

Effect of pressure on the superconductivity of β -(BEDT-TTF) $_2$ I $_3$

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At a pressure above 1 kbar, the β -phase (BEDT-TTF) $_2$ I $_3$ crystals undergo a transition to a superconducting modification, whose maximum transition temperature of 7.5 K depends on pressure. This organic compound has the highest transition temperature recorded to date.

1. At a normal pressure, most of the β -(BEDT-TTF) $_2$ I $_3$ crystals go superconducting at $T_c = 1.5 \pm 0.1$ K (Ref. 1). Some crystals, however, exhibit typical pretransition phenomena, which indicate that these crystals contain superconducting phases whose critical temperatures T_c approach 7 K (Refs. 2–4). A possible reason for the formation of these phases could be the presence of an internal strain in a part of the crystal, which occurs when samples are synthesized or cycled thermally.^{3–5}

We could expect in this case that either an increase in pressure causes the superconducting-transition temperature of the original triclinic modification β -(BEDT-TTF) $_2$ I $_3$ to increase anomalously or the existing low pressure causes this compound to

change to a new state with a higher T_c . In the present letter we are reporting the results of a study of superconducting transitions in β -(BEDT-TTF) $_2$ I $_3$ crystals at pressures up to 6 kbar. We have found that at pressures above ~ 1 kbar, there seems to be yet another superconducting modification of this compound. The transition temperature of this modification peaks at 7.5 K at a pressure slightly above 1 kbar and then begins to fall off with further increase in pressure.

2. The pressure was produced in a piston-cylinder chamber filled with GKZh-94 silicon-organic liquid that was used as the transmitting medium.⁶ The pressure was determined from the shift of the superconducting transition in Sn at a low temperature. In the first measurements of the three samples that were studied, we took no additional measures to improve the uniformity of the pressure. As a result, the temperature-resistance curves of the first two crystals sometimes exhibited slight discontinuities between 50 K and 150 K and the widths of the superconducting transitions reached 1–1.5 K. The third single crystal was studied under extreme hydrostatic conditions produced by using a thin-walled Teflon container with holes. This container separated the small area occupied by the working fluid near the sample from the bulk of the fluid. In this case we saw no discontinuities on the $R(T)$ curves and the transition width did not exceed 0.3 K.

3. Figure 1 shows a pressure-induced shift of the superconducting transition in β -(BEDT-TTF) $_2$ I $_3$. Curves 1, 2, 4, and 5 correspond to the third single crystal and curve 3 corresponds to one of the first two samples studied under inadequate hydrostatic conditions. This curve shows that the transition is rather diffuse and that it has a small jog near 6.5 K, which may be due to a nonuniform pressure.

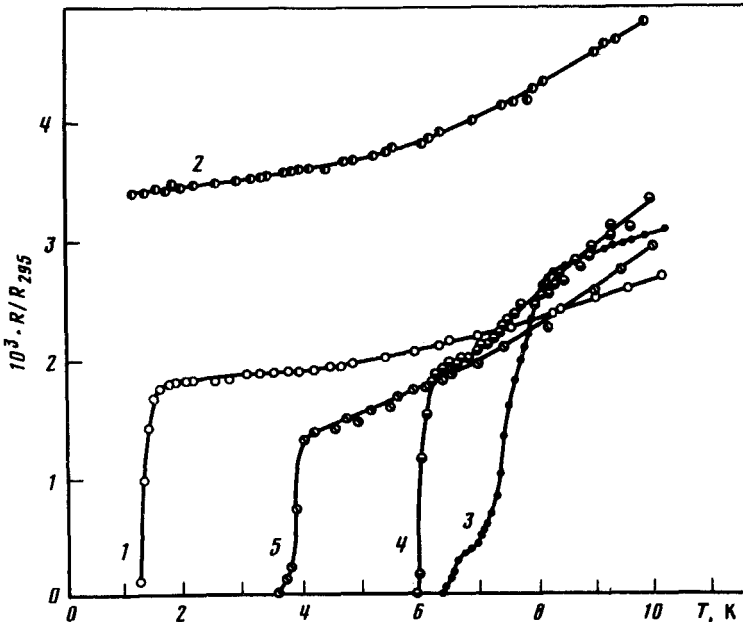


FIG. 1. Pressure-induced displacement of the superconducting transition in β -(BEDT-TTF) $_2$ I $_3$. 1—1 kbar; 2—0.9 kbar; 3—1.2 kbar; 4—1.9 kbar; 5—3.3 kbar.

All the curves, except curve 3, show the ratio of the resistance of the crystal, $R(T)$, at a given temperature to its resistance, R_{295} , before the cooldown. Because the pressure drops as a result of cooling, R_{295} corresponds to a higher pressure than that of $R(T)$. In the experiment represented by curve 3, the crystal crackled slightly during cooldown and its resistance decreased at a slower rate than it did in the experiments represented by curves 1, 2, 4, and 5. To keep the scale of the plot the same, we had to tie curve 3 in with the other curves in the neighborhood of 10 K.

The temperature of the superconducting transition of β -(BEDT-TTF) $_2$ I $_3$ seems to decrease sharply in the low-pressure region. At $P = 0.8$ kbar (curve 2), for example, there is no evidence of a phase transition down to 1.25 K—the lowest temperature obtained in our experiments.

At $P \gtrsim 1.2$ kbar (curves 3–5), the superconductivity is again restored. The superconducting-transition temperature, which is 7.5 K at 1.2 kbar, decreases markedly with further increase in pressure. This behavior of the samples is evidence that at $P \sim 1$ kbar they undergo a transition to a new superconducting state which is characterized by a high transition temperature.

Figure 2 is a plot of the $T_c(P)$ curve based on the data obtained from all three samples. In this figure the dashed line indicates where the phase-transformation boundary accompanied by a sharp increase in T_c might be. We notice that T_c decreases rapidly with pressure, initially at the rate of ~ 2 K/kbar. This rate of decrease of the temperature, almost an order of magnitude faster than the $\partial T_c / \partial P$ recorded in Bechgaard's salts,⁷ is most likely because of the higher compressibility of β -(BEDT-TTF) $_2$ I $_3$. The fact that the compressibility of this compound is high is also indicated by the appreciable pressure-induced decrease of its room-temperature resistance, which is tenfold at 8 kbar.

It would thus be theoretically possible to raise the transition temperature to ~ 10 – 11 K at a normal pressure by keeping the high-pressure phase in the metastable state.

4. The suggestion that the β -(BEDT-TTF) $_2$ I $_3$ crystals have a high-pressure phase with T_c near 7 K thus would seem to be justifiable. This does not mean, however, that

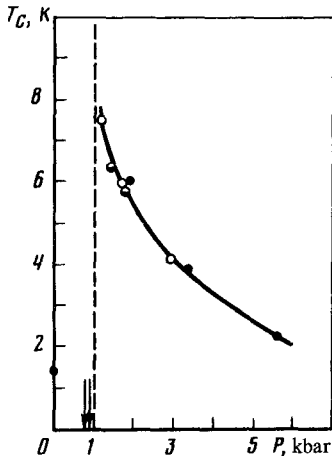


FIG. 2. Pressure dependence of the superconducting-transition temperature for three β -(BEDT-TTF) $_2$ I $_3$ samples. The arrows indicate that T_c of the sample is very likely below 1.25 K at pressures of 0.8 and 0.9 kbar.

the pretransition effects in these crystals have been fully explained. It is conceivable that the compound's slight departure from stoichiometric composition or some other effects may contribute to these phenomena.

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