Beryllium: Effect of Ultra-High Pressure on Resistance

Abstract. *Beryllium, subjected to a pressure of 93 kb at 25°C undergoes a change in structure, as indicated by a 45-percent decrease in resistance. At 55 kb a small change in the resistance-pressure relationship suggests another modification of the usual hexagonal-close-packed structure.*

The resistance of beryllium has been measured as a function of pressure to 105 kilobars at room temperature. Commercially pure beryllium wire (0.05 cm diameter), was supplied by the Brush Beryllium Corporation. A tetrahedral apparatus (National Bureau of Standards type) was used to obtain the pressures and a specimen cell, similar to those described in the literature (*1*), was used for resistance measurements. The tetrahedral apparatus was calibrated from the known transition points of bismuth I to II, 25.4 kb, bismuth II to III, 26.9 kb, thallium II to III, 36.7 kb, and bismuth V to VI, 89 kb. A calibration curve (load against pressure) was plotted and extrapolated to 105 kb.

The effect of pressure on the resistance of beryllium has been reported in the literature by Bridgman (*2*) who found a gradual decrease up to 100,000 kg/cm^2 (98 kb) without any discontinuities or inflections. Kennedy and La Mori (*3*) have corrected Bridgman's results for the currently accepted calibration points, and Bundy and Strong (*4*) have shown that Bridgman had measured the resistance of beryllium as a function of pressure up to the 70 to 80 kb region only. The corrected Bridgman data is shown in Fig. 1. Bridgman also reported (*5*) no marked transition in beryllium below 100,000 kg/cm^2 using volume measurements. However, Rice, McQueen, and Walsh (*6*), using shock-wave volume data, reported a small discontinuity between their data and Bridgman's volume data. I have repeated and extended the resistance data of Bridgman and the results are shown in Fig. 1.

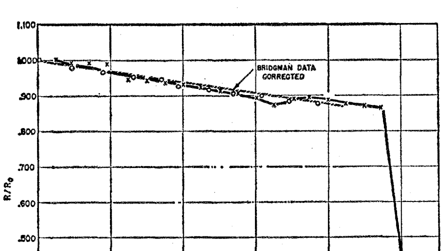

Fig. 1. Resistance of beryllium as a function of pressure, at room temperature (crosses). Superimposed are the corrected data of Bridgman (circles). Resistances are values of the ration R/R_0, where R_0 is the resistance at 25°C and 5 kb.

The resistance of beryllium gradually decreased up to 55 kb at which pressure a small deflection occurred. It is not known whether this change was due to a phase transformation or a change in the c/a ratio of the close-packed hexagonal structure of the element. The c/a ratio is abnormally small (1.5671) compared to the ideal c/a ratio of 1.63.

As the pressure was increased, resistance again began to drop gradually up to 93 kb. At this pressure a discontinuity in the resistance curve was observed, as the resistance dropped approximately 45 percent. This sharp drop, accompanied by drifting of resistance with time, is the characteristic behavior of a first-order phase transition. Upon releasing the pressure, a hysteresis was obtained and complete transformation to the original structure did not occur until 70 kb was reached. It was also noted that the discontinuity at 55 kb on loading was repeated at 50 kb on releasing the pressure.

In order to obtain positive proof that the resistance drop was due to the material and not the apparatus, and to verify the calibration, the resistivity of the apparatus to 105 kb was measured by replacing the beryllium specimen by longer platinum resistance lead wires. No discontinuity was found in the resistance curve. The calibration of the apparatus was proven correct by reproducing the bismuth V to VI transition at 89 kb. In addition, the resistance drop in beryllium was reproduced five times.

Martin and Moore (*7*) have established the phase transition in beryllium at atmospheric pressure and 1250°C from a hexagonal-close-packed structure to a body-centered-cubic structure. This phase transformation is accompanied by an 8.4-percent reduction in volume. The reduction in volume would appear to make the body-centered-cubic phase in beryllium stable under high pressure.

Analogies can be made with titanium and zirconium. These elements are similar to beryllium in that their normal hexagonal-close-packed structures exhibit a phase transition to a body-centered-cubic structure at high temperature and atmospheric pressure. The phase transition to the body-centered-cubic structure is also accompanied by a decrease in volume (6 percent for zirconium and 3 percent for titanium). Jamieson (*8*) demonstrated by x-ray analysis that titanium and zirconium at high pressure undergo phase changes to a distorted body-centered-cubic structure and Young *et al.* (*9*) noted that the body-centered-cubic form of zirconium is denser. Therefore, it may be expected that beryllium behaves in a manner similar to titanium and zirconium under high pressure and that the high-pressure transition in beryllium is from the hexagonal-close-packed structure to body-centered-cubic structure (*10, 11*).

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References and Notes

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10. J. C. Jamieson has informed me that in studies, at high pressures, of Be and several other metals normally hexagonal-close-packed, the only change in x-ray diffraction patterns has been systematic decreases of intensity in certain reflections which he tentatively ascribes to a gross shortening in apparent grain size parallel to the *c* axes. He suggests that such faulting may produce a discontinuity in electrical resistance similar to that of a phase change. Insufficient studies have been made to date either to ascertain the pressure of the onset of this faulting or to completely rule out the possibility that there is a further true phase change in Be since the latter might not have proceeded in the x-ray experiments owing to differing sample purity or stress environment.
11. I thank D. Kump for his initiation of the program.

3 September 1963