SRD1000, a 13-point reference device for precision thermometry below 8 K

W. A. Bosch
HDL
P.O. Box 691, 2300 AR Leiden
The Netherlands

O. W. B. Benningshof
R. Jochemsen
O. Usenko
LION, Leiden University
P.O. Box 9504, 2300 RA Leiden
The Netherlands

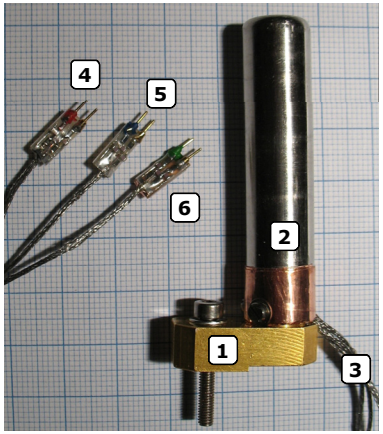
Introduction

The SRD1000 device offers calibrated reference points for thermometry on the PLTS-2000 and ITS-90, based on the superconductive transitions of samples of various materials. Three additional points (In, V, Pb) were tested to cover the range 3 K to 8 K. A CMN1000 thermometer was developed to support continuous thermometry alongside the SRD1000. The MIDS20x type of detection electronics is configured to match the signal parameters of both types of sensors.

SRD1000 superconductive reference device

Constructional details:

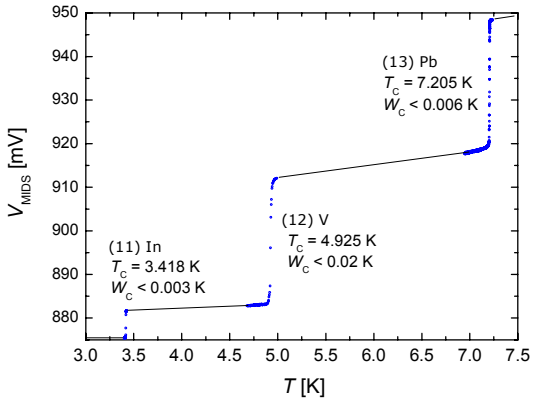
[1] thermal plate / mounting adapter;
[2] sensor body with Cryoperm / Nb magnetic shielding;
[3] shielded twisted pair leads;
[4,5,6] connections with rf-filters of the primary, secondary and compensation coils.



#	material	T_C [mK]	W_C [mK]	U_C [%]
1	W	15	< 0.2	< 0.26
2	Be	21	< 0.3	< 0.28
3	$Ir_{80}Rh_{20}$	30	< 0.5	< 0.34
4	$Ir_{92}Rh_{08}$	65	< 0.5	< 0.16
5	Ir	98	< 0.5	< 0.10
6	$AuAl_2$	145	< 0.5	< 0.06
7	$AuIn_2$	208	< 1	< 0.10
8	Cd	520	< 1	< 0.04
9	Zn	850	< 2	< 0.05
10	Al	1180	< 4	< 0.06
11	In	3400	< 4	< 0.02
12	V	4900	< 20	< 0.08
13	Pb	7200	< 6	< 0.02

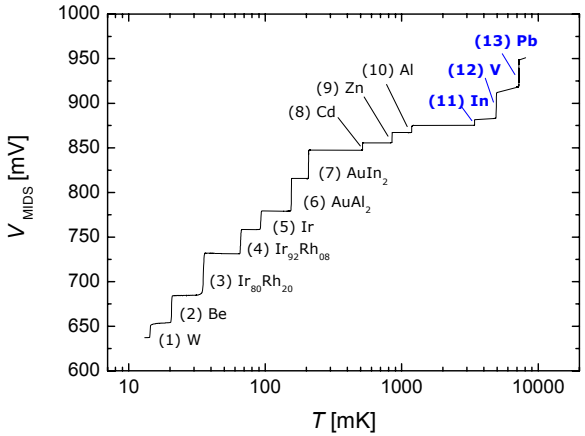
List of reference points with:
- T_C the transition temperature;
- W_C the width of the transition;
- U_C the uncertainty of the realisation of the reference point.

Measurement results additional In, V and Pb points



Output voltage V_{MIDS} of the MIDS20x electronics versus device temperature T:
- T_C and W_C of the In, V, and Pb transitions qualify to support precision thermometry;
- the slope between the points is caused by effects of the In sample and does not influence the quality of the reference points.

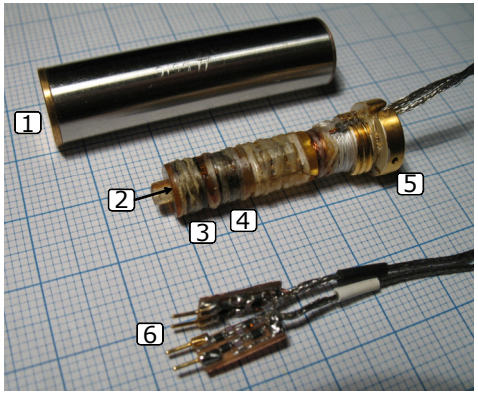
Overview of all transitions of the new 13-point reference device.



CMN1000 paramagnetic susceptibility thermometer

Constructional details:

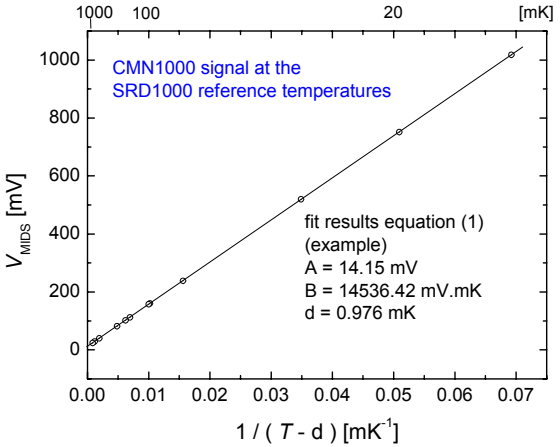
[1] protective cylinder with Nb shield;
[2] sealed capsule (ø 3 x 3 mm) with powdered cerium magnesium nitrate (CMN) sample and silver-foil thermal link;
[3] detection transformer;
[4] compensation transformer;
[5] base for mechanical and thermal connection;
[6] shielded twisted pair leads (primary and secondary coil connections) with rf-filtered terminals.



Signal characteristics:

- the susceptibility X of CMN follows the Curie-Weiss law below approximately 3 K:
  $X_{CMN} \sim C / (T - \theta)$,
  with C the Curie-constant and T the temperature; θ is related to the magnetic ordering temperature of CMN;
- the output voltage V_{MIDS} of the MIDS-20x detection electronics is proportional to the susceptibility X, so approximately:
  $V_{MIDS} (T) = A + B / (T - d)$ (1);
- constants A, B and d of (1) are related to the instrumentation and need to be calibrated for each thermometer;
- useful temperature range of the thermometer: < 10 mK - 2 K.

Measurement results thermometer characteristics



Data set V_{MIDS} versus T:

- data points fit smoothly to the simple equation (1);
- fit error $\Delta T/T$ is less than 0.5% for the range 2 K to 15 mK;
- typical values found :
  A = -100 .. 100 mV,
  B = 1.5 10^4 mV.mK,
  d = 1 mK.

Other results:

- signal to noise related resolution varies between 4 mK at 2 K, 0.2 mK at 500 mK and 10^{-4} mK at 10 mK;
- span 2 K to 10 mK is covered within one range of the MIDS20x electronics;
- (self-)heating effect is negligible down to the lowest temperatures;
- thermal relaxation time is < 5 s at 10 mK and smaller at higher temperatures;
- reproducibility with frequent warming - cooling cycles during a run is within the noise level, and better than 0.2 % after a cycle to room temperature;
- thermometer is well suited for a temperature controller down to < 10 mK;
- thermometer supports accurate thermometry between 10 mK and 2 K alongside the SRD1000 device and MIDS-20x electronics.

Acknowledgements

We would like to thank the Fine Mechanics and Electronics departments of LION for their support in preparing essential parts of the sensors and measurement electronics.
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Further information

HDL
P.O. Box 691
2300 AR Leiden, The Netherlands

Contact Wim Bosch
E-mail HDLinfo@xs4all.nl
Website hdleiden.home.xs4all.nl/srd1000

Japan representative ROCKGATE Corporation
E-mail info@rockgateco.com
Website www.rockgateco.com