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On the theory of kinetic properties of perfect two-dimensional conducting systems

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Abstract. The theory of radio-frequency and dimensional phenomena taking into account the peculiarities of electron-phonon relaxation in two-dimensional metal systems at low temperatures has been presented.

It has been shown earlier that in two-dimensional metal systems (of an intercalated graphite type), the main mechanisms connected with electron-phonon, phonon-phonon, and electron-electron collisions at low temperatures differ qualitatively from analogous ones in a three-dimensional metal. The reason of it is that the two-dimensional systems of interacting electrons and phonons (generally speaking, a three-dimensional one) breaks down into quasi-isolated groups, the momentum exchange between which is realized by extremely low processes of superdiffusion (mixing) [1]. At certain Fermi-surface structure, electron-electron collisions turn out to be of low efficiency.

It is these circumstances that determine unusual radio-frequency properties of pure two-dimensional metals at low temperatures. With increasing frequency ω of the electromagnetic field when phonons depart from electrons and, therefore, the isolated groups are destroyed, essentially more rapid relaxation processes characteristic of a three-dimensional metal appear. However, because of the complicated multistage character of superdiffusion processes, this transition is realized in a wide frequency range and accompanied by qualitatively new effects. In particular, under certain conditions, the electromagnetic field penetration has an intermediate character between the normal and anomalous skin effects, namely

$$\delta \cong \left[\frac{p_F c^2}{ne^2}\frac{1}{\omega}\sqrt{\frac{l_{ep}}{l_i}}\right]^{1/3}, \qquad l_{ep} \ll \delta \ll l_i$$

where δ is the skin layer depth, l_{ep} and l_i are the mean free paths with respect to electron-phonon and electron-impurity scattering, respectively, p_F is the Fermi momentum, n is the electron density.

The physical mechanism responsible for the last result consists in the following. As known, at the anomalous skin effect, high-frequency properties of a metal are determined by a small group of grazing electrons flying almost parallel to a sample surface. As a result of the phonon emission, the electron leaves the grazing group after which it collides quickly with the surface or moves into a metal. The emitted phonon is absorbed only by an electron of an opposite momentum (a peculiarity of the two-dimensional system manifest itself in this), and it also takes an electron out of the group of grazing electrons. The electron disappearance and the appearance of a hole with an opposite velocity direction are the result of these two processes. It reminds us of the Andreev's reflection in superconductors. Following collisions take again the hole into the electron with the same momentum as the initial one. These transitions do not affect evidently the electric current but elongate essentially the effective electron mean free path (see in many respects analogous considerations in [2]).

The effects analogous to the mentioned ones are possible in static electric conductivity of samples with a limited size, i.e. electrons scattered diffusively on the surface and moving into a sample, destroy the isolation of electron-phonon groups and in such way they open new relaxation channels. The result of these processes depends essentially on the orientation of conducting layers with respect to the sample surface and Fermi surface structure.

So, the study of radio-frequency and dimensional phenomena may serve as an effective method of finding qualitatively new relaxation mechanisms in two-dimensional conductors. More detailed treatment of the problems presented above will be given in Sov. J. Low Temp. Phys.

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