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THERMOPOWER OF $(SN)_x$ AT LOW TEMPERATURES

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Résumé.- Nous avons mesuré le pouvoir thermoélectrique de $(SN)_x$ entre 0,1 K et 4,2 K. Au-dessus de 1 K, une importante contribution du processus de "phonon drag" a été observée, ce qui peut être associé à une forte interaction électron-phonon. En dessous de 1 K, on obtient un comportement qui résulte de la présence, d'une part d'une effet Kondo à faible T_K, et d'autre part de la transition supraconductrice.

Abstract.- We have measured the thermoelectric power of $(SN)_x$ from 0.1 K to 4.2 K. A large phonon drag contribution is observed above 1 K which can be associated with strong electron-phonon scattering. The superconducting transition is seen as well as rising thermopower contribution below 1 K resulting from a Kondo effect with low T_K.

The metallic polymer $(SN)_x$ has unusual low temperature transport properties/1/, including a resistivity minimum, an anomalously large thermal conductivity/2/ and a superconducting transition at 0.3 K. In order to investigate the origin of these effects we have investigated the thermoelectric power of $(SN)_x$ in the temperature region 0.1 – 4.2 K. The experiment was performed in vacuum outside the mixing chamber of a dilution refrigerator in a configuration which allowed measurements of resistance, thermal conductivity, thermopower and critical fields on the same sample.

The absolute thermopower is shown in figure 1 for zero applied magnetic field.

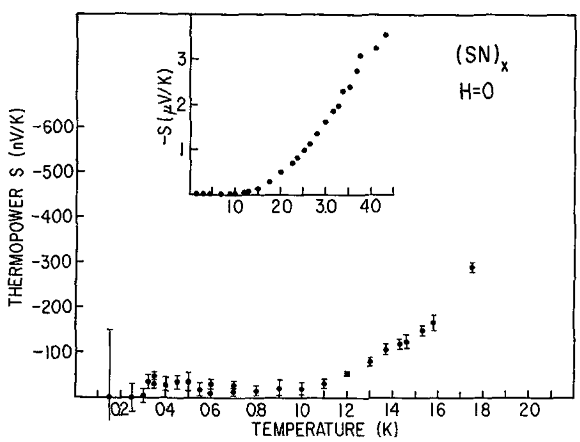

Fig. 1 : Thermopower of $(SN)_x$ in zero magnetic field as a function of temperature.

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The main features of this curve are 1) the superconducting transition at ∿ 0.3 K where the thermopower drops to zero, 2) a small negative thermopower which decreases with increasing temperature between 0.3 and 1 K and, 3) a contribution which increases rapidly with temperature above 1K. Previous thermopower measurements have been performed down to 4.2 K and indicate a phonon drag peak at about 20 K/3/. The present data fit onto previous measurements but gives slightly higher values. We therefore associate feature 3 above with the low temperature tail of the phonon drag peak.

The phonon drag contribution to the thermopower can approximately be written in the form/4/

$$S_\ell = \frac{C_\ell}{ne}\,\frac{1/\tau_{pe}}{1/\tau_{pe}+1/\tau_p} \qquad (1)$$

where C_ℓ is the lattice specific heat, n is the electron density, $1/\tau_{pe}$ is the electron-phonon scattering rate and $1/\tau_p$ is the phonon relaxation rate due to all other processes. From specific heat and Hall effect measurement we can calculate $\frac{C_\ell}{ne} = -0.40T^3$ ($\mu V/K^4$). Between 1 K and 4.2 K the experimental thermopower yields $S = 0.43 \pm 0.04\ T^3(\mu V/K^4)$ with a negligible linear term. We therefore find that the phonon drag term corresponds to the phonon bath traveling with the same drift velocity as the electrons. According to equation (1) this implies that the dominant phonon scattering mechanism is the electron-phonon interaction. It is not possible to determine the dominant electron scattering mechanism from these measurements but it is worth pointing out that the phonon "bottleneck" rules out the electron-phonon interaction as a means of dissipating elec-

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tron energy. Since phonon-phonon scattering and phonon impurity scattering are not dominant we would expect large phonon mean free path as is observed in thermal conductivity measurements/2/.

In order to demonstrate that the vanishing thermopower below 0.3 K was the result of superconductivity, parallel and perpendicular magnetic fields were applied as shown in figure 2 for a sample temperature of 250 mK.

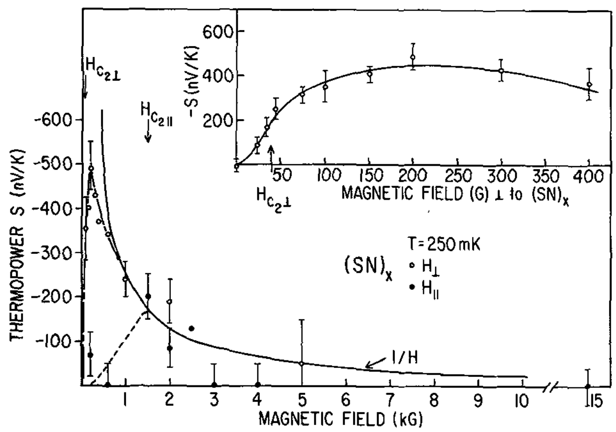

Fig. 2 : Thermopower of $(SN)_x$ at T = 250 mK as a function of magnetic field.

It is known that the critical fields of $(SN)_x$ are highly anisotropic/5/. We have shown $H_{c2\perp}$ and $H_{c2\parallel}$ as measured resistively for this sample at 250 mK. The thermopower rises from zero at the characteristic fields. However two unexpected effects are observed. The maximum thermopower as $H_\perp$ is varied is more than an order of magnitude larger than what would be expected by extrapolation of the data shown in figure 1. Further, the thermopower is not independent of H for fields greater than the critical fields.

We believe these effects are to be associated with a Kondo effect arising from localized spins perhaps located on broken polymer bonds. When the thermopower is measured in a magnetic field it is an increasing function of decreasing temperature as would be expected for a Kondo system with a Kondo temperature $\lesssim$ 0.1 K/4/.

The fact that we are observing an effect associated with localized spins may be ascertained from the similarity of the magnetic field dependence of the thermopower for $H_\parallel$ and $H_\perp$ once the appropriate critical fields have been exceeded. The thermopower for a Kondo system is calculated to vary with 1/H in the limit $g\mu_B H > k_B T$. Such a dependence is approximately observed in the experiments.

A fairly complicated magnetic field dependence to the thermopower above T_c is observed and may be indicative of fluctuations preceding the superconducting transition.

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