OSUL-WJ 67-0492

The authors are indebted to Dr. R. Blinc for many valuable discussions and remarks.

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EFFECT OF HYDROSTATIC PRESSURE ON THE FERMI SURFACE OF Be *

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Received 7 June 1967

The effect of hydrostatic pressure on the Fermi surface of Be has been determined using both solid and fluid He techniques. A comparison is made with the results of recent studies of the oscillatory magnetostriction.

The Fermi surface of Be has been studied by Watts [1] using pulsed field de Haas van Alphen (dHvA) techniques. These results agree with the predictions of the free electron model to a much lesser extent than in the case of Zn [2], where the qualitative agreement with the free electron model has been shown to extend to situations when either the effective valence [3] or the c/a ratio [4] is changed.

In this work we report measurements of the effect of hydrostatic pressures to 4 kbar on three prominent dHvA frequencies in Be single crystals in the temperature range from 1 to 4°K. These results are compared with recent studies of the stress dependence of these frequencies using magnetostriction techniques [5].

The dHvA oscillations were detected using the d.c. field method with audio frequency modulation as discussed previously [4]. Hydrostatic pressures were generated in both solid [4,6] and fluid He [7].

We have examined the α and α' oscillations for $H//[0001]$ corresponding to the maximum extremal and the waist cross sections, respectively, of the cigar electron surface and the γ oscillations associated with the minimum cross section of the waists of the coronet hole surface for $H//[11\bar{2}0]$. The superposition of the α and α' frequencies which differ by 3.0% results in a pattern characterized by strong beating. The dominant frequency α was therefore measured, between beat maxima, to 4 kbar over as many as 18 beats over the field range from 10-30 kOe. The α' frequency was determined from the number of cycles n per beat as given by $n = \alpha/(\alpha - \alpha')$. In the fluid helium measurements [7], the shifts in phase of single oscillations at beat maxima and minima were measured. The pressure dependences of the α and α' frequencies can then be obtained from

$$\frac{\Delta H^{\pm}}{B\,\Delta P} = \frac{\mathrm{d}\ln\alpha}{\mathrm{d}P} + \left[\frac{\mathrm{d}\ln\alpha}{\mathrm{d}P} - \frac{\mathrm{d}\ln\alpha'}{\mathrm{d}P}\right]\left[1 \pm \alpha\mathcal{A}/\alpha'\mathcal{B}\right]^{-1}$$

where $\alpha H^{\pm}$ denotes the effective shift in applied field caused by a pressure change ΔP, B is the magnetic field and $\mathcal{A}$ and $\mathcal{B}$ are the amplitudes of the α and α' oscillations. The plus sign applies to the beat maxima; the minus, to the beat minima. The amplitude ratio $\mathcal{A}/\mathcal{B}$ is obtained from the measured ratio of the apparent amplitude in the beat maximum, $\mathcal{A}+\mathcal{B}$, to that in the beat minimum, $\mathcal{A}-\mathcal{B}$.

The effect of pressure on the minimum cross sectional area of the waists of the coronet was also obtained both by dHvA frequency measure-

* This work was supported by the U.S. Atomic Energy Commission.

Table 1
Comparison of the pressure derivatives of the dHvA frequencies F in Be expressed in 10^{-4} kbar^{-1}.

$\frac{d \ln F}{dP}$	Solid helium technique	Phase shift technique	Magnetostriction method of ref. 5[d]	Simple scaling prediction
$\frac{d \ln \alpha}{dP}$	2.3(± 0.5)	1.6(± 0.4)[b]	10(± 4)	5.8
$\frac{d \ln \alpha'}{dP}$	-0.7(± 0.5)[a]	-1.0(± 0.6)[b]	10(± 4)	5.8
$\frac{d \ln \gamma}{dP}$	-50 (± 8)	-40 (± 10)	-160(± 100) - 50(± 50)[c]	5.8

[a] Value obtained from the pressure derivative of the number of cycles per beat.
[b] Values obtained from the phase shift analysis described in text.
[c] Value for waist cross section for $H//[10\bar{1}0]$.
[d] Error estimated from quoted 20% uncertainty in strain dependence of the cross sectional areas.

ments to 4 kbar and by means of the phase shift method [7]. Again, we find agreement between the methods to within experimental uncertainty. The results are also shown in table 1.

Since Be is very nearly ideal close-peaked (c/a = 1.57), from free electron considerations one would expect (by simple scaling of the Fermi surface) all the cross-sectional areas to increase at a rate given by $\frac{2}{3}$ the volume compressibility (5.8×10^{-4}/kbar) [8]. The small change in c/a would tend to decrease this effect in the case of the waists of the coronet and increase it in the case of the cigar cross sections. However, the magnitude of this contribution is negligible. We observe that the coronet waists decrease rapidly with pressure. The larger cigar cross section increases more slowly than scaling would predict while the smaller cigar cross section actually decreases. These results cannot be explained from free electron considerations.

Our pressure derivatives are in rough quantitative agreement for the coronet waists with the findings of Chandrasekhar et al. [5] (see table 1), who determined the stress dependence of these cross sections by comparison of the amplitudes of the oscillatory components of the magnetostriction and the magnetization. The agreement of the cigar cross sections in poor (see table 1). This disagreement probably stems for difficulties inherent in the magnetostriction method in relating the amplitudes of two different sets of data, each consisting of the superposition of two frequencies.

We conclude that the pressure dependence of the Fermi surface of Be does not agree even qualitatively with the free electron model. We are attempting a more sophisticated approach involving a Heine-Abarenkov [9] type pseudopotential fit as a function of unit cell volume.

We are grateful to Professor W. L. Gordon for the use of the single crystal specimens used in this investigation.

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