ANOMALOUS POLARIZATION OF SODIUM CHLORIDE UNDER IMPACT LOADING

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In the present note we report results of investigation of the polarization of single-crystal sodium chloride under impact loading perpendicular to the cleavage plane (100) in the interval of pressures (P) from 50 to 550 kbar.

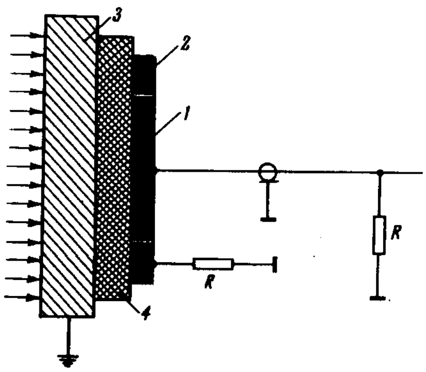

Fig. 1. Experimental setup

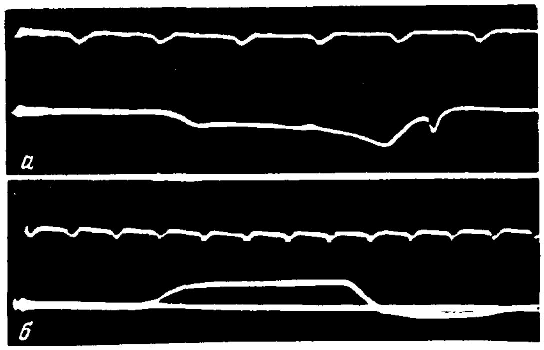

Fig. 2. Typical oscillograms. a - $\sigma = 1.5$ (P = 276 kbar); b - $\sigma = 1.16$ (P = 53 kbar). The time markers show intervals of 0.1 μsec.

The impact loading was by means of the explosive devices used in [1]. A diagram of the measuring circuit is shown in Fig. 1: 1 - measuring electrode (2 cm diameter); 2 - guard ring, equal in area to measuring electrode; 3 - screen of a metal having a known shock adiabat (Al, Cu); 4 - sodium chloride single crystal 0.15 - 0.19 cm thick. The arrows show the direction of motion of the shock-wave front.

The parameters of the shock wave in the single crystal were calculated from the known state of the screen. A measuring line made of RKK-0.3/10 cable of 200 ohm wave resistance and an OK-21 oscilloscope were used in the experiments.

The crystal thickness (l_0) fluctuated between 0.15 and 0.19 cm. The current jump upon emergence of the shock wave to the sample was normalized to $l_0 = 0.18$ cm on the assumption that the initial current jump is inversely proportional to l_0 [2].

Typical oscillograms of the registered signal are shown in Fig. 2. The results of the experiments in the form of a plot of the initial current jump density (I) against the compression behind the front of the shock wave (σ) are shown in Fig. 3. Each point on the plot was obtained in a separate experiment.

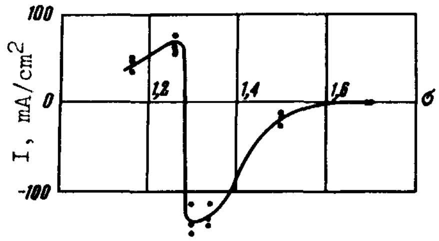

Fig. 3. Plot of $I = f(\sigma)$.

Unlike the analogous plots for polar substances [2], where I increases monotonically with increasing shock-wave intensity, in this case $I(\sigma)$ has an anomaly, wherein the magnitude and direction of the polarization current change sharply following a compression $\sigma = 1.26 - 1.30$ (P = 100 - 150 kbar). With further increase of the shock-wave intensity, a decrease in I is observed, so that when $\sigma = 1.7$ (P = 547 kbar) I lies below the threshold of sensitivity of the employed apparatus (~5 V/mm) 1).

It must be noted that to explain the magnitude of the polarization current at $\sigma = 1.3$ it is necessary to introduce into the measuring circuit a dc source of voltage 2×10^4 V, which is three orders of magnitude larger than the voltage obtained in [3].

Indeed, let us estimate the value of the effective resistance of the capacitor (R_{eff}) produced by the electrode 1 (Fig. 1) and the front of the shock wave. For a unit surface area it can be written in the form [4,5]

$$R_{eff} = \left(\frac{dC}{dt}\right)^{-1}_{t=0} = \frac{4\pi l_0^2}{\epsilon D},$$

where ϵ is the dielectric constant and D the velocity of the shock wave. When $l_0 = 0.2$ cm, $\epsilon \simeq 6$, and $D \simeq 5 \times 10^5$ cm/sec, we obtain $R_{eff} \simeq 1.5 \times 10^5$ ohm-cm², whence $V \simeq 2 \times 10^4$ V.

A polarization current $I = 5.5$ mA/cm² was observed also by shock-wave compression of polycrystalline samples of sodium chloride with initial density 2.13 g/cm³ ($l_0 = 0.3$ cm, P = 250 - 270 kbar).

The authors found no acceptable physical explanation for the observed anomaly in the behavior of the sodium chloride. This fact may be connected somehow with a phase transition which has not been observed hitherto under dynamic loading in the pressure range under consideration [6].

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1) As follows from [7], at 500 kbar the sodium chloride begins to melt under shock compression.