SRD1000: A superconductive reference device for thermometry below 1 K

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Abstract

A Superconductive Reference Device (SRD1000), providing 10 reference points in the temperature range 10 mK - 1 K with dedicated measurement electronics, has been developed and tested to provide direct traceability to the new Provisional Low Temperature Scale (PLTS-2000). We report on the repeatability of the transition temperatures of samples of Ir_xRh_{100-x} alloys (with transition temperatures between 20 and 100 mK) and some single crystals (Cd, Zn, $AuIn_2$, $AuAl_2$ and W).

Key words: thermometry; fixed points; superconductive reference device; PLTS-2000

1. Introduction

The extension of the International Temperature Scale ITS-90 with the Provisional Low Temperature Scale, PLTS-2000 [1], which ranges from 0.9 mK to 1 K, has left the scientific community with the issue of developing accompanying devices to disseminate this scale. The exploitation of very narrow and highly reproducible superconductive transitions as fixed points in the milliKelvin region offers an excellent method to check and calibrate other thermometers. Since the production of the SRM 767 [2] and SRM 768 [3] (by National Institute of Standards and Technology, NIST, USA) was discontinued we have started to develop and produce a new device, the SRD1000 [4–6]. Using high purity materials as well as IrRh-alloys, the first prototypes have been realized. The prototypes are being calibrated on the PLTS-2000 by the NMi van Swinden Laboratorium in Delft, The Netherlands. Other European Metrological Institutes and partners of the European Project "Ultra-Low Temperature Dissemination (ULT)" will evaluate and compare them with their realization of the PLTS-2000 afterwards.

2. Testing and selection of the reference materials

In the course of several years batches of various reference materials have been prepared and tested. These tests covered properties like transition temperature, width of the transition, accuracy and reproducibility. The need to test every batch of material separately follows from the fact that the temperature T_c and the width of the transition are highly sensitive to stress, impurities and crystal defects. Consequently each prototype has nominal values for the T_c but they are not identical and need to be calibrated independently. For all selected materials the superconductive transition has been observed with a repeatability ΔT_c which varied from less than 0.22 % for $Ir_{92}Rh_{08}$ to less than 0.02

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% for $AuIn_2$ (ΔT_c is defined as 12.5% of the transition width, assuming that the determination uncertainty of the transition midpoint is 10% of the voltage signal). Figs. 1 and 2 show the transitions observed for $Ir_{80}Rh_{20}$ and Be, respectively. The application of IrRh alloys, which have a transition temperature between 20 mK and 100 mK depending on the composition, resulted in a device that contains as many reference points as the SRM 767 and the SRM 768 together, homogeneously distributed along the temperature range from 10 mK to 1 K.

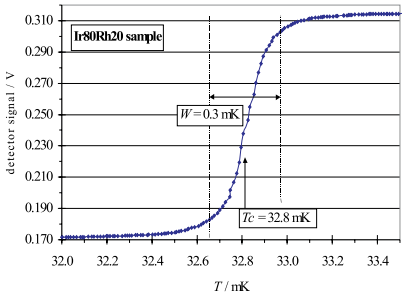

Fig. 1. Transition of IrRh8020 sample

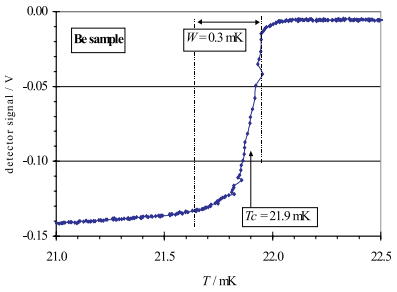

Fig. 2. Transition of Be sample

3. The SRD1000 detection system

The reference materials are attached on two planar mutual inductance detector systems. These are supported by a copper holder and surrounded by shielding against magnetic fields. The dimensions of the sensor are less than 10 mm in diameter and 50 mm in length. The setup may contain up to 12 reference materials and an additional CMN thermometer. By inclusion of an additional coil a check for (the axial component of) residual magnetic fields has been performed, indicating a shift in the transition temperatures of less than 0.05 mK. The electronics [4] provides a high stability DC output signal proportional to the mutual inductance signal. The output signal has a staircase-like behavior when cooling through the various transitions. Figure 3

Fig. 3. Front panel of the SRD1000 electronics

shows the front panel of the main unit of the electronics.

4. Conclusion

A superconductive reference device SRD1000 has been developed. Careful preparation, testing and evaluation of the samples has led to the selection of 10 materials whose batches matched the metrological requirements for reference temperature on the PLTS-2000. The results show that the SRD1000 enables accurate measurement in the temperature range between 15 mK and 1 K. At the moment the first three prototypes of the SRD1000 are assembled and are being calibrated by the NMi. After calibration they will be sent to the European partners to allow them to evaluate the relevant properties of the prototypes. Production will be started after this evaluation. Inclusion of a magnetic thermometer (CMN) is still under consideration.

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