LIQUID CARBON AT TEMPERATURES ∼30 kK AND PRESSURES UP TO 100 kbar

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The pulse method for measuring the physical properties of liquid metals, developed by Sergey Vladimirovich Lebedev (1913–1990), was formulated by him first at the FIAN and then applied at the Institute for High Temperatures Russian Academy of Sciences, starting in 1967. Abroad, he was called a "pioneer" in the study of electrical explosion of conductors. Using this method, refractory metals (Fe, Zr, Hf, Mo, Ta, W) and refractory carbides {ZrC, ZrC+C, HfC, TaC, HfC+TaC, mixed carbide (HfTaTiNbZr)C} were studied at the JIHT of the Russian Academy of Sciences at the melting region and in the liquid state. Along with this, liquid carbon was also studied (melting point at a pressure of up to 1 kbar — about 5000 K) during rapid pulsed heating of graphite. Physical properties (electrical resistance and specific heat C_p and C_V) were measured at the melting region and in the liquid phase up to 8000 K. The achievement of a high temperature for conductor was ensured by Joule heating of the passing current for several microseconds, and does not require the use of expensive equipment for long-term maintenance of high temperature.

Sapphire thick-walled capillary tubes (inner diameter 1 mm, outer 10–12 mm) were used to obtain liquid carbon at high pressures. As it is known, sapphire (Al_2O_3) has high strength, refractory, and retains these qualities for several microseconds of heating. At the same time, according to the calculation, its melting occurred in a very thin layer of contact with heated carbon. This does not affect the change in the properties of the liquid carbon itself, but prevents direct measurement of temperature through the molten layer of sapphire. Temperature (30–35 thousand K) were calculated from the specific input energy H measured by us and the measured (in a separate experiment) specific heat $C_V = 2$ J/g·K.

Graphite samples in the form of rods were made of high-density anisotropic graphite by passing square-section samples through diamond dies with a diameter slightly less than 1 mm. With rapid heating by current, graphite rods, when expanding and resting against the walls of the capillary tube, melted and heated in a liquid state. Since the ends of the tubes were tightly clamped with plates of refractory carbides, liquid carbon was heated in a limited volume with an increasing of internal pressure in the tube. This pressure (up to the destruction of the sapphire) reached 50–100 kbar. The pressure was estimated in comparison with the experiment of M. Togaya (Japan), who previously obtained the dependence

of the electrical resistance of liquid carbon on stationary pressure, up to 100 kbar (without temperature measurement). Note that the destruction of the sapphire tube occurred only along the tube (in 2–3 longitudinal parts); this made it possible to observe after the experiment the visible diameter of the inner hole, which changed little relative to the original one.

Thus, we have obtained measurements for three values of liquid carbon density (from 1 to 2 g/cm^3), at which pressures of 50–100 kbar are reached.

An experimental approach for measuring the physical properties of liquid carbon with a simple method of creating high temperatures and high pressures is demonstrated. Since the input specific energy exceeded the carbon sublimation energy (60 kJ/g), it can be assumed that a state of dense carbon vapor at high pressure has been achieved. It is noteworthy that with increasing pressure, there is an increase in the electrical resistance of liquid carbon (carbon vapor). This effect was confirmed earlier (Neaton J.B., Ashcroft N.W. Letters to Nature, 1999, 400, 141) for lithium at pressures above 600 kbar.