Title

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Publication Date

1986-02-01

LBL-21047 c.2
Preprint

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Submitted to Physical Review Letters

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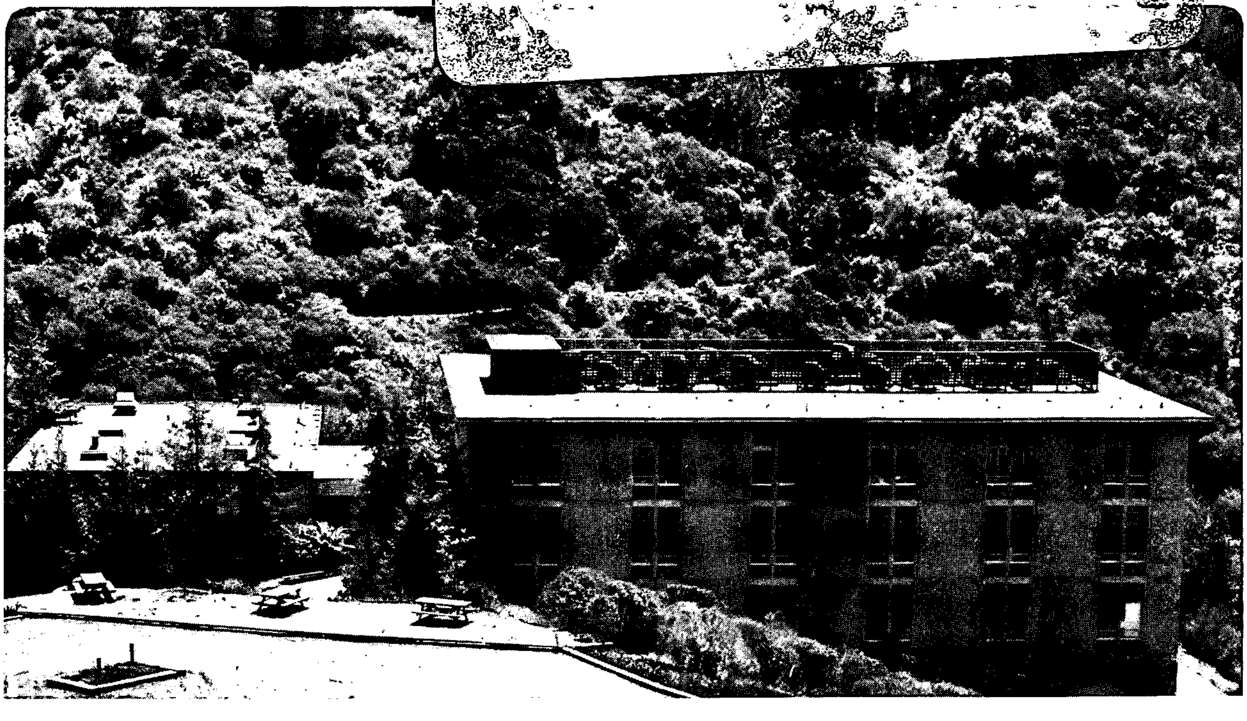
February 1986



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Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

Dependence of Superconductivity Transition Temperature on Pressure in Primitive Hexagonal Si

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Recently Chang et al.[1] (hereafter referred to as I) reported a theoretical prediction and subsequent experimental confirmation of superconductivity in the primitive hexagonal phase of Si. In the experimental part of that work a Bridgeman-type of opposed-anvil device was used to apply quasi-hydrostatic pressure of up to 25 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 versus 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 of T_c versus P in Si but using a diamond anvil cell (DAC) instead. The advantage of the DAC compared to the Bridgeman-type of device is that the pressure inside the cell can be determined by the Ruby fluorescence method. Overall we find very good qualitative agreement with I except that for the same T_c in Si our pressure was typically higher by 3 GPa. To resolve this difference in pressure between the two measurements we have also determined the pressure dependence of T_c in lead. If the value of T_c versus P in lead we determined were used to measure P in I, the results in the two experiments would be in complete agreement.

A detailed description of our DAC will be published elsewhere. The sample ($\sim 5\mathrm{x}60\mathrm{x}100\,\mu^3$ in volume and doped with $3\mathrm{x}10^{14}$ cm^{-3} of phosphorus) is surrounded by $CaSO_4$ (plaster of Paris) as a pressure transmitting medium in a steel gasketed DAC. The pressure is applied to the cell at room temperature with a hydraulic press. After the desired pressure is reached the pressure is locked in by a steel ring and removed from the press. The cell is then cooled in a Janis variable temperature dewar. The temperature of the cell is monitored by a calibrated Si diode mounted adjacent to one of the diamond anvils. The resistance of the sample is measured via a four-probe technique. The wires carrying the current in and out of the cell are insulated from the steel gasket by aluminum oxide powder. The pressure inside the cell is determined by comparing the wavelength of the R fluorescence line of Ruby chips scattered around the sample with that of a Ruby chip outside the cell but maintained at the same temperature. In calculating the pressure we assume that the pressure coefficient of the R_1 line is -3.65 A/GPa independent of temperature. The width of the resistance drop at the superconducting transition is typically less than 0.2 K. From this width we estimated that the pressure variation over the length of the sample is less than 0.5 GPa.

A few of our representative data points are shown as solid and open circles in Fig.1 and those determined in 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 we find differences in the value of P we determine and those reported in I.

The difference between the results obtained by the two different methods cannot be attributed to pressure inhomogeneity inside the cells since from the different Ruby chips scattered throughout the cell we can determine the high and low limits of the pressure inside our cell. These are shown as horizontal bars around the data points in Fig. 1. From the sharpness of the Pb superconducting transition Chang et al[1] estimated an uncertainty of ~0.5 GPa in their pressure determination. This is smaller than the uncertainty of about 1 GPa in our experiment. However to explain the difference in T_c measured by the two groups requires a difference in pressure of > 3 GPa, which is well outside the pressure uncertainties in the two measurements.

Since the T_c versus P dependence in lead as reported by Wittig[2] was used to measure the pressure in I, we have used our cell to determine the pressure dependence of T_c in Pb. A comparison between our results and the result of Wittig[2] is also shown in Fig. 1. A similar difference in pressure of between 3 to 3.5 GPa is found between our pressure and that determined by Wittig at the same T_c.

The difference between the two pressure scales can probably be traced to the assumption in Ref. 2 that the pressure in the cell does not vary between room temperature and low temperature. We find that typically the pressure inside our DAC increases by about 2 to 3 GPa on cooling from room temperature to liquid He temperature.

In conclusion, we have used a DAC to measure the pressure dependence of T_c in the primitive hexagonal phase of Si under high pressure. We confirm the decrease in T_c with P reported in I but we also find a difference of about 3 GPa in the value of pressure we determined from the Ruby fluorescence scale as compared to the pressure reported in I. This difference is reconciled by calibrating the lead manometer scale with the Ruby fluorescence scale at low temperatures.

ACKNOWLEDGEMENTS

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy under Contract Number 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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FIGURE CAPTION

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

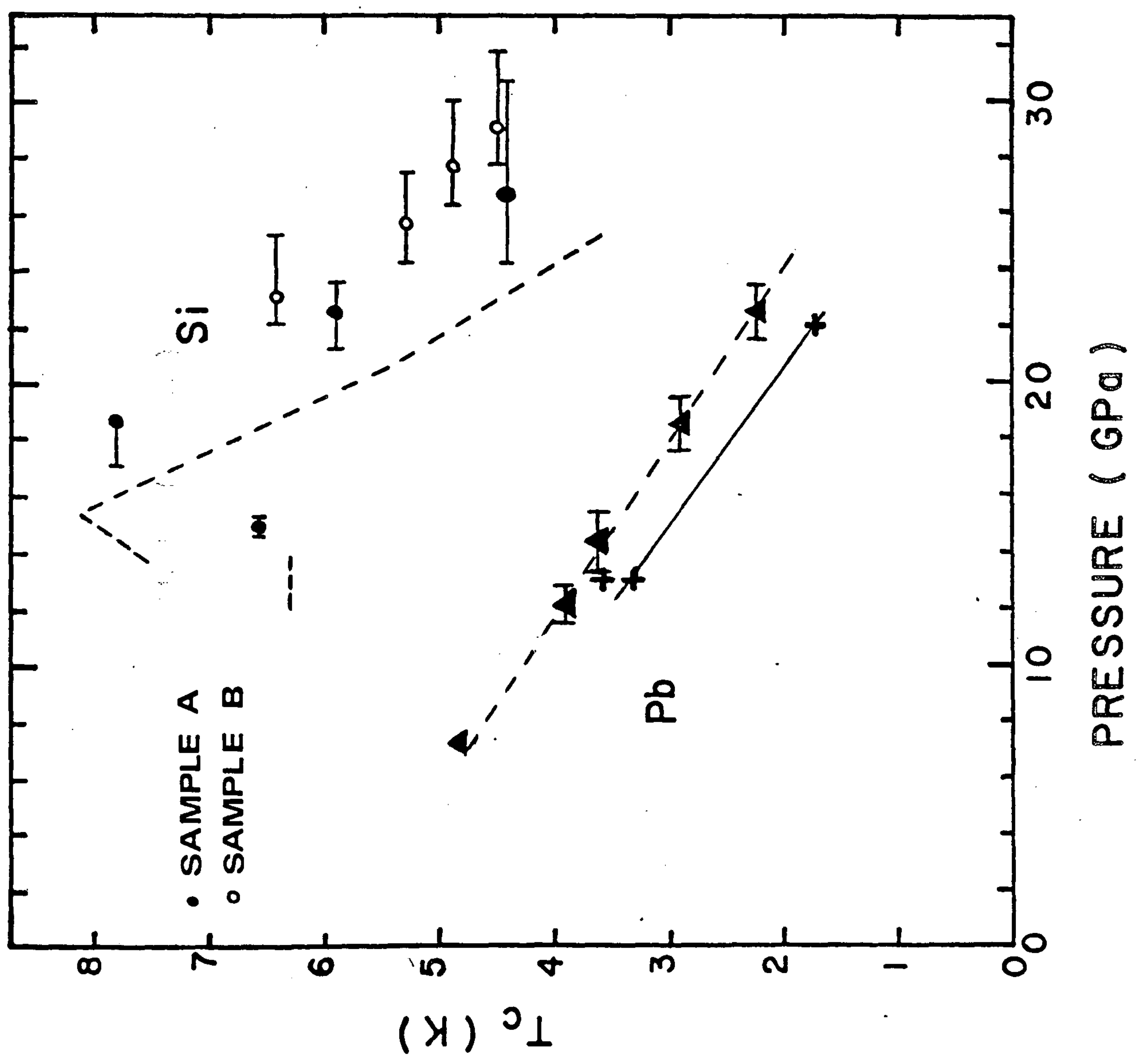

FIGURE 1

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