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Cryostat for Measurement of Thermal Conductivity, Electrical Resistivity and Thermoelectric Power

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Abstract: *A universal double wall cryostat is design for simultaneous measuring thermal conductivity, electrical resistivity and thermoelectric power of superconducting material. The thermal conductivity, electrical resistivity and thermoelectric power measured in the temperature range from 77 K to 300 K for sample of a superconducting material is described. The intension behind to use a double wall cryostat to check out the evaporation rate and amount of cryogen required for the cryostat by total heat loss.*

Keywords—Cryostat for Thermal conductivity, Electric resistivity, Thermoelectric power .

I. INTRODUCTION

The simultaneous study of transport phenomena in the presence of low temperature deformation of metals and alloys gives important information about the scattering of phonons and electrons at new scattering centers created on deformation. There are several problems in the simultaneous measuring of thermal conductivity, electrical resistivity and thermoelectric power which one has to solve in order to be sure that the results obtained are correct: (i) the temperature of two ends of the sample has to be the same and should not vary during the experiment; (ii) the sample has to be part of an electrical chain for precision measuring of its resistivity; (iii) there should be high vacuum in the space around the sample; (iv) both ends of the sample have to be mechanically stabilized, so that the good thermal and electrical contacts remain unchanged during deformation (v) evaporation rate should be minimum. Section 2 discusses the description of experiment apparatus used for measurement of this three properties for the cuprates. Section 5 comprise of results and discussion based on quality analysis. Section 6 concludes the paper.

II. Description of Experiment Apparatus

The investigation of the thermoelectric power, thermal conductivity, electrical resistivity of superconducting material can yield valuable information about their electronic and structural properties. Good thermoelectric can convert heat directly into electrical energy with a reasonable efficiency provided a substantial temperature gradient exists and the material has a high thermoelectric figure of merit (ZT). For efficient high temperature power generation, good thermoelectric materials with large ZT at high temperature are highly desirable. It is essential to evaluate and therefore measure the following key transport parameters: the Seeback coefficient, electrical resistivity, and thermal conductivity. In any case, the measurement should be done with high accuracy and over a wide range of temperatures. Techniques to measure transport properties at low temperature are described in the literature, [1 – 5]. On the contrary fewer papers are available dealing with high temperature transport property measurements. Almost two decades ago Wood *et al.* [6] developed an apparatus for the Seeback coefficient measurement. A brief mention of the experimental technique also appears only occasionally in research papers dealing with high temperature transport studies [7 - 12]. In this paper we describe an apparatus that was setup in our laboratory to measure the Seeback coefficient at temperatures range from 77 K to 300 K.

III. Experimental Procedure

The schematic diagram is shown in figure-1. We have solved above stated problems in the following way: both ends of the sample are firmly attached and soldered to two massive copper blocks and having the temperature of the liquids in two Vessel (nitrogen or oxygen), in order to realize thermal, electrical and mechanical contacts. The liquids in the two Vessel are boiling under the same pressure since their vapours are simultaneously pumped out via the interconnected glass tubes. The distance between the levels of the liquids is kept constant using a bellows system for raising the outer Dewar, and a system for measuring the level of liquids. This distance must be equal to the length of the sample (superconducting material), which in our case was of the order of 7-8 cm. These precautions are necessary in order to ensure the same hydrostatic pressure for both ends of the sample. The flange is fixed and coupled to another flange with bolts passing through insulating rings and an insulating spacer ring made of the synthetic material whose mechanical properties are suitable, insulate the two parts of cryostat from each other. The thickness of the insulating spacer ring depends on the thickness of rubber packing. The dimensions of the stainless-steel tubes are determined by the requirement that their upper ends have to be at room temperature, and the external tube has to be subjected to the stress. The suitable thickness in our case was 1 mm for internal and 2 mm for external tubes. The connection of the sample to the electrical chain can be realized by flanges.

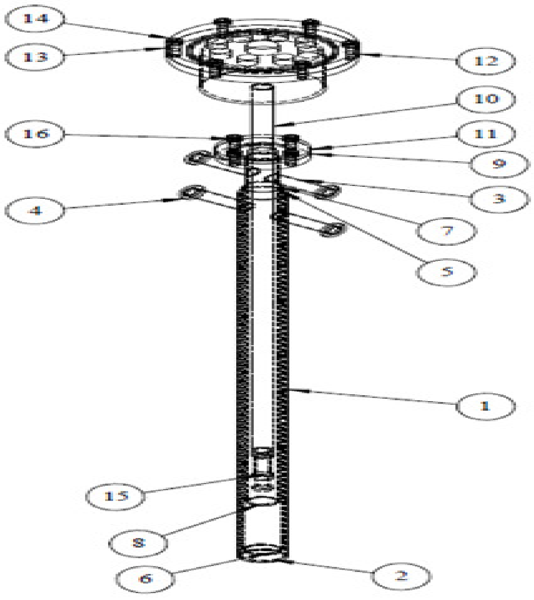
After putting cryostat in cryo vessel the valves are closed for pumping out its vapour. The variation of temperature is carried out by varying the speed of pumping out vapour from the common volume above the liquids in the Dewars. The female copper screw the cylindrical block and the bellows of the internal Dewar make thermal contact possible, and the variation of the length of the samples (of about & 7 mm). After the sample is fit the cover is tin soldered and the volume around the sample is evacuated through the tube. The temperature gradient from the middle to both ends of the sample can be created by electrical current through the sample (the magnitude of the current depends on the sample and is of the order of a few amps), or by a heater fixed in the middle of the sample. In our case the temperature difference between the middle and the ends was of the order of 0.5-2 K for different specimens and was measured using Pt thermometers or a differential constantan /copper-constantan thermocouple. The pumping out of vapour from the two refrigerant baths may be controlled by two valves on each of the tubes so that a suitable (better than if using of heaters into the baths) compensation of the superheating of the order of one tenth of a degree is possible (better than using heaters into the baths), by the creation of an almost negligible difference of the vapour pressure in two baths. Thermal changes of the two ends of the specimen are also partly smoothed by thermal inertia of the copper blocks, and in this way the temperature difference between the ends of the sample was not larger than 0.01 K, which is convenient for performing the experiment.

IV. Method of data acquisition

To begin with the base temperature is stabilized at the temperature of interest and small amount of power is applied to the top of copper disc using the heater attached to it (typically 20 mW to 200 mW depending on the temperature and the thermal conductance of the sample). The temperature oh the top copper disc increase steadily and consequently a small voltage will be developed across the hot and cold end. The temperature difference was typically 0.5 K to 5 K depending on the temperature. If the heater power is sufficient small so that the base temperature does not drift or ΔT/T is small the curve back in the reverse direction if the system is allowed to relax by switching off the heater power. The slope of the straight line thus traced is used to find out the seeback coefficient. In many situations we find that an acceptable straight line is not obtained or the heating or cooling curve shows hysteresis. We found that such situation can come from the following reason.

(1) Base temperature is not properly controlled ;
(2) ΔT is to small (typically ΔT/T < 1% gives problem)
(3) Bed thermal contact between the sample and copper disc and also between thermocouple junctions and copper disc.Widely different equilibration times for the sample and the thermocouple gives rise to hysteresis behaviour if the heating rate is too fast compared to the larger of the time constants.

V. Figure of Experimental set-up



VI. Conclusion

We have described here a simple apparatus of moderate to good accuracy for measuring thermal conductivity, electrical resistivity and thermoelectric power of superconducting material in the range of 77 K to 300 K. The apparatus is simple to use and easily accessible to microprocessor data acquisition . The necessary detail have been given hare and or further detail the authors can be contacted.

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