ELECTRON-PHONON SCATTERING IN DISORDERED METALLIC FILMS

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This work reviews recent progress in our theoretical investigations [1], gives quantitative explanations of available data, and presents original experimental results for ultrathin Hf at ultralow temperatures.

If electron scatterers (impurities and defects) vibrate in the same way as host atoms, the modification of the inelastic electron scattering is described by the dimensionless parameter $q_T l$, where q_T is the wavevector of a thermal phonon, and l is the electron mean free path. We show that this model well describes experimental data in the region of moderate disorder, $q_T l \sim 1$. In the impure limit, $q_T l \ll 1$, the situation is more complicated: even small difference in vibrations of scatterers and host atoms drastically changes the electron-phonon energy relaxation rate. For instance, we expect that possible variation of the electron relaxation time in a conductor with l=1nm at 10 mK spans over the interval from 10μs to 1s.

A number of experimental studies have shown a cubic temperature dependence of the electron-phonon relaxation rate in the case of moderate disorder, $Tl/u \sim 1$. It is commonly believed this experimental dependence is caused by 'pure' electron-phonon interaction. However, an accurate consideration shows that in this case the electron scattering from vibrating impurities/boundaries dominates in the energy relaxation. The electron-phonon scattering rate varies from $T^4 l$ for $ql \ll 1$ to T^2/l for $1 \ll ql < 2(u_l/u_t)^3 \sim$ 20-40 (u_l and u_t are the longitudinal and transversal sound velocities). In a wide temperature range around $T \sim u_t/l$ the relaxation rate should have a T^3 temperature dependence along with a weak l-dependence. We will show that a majority of known experimental data below 1 K fall in this range of parameters and can be quantitatively described by the theory.

We have experimentally studied the electron-phonon relaxation rate in ultrathin Hf films with short electron mean free path at millikelvin temperatures (0.04-1K). Acoustic impedance of Hf is very close to the impedance of sapphire substrate, so vibrations of film-substrate interface are expected to be identical to the phonon modes in the film. The data indicate that the electron-phonon coupling in these films is significantly suppressed by disorder. The electron-phonon relaxation time follows to T^{-4}-dependence with a record-long value $\tau = 25$ ms at T = 0.04K. The relaxation is well described by the theory without any fitting parameters.

1. A. Sergeev and V. Mitin, *Phys. Rev. B.* **61**, 6041 (2000); *Europhys. Lett.*, **51**, 641 (2000).