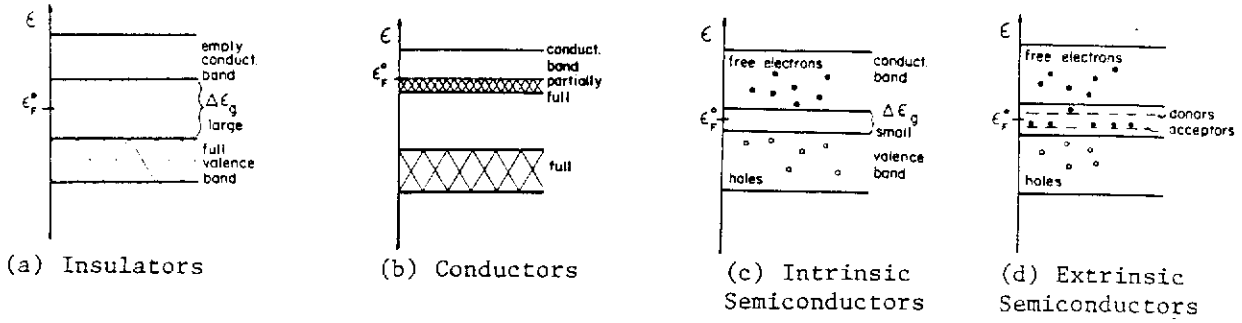

Fig. IIIE-6. Electrical Characteristics

neighbors in a stable covalent bond. This gives a filled valence band that is relatively narrowly separated from the next higher conduction band. The Fermi level is in the forbidden gap. In that respect, semiconductors are like insulators. The difference between them is the magnitude of the gap, $\Delta\varepsilon_g$. In a semiconductor crystal the gap is smaller than that of an insulator. The energy gap of a semiconductor can be overcome by thermal excitation. When the temperature level in the crystal reaches $T \sim \theta_g (= \Delta\varepsilon_g/k)$, electrons are excited into the conduction band where they act as *free electrons*. In addition, the empty states in the valence band provide *"holes"* that allow the bound electrons to change state. (See Fig. IIIE-6c.) Thus, the holes act as *positively charged* carrier particles. A pure substance of this type is called an *intrinsic semiconductor*.

The electrical properties of a semiconductor can be modified by introducing a suitable impurity called a dopant, (Fig. IIIE-6d). Semiconductors with positive carrier particles, *"P type,"* formed by introducing an impurity with empty states just above the valence band. These *acceptor states* are readily occupied by electrons at relatively low temperatures. Similarly, semiconductors with negative carrier particles, *"n type,"* are formed by coping with an impurity with a full, *donor state* just below the conduction band.

When a potential is imposed on a conductor (or semiconductor), the free electrons are accelerated toward regions of high voltage.[22] Without collisions the electrons would continue to accelerate and very high current densities would result, $i'' \Rightarrow \infty$. However, after an electron has been accelerated for a time period that averages a mean free time, it will be scattered by a collision with the lattice.[22] As a result, each electron will, on average, lose the momentum it had acquired in the direction of the applied field. Thus

[22]Each electron that is accelerated shifts to a different energy state. Therefore, it leaves an empty state that is accessible to other electrons. Electrons below the Fermi level accelerate by shifting sequentially into vacant states created by the acceleration of the entire group. Thus, unlike free electron heat transport that involves only electrons near the Fermi level, all of the free electrons participate in charge transport. On the other hand, electron-lattice collisions occur one at a time. A collision must move each electron to an accessible empty state. Thus collisions are limited by the accessibility of empty states and hence by the collision probability of electrons near the Fermi level. Thus, the appropriate mean free time is that of electrons near the Fermi level, $\tau_{c,F}$.