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MAGNETIC PROPERTIES OF THE SUPERCONDUCTING POLYMERS $(SN)_x$ AND $(SNBr_{0.4})_x$

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Résumé.- L'aimantation du polymère supraconducteur $(SN)_x$ a été étudiée en fonction du champ magnétique et de la température sur un échantillon $(SN)_x$ de qualité inférieure. Cependant il y a des différences quantitatives significatives dans les résultats obtenus sur $(SNBr_{0,4})_x$.

Abstract.- The magnetization of superconducting $(SN)_x$ has been studied as a function of magnetic field and temperature for a good quality $(SN)_x$ sample. The results are similar to previous data obtained on poorer quality $(SN)_x$. However, there are significant quantitative differences from the results on $(SNBr_{0.4})_x$.

The inorganic sulphur-nitrogen polymer, $(SN)_x$ has been the object of much experimental and theoretical investigation since the observation of its superconductivity by Greene et al./1/. More recently Gill et al./2/ have observed that the brominated modification $(SNBr_{0.4})_x$ is also a superconductor. We report in this paper quantitative measurements of the magnetization in the superconducting regime on a good quality $(SN)_x$ sample and compare the results to those obtained from earlier measurements /3/ on $(SN)_x$ and recent data/4/ on $(SNBr_{0.4})_x$.

The $(SN)_x$ samples used in this study were prepared at the IBM Research Laboratory at San Jose. The residual resistance ratio of the material, R(300 K)/R(4 K), was 25. This value is considerably higher than the value of 3 obtained for the sample prepared at the University of British Columbia (UBC) and used in the earlier experiments/3/. The actual sample used in the magnetization experiments had dimensions 0.92 mm along the fibre axis, and 0.72 mm and 0.58 mm in the transverse directions.

The specimen was cooled in a dilution refrigerator using a calibrated Speer carbon resistor as a thermometer. A SQUID magnetometer was used to measure the sample magnetization which was compared to that of a piece of In-Pb alloy cut to the same shape as the polymeric specimen/4/. The diamagnetic response was measured in fixed field, H, for both increasing and decreasing temperature. Warming curves were obtained by first cooling the sample in zero field to a low temperature (∿ 60 mK), applying the field, H, either parallel (//) or perpendicular (⊥) to the fibre axis and then monitoring the magnetization as the sample was warmed above the transition temperature, T_c. Cooling curves were obtained by measuring the diamagnetic response as the sample was cooled through T_c in the field H. Considerable flux-trapping was observed as is evidenced in figure 1 which shows the warming and cooling curves for the IBM sample in a field of 0.050 Oe.

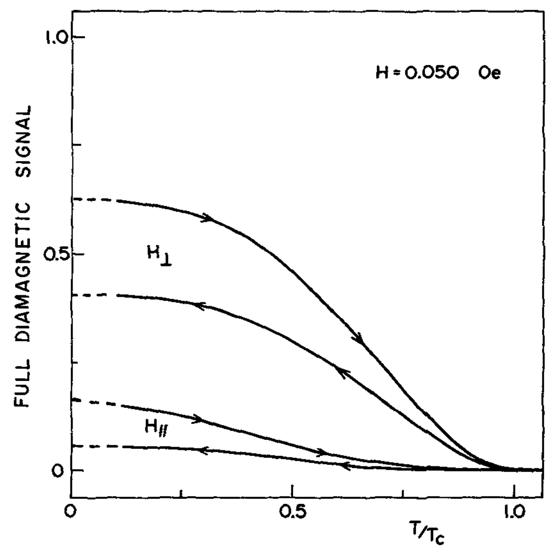

Fig. 1 : The magnetization of $(SN)_x$ as a function of reduced temperature (T_c=0.28 K). The warming curves were obtained after cooling in zero field. Unity on the vertical scale is the full diamagnetic signal as observed for an In-Pb sample having the same demagnetizing factor.

The magnetization, M, measured in the warming procedure can be compared to the values obtained for the UBC $(SN)_x$ sample and the $(SNBr_{0.4})_x$ sample. The curves for a field $H_\perp$=0.025 Oe are shown in figure 2. Some care must be exercised in comparing the curves of figure 2. Although the dif-

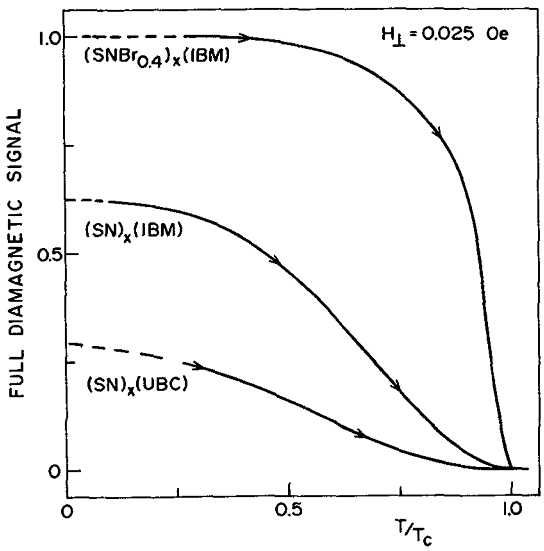

Fig. 2 : Comparison of warming magnetization curves for several samples. See text for comments regarding this comparison.

ferent samples have similar transverse dimensions, the dimensions along the fibre axis are 0.60, 0.92 and 1.20 mm for the UBC $(SN)_x$, IBM $(SN)_x$ and $(SNBr_{0.4})_x$ samples respectively. If field penetration is more effective along the fibres, the apparent differences in figure 2 may well be reduced. In fact, crude penetration depth calculations show that within experimental error the two $(SN)_x$ samples would have the same diamagnetic response if they were the same length, but would still be less than response of a $(SNBr_{0.4})_x$ sample of equal length. Further experiments to investigate this possible size effect would be useful.

The M vs.H curves for the IBM $(SN)_x$ samples were extracted from the M vs.T data and are similar to those reported previously /3/. These can be compared with magnetization curves obtained for $(SNBr_{0.4})_x$ /4/. For the brominated sample the peak of the magnetization curve occurs at $H_{peak,\perp} = 2.25$ Oe T = 59 mK wherease $H_{peak,\perp} = 0.66$ Oe for IBM $(SN)_x$ at the same temperature. The corresponding value for UBC $(SN)_x$ is 0.70 Oe, i.e. the two $(SN)_x$ samples exhibit values for $H_{peak,\perp}$ that are approximately the same. The values observed for $H_{peak,//}$ are 0.2 Oe, 0.2 Oe and 0.75 Oe for the IBM $(SN)_x$, the UBC $(SN)_x$ and the $(SNBr_{0.4})_x$ samples respectively. Demagnetizing corrections will shift these fields to higher values, but will not alter the facts that (i) the two $(SN)_x$ samples have very closely the same peak field, (ii) the peak fields for the brominated sample are about three times as large as those for $(SN)_x$ and (iii) all the samples show an anisotropy such that the ratio of $H_{peak,\perp}$ to $H_{peak,//}$ is $\gtrsim 3$.

As noted previously /3/, the magnetization curves are non-linear below H_{peak}. To explain the observed diamagnetism and flux trapping we propose that the fibres of these materials form filamentary networks, the inter-fibre linkage being due either to current-limited metallic shorts or to Josephson coupling.

In conclusion we report data on higher quality $(SN)_x$ which is in basic agreement with our earlier work. Compared to $(SN)_x$, the brominated modification $(SNBr_{0.4})_x$ exhibits increased diamagnetism and higher peak magnetization fields.

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