Isentropic compression of quartz by the pressure of a superstrong magnetic field

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The isentropic compressibility of crystalline quartz was plotted up to ~1.5 Mbar, and it can be concluded from the curve that quartz undergoes a phase transition into a high-density modification at a pressure 1.25±0.15 Mbar.

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Interest in the study of the compressibility of quartz in the megabar range of pressures is due to the recently obtained data on its transition to the conducting state.[1,2] However, the static experiments in which this transition was observed do not yield any information of the density of metallic phase of the quartz, and only qualitative information on the phase-transition pressure. On the other hand, none of the required density jumps were registered under dynamic compression of quartz in shock waves up to pressures ~7 Mbar.[3]

The use of the pressure of a superstrong magnetic field produced in an MK-1 magnetic-implosion generator[4] leads to a slower energy transfer from the explosive to the sample than in the shock waves. The process of sample compression is isentropic in this case to a considerable degree and is not accompanied by the sample heating typical of shock waves. Therefore, the dynamic experiments using the pressure of an ultrastrong magnetic field are of undoubted interest.

In the present study we used a magnetic-implosion generator MK-1 developed by us, with an initial shell diameter 140 mm, in which, at initial magnetic fields 100–180 kG the final values of the magnetic field exceed 5 MG, corresponding to a pressure of more than 1 Mbar. To transmit this pressure to the sample we used a copper tube of 2 mm thickness. Crystalline quartz of 13 mm diameter and length from 70 to 180 mm were tightly fitted into the tube.

To determine the pressure in the sample and to estimate the pressure in the tube we used pulsed gammagraphy of the central cavity of the generator with the tube, using a pulsed iron-free betatron of the type described in[5] at instants close to the instant of the maximum magnetic field in the generator. Densitometry measurements of the preliminary and experimental photographs were used to determine respectively the initial and final internal and external boundaries of the tube with the sample. The square of the ratio of the final and initial diameters of the tube determines the compression of the sample at the instant of the gammagraphy. The pressure in the sample

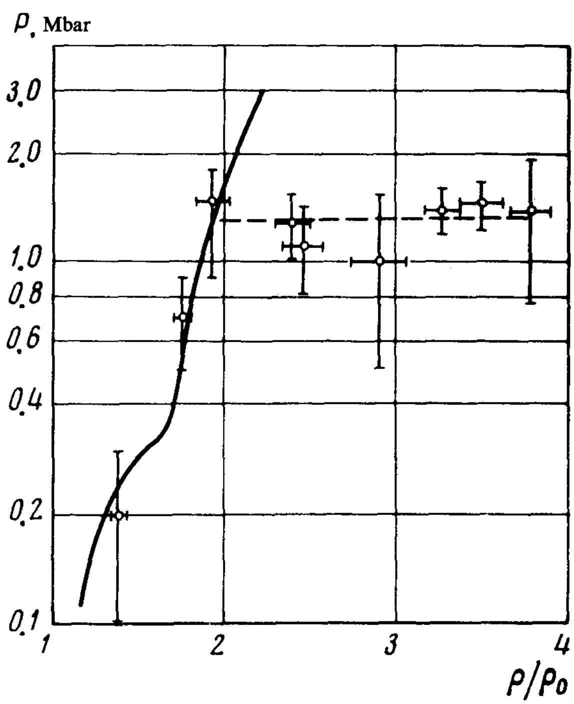

FIG. 1.

at this instant of time was estimated indirectly, from the compression of the tube material, using the known equation of state of this material. In the calculation of the density and of the pressure they were assumed to be the same over the entire cross section of the sample and the tube.

The aggregate of the experimental data obtained as a result of the investigation is shown in Fig. 1 with the pressure (P) and compressibility ρ/ρ_0 as the coordinates. The solid line in Fig. 1 is a plot of the dynamic compressibility of crystalline quartz as given in[3]. As seen from Fig. 1, the experimental points form a clearly pronounced shelf on the compressibility curve (shown dashed in Fig. 1), i.e., quartz states with greatly varying densities correspond to the same pressure. This can serve as a basis for the conclusion that a phase transition into a denser modification takes place in quartz. The pressure corresponding to this transition, obtained by averaging over seven experimental points, is 1.25 Mbar with an rms error ± 0.15 Mbar. The quartz density increases in this case to ~ 10 g/cm^3.

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