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Magnetoresistivity Dynamics in Microfine Graphite under Pressure

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The basal plane resistivity of packed pyrolytic graphite was measured as a function of temperature, high hydrostatic pressure up to 1,6 GPa and magnetic fields up to 1 T. Our graphite sample shows a transition from negative magnetoresistivity at some low temperatures to positive one with the temperature growing. Resistivity behaviur suggests for ordering transition about 0,5 GPa. Pressure over the ordering transition suppresses magnetoresistivity of both signs and shifts zero magnetoresistivity point to the lowest temperatures. All of the effects are of elastic character – no change with high accuracy in the resistivity dependencies after unloading to normal pressure can be detected.

Keywords: High pressure, Graphite, Magnetoresistivity, Ordering transition.

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73.05. jt

1. INTRODUCTION

The magnetic field has an effect on the conductivity of graphite single crystals with a change from square form of dependence to line one, significant influence of impurities and imperfections of the crystal shown as far as in [1]. Anisotropy, the 30-times difference in compressibility of above and orthogonal direction of the c-axe, leads to the fact that the volume's compressibility of the spectral-clear and Ceylon graphite's is determined mainly by the c-axe compressibility which is the effect of weak interactions between the planes [2]. New properties of graphites such as negative magnetoresistivity are connected not only with chemical doping but with the presence of edge-states, defects, surfaces, size effects and mesoscopic structure organization [3-5]. High pressure does not lead to structural transitions in nanotubes [6] however the transitions were observed for fullerenes [7] and plane structures [8], being associated, mainly, with an ordering. In general, the results for graphite structures analysis under pressure are more numerous than experimental results on properties, better studied under magnetic field influence. Simultaneous effect of high pressure, magnetic field and temperature on resistivity of graphite presented in our research may be of multidisciplinary interest.

2. EXPERIMENTAL

Macroscopic sample (2 × 8 × 0,2 mm) of packed pyrolytic graphite with structural parameters $d_{002} = 3,44$ Å and $La = 200\text{-}300$ Å, represented by L.Y. Matzui group from Kiev National University, was studied.

Contacts on the sample were made by silver past. To obtain the hydrostatic pressure up to 1.6 GPa double-layered nonmagnetic cell was used, as shown on Fig 1 and in detail described in [9]. Three different liquids: oil, kerosene and its mixture was used as a pressure transmitting medium. Manganin pressure gauge and a copper resistance thermometer inside the cell were used for temperature and hydrostaticity control.

Measurements performed in basal plane by the four-probe method with no field applied and weak magnetic fields up to 1 T, directed orthogonal to the basal plane. Resistivity values were calculated from sample geometry and voltage on potential electrodes at direct current 90 mA.

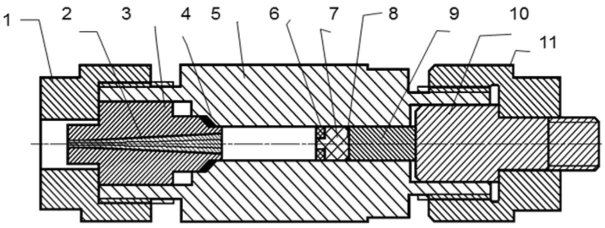

Fig. 1 – High pressure cell (1- obturator check-nut; 2- electric wires; 3- obturator; 4- obturator seal; 5- double-layered body; 6- rubber ring; 7- ptfs seal; 8- bronze ring; 9- piston; 10- plunger; 11- check nut)

3. RESULTS AND DISCUSSION

Resistivity changes from low positive in room temperatures to negative in nitrogen region (Fig. 2).

Resistivity of the sample at room temperature shows a transition about 0,4 GPa region (Fig. 3). It manifested moreover in a slope change of normalized resistivity (Fig. 4) – zero pressure curves significantly differs from the obtained under high pressure ones.

An influence of magnetic field at fixed temperatures (Fig. 5) reveals itself clearly upon the ordering transition. Slope change of normalized resistivity in whole region of magnetic field applied directly shows a suppression of its effect. On the background of changes in absolute values of resistivity (inserts on Fig. 5), only at pressures upon 0,6 GPa normalized resistivity changes significantly. Resistivity transition from negative to positive shows dynamics under pressure (Fig. 6) upon the ordering transition as a zero magnetoresistance temperature shift to the lowest temperatures.

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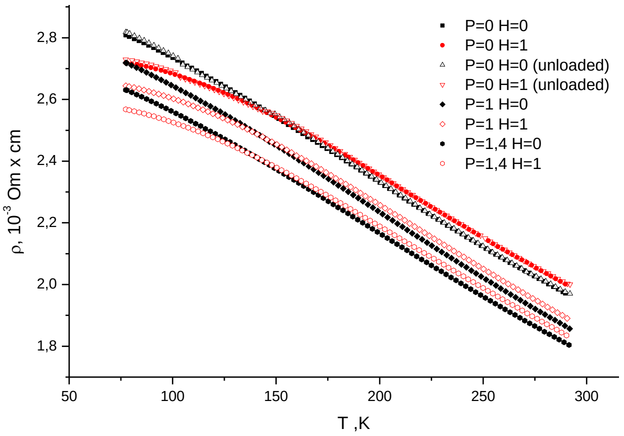

Fig. 2 – Temperature dependence of resistivity at fixed pressure (*P*, GPa) and magnetic field (*H*, T)

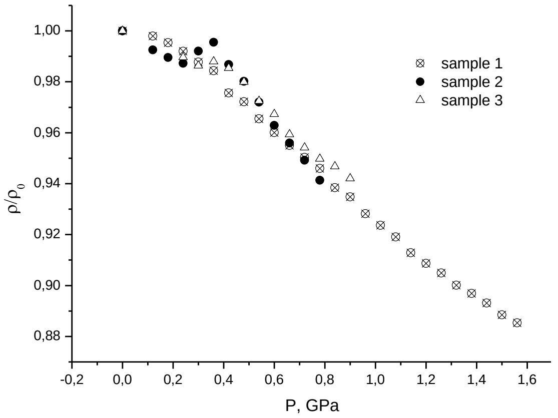

Fig. 3 – Normalized resistivity under pressure at room temperature

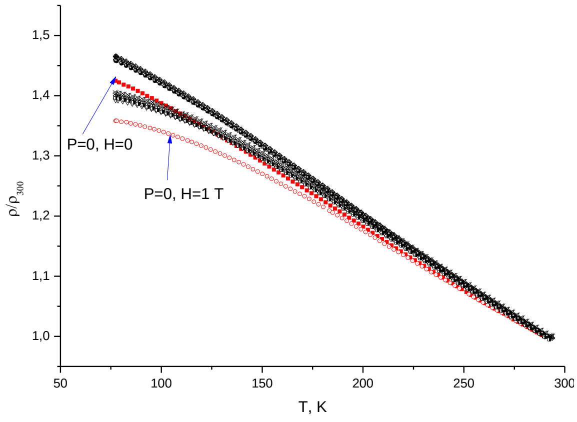

Fig. 4 – Normalized resistivity at fixed pressure (*P*, GPa) and magnetic field (*H*, T) vs. temperature.

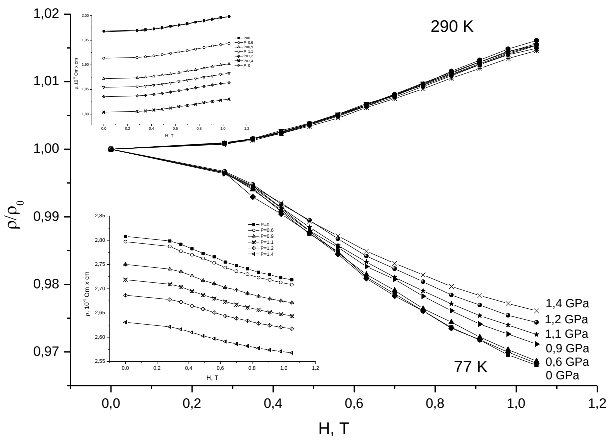

Fig. 5 – Temperature dependence of resistivity at fixed pressure (*P*, GPa) and magnetic field (*H*, T)

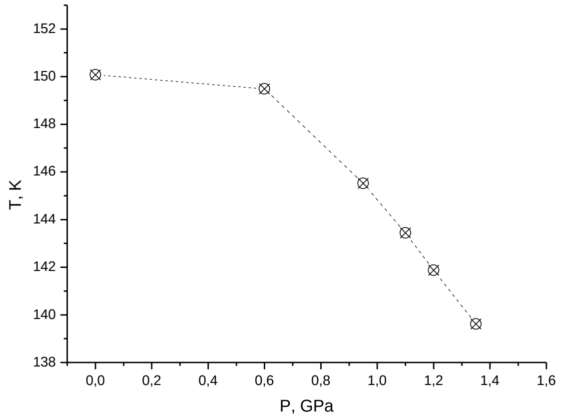

Fig. 6 – Temperature dependence of resistivity at fixed pressure (P, GPa) and magnetic field (H, T).

Negative coefficient of resistivity in micro fine graphite structures is usually connected with weak localization and interaction effects and preferentially associated with current carrier scattering on crystallite boundaries. The magnetic field effect is suppressed under pressure upon the transition in low temperatures from 3 % to 2 %, while low positive magnetoresistance (1,5 %) at room temperatures does not have significant change. An effect of pressure on resistivity is only about 12 % suggesting for a dense solid, while in the studied temperature range resistivity changes about 50 %.

All the effects are of elastic character – no change with high accuracy in the resistivity dependencies after unloading to normal pressure can be detected.

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