

Hydrodynamic effects in electric conductivity of two dimensional metals

Autor(en): **Gurzhi, R.N. / Kalinenko, A.N. / Kopeliovich, A.I.**

Objekttyp: **Article**

Zeitschrift: **Helvetica Physica Acta**

Band (Jahr): **65 (1992)**

Heft 2-3

PDF erstellt am: **02.05.2024**

Persistenter Link: <https://doi.org/10.5169/seals-116432>

Nutzungsbedingungen

Die ETH-Bibliothek ist Anbieterin der digitalisierten Zeitschriften. Sie besitzt keine Urheberrechte an den Inhalten der Zeitschriften. Die Rechte liegen in der Regel bei den Herausgebern.

Die auf der Plattform e-periodica veröffentlichten Dokumente stehen für nicht-kommerzielle Zwecke in Lehre und Forschung sowie für die private Nutzung frei zur Verfügung. Einzelne Dateien oder Ausdrucke aus diesem Angebot können zusammen mit diesen Nutzungsbedingungen und den korrekten Herkunftsbezeichnungen weitergegeben werden.

Das Veröffentlichen von Bildern in Print- und Online-Publikationen ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Die systematische Speicherung von Teilen des elektronischen Angebots auf anderen Servern bedarf ebenfalls des schriftlichen Einverständnisses der Rechteinhaber.

Haftungsausschluss

Alle Angaben erfolgen ohne Gewähr für Vollständigkeit oder Richtigkeit. Es wird keine Haftung übernommen für Schäden durch die Verwendung von Informationen aus diesem Online-Angebot oder durch das Fehlen von Informationen. Dies gilt auch für Inhalte Dritter, die über dieses Angebot zugänglich sind.

Hydrodynamic effects in electric conductivity of two dimensional metals

By R. N. Gurzhi, A. N. Kalinenko and A. I. Kopeliovich

Institute for Low Temp. Phys. & Engn., Ukr. Acad. of Sciences, Lenin Ave, 47, 310164, Kharkov, USSR

Abstract. The qualitatively new mechanisms of electric conductivity of a hydrodynamic type having no analogs in a three-dimensional case and connected with the specificity of electron-phonon relaxation in two-dimensional systems have been predicted.

Introduction

Recent experimental discovery of a temperature minimum of electric resistivity of a potassium thin samples and anomalies in the temperature behaviour of resistivity in a number of other metals once again drew attention to the role of normal collisions between quasiparticles in electric conductivity [1, 2], and, in particular, to the hydrodynamic relaxation mechanism. In a hydrodynamic situation, frequent normal collisions and scattering on the boundary form the Poiseuille flow of electron gas [3], with the sample resistivity being decreased with increasing temperature. However, in ordinary metals it is extremely difficult to observe this effect alone.

New effects

We have shown that in two-dimensional (layered) metallic systems, qualitatively new mechanisms of the influence of normal collisions on momentum relaxation processes having no analogs in a three-dimensional case can manifest themselves. The region in which the effect of the N -process on electric conductivity can appear is rather broader for two-dimensional systems than for three-dimensional metals. A characteristic property of these mechanisms is close interrelation of specific processes of electron-phonon relaxation in 2D-systems [4] with quasiparticle motion in coordinate space. Below we shall explain the physical nature of the effects proposed (more detailed explanation may be found in [5]).

At the most natural configuration, when conducting layers are parallel to the sample surface, the formation of the electron-phonon mechanism of a hydrodynamic type is connected with taking into account the quasi-two-dimensionality of an electron spectrum leading to electron scattering on the sample surface. Here, as

it is in 2D-case, the phonon exchange is possible between electron states with opposite momenta which, however, turn out to be nonequivalent owing to spatial inhomogeneity of the problem. As a result, diffusion of a nonequilibrium momentum appears in the coordinate space with the step time $\sim l_{ep}/v$ and step length $\sim \gamma l_{ep}$ ($l_{ep} \propto T^{-5}$ is the ordinary mean free path with respect to normal electron-phonon collisions, v is the Fermi velocity, $\gamma \ll 1$ is the characteristic angle of the Fermi surface deviation from a cylindrical form). The temperature dependence of resistivity is of anomalous character: $d\rho/dT < 0$.

On the other hand, if an electron spectrum is sufficiently close to a two-dimensional one, a mechanism connected with spatial phonon diffusion is to be taken into consideration. Phonons can provide transfer of a momentum between layers and its escape to the boundary. A phonon reaches the boundary as a result of random roaming caused by collisions with electrons. The total path to approach the surface is $\sim d^2/l_{pe}$ ($l_{pe} \propto T^{-1}$ is the phonon-electron m.f.p.). Correspondingly, for the electron system this mechanism leads to the effective relaxation time $\sim d^2 l_{ep}/l_{pe}^2 v$. It is interesting that in the present case $d\rho/dT > 0$, though with increasing temperature the phonon path to the boundary is elongated, but this hydrodynamic effect is suppressed by more rapid growth of phonons number.

The estimations show that the conditions of the experimental realization of the effects predicted are considerably easier than both the Poiseuille flow of electrons in the three-dimensional case and volume two-dimensional effects.

REFERENCES

- [1] BASS J., PRATT W., JR., SCHROEDER P. A., Rev. Mod. Phys., 62, 690 (1990).
- [2] GURZHI R. N., KALINENKO A. N., KOPELIOVICH A. I., Solid State Comm., 72, 777 (1989).
- [3] GURZHI R. N., Uspekhi Fiz. Nauk, 94, 689 (1968).
- [4] GURZHI R. N., KOPELIOVICH A. I., RUTKEVICH S. B., Adv. Phys., 36, 221 (1987).
- [5] GURZHI R. N., KALINENKO A. N., KOPELIOVICH A. I., Fiz. Nizk. Temp. (Soviet Journal of Low Temp. Phys.), 1991, to be published.