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ANISOTROPIC LENGTH CHANGES AT THE SUPERCONDUCTING TRANSITION OF ZINC

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The length changes of zinc single crystals have been measured at the field induced transition from the superconducting to the normal state between 0.3 K and 0.8 K. A strong anisotropy in the deformations parallel and perpendicular to the hexagonal axis was observed. At $T = 0$ K the relative length changes are $(l_s - l_n)/l_s = 1.4\times10^{-8}$ parallel and $(l_s - l_n)/l_s = -0.4\times10^{-8}$ perpendicular to the hexagonal axis. From the experimental data we have calculated the pressure dependences of the critical field H_c and the critical temperature T_c.

In a previous publication [1] we have given the results of length change measurements on gallium single crystals. It was found that there were certain discrepancies between experimental data and theoretical estimates of the effect. To extend such investigations to further substances we have now measured the length changes of zinc single crystals parallel and perpendicular to the hexagonal axis at the magnetic field induced transition from the superconducting to the normal state.

The results of our investigations on high purity (6N) zinc single crystals are shown in fig.1. As in the case of gallium [1], thallium [2] and indium [3] the length change $l_s - l_n$ has a different sign for the two orientations.

The relation between the stress dependence of the critical field $\partial H_c/\partial\sigma$ and the relative length change $(l_s - l_n)/l_s$ is given by [4]

$$(l_{si} - l_{ni})/l_{si} = (1/4\pi)\, H_c\, \partial H_c/\partial\sigma_i \qquad (1)$$

where σ_i is an uniaxial tensile stress in the i-direction in which the change of length is observed. In writing formula (1) we have neglected the much smaller pure magnetostrictive term.

From our data and the knowledge of $(\partial H_c/\partial T)_{T=T_c}$ it is possible to calculate the pressure dependences of the critical field at zero temperature, H_0, and of the critical temperature T_c. The values obtained are shown in table 1. To our knowledge the only published work on the pressure effect on superconductivity in zinc deals with hydrostatic pressure [5,6]. One may, however, compare our results with these data. The comparison is also shown in table 1.

The temperature dependence of the relative length change is related to the logarithmic volume derivatives of H_0 and T_c, which may be calculated from the pressure coefficients of these values and the appropriate compliance factors. The relevant calculations are given in detail in an earlier publication [7] for the case of a parabolic temperature dependence of the

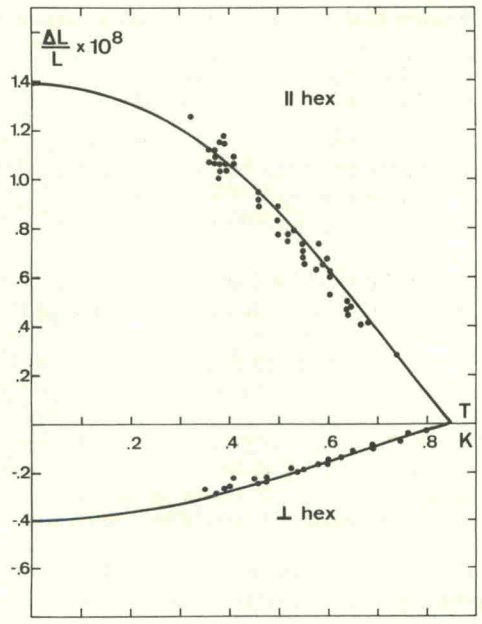


Fig. 1. The relative length change $(l_s - l_n)/l_s$ for zinc single crystals parallel and perpendicular to the hexagonal axis. The solid curves are calculated from the stress dependences of T_c and H_0, consistent with our experimental data.

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Table 1
Comparison of the stress dependences of T_c and H_c from pur work with those taken from hydrostatic pressure work

	//	⊥	// + 2⊥	ref.[5]	ref.[6]
$\partial H_0/\partial\sigma_i$ $\times 10^3$ Oe/atm	+ 3.3 ± 0.2	−0.95 ± 0.1	+ 1.4 ± 0.4	+ 1.4	-
$(\partial H_c/\partial\sigma_i)T=T_c$ $\times 10^3$ Oe/atm	+ 3.15 ± 0.2	−0.7 ± 0.1	+ 1.75 ± 0.4	+ 1.8	-
$\partial T_c/\partial\sigma_i$ $\times 10^5$ K/atm	+ 3.15 ± 0.2	−0.7 ± 0.1	+ 1.75 ± 0.4	+ 1.6	+ 2.4

critical field H_c. Even small deviations from a quadratic law may, however, cause considerable changes in the form of the temperature dependence of the length change. We have taken this into account using the H_c versus T relation given by Fassnacht and Dillinger [8]. The curves obtained are shown in fig.1.

In previous work on this subject [9] it has been pointed out that one may compare the observations with theory by defining a property ϕ_i, where

$$\frac{(\partial \ln T_c/\partial \ln l_i) + \gamma_{gi}}{\ln\theta/T_c} \equiv \phi_i = \frac{2\gamma_{gi}}{1+\lambda}$$

and where γ_{gi} is an anisotropic Grüneisen parameter and λ is the electron phonon interaction. The calculation are to be made for the case of uniaxial deformations rather than that of uniaxial stress or pressure.

Extending the work of former authors [9] and taking into account the volume dependence of C which enters the expression for $\lambda = C/M\theta^2$ one finds with the aid of pseudopotential calculations [10] that, for the case of zinc, one should write

$$\phi_i = \frac{2\gamma_{gi} - 1.39}{1+\lambda} \quad \frac{(1+\mu^*)\lambda}{\lambda-\mu^*} \qquad (2)$$

where μ^* is the Coulomb repulsion coefficient [11].

From formula (2) one may deduce theoretical values for $\partial T_c/\partial\sigma_i$. We have done this, using the low temperature values of the thermal expansion [12], the elastic constants [13] and the specific heat [14]. The comparison of these theoretical values with our experimental results is shown in table 2. Considering the possibility that the errors in the constants used may be considerable it may be seen that there is fair agreement between theory and experiment.

Table 2
Comparison of observed and calculated values of $\partial T_c/\partial\sigma_i$

	//	⊥
$\partial T_c/\partial\sigma_i$ $\times 10^5$ K/atm (calc.)	+ 3.6	−0.6
$\partial T_c/\partial\sigma_i$ $\times 10^5$ K/atm (exp.)	+ 3.15	−0.7

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References

[1] H. R. Ott, Solid State Comm., to be published.
[2] J. L. Olsen and H. Rohrer, Helv. Phys. Acta 30 (1957) 49.
[3] J. G. Collins, J. A. Cowan and G. K. White, Cryogenics 7 (1967) 219.
[4] D. Shoenberg, Superconductivity (Cambridge University Press, London, 1965) 74.
[5] D. Gross and J. L. Olsen, Cryogenics 1 (1960) 91.
[6] I. V. Berman, N. B. Brandt and N. I. Ginzburg, Zh. Eksp. i Teor. Fiz. 53 (1967) 124, Soviet Phys. JETP 26 (1968) 86.
[7] K. Andres, J. L. Olsen and H. Rohrer, IBM J. Res. Develop. 6 (1962) 84.
[8] R. E. Fassnacht and J. R. Dillinger, Phys. Rev. 164 (1967) 565.
[9] J. L. Olsen, K. Andres and T. H. Geballe, Phys. Letters 26A (1968) 239.
[10] R. S. Sorbello, private communication.
[11] P. Morel and P. W. Anderson, Phys. Rev. 125 (1962) 1263.
[12] R. D. Mc Cammon and G. K. White, Phil. Mag. 11 (1965) 1125.
[13] G. A. Alers and J. R. Neighbours, J. Phys. Chem. Solids 7 (1958) 58.
[14] G. Seidel and P. H. Keesom, Phys. Rev. 112 (1958) 1083.

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