

ELECTRICAL CONDUCTIVITY

Understanding how the electrical resistance varies with temperature is a problem of great importance. We shall be concerned with the periodic structure of metals, i.e., the alkali metals, and the other. On the other hand, theoretical developments relating to the periodic structure of metals, i.e., the alkali metals, have been made (e.g., Vasvári *et al.*, 1967) and the findings of Drickamer and co-workers (1963; Drickamer 1965; see also Landwehr, 1965).

SCATTERING PROCESSES

Understanding some of the mechanisms of electrical resistance in metals. The electric current is carried by the conduction electrons in the monovalent metals, which form a highly degenerate electron gas. The resistance is estimated on the assumption of a free electron gas confined within a volume V (e.g., from about 80,000° K in Cu at normal pressure). We see therefore that the resistance depends on the temperature through the kinetic energy of the electrons, which is of the order of a typical thermal energy kT . In a perfect lattice (i.e., a lattice with no defects) the conduction electrons move in a perfect periodic structure. When they are scattered, and the metal resistance is not to be confused with the resistance of the lattice, it is quite different and distinct from the resistance of the lattice.

For physical imperfections, inductivity of the metal in its pure state is called the residual resistance; typically, in such a case, the resistance is of the order of the residual resistance.

The periodicity of the ideal lattice thus explains the vanishing of resistance in pure, perfect metals as the absolute zero is approached. The success of the picture in this respect has tended to focus attention on the periodic structure of metals even when their electrical conductivity at high temperatures is under consideration. As we shall see below, this is in some ways a mistaken approach and for high-temperature purposes this emphasis on the periodic lattice is not necessarily the most helpful.

In addition to the electrical resistivity that arises from the scattering of the conduction electrons by chemical impurities and physical imperfections there is also, at any temperature above the absolute zero, scattering due to the thermal vibrations of the lattice, i.e., to phonons. It is this scattering by phonons that gives rise to the temperature-dependent part of the electrical resistivity ρ_{ph} . As a first approximation we assume that the total electrical resistivity, ρ , at any temperature is given by:

$$\rho = \rho_{ph} + \rho_0 \quad (36)$$

This is known as Matthiessen's rule, and although a valuable generalization it is not strictly valid, and as we shall see below it can, in certain circumstances, give misleading information.

We turn now to a more detailed discussion of the scattering of electrons by phonons. Suppose that an electron of wavenumber k and energy E_k is scattered by absorbing a phonon of wavenumber, q , frequency ω and energy $\hbar\omega$ into a state k' of energy $E_{k'}$. Conservation of energy then requires that:

$$E_{k'} - E_k = \hbar\omega \quad (37)$$

We also require that:

$$k' - k = q + G \quad (38)$$

where G is a reciprocal lattice vector. This relationship is in some way analogous to conservation of momentum. When G is zero, we have a so-called normal process and when G is non-zero we have an Umklapp process. The Umklapp process (U-process, for short) can be interpreted in the following way. If $k' - k = G$, this means that the electron satisfies the Bragg condition for reflection from the lattice planes corresponding to the reciprocal lattice vector G ; consequently, we may think of the scattering process, described by the process above, as implying that the electron is scattered by a phonon of wavenumber q .