Distribution of Pressure in an Opposed-Anvil, High-Pressure Cell

H. C. DUECKER E. R. LIPPINCOTT

Optical studies under very high pressure suffer from the lack of well-standardized experimental equipment and procedures. A preliminary requirement for this standardization is an understanding of the classical fixed anvil-high pressure cell of Bridgman, since other types of cells are generally calibrated using transition pressures reported by him. The distribution of pressure within a Bridgman-type cell is of particular concern.

A Bridgman-type cell with diamond optics anvils has been described (1)[1] and its application to spectral (2) and optical studies (3) has been reported. The optical quality of the diamonds permits high-resolution optical observations and photography as well as spectral measurements. The fact that materials can be viewed simultaneously under a continuous range of pressures, from 1 atm to about twice the applied pressure, makes it particularly well adapted to the study of pressure-induced phase changes (4).

A substance whose spectral characteristics are known as a function of pressure may be applied to the determination of the pressure distribution within this cell if spectral data can be obtained from different microsections of the sample (5).

HISTORICAL

Bridgman was aware of a pressure gradient (6) but he was unable to evaluate it satisfactorily so that the pressures reported in his studies are "mean applied pressures."

Bridgman gave a qualitative description of the factors leading to an uneven pressure distribution; viz., the coefficient of friction of the sample at the anvil surface, the applied pressure, the radius of the piston and the thickness of the sample film between the pistons. A quantitative description of the effect of these factors has been derived recently and will be discussed.

Perhaps, the earliest evidence indicative of a pressure gradient was the formation of a depression in the surface of the hardened-steel pistons after only a few experiments. In this regard, he was able to measure only the permanent deformation at 1 atm and not the deformation of the piston under pressure during the experiment. The measurement of this depression led him to believe that the pressure is greatest in the center of the piston. However, he felt that under certain conditions the portion of the piston under the highest pressure would yield, with the result that the pressure may be greater at some distance away from the center. In conclusion, he was unable to arrive at any consistent pattern with the many materials tested, and thus used average pressure values. The introduction of less deformable anvils, e.g., pyrophyllite and diamond, presumably should lead to a less complicated pressure distribution than that observed by Bridgman. Recently, there have been attempts to assess the pressure variation in opposed anvil-high pressure cells. Roy et al (7) have observed the location i.e., distance from the center, of the Bi_{I-II} transition at 25.4 kbar for various applied pressures. The somewhat limited data indicate an increase in pressure from the edge to the center such that the maximum pressure at the center is about 2.5 times the applied pressure. Christiansen et al (8) compressed silica glass in a similar type of pressure cell and have used the densification of the glass to evaluate the pressure distribution. The resulting pressure distribution is different from that reported by Roy et al, being lower in the center than at the edge. Deaton and Graf (9), using the Bi_{I-II} transition, have compared the pressures at the center, edge and face of a tetrahedral anvil-high pressure cell. While the pressure at the face and center were within a few percent of each other, pressures nearer the edge were only 70 percent of the value at the center.

A number of attempts have been made to evaluate mathematically the pressure distribution under rigid Bridgman type anvils (10-12). These derivations arrive at a relation of the form,

$$P = P_o\, G(r)\, e\, (2f/h)(r_o - r)$$

where f is the coefficient of friction, h the distance between the anvils, P the pressure at radius r and G(r) is a function of r, or unity. Jackson and Waxman (12) have discussed the expected pressure distribution for elastic as well as plastic materials with different arrangements of anvil and sample. For plastic materials such as those with which we are concerned, an exponential pressure increase toward the center is predicted requiring an abrupt (and presumably objectionable) pressure rise at the center.

Thus, a need for a more precise measurement

[1] Underlined numbers in parentheses designate References at the end of the paper.