

Structural Aspects of the Electrical Resistivity of Binary Alloys*

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Using the weak scattering approximation and the Van Hove correlation-function technique, it is shown that the scattering function for a binary alloy (solid or liquid) is quite generally expressible in terms of three structure factors $S_{XX}(\vec{q})$, $S_{XC}(\vec{q})$, and $S_{CC}(\vec{q})$ constructed from the Fourier transforms of the local number density and concentration in the alloy. These structure factors have the property that at temperatures above the Debye temperature and in the long-wavelength limit ($q \rightarrow 0$), $S_{XX}(0)$ and $S_{CC}(0)$ represent, respectively, the mean square thermal fluctuations in the particle number and concentration, and $S_{XC}(0)$ the correlation between these two fluctuations. Thermodynamic formulas for these fluctuations are given and their concentration and temperature dependence examined for various types of mixtures (regular, order-disorder type, athermal, etc.). It is concluded that the present formalism, because of its ready link with the thermodynamic properties of the alloy, can be helpful in interpreting the various experimental data and provides useful insight into the partial structure factors introduced in the Faber-Ziman theory of liquid alloys.

I. INTRODUCTION

In the current treatment of the problem of electrical conductivity of metals (liquid or solid), the relevant scattering function describing the scattering of electrons is given by the product of two factors: a structure factor which depends only on the relative positions of the ions in the metal, and the atom form factor or the pseudopotential matrix element which describes the scattering due to the individual ions in the metal.¹⁻³ The method depends on assuming that the total potential, responsible for scattering, in the metal may be written as the sum of the potentials due to individual ions in the metal and that it can be regarded as weak. Faber and Ziman⁴ (FZ) have generalized this approach to discuss the electrical resistivity of liquid alloys. For a binary alloy the scattering function depends upon, in general, three independent partial structure factors which completely describe the structure of the alloy and the two form factors.

The transport properties of alloys have also been discussed on another, and seemingly unrelated, approach which is valid in the long-wavelength limit and which attributes the scattering of electrons - in analogy with the well-known theories^{5,6} of light

scattering in liquids and liquid mixtures - to the local thermal fluctuations in the density and concentration of the alloy. In particular, Krishnan and Bhatia⁷ showed that the observed strong temperature dependence of the resistivity of an order-disorder type of alloy near its critical point may be attributed to the corresponding temperature dependence of the concentration fluctuations. A somewhat similar approach has been recently suggested by Takeuchi and Endo¹⁰ for liquid alloys; see also Tomlinson and Lichter.¹¹

The work of the present paper may, in a sense, be regarded as constituting a generalization of the above fluctuation approach so that it is applicable at shorter wavelengths and low temperatures. It is shown that in the aforementioned weak scattering approximation, the scattering function for a binary alloy (solid or liquid) is quite generally expressible in terms of three structure factors $S_{XX}(\vec{q})$, $S_{XC}(\vec{q})$, and $S_{CC}(\vec{q})$, which are derived from the Fourier transforms of the local number density and concentration of the alloy. For liquid alloys and for solids above the Debye temperature, these structure factors have the property that in the long-wavelength limit ($q \rightarrow 0$), $S_{XX}(0)$ and $S_{CC}(0)$ represent, respectively, the mean square fluctuations in the particle

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