QUASI-METAL PROPERTIES OF LIQUID CARBON AT HIGH TEMPERATURES AND PRESSURES

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Planets of our solar system (Mercury, Venus, Earth and Mars) are made out of silicates on the base of Si. However, it has been proposed by the astronomers, that planets made mostly out of carbon could exist. Carbon planets are believed to be frequent near the center of the galaxy, since the concentration of carbon is higher than near the Solar system. The main content of carbon planet should be a carbon in different phase states. That is why to know the carbon properties at high P and T – is the main task of the high pressure physics.

Experiment looks like fast electrical explosion, e.g. it is pulse heating of graphite by electrical current during 1-3 microseconds. We used anisotropic graphite with high initial density (2.2 g/sm^3). The anisotropic specimens of square section, cut along the deposited planes, undergoes by diamond instruments to be converted to cylindrical specimens (diameter 0.8 mm). Then the specimens were placed inside thick walled sapphire tubes (inner diameter ~ 1 mm, outer: 10-12 mm). Thus, the attitude of inner tube volume V to the initial graphite volume V_0 equals $V/V_0 = 1.25 – 2.0$. We supposed that the graphite expansion in solid state under heating and further heating of liquid carbon filled all the inner tube volume and lead to heating under quasi-isochoric heating. Pulse heating (68 kA) ensure pinch pressure 4.5 kbar, average for the section, thus specimen may be melted even before filling of the inner tube volume. (Fig.1).

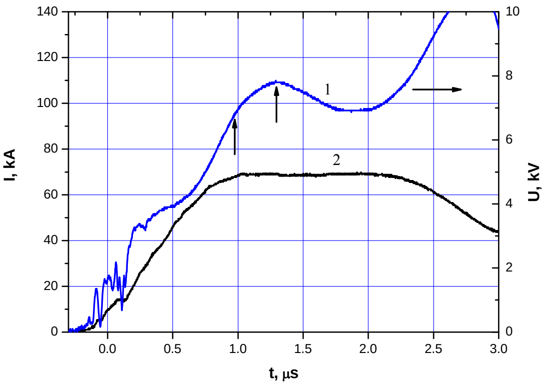

Fig.1. The voltage U (curve 1) and the current I (curve 2) vs. time for the case $V/V_0 = 1.25$ (curve 2 in Fig.2).

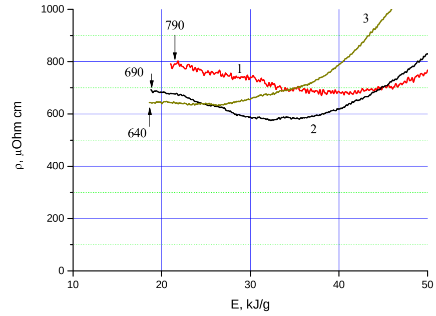

Fig.2. Specific resistivity ρ (with the expansion included) of the carbon versus input energy E.
Thermal expansion (filling the inside volume of the sapphire) is included, starting with the finish of the melting (arrows). Beginning with the marked arrows, isochoric heating is established. Curve 1 – $V/V_0 = 2.0$; density $\gamma = 1.1$ g/cm^3.
Curve 2 - $V/V_0 = 1.25$; density $\gamma = 1.76$ g/cm^3.
Curve 3 - $V/V_0 = 1.17$; density $\gamma = 1.88$ g/cm^3.

The results of quasi-isochoric heating of liquid carbon are shown in Fig.2; begin with finish of melting (arrows) up to input energy near 50 kJ/g. Numerators of the resistivity near the melting point show that the resistivity diminishes with the rising pressure. This result is in accordance with the data of Motohiro Togaya, who used high static pressure (20-100 kbar) and pulse millisecond heating. The main experimental result is shown in Fig.3.

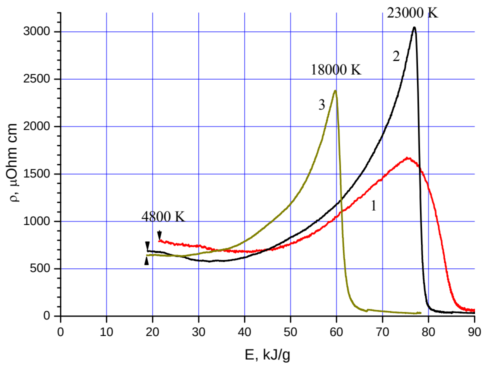

Fig.3. **Specific resistivity of the liquid carbon up to ~20000 K.**
(The pulse heating from E = 0 to the melting region is excluded). Isochoric heating started from the end of melting (arrows at 4800 K). The peaks of all the curves show the start of the tube destruction.
1 – Density in liquid state $\gamma = 1.1$ g/cm^3, $V/V_0 = 2.0$.
2 – Density in liquid state $\gamma = 1.76$ g/cm^3, $V/V_0 = 1.25$.
3 – Density in liquid state $\gamma = 1.88$ g/cm^3, $V/V_0 = 1.17$. The destruction of the tube for curve 3 begins earlier because of the higher carbon density and the highest pulsed pressure at the definite input energy.

The estimation of T was fulfilled through heat capacity at constant volume C_V for liquid carbon: $\Delta E = C_V(T – T_{melt})$. Pyrometer temperature measurements were impossible because of the melting of thin sapphire layer (2-3 microns).

1. The derivative dρ/dE was changed from negative to positive value for quasi-isochoric process of heating (up to E = 75 kJ/g, T ≈ 23,000 K), the derivative dρ/dE was changed in a wide range of input energy (E = 25 - 40 kJ/g).
2. The main interesting result in the range (E = 40-75 kJ/g) - the dependence of resistivity against density: the more density – the more resistivity of the liquid carbon. The like property of liquid Li at high pressure was predicted by Neaton J.B. and Ashcroft N.W. (Nature, 1999). The confirmed result was obtained for Lithium in explosive experiments at very high pressures (~ 600-2000 kbar); this problem was discussed in: Maksimov EG, Magnitzkaya MV, Fortov VE. Non-simple behavior of simple metals at high pressure. Physics Uspekhi, 2005; 175(8): 793-813. The additional information on the pulse heating of dense isotropic graphite (in the same experimental conditions) will be published in the oral report.

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