Experimental investigation of thermophysical properties of rhenium near its melting point

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Abstract. An experimental technique of millisecond electrical pulse heating was used for experimental investigation of Re near its melting point. Experimental data on the specific enthalpy and thermal expansion of rhenium at the temperatures close to the melting point were obtained during the experiments.

1. Introduction
Millisecond electrical pulse heating is a prominent technique for investigation of conductive refractory materials at high temperatures. Meanwhile, some properties of such materials, e.g. refractory metals and carbides are still insufficiently investigated at this region.

This work contains the experimental study of the temperature dependences of thermophysical properties of rhenium in the melting region. The properties studied include: specific enthalpy, electrical resistivity and thermal expansion of the material.

2. Experimental technique
The experimental technique consists in the fast heating of the sample to the melting temperature and higher in about 1 ms due to the volumetric heat release when a high-density electric current passes through the sample. Heating is carried out in isobaric conditions in a high-pressure chamber with a static pressure of a buffer (inert) argon gas of about 50 bar. The input energy or enthalpy change can be determined by measuring the current and the voltage drop between the potential probes in the middle of the sample.

Temperature measurements are performed by a two-channel optical pyrometer using the spectral ratio method. Thus, by measuring the surface temperature of the sample during the experiment \(T(t)\), current \(I(t)\) and voltage \(e(t)\), one can determine the dependence of the enthalpy change \(\Delta H(T)\), as well as the heat capacity \(C_p(T)\).

In addition, this setup is equipped with a spectrometer with a spectral measurement range of 240–795 nm and a minimum exposure time of about 1 ms, allowing measurement of the true temperature of the sample after stopping heating at a given temperature. Simultaneous measurement of the true temperature using a spectrometer and brightness temperatures at 650 nm and 862 nm via the pyrometer allows to determine thermodynamical temperature of the material under investigation [1].

For visual control of the sample integrity, a high-speed video camera with a resolution of 1280x1024 pixels and a typical time between frames of about 200 µs is used. It uses thermal radiation of the heated sample, which also allows one to control the uniformity of heating. This camera is also used for the thermal expansion measurements. The pictures of the heated sample allow to measure...
longitudinal geometrical size of the sample at the given temperature (4-7 pictures per experiment) and to calculate the thermal expansion coefficient at high temperatures.

A simplified scheme of the experimental setup is shown in figure 1. A detailed description of the setup is presented, for example, in [1-2].

![Figure 1. Scheme of the experimental setup.](image)

The system of photographic registration is based on a high-speed digital CCD camera "VideoSprint", implemented on a CMOS CCD sensor. The setup is also equipped with the AvantesAvaspec-2048 spectrometer with a spectral range of 240–795 nm, the exposure time is 1.05 ms. The spectrometer has a 2048 pixels linear image sensor and fast 16-bit adc.

3. Experimental data

During the experiments, measurements of such parameters of a heating pulse as current and voltage drop across the part of the sample bounded by potential probes were made. Knowing these values, as well as the geometrical dimensions of the sample under study, it is possible to obtain the time and temperature dependences of the electrical resistivity of rhenium at high temperatures. This dependence is in good agreement with the well-known literature dependences.

Figure 2 shows the brightness thermograms at a wavelengths 650 nm and 862 nm, it is clearly seen that thermograms have a melting plateau in this experiment. The brightness melting temperatures show good agreement (±10 K) with those measured in [3] by the subsecond pulse heating.
Figure 2. Typical experimental dependence of the brightness temperatures of rhenium.

The experimental data obtained allow us to construct the temperature dependence of the enthalpy change of rhenium up to the melting temperature. Comparison of this dependence with the literature data is shown in figure 3.

Figure 3. Experimental dependence of the specific enthalpy of rhenium in comparison with the literature data [4-5].
Obtained experimental data for the linear thermal expansion in comparison with the literature data are depicted in figure 4. As one can see from the picture, the coincidence is good with [4] and [6], but the disputable data from [5] differ with experiment.

**Figure 4.** Experimental dependence of the linear thermal expansion of rhenium in comparison with the literature data [4-6].

4. Conclusion
During the experiments, experimental data on the specific enthalpy and linear thermal expansion of rhenium at the temperatures close to the melting point were obtained. The experimental data are in good agreement with those available in the literature.

The obtained temperature dependences of the thermophysical properties of rhenium are of interest, in particular, for constructing wide-range equations of state, as well as for use in high-temperature engineering.

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