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Measurement of resistance at low temperatures

Anupam Srivastava and Atul Shukla

Deptt. of Physics and Electronics, Dr. Rammanohar Lohiya Avadh University, Faizabad(U.P.), India

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ABSTRACT

The resistance of superconductor has to be measured at different temperatures. This resistance, being very low, requires 4-wore measurement technique to eliminate lead resistance. Four electrical contacts were made in a line on the surface of the specimen. The current was passed through the two outer connections and voltages measured at two inner points of contact. The voltage measurement was taken for two opposite directions of current and then averaged so as to cancel any thermal effects the temperature was measured by chromel-alumel thermocouple. The sample, in a pallet form was mounted on a Cu sheet and in thermal contact with it. One end of thermocouple was attached to the Cu sheet. The sample assembly was kept in a glass tube which in turn was cooled in a Dewar flask. Dewar flask was half filled with liq. N2 so that a thermal gradient sets up in the space above liquid nitrogen. The temperature of the sample was varied by changing the position of it in this space.

Keywords: Superconductor, thermocouple, resistance, Dewar flask.

INTRODUCTION

The resistance of superconducting sample is typically few ohms to ideally zero ohm. Therefore low values of resistance require 4-wire measurement technique to eliminate lead resistance which mars the low resistance measurements in 2-probe method [1].

Errors from thermally induced voltages appearing due to formation of thermocouple at the point of contact of electrical leads with sample can still cause errors in the measurement loop. Some control of thermal gradient is possible if cold trap can be used before taking the measurements.

The use of a.c. signal for resistance measurement may be useful in rejecting thermal voltages which are d.c., but then stray inductance and capacitance can cause errors in system. We used 4-probe quasi d.c. technique. Two measurements of voltage were taken by reversing the current direction manually after few seconds' interval and the amplitudes of the measured voltages were averaged. Actually the reading should be noted at equilibrium temperature; but in real systems, one rarely waits for temperature to attain full equilibrium, hence connections to the sample (other connections can be made using Cu wire only) will inevitably cause a thermocouple to form. If the temperature difference of the two thermocouples (at two points of contact) does not change during the two voltage measurements, the thermal voltage will remain cancelled in quasi d.c. technique, but as already said above the voltages do not completely cancel and an error term enters in the calculation for resistance. The error term is a function of the change in temperature difference between the two thermocouples over time. This error term can be limited by making sure that voltage readings are taken close together in a small time interval this time interval can also be kept to a very small fraction of the sample cooling ratio by proper design of cryostat and using cold trap.

2. Design of the system: 4-probe quasi
d.c. method for resistance measurement was used. In this method 4-probes are attached at four points in a line on the sample surface. Current is passed between two outer contact points and the voltage is measured between the other two points. Resistance is calculated using equation R=V/I. Cryostat was designed for cooling the sample well below Tc of the material. Details of design of the system and experimental procedure are discussed below:

(i)

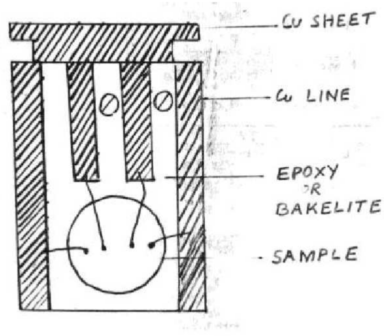

FIG.1. SAMPLE MOUNTING
(EXAGGERATED VIEW)

unting: The sample was mounted as shown in fig.1.

A copper coated bakelite sheet (epoxy resin can also be used) was take and cut to the size (18x40 cm2) and unwanted Cu was etched away after making ghe desired pattern with paint. A portion of bakelite was removed for sample mounting and the bakelite sheet was mounted on a 2mm thick Cu sheet with screws. The sample was mouned on Cu sheet with electrical insulation in between (Cu sheet makes a good thermal contact with the sample). The connections with the Cu lines were made with bare Cu wires using silver paint. And again the connections were taken out from other ends of Cu lines for passing current and voltage measurement. Chromel-alumel thermocouple was used for sample temperature measurement. One end of thermocouple was attached onto the rear Cu sheet and the other end was kept at room temperature. The whole mounting assembly was pushed inside the Pyrex glass tube of 60 cm length and connections were taken out.

(ii) Cryostat design: Dewar flask of 280x(30)2 mm2 capacity was taken for storing leq. N2. A flange made of Perspex sheet was fixed to the cryostat with neoprene o-ring in a groove to isolate it from atmosphere. A groove of size of flask dia. And 6mm thickness was cut in the bottom flange and attached permanently to the mouth of the flask with araldite. A hole of 32 dia. was made and a quick coupling made of brass attached to the top flange for holding the glass tube (used for sample mouning. The top and bottom flanges brought together with the neoprene o-ring in between with screws. A thin glass tube was also provided to connect the flask to the rotary pump for evacuation in order to get temperature down to below 770K.

MATERIALS AND METHODS

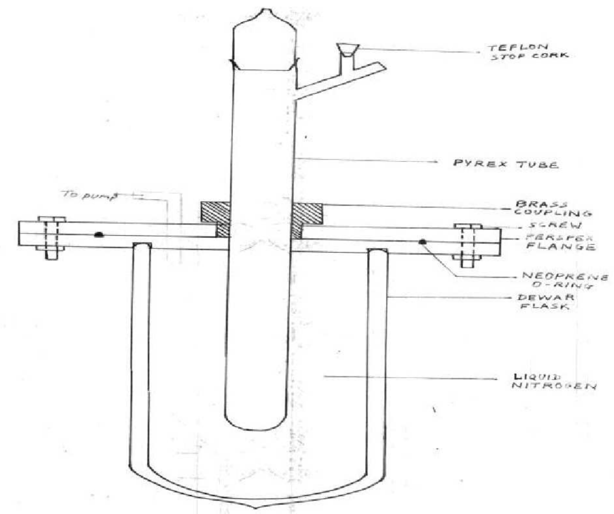

FIG.2. SET UP FOR SAMPLE MOUNTING IN FOUR PROBE METHOD

The sample was mounted and kept inside the glass tube. This tube is closed with sop cork to isolate it from atmosphere. D.C. current of 10 mA value was passed between two outer points on the sample surface and voltage readings were taken for two opposite directions of current flow on 5 ½ digit Keithley voltmeter.

The glass tube was pushed inside Dewar flask through the flexible brass coupling and the measurement of the voltages at constant current taken from room temperature to 500K by pushing the tube further down gradually with the help of quick coupling (of brass) as shown in fig.2.

The low temperature (< 770K) was attained by evacuating Dewar flask by rotary pump.

RESULTS AND DISCUSSION

A superconducting sample

Bi2Ca1.5Sr1.2Cu2O6+ was taken and a graph of Resistance vs temperature was plotted (fig. 3.).

Thermocouple readings are directly plotted on x-axis. The critical temperature comes out to be 90)K. Thermocouple readings can be converted to temperature readings using standard conversion tables and correction factor added if the other end of thermocouple is kept at room temperature.

Because the removal of gases above liq. N2 level lowers down boiling point of it ad thus temperature below 770K can be attained. Instead of pushing down or pulling up the tube for changing the temperature, a heater can be used but it will increase evaporation rate and hence the consumption of liq. N2.

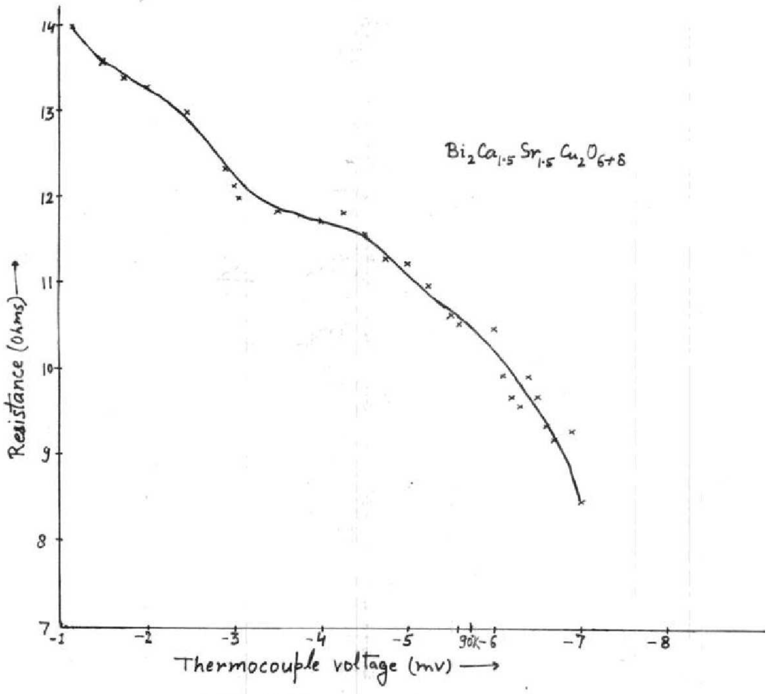

FIGURE 3.

CONCLUSION

In the present system, Data Acquisition System can be used [2]. The graph R vs T is shown in fig. 3. which does not show sharp transition at Tc. This indicates that the sample is not pure. Also, because the sample was not kept in vacuum, therefore condensation due to moisture on sample surface prohibits proper measurements. It has also been thought that if the sample has been used several times, the repeated cycles of heating and cooling may spoil the property of superconductor but it is not evident yet.

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