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Point contact characteristics of $NbSe_3$-$NbSe_3$ at low temperatures.

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Point contact spectroscopy in $NbSe_3$-$NbSe_3$ show reproducible features. At temperatures below 4K we observe structure in the I vs V and dV/dI vs V characteristics that resemble a type of Josephson effect. d^2V/dI^2 vs V reveal additional structure which can be related to the Eliashberg coupled function $\alpha^2(\omega)F(\omega)$.

1 Introduction

The study of the properties of systems of restricted dimensionality is a topic of considerable activity, because they exhibit interesting collective properties [1,2]. Among the physical phenomena that may appear when such a system is cooled are; charge density waves (CDW), spin density waves (SDW), and superconductivity at low temperatures. These effects are strongly dependent on the type of the predominant electronic interaction that occurs in the system. Two of the above listed phenomena occur through nesting of, part, or all of the Fermi surface. However, in general, in most cases only some parts of the Fermi surface are nested. Those electrons which take part in this nesting process are those that are directly responsibly for the formation of the energy gap in the new condensate state. If the electronic interactions are mediated by phonons, then in general there will be a competion between the formation of a CDW ground state, or one with a superconducting character. Both kind of phenomena are self excluding, since they generally compete for the same portion of the Fermi surface. One system in which this behavior may be clearly observed is $NbSe_3$. The CDW ground states, appear at $T_1 = 145$ K and $T_2 = 59$ K, through the use of different portions of the Fermi surface and this, therefore, excludes the possibility that the material could be superconducting. However, if an external pressure of 5-6 kbar is applied, $NbSe_3$ becomes superconducting with maximum transition temperature of 3.5 K [3]. This phenomenon occurs because of the suppression of the second CDW transition, which permits the appearance of an energy gap in this now unnested part of the Fermi surface.

An interesting point concerning both types of condensates is that they are very similar, so that many of the phenomena involved in the CDW, also appear in the superconducting state. For example, much of the physics used to explain both types of condensate is similar in form; i.e. the change in the energy gap with temperature can be expected to be the same in both systems, and in principle the strength of coupling can also be expected to be similar. Thus the e-ph interaction must follow the BCS general model. Following this line of reasoning, in this paper we present the results of studing $NbSe_3$ using point contact spectroscopy at low temperatures. The point contacts were fabricated by laying two ribbons of $NbSe_3$ across each other at right angles, a low resistance was achieved by pressing the ribbons together. We report measurements taken at low temperatures in the range $1.2K \leq T \leq 5K$.

2 Results and Discussion

High purity $NbSe_3$ with resistance ratios $R_{300K}/R_{4K} \sim 200$ were used throughout. The ribbon widths were of the order of 10 to $30\mu m$, with the ribbons faces parallel to each other. The use of ribbons of high purity preclude the existence of filamentary superconductivity, as might occur if Nb impurities were present. Fig. 1 shows typical current vs voltage curves taken at temperatures between 1.2 K to 4.2 K. The insert shows

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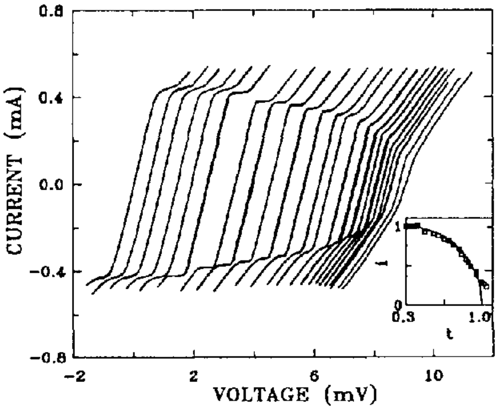

Fig. 1: I-V curves of $NbSe_3 - NbSe_3$ point contact measurements at different temperatures, the curves have been displaced horizontally for clarity. The insert shows the evolution of the critical current vs the temperature, the normalization temperature was 4K.

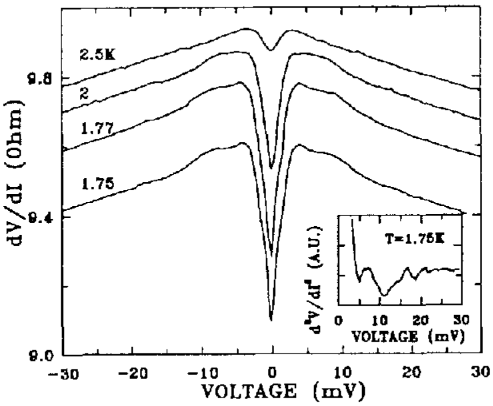

Fig. 2: dV/dI vs V curves of a contact showing details of the observed structure, the insert shows one half of the d^2V/dI^2 vs V relationship taken at 1.7 K.

the temperature evolution of a feature that develops at low voltages $\sim \pm 0.8$ meV, we call this feature the *critical current* (I_c). It should be noted that to be able to observe this feature the resistance of the contacts must be $R \leq 20$ ohms. As the resistance of the contact decreases both the value of the I_c and the slope of the current vs voltage graph increases. The transition temperature also varies, diminishing as the resistance of the contact increases. Fig. 2 shows the additional structure which can be observed when dV/dI, and d^2V/dI^2 measurements vs temperature are taken. The peak at still lower voltages, of the order of 0.5meV, (in other contacts this voltage was seen to be as small as $50\mu V$) can also be observed in the I-V characteristics as a very small, nearly vertical straight line in the I_c curves of Fig. 1, but only in contacts with very small resistance, much less than 1Ω. It should be noted that the structure observed in the first and second derivative curves is symmetrical with respect to the origin, in the insert in Fig.2 we have plotted only one half of the curve. According to Yanson [4,5] the second derivative of the point contact characteristic in the Sharvin or Maxwell limit, can be related to the Eliashberg coupled function. In Fig. 2 we can appreciate several peaks, at energies of 6.5, 14.0, 16.75, and 20.75 meV, that may be related with the phonon density of states, $F(\omega)$ of the compound.

In conclusion we have studied point contacts between two NbSe$_3$ ribbons at low temperatures. We have observed a number of interesting phenomena that merit further analysis. Studies are at present in progress the results of which will be reported in the near future.

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