THE HEAT CAPACITY OF GRAPHITE IN THE TEMPERATURE RANGE 1750°–2850° K

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So far, the heat capacity of graphite at temperatures above 1800° K has been determined experimentally only by Rasor and McClelland [1,2]. An impulse method was used, with a measurement accuracy of ±5%, according to the authors' data. The present paper gives the results of measurements of the heat capacity of graphite in the range 1750°–2850° K in which a modulation method [3] was used, together with color pyrometry.

Spectrally pure graphite of specific weight 1.61 was made into bars of diameter 0.4–0.6 mm and length approximately 40 mm. Smaller diameters were not possible owing to the porosity of the initial material, while larger diameters would have caused a decrease in the amplitude of the temperature fluctuations and thus lowered the accuracy of the measurements. The sample was heated by 50-cycle alternating current. In the temperature range 1750°–2200° K the measurements were carried out in vacuum. At higher temperatures graphite begins to vaporize in vacuum, and therefore in the temperature range 2000°–2850° K the measurements were carried out in argon at 15–17.5 kg/cm^2. The heat capacity was calculated from the equation

$$mc = P/2\omega\theta . \qquad (1)$$

Here P is the power supplied to the sample, ω is the frequency of the current to the sample, and θ is the amplitude of the temperature fluctuations on the sample.

The mass and power were determined for a central section of the sample of length 17–19 mm, alongwhich the temperature is almost constant. This section was delimited by two tungsten potential leads of diameter 0.03 mm; the distance between them was found using a cathetometer. In [4,5] a description is given of optical methods for determining temperature fluctuations, based on the fluctuations in luminosity of the sample. In [4] the following expression is used

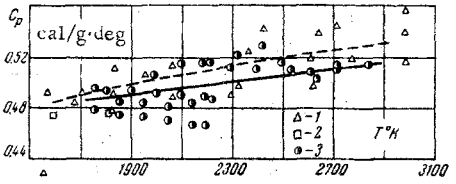
$$\theta = \frac{i}{dI/dT}. \qquad (2)$$

Here I is the photomultiplier current and i is its alternating component. The derivative of current with respect to temperature, determined experimentally, was a source of error which was especially evident at high temperatures and limited the accuracy of the experiment. In addition, the photomultiplier current increases rapidly with increasing sample temperature. The derivative of current with respect to temperature can therefore be determined only over a comparatively narrow temperature range which, in turn, limits the accuracy of the measurements.

In [5] Eq. (2) was used in a form which follows from Wien's law, when the emissivity is independent of temperature

$$\theta = \frac{i}{I}\frac{T^2}{\alpha}. \qquad (3)$$

However, as the authors themselves acknowledge, the emissivity does change appreciably with temperature and α is not constant. A similar equation was used in [2] to determine the rate of temperature change of the sample, but it was used for a model of an absolutely black body.



In the present work a method of measurement based on the color temperature is used, which allows the accuracy of the results to be increased. The essence of the method is to measure fluctuations in sample luminosity by using two different color filters (for example, red and blue). It follows from Wien's law that

$$\ln (I_1/I_2) = B - A/T. \qquad (4)$$

Here I_1 and I_2 are the constant components of the photomultiplier current and A and B are temperature-independent coefficients. Differentiation of (4) gives

$$\theta = \frac{T^2}{A}\left(\frac{i_1}{I_1} - \frac{i_2}{I_2}\right). \qquad (5)$$

Here i_1 and i_2 are the amplitudes of the fluctuations in the photomultiplier current. Use of the color temperature imposes less stringent demands on the experimental conditions, since the correction for coefficient α depends on the change in the emissivity ε with temperature, whereas the correction for coefficient A depends on the change in $\varepsilon_1/\varepsilon_2$ with temperature, which is much slower.

Graphite is gray at room temperatures [6], while its spectral emissivity is independent of temperature up to at least 2100° K [7]. Therefore in this work the color temperature was measured and it was assumed that it was the same as the true temperature of the sample.

The correction for nonmonochromaticity of the color filters in the measurement of color temperature depends on correlating the spectral characteristics of the photomultiplier and color filters. We selected filters which caused no distortion of the linear relationship (4) in the working range, whereas in [2] coefficient

α varied by about 3% in the same range. Equation (5) is valid at an arbitrary value of the constant component of the photomultiplier current. This makes it possible to work over the whole temperature range under the most favorable conditions, maintaining the optimum value of the photomultiplier current by changing the objective aperture.

The photomultiplier was calibrated with a second-class temperature-calibrated chromatic standard lamp in the range 1700°–3000° K. It was checked at 2100°–2550° K with a thin tungsten filament. The temperature was determined on the basis of the integrated emissivity of tungsten [8], corrected for the color temperature [9] and for deviation from Lambert's law [10]. These calibrations did not differ by more than 7.5° over the range of measurements. During calibration checks were made for linearity of the photomultiplier current and for reproducibility of the data for different arrangements of the optical system; it is considered that the temperature calibration is accurate to 0.5%.

Fluctuations in the sample temperature, found using Eq. (5), fell within the limits 1°–15° and increased with increasing temperature.

The results obtained for the heat capacity of graphite in the temperature range 1750°–2850° K are shown in the figure. Five samples were tested, and the average values are represented by the continuous line. Points designated by the numeral 1 represent data from [1]; points 2 are from [11]; points 3 are the present results. In view of the fact that in [1] the authors drew the average heat capacity curve above their experimental points, our curve is compared with the average curve, taken from [1], in the handbook [12], which is represented here by a broken line. As may be seen from the figure, the scatter does not exceed that in [1], and within these limits our measurements are in agreement with the previous work [1,11]. The accuracy of the measurements in ±5%.

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