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The results of measuring the emissivity of a number of metals of the copper subgroup at transition temperatures through the melting point

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The emissivity of copper, silver and gold has been experimentally determined in the temperature range, including the solid–liquid phase transition. The measurement error ranged from 5 to 8%.

Keywords: experimental cell, thermal radiation, phase transition, the metal under study.

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Introduction

Knowledge of heat radiation, its relation with the structure is necessary for the development and design of many technological processes, heat engineering calculations in the metallurgical industry. This information is also relevant and important for melt temperature control in radiation non-contact pyrometry, in particular, plasma and laser cladding technologies, where non-contact pyrometry methods are the only way to control temperature. In addition, the thermal radiation of metals carries valuable information about their structure and behavior [1–5].

Quantitative calculations of radiation heat transfer are impossible without knowledge of the radiation characteristics of structural materials, in solid and liquid states. The need for such data is increasing due to the fact that the intensification of technological processes is carried out by increasing operating parameters — temperature and pressure. Despite the great successes achieved in the study of the radiation properties of substances [6], the methodology of their calculations for solids is far from perfect.

Modern theoretical methods for finding the radiation properties of substances, which have recently become widespread, have a fairly good agreement with experimental data [7]. However, the most reliable source of knowledge about the radiation properties of solid and liquid metals, including the phase transition, is experiment.

This paper presents experimental determination at temperatures of transition through the melting point of the blackness degrees of chemical elements of group XI of the periodic table — a subgroup of copper. Copper (Cu), silver (Ag) and gold (Au) were investigated on the developed stand by the authors of this paper.

The experimental studies used the absolute radiation method for measuring the blackness degree. A radiometer with apertures determining the solid angle of vision was used. Metals were measured in solid and liquid phases, in an inert gas atmosphere or vacuum.

The main elements of the experimental cell are: a radiometer, a resistive heater with the substance under study, and a model of an absolute black body (ABB) (Fig. 1).

A detailed description of the experimental unit, the cell, the gradient measurements, and the methodology of the experiment were outlined in [8].

The experiment error was estimated according to the existing methodology, including the calculation of the permissible basic error in the measurement of thermal EMF for the two extreme cases (400 and 2000 K). The statistics

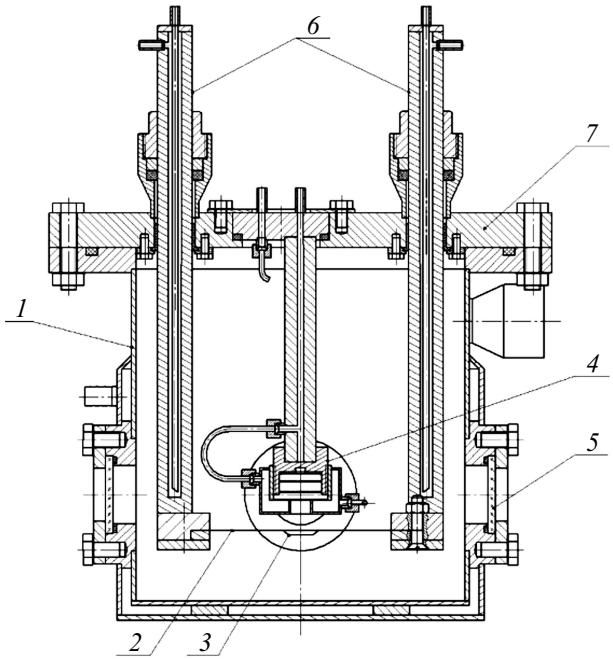

Figure 1. Experimental cell design: *1* — housing with thermostatically controlled jacket, *2* —resistive heater, *3* — metal to be tested, *4* - radiometer, *5* — porthole, *6* —cooled current leads, *7* — cover.

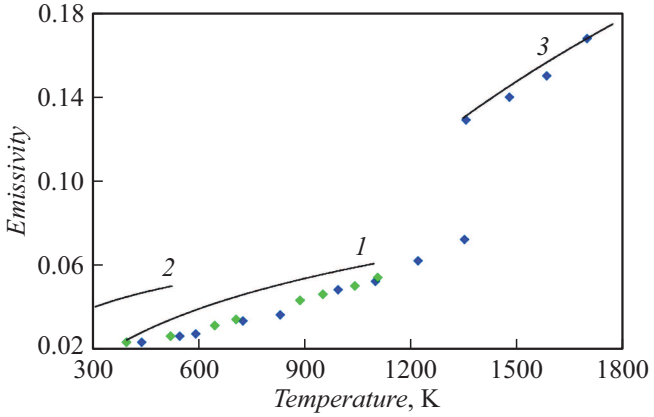

Figure 2. The relation between the blackness degree of copper and temperature: *1* — [1], *2* [6], *3* — [9] green rhombs (in on-line version) — [8], blue rhombs (in on-line version) — data from the authors of this paper.

are multiples of ten measurements for each case. The absolute systematic error was 0.3%. The total relative error of measurements according to the experiment was 5%. Thus, the maximum measurement error ranged from ±5% (2000 K) to ±8% (400 K).

The reliability of the experimental unit was verified by comparing the obtained degrees of metals blackness with those available in the literature in both the solid and liquid phases.

1. Results of experimental studies

The copper blackness degrees (Fig. 2) agree well with the available measurements [1,6,8,9] in the solid and liquid states. The deviation from the recommended guide values [1] can be explained by the chemical purity of the metal under study. When copper melts, the emissivity jump is about 80%.

The magnitude of the jump in the emissivity of the phase transition was calculated by the authors with respect to the solid phase.

Silver blackness degrees (Fig. 3) agree with the available measurements in the solid state [1]. Our experiment showed that silver radiation monotonically increases with increasing temperature and at the phase transition, (solid–liquid) jumps by 68% on average and continues to increase with temperature.

Polished gold blackness degrees (Fig. 4) are in satisfactory agreement with the available measurements. The phase transition with increasing temperature gives a jump in emissivity of up to 63%. The blackness degree behavior of gold corresponds to the jump change in the emissivity of titanium subgroup metals during the solid–liquid [10] phase transition.

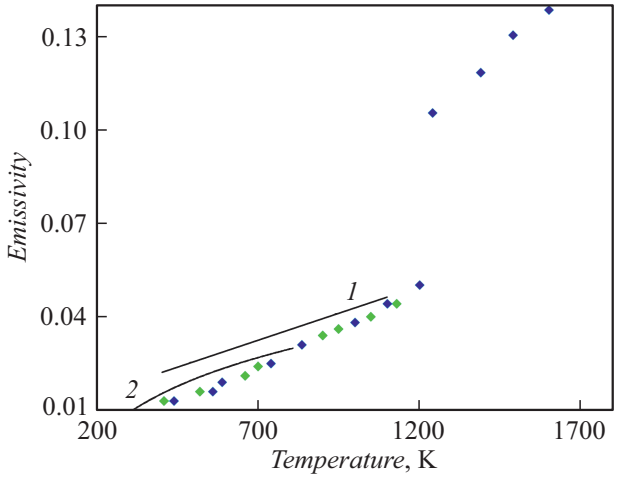

Figure 3. Dependence of silver blackness degree on temperature: *1* — jcite1, *2* — jcite6, green rhombs (in on-line version) — jcite8, blue rhombs (in on-line version) — data of the authors of this paper.

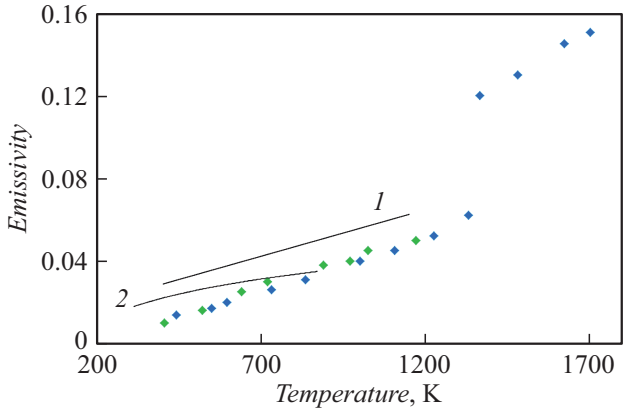

Figure 4. Dependence of gold blackness degree on temperature: *1* — jcite1, *2* — jcite6, green rhombs (in on-line version) — jcite8, blue rhombs (in on-line version) — data of the authors of this paper.

Conclusions

Experimental determination of the integral hemispherical blackness degrees of copper, silver and gold in the liquid and solid polished state phases, including the areas of their melting points, was carried out.

The studies were carried out by the absolute radiation method without focusing optics in the temperature range limited by the vapor elasticity of the studied metals.

The experimental results obtained are in satisfactory agreement with the results of reliable studies [1,6,9] within the margin of error of the experiment conducted by the authors.

Experimental determination of the blackness degrees of copper, silver, and gold showed a confident increase and jump change in emissivity during melting in the considered temperature range of the experiment.

Conflict of interest

The authors declare that they have no conflict of interest.

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