Experimental study of thermophysical properties of W-Re alloy at high temperatures

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Abstract. This article presents data on thermophysical properties of a tungsten-rhenium alloy W-Re (27 at. % of Re) in the temperature range of 2400–3100 K. Data on the thermal expansion and specific electrical resistance of this substance at premelting region are obtained, and the emission spectra of the alloy are obtained at high temperatures.

1. Introduction
There are no experimental data in the literature on the thermal expansion coefficient of the W-Re (27 at. % of Re) alloy in the temperature range close to the melting point at present. The thermoradiation properties of this material at high temperatures, for example, the spectral emissivity, are also unknown. Meanwhile, such data are necessary for its use in high-temperature engineering, as well as for the construction of wide-range equations of state of this material [1–3]. There are high-temperature data for alloys of close [4] and identical [5] stoichiometry in the literature, which allows a comparison with the experimental data obtained, but data for some properties for temperatures above 2800 K are not available.

In this work we used the experimental technique for investigation of thermophysical properties of refractory materials in the high-temperature region up to the melting point at high pressures, as described, for example, in [6]. Using this method, an experimental determination of the thermal expansion coefficient, electrical resistivity and emission spectra at premelting region of this alloy have been carried out.

2. Experimental method
A tungsten-rhenium industrial alloy W-Re (27 at. % of Re) was investigated. The high heating rate made it possible to measure thermal expansion up to the melting temperature without changing the shape of the samples. An installation that allows measurements of the thermal expansion of refractory materials is described in detail, for example, in [7]. The method for measuring thermoradiation properties is similar to that described in [8].

The samples were heated in about 1–2 ms to the melting temperature, which was confirmed by the presence of an inclined melting plate on the thermograms. The brightness temperature of the beginning of the melting plateau was about 3000 K. During the experiments the geometrical dimensions of the sample were measured, so the coefficient of thermal expansion of the material under study can be calculated later. The calculation of the true temperature was carried out...
using available literature data on the temperature dependence of the electrical resistivity on
temperature for this alloy [5].

In addition, when the heating pulse was turned off, a spectrometer with exposure time of
1.05 ms was launched. One needs to notice, that both the temperature and the optical properties
of this alloy remain constant throughout the work of the spectrometer. In the case when the
heating of the sample did not stop until its transition into the liquid phase, the pyrometer fixed
the melting plateau, which had a pronounced slope, which is caused by the composition of the
alloy under study and the difference in the melting temperature of the components of the alloy.
Typical thermograms of the inclined melting plateaus are presented in figure 1.

3. Experimental data on thermal expansion
The samples had a form of parallelepiped with dimensions of about 0.1 × 1 × 10 mm³, 14
experiments were conducted. The experiments were carried out in high purity argon atmosphere
at a static pressure of about 85 bars.

The experimental data obtained indicate that the thermal expansion coefficient of the W-Re-27
alloy in the temperature range of 2400–3100 K is close to a constant. Experimental points are
shown in figure 2. The thermal expansion coefficient (CTE) of this tungsten–rhenium alloy in
this temperature range can be taken equal to α = 1.3(±0.2) × 10⁻⁶ K⁻¹. A comparison with the
literature data for the alloy with a close stoichiometry [4], calculated via presented in the article
thermophysical properties, such as thermal conductivity, thermal diffusivity and heat capacity,
confirms the efficiency of the chosen method and the reliability of the data obtained.

Figure 1. Typical brightness thermograms of heating and melting of the material under study
for two wavelengths of 862 and 650 nm.
Figure 2. Experimental data on the relative linear thermal expansion of this W-Re alloy in comparison with the literature data for the alloy with similar stoichiometry [4].

4. Experimental data on thermoradiation properties
Simultaneously with the measurement of the thermal expansion of the alloy under study the emission spectra of the samples in the wavelength range of 450–795 nm were measured in experiments. Measurements were made after the end of heating when the material under study reached a predetermined brightness temperature.

The spectra of thermal radiation of the alloy under study obtained using the Avaspec-2048 spectrometer allow to calculate the true temperature of the sample after the end of heating. For this, an assumption about the weak linear spectral dependence of the emissivity of this W-Re alloy in the temperature range under study was made. When this condition is fulfilled, the true temperature of the sample in the experiment is calculated by the slope of the experimental straight line in Wien coordinates [8]. Figure 3 shows the dependence obtained for the thermal radiation of this W-Re alloy at true temperature of 2980±50 K. Thus the true temperatures, to which the sample was heated in each of the experiments, were found.

5. Conclusion
This article presents data on the measurement of the thermal expansion coefficient of the W-Re (27 at. % of Re) alloy in the temperature range of 2400–3100 K in the premelting region. In addition, the emission spectra of the alloy in this temperature range were measured.

Comparison of the experimental data on the relative thermal expansion of this W-Re alloy with the literature data for the alloy with similar stoichiometry [4] confirms the reliability of the data obtained.
Figure 3. The dependence of the expression \( \ln(\lambda^5 I) \) on \( C_2/\lambda \) for thermal radiation of this W-Re alloy at the temperature of 2980±50 K.

Acknowledgments
This work is supported by the program of fundamental research of the Presidium of the Russian Academy of Sciences No. 13 – Condensed matter and plasma at high energy densities”.

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