

Thermodynamic temperature determinations of Co-C, Pd-C, Pt-C and Ru-C eutectic fixed points cells

K. Anhalt, J. Hartmann

Physikalisch- Technische Bundesanstalt Braunschweig und Berlin, Germany

D. Lowe, G. Machin

National Physical Laboratory, Teddington, UK

M. Sadli

CNAM- INM, Paris, France

Y. Yamada

National Metrology Institute of Japan, AIST, Tsukuba, Japan

Abstract. Thermodynamic temperatures of Co-C, Pd-C, Pt-C, and Ru-C metal-carbon fixed-point cells manufactured by CNAM-INM, NMIJ and NPL were determined by absolutely calibrated PTB filter radiometers and a radiance comparison method using an IKE LP3 radiation thermometer.

Introduction

In order to implement metal-carbon (M-C) eutectic fixed-points in thermometry and radiometry it is essential that their thermodynamic melting temperature is determined by means of absolute radiometric methods. At PTB the use of precision apertures in conjunction with absolutely calibrated filter radiometers is a well established approach for the measurement of thermodynamic temperature in the irradiance mode [1]. However an irradiance measurement involving fixed-point cells and precision apertures requires radiating cavities with a minimum aperture diameter of 8 mm, necessitating rather voluminous fixed-point cells [2]. For the determination of the fixed-point melting temperature the temperature homogeneity across the cell is critically important [3]. In the furnace systems available up to now the best temperature homogeneity is such that only cells at most 50 mm in length can be used. To keep good emissivity the apertures of the radiating cavity in the eutectic fixed point cells investigated here are 3 mm in diameter only. Since such cells can only be measured in radiance mode a radiance comparison method was developed to determine the thermodynamic temperature of the eutectic fixed-point cells.

Measurement principle

Two high-temperature furnace systems are used: one which holds the eutectic fixed-point cells and a second as a reference source of thermal radiation. The thermodynamic temperature of the reference source is determined by an irradiance measurement with filter radiometers. The thermodynamic temperature of the eutectic fixed point can be derived via a radiance comparison by means of a radiation thermometer on the basis of Planck's law of blackbody radiation.

Experimental setup

An overview of the experimental setup is given in Figure 1.

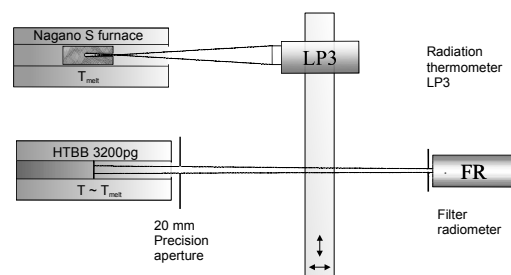


Figure 1: Experimental setup for the thermodynamic temperature measurements of M-C fixed point cells

Furnace systems PTBs high-temperature blackbody HTBB3200pg was used as the reference source of thermal radiation. The eutectic cells were placed in the NMIJ Nagano S furnace VR10-A20, a smaller variant of the Nagano M VR10-A23 described in [4].

Irradiance measurement The high- temperature furnace HTBB3200pg was operated at a temperature close to the melting temperature of the fixed points in question. A 20 mm precision aperture in front of the HTBB defines the radiating area for measurements with a filter radiometer positioned at about 1110 mm from this aperture. Two narrow- bandwidth interference- filter radiometers with center wavelengths around 676 nm and 800 nm have been used to determine the thermodynamic temperature of the HTBB. The spectral irradiance responsivity of the filter radiometers has been calibrated traceable to the cryogenic radiometer of the PTB [5].

Radiance comparison An LP3 radiation thermometer was positioned for a radiance measurement 700 mm in front of the HTBB and focused onto its entrance such that both LP3 and filter radiometer see an equivalent area at the bottom of the HTBBs cavity. For the radiance measurement at the metal-carbon eutectic melting temperature the LP3 was repositioned in front of the Nagano S furnace at a distance of 700 mm from the aperture of the fixed- point cell, and

aligned to the center of this aperture. Four melts and freezes were initiated with temperature steps of +30, +20, +10, +30.

Stability measurements The radiance and irradiance measurements of the HTBB were repeated with both filter radiometer and radiation thermometer after the M-C cell measurement to check the stability of the LP3.

SSE For assessing the size-of-source corrections horizontal scans of the spectral radiance across the aperture of the HTBB and the fixed-point cell in the Nagano S-furnace were taken. This procedure was applied during 12 days for Co-C, Pd-C, Pt-C and Ru-C eutectic fixed-point cells produced by NPL, CNAM-INM, and NMIJ [6].

Uncertainties Uncertainty components in the assignment of the thermodynamic melting temperatures are the uncertainties in the thermodynamic temperature of the HTBB and in the radiance comparison via the radiation thermometer LP3. Uncertainties in emissivities are included.

Results

In each case the average of four measurements was corrected for SSE and drift. The resulting thermodynamic melting temperatures for Co-C, Pd-C, Pt-C and Ru-C are presented in Table 1.

		<i>T</i> / K	<i>U</i> / K, <i>k</i> =2
Ru-C	NMIJ	2227.44	0.40
Ru-C	NPL	2227.22	0.39
Ru-C	BNM	2226.96	0.37
Pt-C	NMIJ	2011.88	0.33
Pt-C	NPL	2011.74	0.32
Pt-C	BNM	2011.74	0.30
Pd-C	NMIJ	1765.19	0.26
Pd-C	NPL	1765.07	0.27
Pd-C	BNM	1765.00	0.26
Co-C	NMIJ	1597.30	0.23
Co-C	NPL	1597.16	0.22
Co-C	BNM	1597.23	0.21

Table 1: Thermodynamic melting temperatures of Co-C, Pd-C, Pt-C and Ru-C eutectic fixed-point cells manufactured by NPL, BNM-INM and NMIJ

Discussion

The results of the thermodynamic-temperature measurements of the 12 eutectic fixed-point cells can be compared with results of a previous study on the differences in radiance temperature of the melting points of all cells and with results of a comparison of local thermodynamic temperature scales for a subset of the fixed point cells.

Temperature differences The same eutectic fixed point cells were investigated in a previous study with regard to differences in radiance melting temperature [6]. The results are confirmed by this work: The largest temperature

differences between cells are seen for Pd-C and Ru-C; the cells produced by the NMIJ always showed the highest melting temperatures. Keeping in mind the complexity of the thermodynamic temperature determination this is a remarkable result, which shows the general applicability of the presented technique as well as the long- and mid-term stability of the setup.

Thermodynamic temperature scale 9 months prior to the PTB measurements described here the NPL fixed-points thermodynamic melting temperatures were determined at NIST using a Thermo Gage furnace and an absolutely calibrated radiation thermometer [7]. The agreement between these data and the measurement presented here is better than 500 mK over the whole temperature range and just within the combined extended uncertainty (*k*=2).

Conclusion

Thermodynamic temperatures during the melt of Co-C, Pd-C, Pt-C, and Ru-C eutectic fixed points were determined with uncertainties below 400 mK at temperatures up to 2250 K. The excellent agreement with previous measurements shows the applicability of the described technique. Furthermore it demonstrates the potential of eutectic metal-carbon systems in metrology. A thermodynamic-temperature scale comparison involving detectors would be far more time consuming and more delicate, since it involves sending and handling sensitive optical equipment.

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