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Superconducting Behaviour of Carbon Nanotube (CNTS)

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Abstract: *In our present article the concentration is given to the superconducting behaviour of CNTs. The superconductivity of a material depends on transition temperature T_c. the impact of coulomb interaction is also taken into account. A theory have been developed with resistivity and coherence length from the earlier experimental curve between transition temperature and resistivity for a single wall nanotube.The curvature of CNTs leads to the creation of new electron –phonon interaction can introduce superconductivity. In this part the resistivity of carbon nanotube has been derived theoretically with relaxation time and Fermi velocity.*
Keywords: *1transition temperature, 2coherance length, 3coulomb interaction, 4electron –phonon interaction*

I. Introduction

In our recent development of nanotechnology CNTs are studied in different arena. The conductivity of nanotubes have been determined by a number of workers. The superconductivity is to be discussed along that way. It is familiar the superconductivity of a material depends on transition temperature T_c. it is the main task before the workers how to decrease the temperature and to bring at transition point where the resistivity comes to zero.

From the experiment between the transition temperature and resistivity, several curves appear in the graph for a single wall nanotube [1].when the curvature of CNTs leads to the creation of new electron-phonon scattering channels and consequent attractive electron phonon interactions [2] can induce superconductivity. It means with rise in transition temperature, resistivity initially increases. However at a certain value of T_c, resistivity comes down. The impact of coulomb interaction have been also introduced with resistivity.The present article consists of introduction in section (I) a model (theory an technique) in section (II) result and discussion in section (III), conclusion in section (IV), acknowledgement in section (V) and references in section (VI).

(I) Model:
Let a nanotube of length ξ resistance R resistivity ρ for a certain range.

$\rho \propto T_c$ $(x \leq a)$ ………………………………………..(1)

And $\rho \propto \frac{1}{T_c}$ $(x \geq a)$……………………………. .(2)
Where T_c is the transition temperature

Since resistivity, $\rho = RA \backslash \xi$……………………… .(3)

Where ξ is a coherence length
From Bardeen-cooper-schriffer (BCS) a coherence length with a superconducting gap, Δ and Fermi velocity v_f is

$$\xi = \sqrt{\frac{\hbar v_f l_{mfp}}{\Delta}}$$

Where l_{mfp}=mean free path=λ (conveniencially)

$$\xi = \sqrt{\frac{\hbar v_f \lambda}{\Delta}}$$

From eqn.(3) $\rho=\frac{RA}{\sqrt{\frac{\hbar v_f \lambda}{\Delta}}}$ ………………………………….(4)

If the coulomb interaction ie.interaction between electron-electron, a resistance may occur say R_c then eqn.(4) is rewritten as

$$\rho=\frac{(R_c+R)A}{\sqrt{\frac{\hbar v_f \lambda}{\Delta}}}$$

In superconducting state, coulomb interaction will be unaffected. So the resistance R_c is neglected i.e.

$\rho=\frac{RA}{\sqrt{\frac{\hbar v_f \lambda}{\Delta}}}$ ………………… (5)

If m is the mass of an electron, n, the number of electrons and τ is the relaxation time and A is the cross sectional area of the nanotube.

$$A=\pi r^2$$
$$=\pi\left[[\frac{2r}{2}]^2\right]$$
$$==\pi\left[[\frac{d_t}{2}]^2\right]$$
$$=\pi d_t^2\backslash 4$$

Where d_t is the tube diameter,i.e.

$d_t==\frac{\square^3}{\square}(m^2+mn+n^2)^{1\backslash 2}$

here m and n are integers.

From eqn (5)

$\rho\quad =R\frac{\frac{\square^3}{\square}(m^2+mn+n^2)^{1\backslash 2}}{\sqrt{\hbar v_f \lambda}}$………………………(6)

In our general idea, the resistance with relaxation time τ is related to

$$R\propto\frac{1}{\tau}$$
$$R=\frac{k}{\tau}$$ where k is a constant.

From eqn. (6)

$\rho\quad =\frac{k}{\tau}\frac{\frac{\square^3}{\square}(m^2+mn+n^2)^{1\backslash 2}}{\sqrt{\hbar v_f \lambda}}$………………….(7)

Where k is a constant

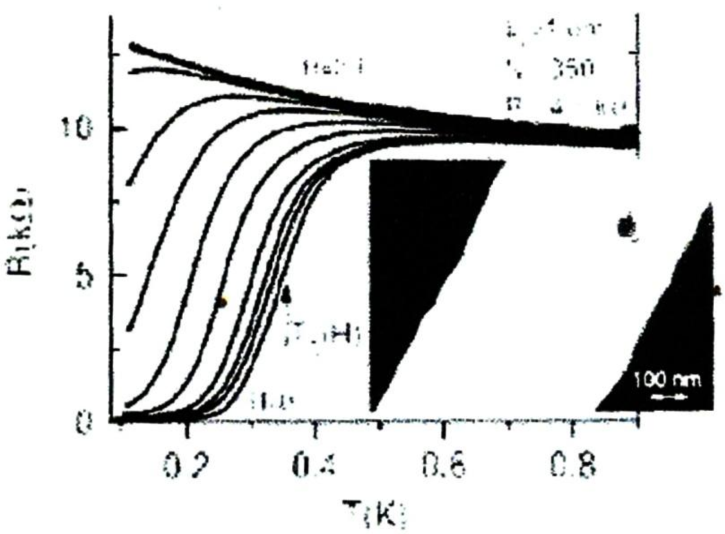

Fig. a graph between resistivity and temperature.

II. Result And Discussion

A T_c of~0.55k was measured [*]3 in ropes of SWNTs. $\Delta = 1.76K_BT_c$~85μev and a coherence length ξ=300nm was inferred.

For a mean free path length, λ of 18nm and a Fermi velocity, v_f of 8.0×10^5m\s.
A higher T_c of 15k was reported [*4] in 04nm SWNTs embedded in a zeolite Matrix, accompanied by the observation of an anisotropic Meissner effect, characteristic to one dimension.
Such an effect is very intriguing in that a strictly one-dimensional system is unstable to any fluctuations and true superconducting behaviour can also be observed at T=0k.

It was also shown that [5] superconductivity could be induced in a metallic nanotube bundle in close proximity with a superconducting electrode on a characteristic length scale, bounded by both the phase coherence length and the thermal diffusion length. Induced superconductivity was inferred through the existence of Josephson supercurrents, with a magnitude exceeding the theoretically predicted value of $\frac{\pi\Delta}{eR_N}$ R_N is the resistance of the junction. It is hypothesized that the superconducting state in the nanotube could have been stabilized by the microscopic superconductivity of the contacts, tuned by varying a backside gate voltage V_g.

Contacts were varied between high and low transparency to incident electrons.

An incident electron at the contact is converted into a cooper pair with the concomitant introduction of a reflected hole. In this case contacts are relatively opaque to the incident current.

In I-V characteristics with electron-electron interaction lead to non- superconducting state. The superconducting behaviour shows at low temperature.

In our theoretically derived formula eqn.(7) consists of relaxation time, c is to be measured experimentally. In earlier result relaxation time was not considered. It might be merged with some constant. More- over, coulomb interaction have also been neglected.

III. Conclusion

When there is interaction between electro –electron, the relaxation time τ decreases.it tends to produce larger resistivity. If weak interaction be managed so that the Fermi velocity increases. Through this way the resistivity tends to decrease and leads to superconducting behaviour.

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