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SUPERCONDUCTING PROPERTIES OF K_3C_{60} AND Rb_3C_{60} SINGLE CRYSTALS IN HIGH FIELDS.

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Abstract The critical superconducting temperature of Rb_3C_{60} and K_3C_{60} single crystals was measured in static magnetic fields up to 23 T by a resistive method. It is shown that within the experimental accuracy no enhancement of the critical field H_{C2} is found at low temperature. The $H_{C2}(T)$ follows the Werthamer, Helfand and Hohenberg theory quite well.

INTRODUCTION

Some recent measurements performed on K_3C_{60} compounds in powders [1] seem to show an enhancement of the critical field H_{C2} above the values predicted by the Werthamer, Helfand and Hohenberg (WHH) theory [2]. The knowledge of the $H_{C2}(T)$ curve may give important information for the understanding of the pairing process in these materials. We present here first results obtained on K_3C_{60} and Rb_3C_{60} single crystals.

SAMPLE PREPARATION

The preparation of the compounds has been described in details elsewhere [3] and will be only briefly given here. Single crystals of C_{60} are synthesized starting from pure C_{60} powder at about 450°C using a vapor transport method. The fcc crystal structure and lattice constant were confirmed by X-rays experiment. The samples were mounted with electrical contacts and sealed together with fresh potassium in a Pyrex glass apparatus. Uniform doping was accomplished using a repetitive dope-anneal process until the resistance of the sample reached a minimum. For the case of K_3C_{60} the room temperature resistivity ratio is typically 2, indicating a metallic behavior [3].

EXPERIMENTAL

The sample cell was filled with helium gas to ensure good thermal contact at low temperature. A 100 ohm Allen-Bradley resistor was glued against the Pyrex cell at the sample position. The resistance measurements were made by raising the temperature in a constant magnetic field from 4 to 5 K up to about 30 K at a maximum rate of .5 K/mn. No difference was observed between the magnetoresistance curves obtained by slowly sweeping the temperature or stabilizing it. This shows that there was no detectable temperature gradient between the sample and the thermometer.

The magnetoresistance of the samples was measured using a four probe method with an ac effective current of 100 μA. We have checked that no current effect on T_c was present up to 100 μA. The thermometer calibration was carefully undertaken as a function of the field up to 23 tesla.

The static field was produced by resistive coils (23 T, K_3C_{60} samples) and a superconducting 17 T magnet (Rb_3C_{60}).

RESULTS

We have measured two potassium compounds of nominal chemical formula K_3C_{60}. The transition width at T_c ranges from .5 K at B = 0 up to 2.4 K at B = 23 T for the first one and from .5 K to 1.2 K for the second one. For the Rb_3C_{60} compound the values are .4 K (B = 0) and 3.2 K (B = 17 T). On figure (1) two transition curves are displayed at B = 0 and B = 23 T for the most homogeneous K_3C_{60} compound (n°2). The value of T_c is chosen at the midpoint of the transition width ΔT.

On figures (2) and (3) we have reported the H_{C2} (T) curves for the two K_3C_{60} compounds and the Rb_3C_{60} compound respectively. The continuous lines are obtained with the WHH theory [2] assuming no spin-orbit and no paramagnetic effects. It can be seen that at least for the K_3C_{60} compounds a quite good agrement between theory and experiment is obtained, within experimental accuracy. For the case of Rb_3C_{60} the restricted range of magnetic field (0-17 T) does not allow a clear conclusion.

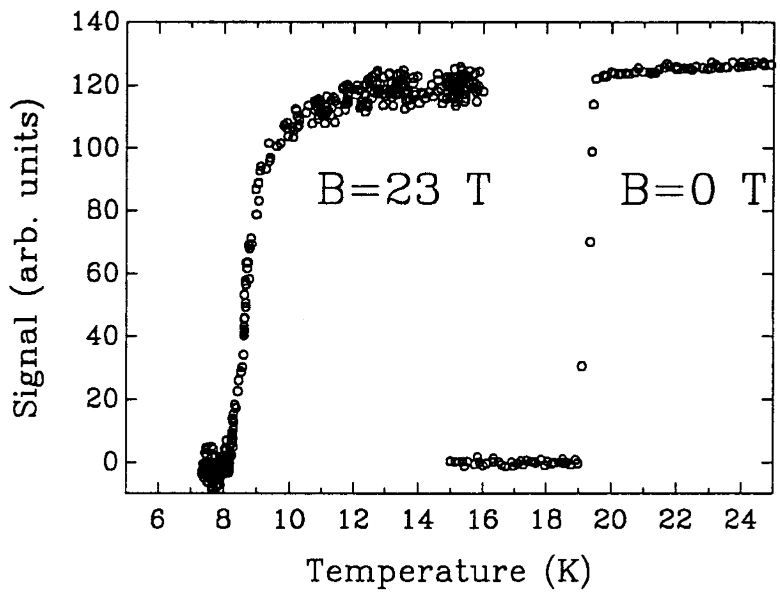

FIGURE 1 Resistive transitions for the K_3C_{60} compound n° 2 at 0 and 23 T respectively.

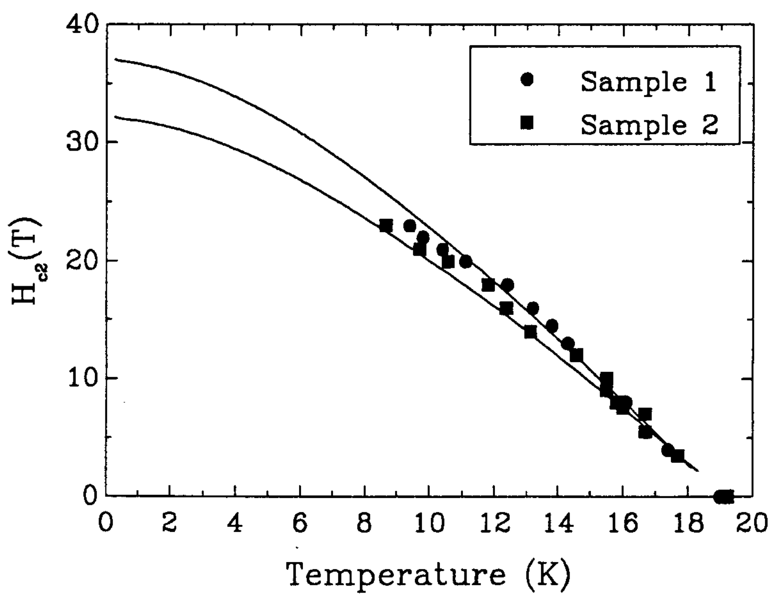

FIGURE 2 Higher critical field H_{C2} as a function of temperature for K_3C_{60} compounds n°1 (full squares) and n°2 (full circles). Continuous lines are WHH fits adjusted with the initial slope at T_C.

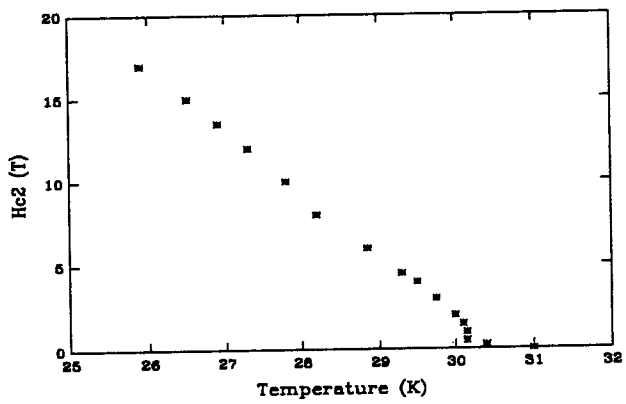

FIGURE 3 Higher critical field H_{C2} as a function of temperature for Rb_3C_{60}

TABLE 1 Main superconductivity parameters of the potassium and rubidium doped fullerenes.

Parameters	K_3C_{60} n°1	K_3C_{60} n°2	Rb_3C_{60}
T_c (0) (K)	18.9	19.2	31
H_{C_2} (0) (T)	37.8	30.1±1	61
ℓ (Å)	27±7		
ξ (0) (Å)	29	32.5	22.8
ξ_0 (Å)	131		
$\sqrt{\ell\xi_0}$ (Å)	59		
$\left(\partial H_{C_2}/\partial T\right)_{T=T_c}$ (T/K)	-2.9	-2.27	-2.85

On table (1) we have gathered the main parameters of the superconductivity for these compounds. H_{c2} (0) is the extrapolated value given by the WHH theory : $H_{C_2}(0)=0.69\cdot\left(\partial H_{C_2}/\partial T\right)_{T_c}\cdot T_C$. The Ginzburg-Landau coherence length $\xi(0)$, in the clean limit, is obtained with the formula : $H_{C_2}(0)=\Phi_0/2\pi\xi(0)^2$ where Φ_0 is the flux quantum. The BCS length is given by $\xi_0=0.18\hbar v_F/k_B T_C$, where v_F, the Fermi velocity can be estimated 5.10^6 cm./s [4]. From the resistivity ratio the electronic mean free path

ℓ can be deduced [4] and also the coherence length in the dirty limit : $\xi=\sqrt{\ell\xi_0}$. We see from this data that K_3C_{60} is neither in the clean nor in the dirty limit.

CONCLUSION

We have measured the critical field of single crystals of Rb_3C_{60} and K_3C_{60} compounds using a resistive method up to 23 T. Within experimental accuracy a good agrement with the WHH theory is found. This indicates that these compounds have conventional BCS superconducting properties as was already found on powdered samples [5-6]. Since the compounds are not in the clean limit ($\ell >> \xi_0$) the observation of the Fulde-Ferrell state [7] seems to be most improbable.

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