Ytterbium: Effect of Pressure and Temperature on Resistance

Abstract. *The electrical resistance of ytterbium, measured as a function of pressure, shows a sharp maximum at 38 kb, both at 300°K and 77°K. At low pressures ytterbium is a metal because of overlap between filled and empty bands. From about 20 kb to the resistance maximum it is a semiconductor, indicating that the overlap disappears. At the maximum there is a phase transition, and beyond this pressure ytterbium is again metallic.*

The resistance of ytterbium has been measured as a function of pressure to 500 kb at room temperature and at liquid-nitrogen temperature. Several isobars have also been obtained from 77°K to 300°K at critical pressures as discussed below. The ytterbium used was 99.9+ percent pure material obtained from Kleber Laboratories. The high-pressure–resistance techniques included both the electrical cell used for previous work in this laboratory, and described in detail in the literature (*1*), and a Bridgman (*2*) tapered anvil cell.

At room temperature the resistance increases by a factor of about 6 to a distinct maximum about 38 kb. Above this pressure there is a sharp drop accompanied by drifting of resistance with time, which is typical of behavior at a first-order phase transition. This resistance maximum was first observed by Bridgman (*3*). At liquid-nitrogen temperature the rise in resistance with pressure is much larger $[R_{max}/(R_0 \sim 80) = 100]$.

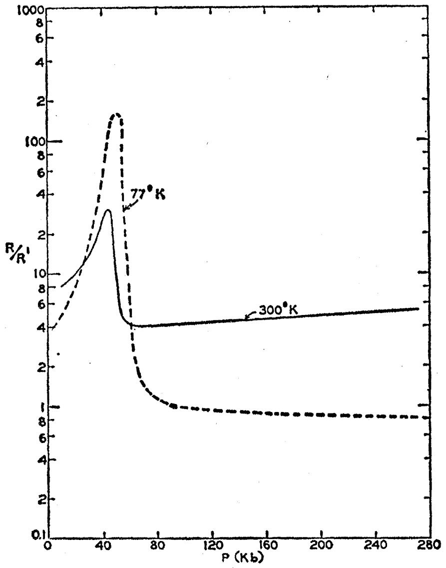

Fig. 1. Resistance of ytterbium as a function of pressure, at 77°K, and as a function of pressure and change of temperature to 300°K. Resistances are values of the ratio R/R', where, for *both* curves, R' = resistance at 77°K and 100 kb.

The maximum at 77°K is little, if any, displaced and is just as sharp as at room temperature, which is unusual for diffusion-controlled transitions. Typical isotherms are shown in Fig. 1. Isobars have been obtained at a number of pressures between 15 and 65 kb. These confirm the fact that from about 20 kb to just beyond the resistance maximum ytterbium is a semiconductor. The greatest activation energy for conduction is about 1 kb at or near the maximum of resistance. The material was the purest available, but it was, undoubtedly, electronically very impure and there may well have been a large number of carriers available with energies between the valence and conduction band. This energy then, is only a measure of the minimum possible energy gap. As well as could be determined, ytterbium becomes a metal again immediately above the transition. Ytterbium at atmospheric pressure probably consists entirely of filled atomic shells (14 4*f* electrons). It is then a metallic conductor only because of overlap between the valence band—undoubtedly the Γ_1 state arising from 6*s* atomic levels—and some empty band—quite possibly the Γ_{25} or Γ_{12}' crystal bands (*4*) 15—arising from the atomic 5*d* levels in the crystal field. Apparently the levels are deformed with pressure in such fashion that the overlap disappears and ytterbium becomes a semiconductor.

Recent work by Hall *et al.* (*5*) indicates that the transition is to the body-centered cubic structure and is accompanied by a large decrease in volume which they attribute to the promotion of an atomic 6*s* electron to the empty 5*d* shell (or to the corresponding crystal band or bands).

The metallic conductivity of the high-pressure phase could then be due to the partially filled 5*d* shell (or corresponding crystal band) or to overlap of crystalline 5*d* and 6*s* shell in the new band structure. In any case, our results are entirely consistent with theirs (*6*).

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References and Notes

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6. Supported in part by the U.S. Atomic Energy Commission.

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Dosimetry of Atomic Bomb Radiation in Hiroshima by Thermoluminescence of Roof Tiles

Abstract. *Thermoluminescence dosimetry is a powerful tool for obtaining the distribution of gamma dose, heretofore unknown, from the atomic bombs dropped on Hiroshima and Nagasaki. Roof tiles irradiated by the bombs show intense thermoluminescence, and the radiation dose for samples irradiated below 100 r by the bomb can be measured by this method.*

Much effort has been devoted to studying the genetic and medical damage to human beings who were irradiated by atomic bombs in Hiroshima and in Nagasaki, and detailed data have been collected. But only a few results concerning the distribution of absorbed dose of bomb radiation have been reported, and they are not conclusive about the relationship between radiation hazard and radiation dose. No method has been found for estimating the gamma-ray component except an indirect one through the value of thermal neutron dose.

Recently thermoluminescence dosimeters have been developed by employing synthetic crystals of manganese-activated calcium fluoride (*1*) or powder of pure lithium fluoride (*2*). This method has some advantages in its high sensitivity, low fading, and excellent linearity to absorbed dose. If we take the high-temperature part in the glow curve of thermoluminescence dosimeter, it serves as a dosimeter which can show total absorbed dose integrated over a very long period because the lifetime of trapped electrons corresponding to the high-temperature part of the glow curve is sufficiently long.

Radiation-induced thermoluminescence is a phenomenon widely observed in natural substances (*3*). Consequently, measurement of the thermoluminescence of some substances in na-