SUPERCONDUCTIVITY AND DIELECTRIC CONSTANT OF HIGHLY CONDUCTIVE COMPLEXES OF TETRACYANOQUINODIMETHANE (TCQM)

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We investigated the temperature dependence of the conductivity and of the dielectric constant of single crystals of well-conducting organic complexes $(TCQM)_2$ of acridine (I) and (TCQM) of N-methylphenazine (II) at 10^{10} Hz in the temperature interval 4.2 - 300°K. The measurement method consisted of determining the shift of the resonant frequency and the change of the transmission band of a H_{011}-mode 3-cm resonator with the investigated single crystal placed in the antinode of the electric field. Typical sample dimensions were: diameter ∿10 - 30 μ, length ∿2 mm.

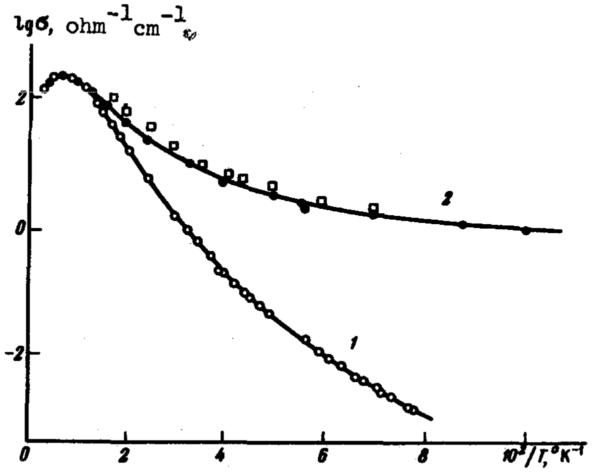

Fig. 1. Temperature dependence of conductivity of complex I: 1 - direct current, 2 - 10^{10} Hz.

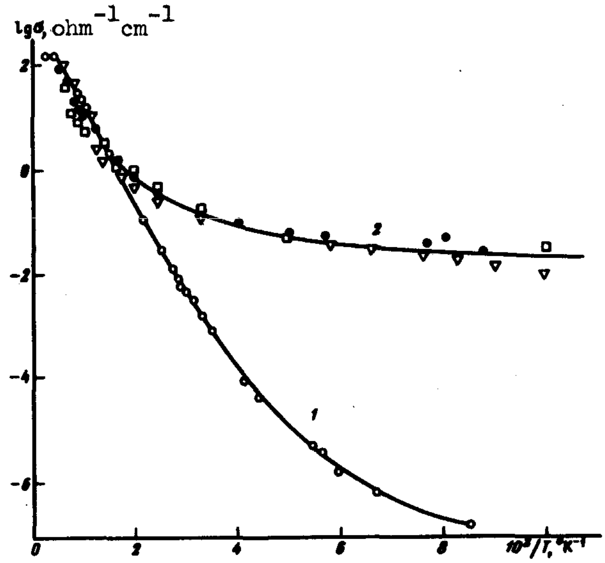

Fig. 2. Temperature dependence of the conductivity of complex II: 1 - direct current, 2 - 10^{10} Hz.

The measurement results are shown in Figs. 1 and 2. The figures also show data on the dc conductivity measured on the corresponding single crystals by a four-contact method [1, 2]. In the region of high temperatures (approximately up to nitrogen temperature) the microwave conductivity and the dc conductivity practically coincide within the limits of the mutual measurement accuracy; the values of the room-temperature conductivity shown in Figs. 1 and 2 are therefore averages of dc and microwave measurements made on several different crystals. Below nitrogen temperature, the microwave conductivity decreases much more slowly than the dc conductivity and is higher by several orders of magnitude at the lowest temperatures.

Figure 3 shows the temperature dependence of the dielectric constant ε' of complexes I and II in the temperature interval from 4.2°K to nitrogen temperature. At higher temperatures, the rapidly increasing conductivity of the complexes makes an exact determination of ε' impossible. Attention is called to the anomalously large value of the dielectric constant: at 4.2°K, ε' = 800 ± 100 for the complex I and 350 ± 50 for the complex II.

The noticeable magnitude of the microwave conductivity observed at low temperatures cannot be attributed to relaxation losses connected with effects of electronic polarization, because an estimate of the Q of the corresponding oscillators, $Q \simeq (\omega/\omega_0)(\varepsilon'/\varepsilon'')$ (here ω - observation frequency, ω_0 - natural frequency, ε' and ε'' - real and imaginary parts of the complex dielectric constant), leads to values $Q \sim 0.1 - 1$ at natural frequencies $\omega_0 \sim 10^{13} - 10^{14}$ Hz. Much lower natural frequencies could be characteristic of the mechanisms of dipole-orientational polarization, but there are no grounds whatever for suggesting the presence of such mechanisms in the investigated structures.

The dispersion of the conductivity and the large value of the dielectric constant indicate apparently that the system contains some inhomogeneities that inhibit the uninterrupted motion of the electrons. The role of such inhomogeneities may be, for example, impurity centers or local defects, near which the electrons stopped by them can execute jumps [3]. Another possibility may be that the conductivity of the compounds in question is apparently strongly anisotropic and is effected mainly along stacks of TCQM molecules, which set the characteristic pattern of their crystal structure [4]. The presence of different types of imperfections in such a linear conducting chain may lead to the occurrence of potential barriers that are destructive to the carrier mobility. Such a model, in particular, is necessary if an attempt is made to compare the temperature dependence of the susceptibility of the well-conducting TCQM complexes with the temperature dependence of their conductivity within the framework of the band concepts [1]. A more attentive analysis of the behavior of the conductivity and of the thermoelectric power of these classes of compounds [2] makes this model, however, not very probable. It may turn out, finally, that the required inhomogeneities are produced by the electrons of the linear conducting chains themselves, which prevent each other from moving.

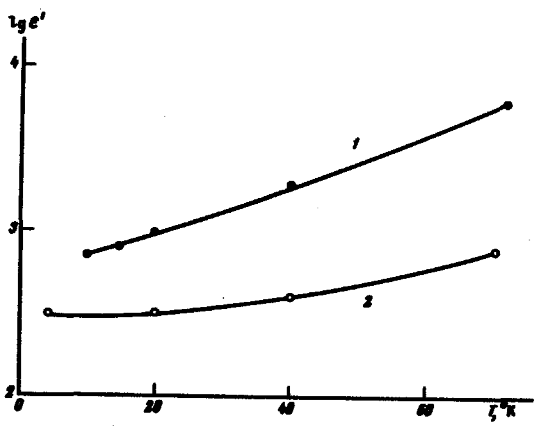

Fig. 3. Temperature dependence of the dielectric constant: 1 - complex I, 2 - complex II.

A study of the well-conducting TCQM complexes was initiated by us in connection with the recently popular ideas concerning the synthesis of organic superconductors; it is more likely, however, that they attempt to become superdielectrics rather than superconductors.

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