A new superconducting reference device for thermometry below 1000 mK

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Abstract

To provide a means for dissemination of a new temperature scale below 0.65 K, a device is being developed consisting of a number of superconducting reference points, the SRD1000. In comparison with the former SRM768 of NIST, the poisonous Be has been omitted, and IrRh alloys are introduced to fill in the gap between 15 mK and 100 mK. At the high temperatures Al and Zn are used to provide overlap with ITS-90. A new detection system for the transitions was developed consisting of planar microcoil systems with dedicated electronics. A prototype of the sensor has been constructed and ten materials have been selected to be included in the sensor. For 8 materials good results have been obtained and transition temperatures can be defined with an accuracy of better than 0.5 %.

Keywords: Thermometry; Superconducting Reference Points.

1. Introduction

Research has been carried out on the development of a new superconducting reference device. The device uses the normal to superconducting transition of various materials to establish temperature reference points between 15 mK and 1.2 K. When calibrated against a ^{3}He melting curve thermometer this device enables dissemination of a future ultra-low temperature scale. A prototype SRD1000 is currently being developed as part of a European project (SMT4-CT96-2052). The technique used to detect the superconducting transitions is based on the familiar principle of exclusion of flux in the superconducting state. The change of magnetization is detected by a planar microcoil system, realized by a thin film niobium structure on a silicon wafer substrate. A dedicated phase-sensitive detector has been developed to detect the change in mutual inductance. Due to the miniaturization of the coils a total of ten materials can

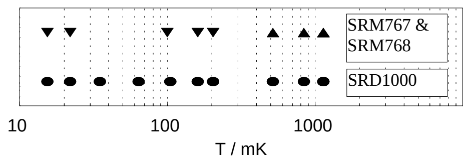

Fig. 1. Superconducting reference points selected for inclusion in the SRD1000 sensor.

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Table 1
Results for SRD1000 reference points

Material	T_c mK	Width mK	Estimated accuracy % of T_c
W	15	x	x
$Ir_{73}Rh_{27}$	22	x	x
$Ir_{80}Rh_{20}$	35	0.9	0.32
$Ir_{92}Rh_{08}$	61	0.5	0.10
Ir	106	1.5	0.18
$AuAl_2$	160	0.3	0.02
$AuIn_2$	208	0.4	0.02
Cd	530	3.5	0.08
Zn	850	3	0.04
Al	1100	10	0.11

x : Transition not yet observed with the present prototype

now be included in one, self-contained sensor.

The SRD1000 sensor is contained within a Cryoperm 10 [1] magnetic shield and a Nb superconducting shield, to prevent shifts of T_c due to magnetic flux. Experiments have shown that the residual field at the location of the samples is below $0.5\,\mu$T, leading to a maximum shift of T_c of $70\,\mu$K.

2. Selected materials and results

Seven out of ten selected materials for the SRD1000 have been used in the former SRM767 [2] and SRM768 [3] devices (see figure 1). Research was carried out to establish new reference points between the tungsten ($T_c = 15\,$mK) point and the iridium ($T_c = 106\,$mK) point. Good results have been obtained with alloys of iridium and rhodium, a material that shows a superconducting transition dependent on composition. The general T_c vs composition relation is described in ref. [4].

The superconducting transitions of over 40 samples have been measured. T_c is defined at the midpoint of the transition and the width W is defined as the temperature interval in which the central 80 % of the transition occurs. Assuming that the actual shape of the transition can be resolved to within 10 % of the total mutual inductance change associated with the transition, it is estimated that T_c can be defined with a relative accuracy of $\frac{(W/8)}{T_c}$.

In table 1 the best results are given for each material, as measured with the prototype SRD1000 sensor. The tungsten and the $Ir_{73}Rh_{27}$ point have not yet been realized. Experiments on reproducibility upon thermal cycling still have to be performed, but experience with the SRM767 and SRM768 devices has shown that reproducibility of order 0.1 mK is possible using such superconducting reference points.

3. Conclusions

Research has been carried out on a new superconducting reference device for use between 15 mK and 1.2 K. Ten reference materials have been selected for the first prototype, and for eight materials high quality transitions have been obtained, that can be used to establish reference points with an estimated accuracy of better than 0.5 %. The superconducting transitions of the tungsten and $Ir_{73}Rh_{27}$ samples have not yet been observed with the present prototype sensor.

Acknowledgement

We would like to thank Dr. R.J. Soulen for giving us several useful samples and materials, and Dr. D. Hechtfischer (PTB) for his suggestion to use IrRh alloys as reference points.

References

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