

NOV 12 1965

Superconducting Indium Antimonide

Indium antimonide transforms from a semiconducting to a metallic state at 22.5 kb at room temperature (1). X-ray powder photographs taken at high pressures show that the metallic phase has the white-tin structure with a random distribution of the In and Sb atoms (2). As In and Sb are virtually indistinguishable by ordinary x-ray techniques, no information about possible ordering of the atoms has been reported.

At atmospheric pressure the lattice constant of zinc-blende type InSb is nearly the same as that of gray tin, and it appeared probable that if the metallic phase of InSb could be obtained in a metastable state at 1 atmosphere the volume of the unit cell would be very nearly that of white tin. On considering especially the importance of the volume (3) and the lesser importance of the electron-atom ratio, we thought that the metallic form of InSb would be a superconductor with a transition temperature near that of white tin.

The high pressure transition in InSb is reported to be very sluggish, especially if a single crystal is compressed hydrostatically (4). Our attempts to recover the metallic form by the use of a Teflon cell and a 40-centistoke silicone oil as the pressure cell and transmitting medium respectively, in a piston-cylinder apparatus designed by Boyd and England (5) and Kennedy (6) failed.

Work done at the University of California, Los Angeles (7), indicated that the metallic form of InSb could be recovered at liquid-nitrogen temperatures.

Accordingly, we made an opposed-anvil apparatus from hardened tool steel. The sample cell was similar to the Bridgman (8) design. This cell has a retaining ring of isomica (9) that is 0.016 inch thick and has an outside diameter of $\frac{1}{2}$ inch and an inside diameter of $\frac{3}{16}$ inch. The sample cell has a silver chloride disk 0.012 inch thick by $\frac{3}{16}$ inch in diameter. The InSb sample itself is 0.012 inch thick by $\frac{3}{32}$ or $\frac{3}{16}$ inch in diameter. The anvil assembly was placed in a stainless-steel beaker with a Styrofoam jacket and was partially insulated from the press by insulating blocks composed of alternating sheets of stainless steel and mica.

The resistivity was monitored by measuring the drop in voltage across the anvils per unit of applied current. As the transition on a single crystal sample is sluggish under quasi-hydrostatic conditions, the samples were kept above the transition pressure for 3 to 4 days. Then liquid nitrogen was added to the beaker and the pressure was released.

Three consecutive experiments were performed in this apparatus: (i) the nitrogen was evaporated and the resistivity was monitored as the sample warmed to room temperature, which proved that the metallic form had been stabilized at the temperature of liquid N₂ and even higher; (ii) an attempt was made to take an x-ray powder photograph at low temperatures to verify the volume and structure of the metallic form, but as a result of the difficulty of loading the camera at low temperatures the experiment failed; (iii) the sample was transferred to a helium-3 cryostat and was tested for superconductivity by the alternating-current method of Schawlow and Devlin (10).

This sample was superconducting at $2.1 \pm 0.2^\circ\text{K}$. Measurements of critical fields were made down to 0.3°K with the plane of the disk-shaped sample parallel to the magnetic field. The results can be extrapolated to a critical magnetic field at $T = 0^\circ\text{K}$ of 1.1 kgauss. This high value is undoubtedly due to strains (11).

S. GELLER
D. B. MCWHAN
G. W. HULL, JR.

Bell Telephone Laboratories,
Murray Hill, New Jersey

References and Notes

1. H. A. Gebbie, P. L. Smith, I. G. Austin, J. H. King, *Nature* **188**, 1095 (1960); A. Jayaraman, R. C. Newton, G. C. Kennedy, *ibid.* **191**, 1288 (1961).
2. J. C. Jamieson, private communication; P. L. Smith and J. E. Martin, *Nature* **196**, 762 (1962); M. D. Banus, R. E. Hanneman, A. N. Mariano, E. P. Warekois, H. C. Gatos, J. A. Kafalas, *Appl. Phys. Letters* **2**, 35 (1963).
3. B. T. Matthias, *Phys. Rev.* **92**, 874 (1953).
4. M. D. Banus, J. A. Kafalas, S. D. Nye, H. C. Gatos, *Solid State Res. Rept. Lincoln Lab. No. 3* (1962), p. 18.
5. F. R. Boyd and J. L. England, *J. Geophys. Res.* **65**, 741 (1960).
6. G. C. Kennedy and P. N. Lamori, *Progress in Very High Pressure Research* (Wiley, New York, 1961), p. 304.
7. G. C. Kennedy, Institute of Geophysics and Planetary Physics, U.C.L.A., private communication.
8. P. W. Bridgman, *Proc. Am. Acad. Arts Sci.* **81**, 165 (1952).
9. P. W. Montgomery, in preparation.
10. A. L. Schawlow and G. E. Devlin, *Phys. Rev.* **113**, 120 (1959).
11. In the course of the running of our final experiment we were informed that H. E. Bömmel and W. F. Libby and their co-workers A. J. Darnell and B. R. Tittman of U.C.L.A. had found that InSb was superconducting. Bömmel informed us that the transition temperature that they found was 2.1°K , and therefore, our result corroborates theirs. We thank Dr. T. H. Geballe for his interest and part in the superconductivity measurements, Dr. R. L. Baidorf for the high-purity InSb crystals, and Mr. A. L. Stevens for technical assistance.

4 March 1963