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Influence of Composition Faults on the Anisotropic Conductivity of Layered Semiconductors

By

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The influence of potential barriers due to extended composition faults between layers of laminar $ZnIn_2S_4$(III) appears to be responsible for its anisotropic conductivity. This anisotropy and its temperature dependence are examined for different heights of the potential barriers.

Der Einfluß von Potentialbarrieren infolge von ausgedehnten Kompositionsfehlern zwischen Schichten von laminaren $ZnIn_2S_4$(III) scheint für die anisotrope Leitfähigkeit verantwortlich zu sein. Diese Anisotropie und ihre Temperaturabhängigkeit werden für verschiedene Höhen der Potentialbarrieren untersucht.

1. Introduction

$ZnIn_2S_4$(III) shows a strong anisotropy of the electrical conductivity, which is nearly independent of temperature [1]. Previous published theories cannot explain this behaviour (Section 4).

In $ZnIn_2S_4$(III), however, layer packets with stoechiometric deviation exist perpendicular to the c-axis, which we have called composition faults in the preceding paper [1]. In the present paper we will show that such composition faults can explain the observed anisotropy, if one assumes that the composition faults give rise to potential barriers.

2. General Considerations

We assume that the composition faults between the layers extend from one side of the crystal to the other one and that their concentration is low compared with the total number of the layers, i.e.: only every ≈ 10 layers such a composition fault appears. Furthermore we assume that the potential barrier introduced by a composition fault in the periodic lattice along the normal $\mathbf{c}$ to the layers is represented by a rectangular barrier of height H and thickness l_0, Fig. 1.

Between two succesive faults the electrons can move freely in the layer planes, i.e.: perpendicular to the c-axis. Across the layers, i.e.: parallel to c-axis, the motion of the electrons is restrained by the potential barriers of the composition faults. The electrons must pass over or tunnel through these barriers, in order to contribute to the conductivity parallel to the c-axis, Fig. 1.

We assume that the electric field $\mathcal{E}$ applied along the c-axis deforms the rectangular shape of the barriers as sketched in Fig. 2, i.e.: $e\mathcal{E}l_0 \ll H$. Further, we assume that the free electrons incident on both sides of the barriers have a mean thermal velocity u_{th}, so that $e\mathcal{E}l_0 < \frac{1}{2} m u_{th}^2 < H$.

The net current density $j_{\parallel}$ through the barriers will be calculated for free electrons incident on both sides with a velocity component u_z perpendicular to the barriers.

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