Dependence of Superconducting Transition Temperature on Pressure in Primitive Hexagonal Si

Recently Chang *et al.*[1] (hereafter referred to as I) reported superconductivity in the primitive hexagonal phase of Si. A Bridgman type of opposed-anvil device was used to apply quasihydrostatic pressure of up to 26 GPa to Si. The pressure (P) of the sample was determined by measuring the superconducting transition temperature (T_c) of a piece of lead placed near the Si sample. The T_c vs P curve of Pb measured by Wittig[2] using a similar device was then used to deduce P. In this Comment we report a similar measurement in Si, but made by means of a diamond anvil cell (DAC) instead. The advantage of the DAC is that the pressure inside the cell can be determined by the ruby fluorescence method.[3] Overall we find good qualitative agreement with I except that for the same T_c our pressure was typically higher by 3 GPa. To resolve this difference the pressure dependence of T_c in lead was measured with the same DAC. With the new values of T_c vs P in lead our results agree quantitatively with I. This is significant since recently Lin *et al.*[4] measured the pressure dependence of T_c in crystalline powder of Si and reported results substantially different from those of I.

A detailed description of our DAC will be published elsewhere. The sample ($\sim 5\times 60\times 100\ \mu\text{m}^3$ in volume and doped with $3\times 10^{14}\ \text{cm}^{-3}$ of phosphorus) is surrounded by $CaSO_4$ powder as a pressure transmitting medium in a steel-gasketed DAC. The cell is pressurized at room temperature and then cooled in a variable-temperature optical Dewar. The sample temperature is monitored by a calibrated Si diode in contact with one of the diamond anvils. The sample resistance is measured via a four-probe technique. The pressure is determined from the wavelength of the R_1 fluorescence line of ruby chips next to the sample. We assume that the pressure coefficient of the R_1 line is -3.65 Å/GPa independent of temperature.[5] The transition width is typically less than 0.2 K.

Our data points are shown as solid and open circles in Fig. 1 while the results of I are represented by a broken line. The general decreasing behavior of T_c with increase in P is well reproduced in our experiment but at the same T_c there are differences in the values of P between the two measurements. This difference cannot be attributed to pressure inhomogeneity inside the cells. From the different ruby chips in the cell we can determine the high and low limits of P inside our cell. These are shown as horizontal bars around the data points. Chang *et al.* estimated an uncertainty of ~ 0.5 GPa in their pressure determination as compared to 1 GPa in our experiment.

To resolve this difference we have also determined the P dependence of T in Pb. A comparison between our results and those of Ref. 2 is shown in Fig. 1. A similar difference of between 3 and 3.5 GPa is found between the two measurements. This difference can probably be traced to the assumption in Ref. 2 that P does not vary between room temperature and low temperature. We find that typically P inside our DAC increases by about 2 to 3 GPa on cooling.

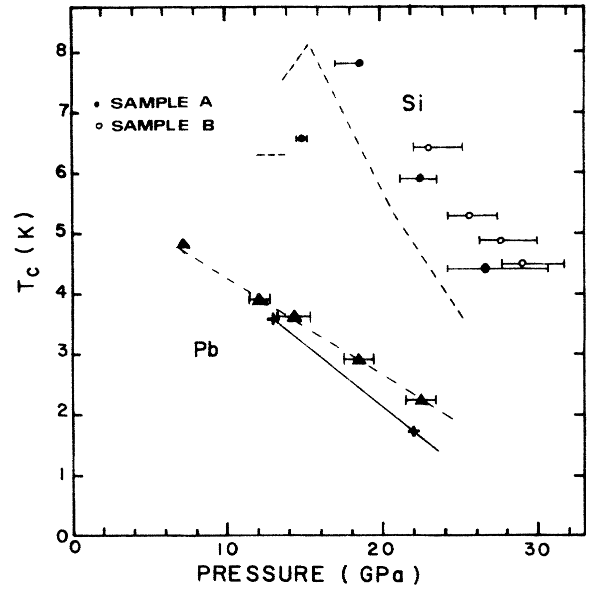

FIG. 1. Comparison of T versus P in Si and Pb as determined by a DAC and by a Bridgman type of opposed-anvil device. The DAC results are represented by solid and open circles for Si and by solid triangles for Pb. The Bridgman-anvil results are obtained from Ref. 1 for Si (broken curve) and Ref. 2 for Pb (crosses). In the case of Pb the solid and broken lines drawn through the experimental results are for guidance of the eyes.

This work was supported by the U. S. Department of Energy under Contract No. DE-AC03-76SF00098. We wish to acknowledge extensive discussions and advice from G. Martinez, M. L. Cohen, R. Jeanloz, and R. Reichlin.

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Received 7 February 1986
PACS numbers: 74.30.Ek, 62.50.+p

[1] K. J. Chang, M. M. Dacorogna, M. L. Cohen, J. M. Mignot, G. Chouteau, and G. Martinez, Phys. Rev. Lett. **54**, 2375 (1985).

[2] J. Wittig, Z. Phys. B **38**, 11 (1980).

[3] J. Barnett, S. Block, and G. Piermarini, Rev. Sci. Instrum. **44**, 1 (1973).

[4] T. Lin, W. Dong, K. Dunn, C. Wagner, and F. Bundy, Bull. Am. Phys. Soc. **31**, 640 (1986).

[5] D. Fabre and M. M. Thiery, J. Phys. (Paris) **8**, 405 (1984).