Superconductivity of NaCl at high pressure

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A transition to the superconducting state of the metallic modification of NaCl at high pressure was observed.

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Sodium chloride is studied extensively in high-pressure physics, particularly as a substance that can be used to determine pressure.[1] It was established that under pressure sodium chloride can be converted to a denser modification with the structure CsCl, whose transtion pressure is 292 ± 10 kbar.[2] This modification, like the original one, is a dielectric.

The metallization of NaCl was discussed extensively in the literature.[3–5] Zhdanov *et al.*[6] calculated the thermodynamic potentials of sodium chloride in the CsCl structure for the dielectric and metallic states. It was determined that at $P \sim 1.35$ mbar the metallic state is more stable. Vereshchagin *et al.*[7] observed experimentally the conversion of NaCl to a conducting state at high pressure.

The aim of this work is to determine whether the modified NaCl is superconducting. A small screw press and a high-pressure chamber are shown schematically in Fig. 1. In the experiments we used anvils 2 (see Fig. 1) made of synthetic "Carbonado" diamonds.[8] This chamber was used earlier to study superconductivity at high pressure.[9,10]

According to the developed technique, an $\sim$0.1-mm-thick NaCl layer is deposited on the flat surface of the diamond anvil. To remove the moisture, we dried the press and the high-pressure chamber at $\sim$120 °C.

The modification was produced by compressing NaCl between the anvils 2 in the screw press 4. The resistivity of the sample was measured potentiometrically. The potential electrodes were soldered to the metallic mandrels 1 near the working surface of the anvil 2. The measuring current was passed through the anvils 2 and through the sample 3. Note that the conductivity of the anvils 2 depends on the superconductivity impurities in the synthetic Carbonado diamond. To improve the reliability of the electrical contact between the anvils 2 and the sample 3, we coated the surface of the anvils with a thin ($h \sim 0.1$ μm) aluminum film.

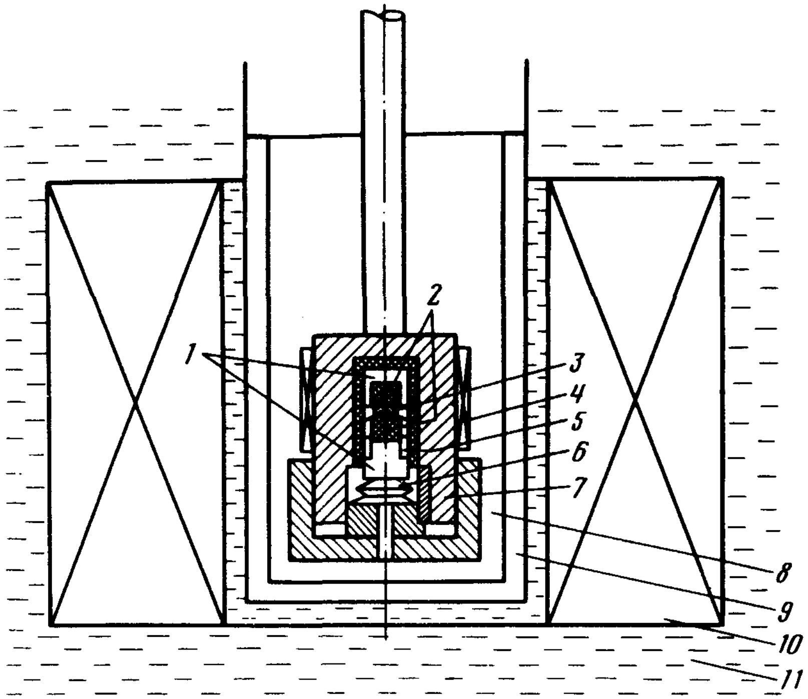

FIG. 1. Experimental setup for observation of superconductivity at high pressure: 1, Beryllium bronze mandrels for the anvils; 2, anvils may of synthetic "Carbonado" diamonds; 3, sample; 4, heater; 5, manganin thermometer and a superconducting temperature reference point (lead); 6, disk springs; 7, screw press made of beryllium bronze; 8, helium for heat transfer ($P \sim 10$ mmHg); 9, vacuum jacket; 10, superconducting solenoid; 11, liquid helium.

We ran check tests before conducting the NaCl experiments. The anvils were compressed by the screw press without the sample. The resistance of the two pairs of anvils, which were used for the NaCl experiments, decreased monotonically, according to an almost linear law, with increasing temperature from 2 to 20 K (see Fig. 2).

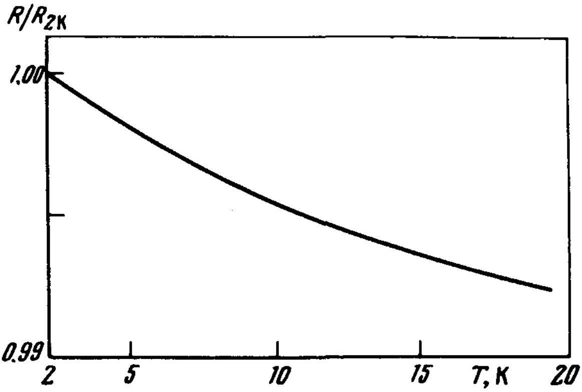

FIG. 2. Temperature dependence of the resistivity of the anvils.

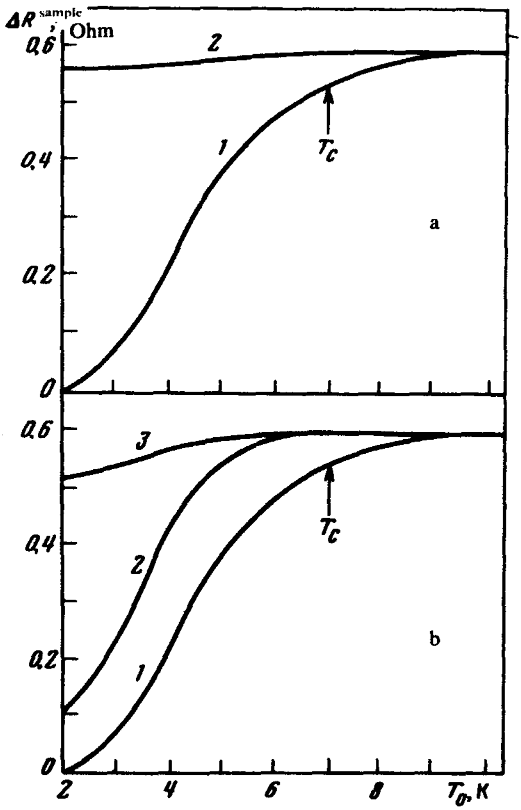

FIG. 3. Temperature dependences of the resistivity of the NaCl sample (a) for different measuring currents: 1, 100 μA; 2, 500 μA and (b) in external magnetic fields: 1, $H = 0$ kG; 2, $H = 12$ kG; 3, $H = 24$ kG. ($J = 100$ μA.)

The resistivity decreased from $R > 10^8$ to $R \sim 10$–100 ohms as a result of compression of the NaCl sample between the anvils. The temperature dependence of the resistivity was measured 1) at different measuring currents ($J = 1$–500 μA and 2) in external magnetic field ($H \leqslant 24$ kG). As a result of evaluation of the experimental data, we obtained temperature dependences of the variation of resistivity of the sample

$$\Delta R_{\text{sample}} = R_{\text{sample}}(T, J, H) - R_{\text{sample}}(2\text{K}, 100\ \mu\text{A}, 0\ \text{kG})$$

which are shown in Fig. 3.

It can be seen in Fig. 3a that the sample's resistivity increases by approximately 0.5 ohm in the temperature range 2–7 K as a result of passing a 100-μA current through the sample. If the current increases to 500 μA, the resistivity of the sample remains almost constant in the range 2–7 K.

The external magnetic field (Fig. 3b) also decrease the resistivity variation of the sample.

On the basis of the experimental data we can conclude that the modified sodium chloride is superconducting and temperatures below 7 K. The width of the superconducting transition of >5 K may be due to the nonuniform pressure in the sample. The critical magnetic field is >24 kG.

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[1]D.L. Decker, J. Appl. Phys. **42**, 3239 (1971).
[2]G.J. Piermarini and S. Block, Rev. Sci. Instr. **46**, 973 (1975).
[3]W. Harrison, Solid State Theory, Mir, M., 1972 (McGraw-Hill, N.Y., 1972)].
[4]P. Löwdin, A. Theoretical Investigation into Some Properties of Ionic Crystals, Upsala, 1948.
[5]L. V. Al'tshuler, N.I. Brazhnik, and M.N. Pavlovskiĭ, Fizika goreniya i vzryvov **5**, 513, 1969. [Combustion, Explosion and Shock Waves (1969)].
[6]V.A. Zhdanov, V.A. Kuchin, and V.V. Polyakov, Izv. vyssh, uch. zav., ser. fizika, University Bulletin, Physical Series, No. 3, 1973.
[7]L.F. Vereshchagin, E.N. Yakovlev, B.V. Vinogradov, and V.P. Sakun, Pis'ma Zh. Eksp. Teor. Fiz. **20**, 540 (1974) [JETP Lett. **20**, 246 (1974)].
[8]L.F. Vereshchagin, E.N. Yakovlev, G.N. Stepanov, K. Kh. Bibaev, and B.V. Vinogradov, Pis'ma Zh. Eksp. Teor. Fiz. **16**, 240 (1972) [JETP Lett. **16**, 169 1(972)].
[9]L.F. Vereshchagin, E.N. Yakovlev, Yu. A. Timofeev, and B.V. Vinogradov, Pis'ma Zh. Eksp. Teor. Fiz. **26**, 61 (1977) [JETP Lett. **26**, 55 (1977)].
[10]E.N. Yakovlev, G.N. Stepanov, Yu. A. Timofeev, and B.V. Vinogradov, Pis'ma Zh. Eksp. Teor. Fiz. **28**, 369 (1978) [JETP Lett. **28**, 340 (1978)].