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TUNNELLING EXPERIMENTS ON Cu$_{1.8}$Mo$_6$S$_8$.

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Résumé.- L'énergie du gap $\Delta_\phi$ et des structures dans la densité d'état tunnel dues aux phonons ont été mesurées pour Cu$_{1.8}$Mo$_6$S$_8$ à l'aide de contacts à pointe. Le rapport $2\Delta_\phi/k_BT_c$ excède 4.0, ce qui indique un fort couplage électron-phonon. Suivant nos résultats de dérivée seconde, les vibrations optiques des atomes de Cu à basses énergie contribuent à la supraconductivité.

Abstract.- The energy gap $\Delta_\phi$ and phonon-induced structures in the tunnelling density of states have been measured for Cu$_{1.8}$Mo$_6$S$_8$, using point contacts. The ratio $2\Delta_\phi/k_BT_c$ exceeds 4.0, indicating strong electron-phonon coupling. From our second derivative data we infer that the low lying optic vibrations of the Cu atoms contribute to superconductivity.

The generalized phonon density of states $F(\omega)$ is known for Chevrel phases $\mathrm{M}_x$Mo$_y$S$_z$ from neutron scattering experiments. The compounds are regarded as molecular crystals composed of two constituents, metal atoms M and Mo$_y$S$_z$ units /1,2/. In this model the vibrational modes are divided into two groups: low-frequency external modes of M and Mo$_y$S$_z$, and high-frequency internal modes within the Mo$_y$S$_z$ units.

It is commonly assumed that the superconductivity in these compounds is mainly determined by the low-lying external modes, the translational and the torsional motion of the Mo$_y$S$_z$ units being more important than the optic motion of the M atoms /1,3/. Recent band structure calculations indicate that it is the internal contribution of the units which is essential for the electronic part $N(0)\Phi^{1/2}$ of the electron-phonon coupling parameter $\lambda$ /4/.

The contribution of distinct phonon frequencies to the superconducting properties is described by the function $\alpha^2F(\omega)$. This function can be evaluated from tunnelling experiments. The directly measured second derivative $d^2I/dV^2$ of the current-voltage characteristic reflects the structure of $\alpha^2F(\omega)$.

We have done electron tunnelling experiments on Cu$_{1.8}$Mo$_6$S$_8$. We chose the point contact method since it is very difficult to fabricate thin films or to obtain sufficiently smooth surfaces on bulk Chevrel-phase material for vapour deposition of a counter electrode. The naturally grown oxide on Al tips and the Schottky barrier of GaAs tips are used as tunnelling barriers. Both types of junctions yield similar results.

Figure 1 shows the tunnelling conductance $dI/dV$ for Cu$_{1.8}$Mo$_6$S$_8$ ($T_c = 10.6$ K). Values up to 20 have been measured for the ratio of the zero bias tunnelling conductance in the normal state to that in the superconducting state. The smearing of the gap structure presumably originates from inhomogeneities introduced by the high pressure at the point contact area and the strong pressure dependence of $T_c$ for the Chevrel phases /5/.

![Fig. 1: Differential conductance $dI/dV$ versus voltage of an Al-oxide-Cu$_{1.8}$Mo$_6$S$_8$ point contact junction at 1.2 K. For the energy gap the peak position minus 7% is chosen, thus taking into account thermal smearing.](http://dx.doi.org/10.1051/jphyscol:19786160)
At higher energies the junctions have been too noisy. Instabilities in the tunnelling current have also affected the measurements below 12 meV.

Fig. 2: $d^2I/dv^2$ versus energy measured from the gap edge for an Al-oxide-Cu$_{1.8}$Mo$_8$S$_{8}$ point contact junction at 1.2 K. The ac modulation was 1 meV. The bars show the positions of the minima for different junctions. The intensity of the structure also varied from junction to junction.

The positions of minima in $d^2I/dv^2$ pointing to maxima in $\alpha^2F(\omega)$ are confirmed by the results for about 10 junctions. The variation of the positions for different junctions is marked by bars in figure 2 and is to some extent caused by different contact pressures. Minima at about 6 and 10 meV agree with maxima in $F(\omega)$ obtained from n-scattering experiments. Additional structures are observed at 2 and 3.5 meV, which have no counterpart in $F(\omega)$ as measured in Ref. /2/.

From our results we could like to conclude that the motion of the Cu atoms (6 meV) in Cu$_{1.8}$Mo$_8$S contributes to superconductivity with about equal strength as the translational motion (10 meV) of the Mo$_8$S units. Since a direct coupling of the M atom vibrations to the electronic system is assumed to be weak, an indirect coupling via the torsional motion of the units is considered /6/. The importance of the torsional motion for the superconductivity in Chevrel phases should be clarified by tunnelling experiments at higher energies. Such experiments are underway.

References


/2/ Schweiss, P., Renker, B. and Suck, J. B., Progress Report KFK 2538, KFK Karlsruhe (1977) 23 and to be published.


