

THE STRESS DISTRIBUTION IN A DIAMOND ANVIL AT 5.5 MILLION ATMOSPHERES

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Experiments show that the first order Raman shift of a diamond anvil may be used not only as an approximate measurement of the pressure, but also as a scale for the stress in the diamond anvil. According to this method, we measured the stress distribution in a diamond anvil maintained at 550 GPa pressure, and found that the high stress zone was limited to a thin layer around the diamond anvil culet.

Experimental high pressure research with the diamond anvil cell technique has improved to around 550 GPa recently^{1),2)}. A diamond anvil high pressure cell consists of a pair of diamond anvils (Fig. 1) with the anvil parameters: the anvil culet A , top flat B and bevel (θ). Several pieces of ruby chips are distributed on the top of a sample hole so that they contact the sample and the upper diamond directly. The wavelength of the fluorescence R_1 line of these ruby chips shifts to the red side at high pressures, which is used as a secondary

pressure scale²⁾⁻⁴⁾. But there is still a problem in the pressure measurement within the range of 200–400 GPa, resulting from the disappearance of the ruby fluorescence⁵⁾, as shown in Fig. 2.

A special method to measure the pressure has been suggested⁶⁾ based on the pressure dependency of the first Raman peak of the diamond anvil itself. It was expected to be a perfect calibration method in the diamond anvil cell technique, because there is no need for special pressure sensor materials to be loaded in the high-pressure cham-

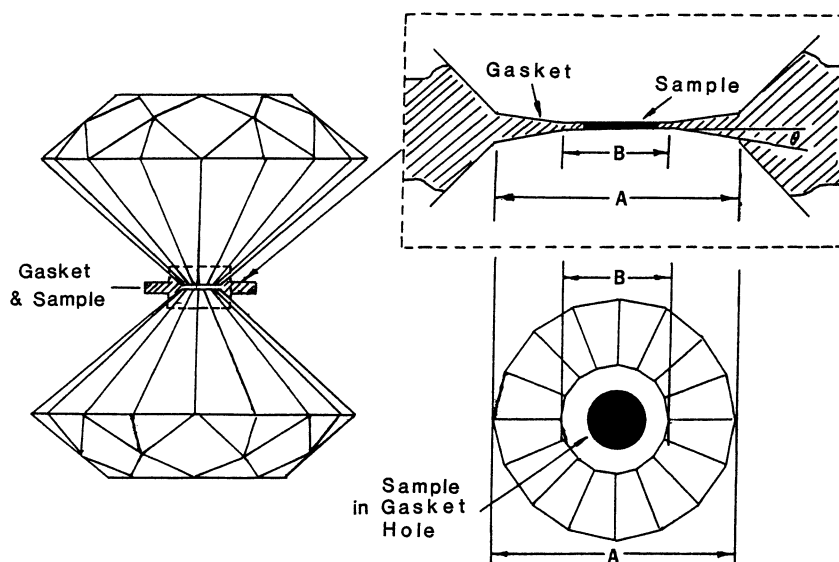


Fig. 1. A basic gasketed diamond anvil configuration: the culet A , its flat top B and the bevel angle θ .

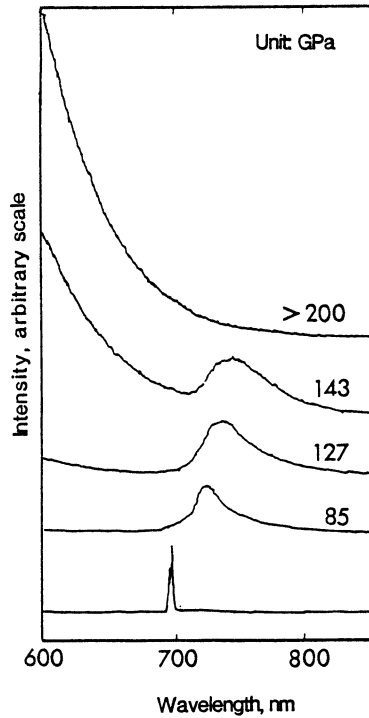


Fig. 2. Ruby R_1 fluorescence spectra at various pressures. Here, the intensity is shown as an arbitrary scale, but the real intensity can be estimated from the S/N ratio for every curve.

ber. A linear relationship between the first order Raman frequency shifts of a diamond anvil and pressures in the low pressure range was found; this appears to be a good pressure calibrative relation⁶.

Unfortunately, we found that the calibrative relations are different for different points on the diamond anvil culet; this means that there is not a single function for the pressures with the Raman shift. Figure 3 shows a family of calibrative relations at different distances from the center of a diamond anvil culet. Each curve of this family starts from 0 (the edge of the diamond culet) and stops at the highest pressure (the center of the diamond anvil culet). This phenomena comes from the complex stress distribution in the interior of the diamond anvil. In Fig. 3, the Raman shift at various points with different distances (r) from the center of the diamond anvil culet are also shown.

The points with the simplest stress situation are on the z -axis of the diamond anvil. Therefore, an approximate relationship between the Raman shift

and pressure in the z -axis might be found, which is shown in Fig. 4, based on experiments with 3 pairs of different diamond anvils: $A_1=600\ \mu\text{m}$, $B_1=400\ \mu\text{m}$; $A_2=600\ \mu\text{m}$, $B_2=200\ \mu\text{m}$; and $A_3=300\ \mu\text{m}$, $B_3=100\ \mu\text{m}$; all of the bevels are 7° . Although the experimental points are only a little more than 10, an experimental relationship can be obtained by the least squares method as:

$$p\ (\text{GPa}) = 40.09[(1 + dv/v_0)^{9.804} - 1], \quad (1)$$

where v_0 and dv are the frequency of the first order Raman peak at ambient conditions ($1333\ \text{cm}^{-1}$) and its shift at the pressure p (GPa). The initial pressure coefficient of frequency can be calculated

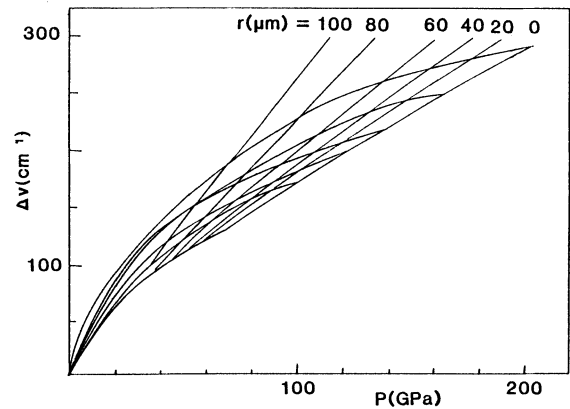


Fig. 3. The family of Raman shifts vs pressures at different points on the culets of a diamond anvil. Here, r is the distance from the measured point to the center of the culet.

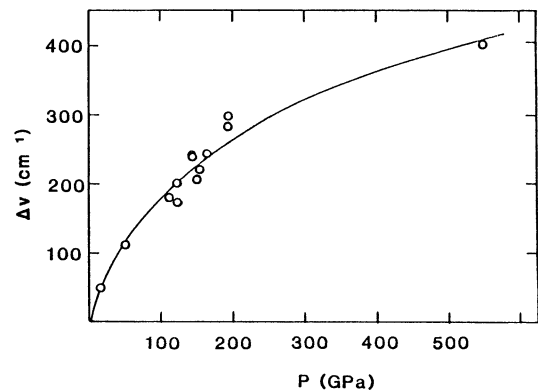


Fig. 4. The calibrative relationship between the Raman shift and pressure at the center point of the diamond anvils.

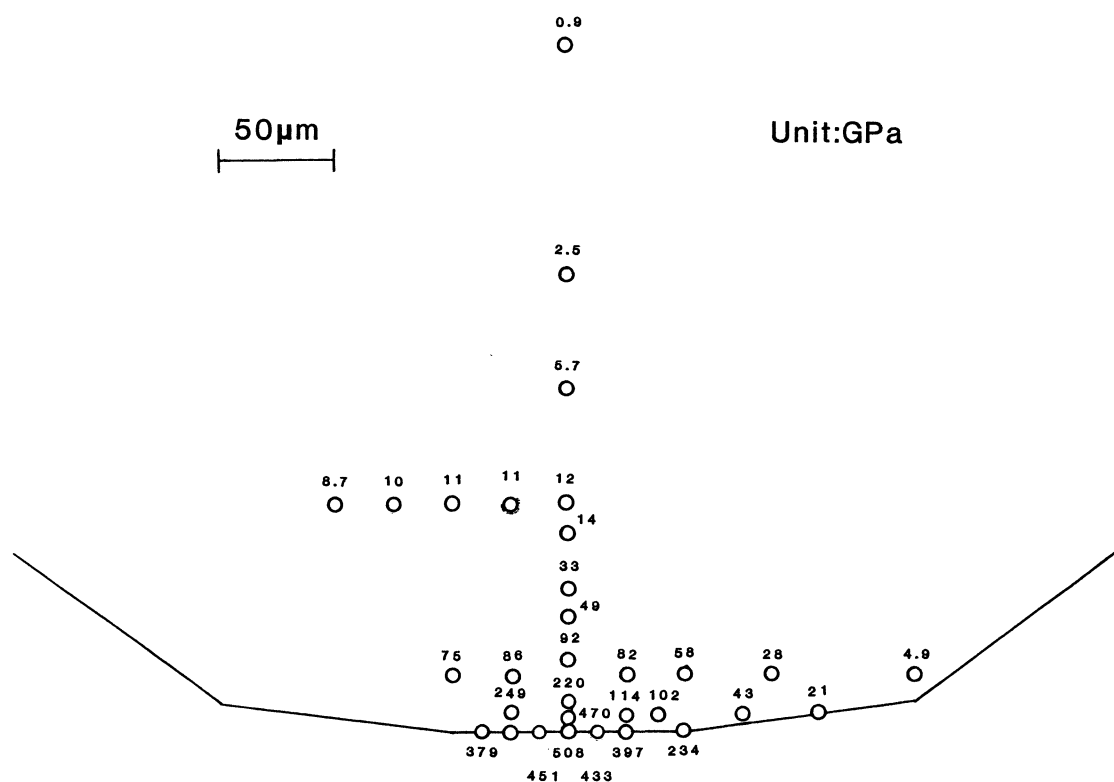


Fig. 5. The stress distribution in the diamond anvil while being maintained at 550 GPa pressure.

from Eq. (1) as $3.38 \text{ cm}^{-1}/\text{GPa}$, which is close to the values of 2.8, 2.96, 3.2 and $3.6^{(8)-11)}$ measured under hydrostatic conditions and much larger than its previous value 2.37 and $2.3^{(6),7)}$ under non-hydrostatic conditions. This might be caused by the fact that near hydrostatic conditions were maintained at the center point of the diamond anvil culet.

According to Eq. (1), we can estimate the stress for the various points in the interior of the diamond anvil by focusing an exciting laser beam at these points. Figure 5 shows the stress distribution pattern for the diamond anvil maintained at 550 GPa. The high stress zone (higher than 100 GPa) obtained by this method is concentrated in a very thin layer (less than $25 \mu\text{m}$).

Acknowledgements. The author sincerely appreciates all the help he has gotten during his research from Dr. H. K. Mao and Dr. P. M. Bell in the Geophysical Laboratory, the Carnegie Institute of Washington, and thanks Mrs. Doreen Brom-Bastas and Mr. Zhan Xiong Peng for the preparation of this manuscript.

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