Letters to the Editor

ON THE PROBLEM OF CALCULATING THE DIAMAGNETIC SUSCEPTIBILITY OF HELIUM

P. Sh. FRIDBERG and V. K. SHUGUROV

Submitted to JETP editor August 20, 1962

J. Exptl. Theoret. Phys. (U.S.S.R.) **43**, 2308 (December, 1962)

DAMBURG and Iolin [1] used Hylleraas functions with 80 variable parameters to obtain $\overline{r^2} = 1.1935$ (in atomic units) for an electron in the ground state of helium. These authors suggested that it is desirable to check the experimental value of the magnetic susceptibility. However, it seems to us there are no sufficient reasons to doubt the experimental value. The reason for the discrepancy between the theoretical calculations and the experimental data ($\overline{r^2} = 1.220 \pm 0.006$) is the poor convergence of the selected functions, which was mentioned by Damburg and Iolin themselves. We wish to point out that the high precision of the calculated values of the energies is proof of the satisfactory nature of the functions only for medium distances, while in calculations of $\overline{r^2}$ it is the large distances which are important.

We have calculated $\overline{r^2}$ using functions [2,3] of the extended Fock method [4] in one-, two-, and three-configuration approximations. In the three-configuration approximation (five variable parameters) there is better agreement with experiment (we rounded out the value of the parameter [2] to 2.19) than that obtained in [1]:

	$1s^2$	$1s^2, 2p^2$	$1s^2, 2s^2$	$1s^2, 2s^2, 2p^2$
$\overline{r^2}$:	1.233	1.233	1.207	1.208

A very rough estimate of the contribution of the configurations $3s^2$, $3p^2$, $3d^2$ indicates that the agreement may be improved by another 0.005.

Thus the functions of the extended Fock method are well-behaved not only at small and medium distances, which is confirmed by energy and hyperfine structure calculations, [5] but also at large distances.

[1] R. Ya. Damburg and E. M. Iolin, JETP **42**, 820 (1962), Soviet Phys. JETP **15**, 572 (1962).

[2] Skvortsova, Shugurov, and Éringis, Trudy AN LitSSR **B4**, 27 (1959).

[3] Éringis, Fridberg, and Shugurov, Optika i spektroskopiya **11**, 297 (1961).

[4] Vizbaraite, Éringis, and Yutsis, DAN SSSR **135**, 809 (1960), Soviet Phys. Doklady **5**, 1251 (1960).

[5] D. A. Goodings, Phys. Rev. **123**, 1706 (1961).

Translated by A. Tybulewicz
394

DEPENDENCE OF THE FORBIDDEN-BAND WIDTH OF SEMICONDUCTING FILMS ON THEIR THICKNESS AND TEMPERATURE

V. B. SANDOMIRSKIĬ

Institute for Radio Engineering and Electronics, Academy of Sciences, U.S.S.R.

Submitted to JETP editor September 10, 1962

J. Exptl. Theoret. Phys. (U.S.S.R.) **43**, 2309 (December, 1962)

QUANTUM effects should appear in solid films when their thickness becomes comparable with the effective wavelength (λ) of the charge carriers. [1] The cited papers refer to metals for which the appropriate film thicknesses are very small, 10^{-8}—10^{-7} cm, owing to the large Fermi energy. In the case of semiconductors, however, the situation is much more favorable. Indeed, since $\lambda \propto h/\sqrt{2mkT}$, and assuming the effective mass to be $m \approx 10^{-2}m_0$, we find that at $T \approx 100°K$ the wavelength is $\lambda \approx 10^{-5}$ cm. In the case of degenerate semiconductors we should use $kT\mu^*$ instead of kT, where μ^* is the reduced Fermi level. Obviously this does not greatly alter the estimate of the wavelength.

Owing to carrier scattering at the film boundaries, which is diffuse in the classical limit, the quantum effects may be strongly masked.

It follows from the uncertainty principle that, irrespective of the details of the energy spectrum, the continuous spectrum for semiconducting films should be shifted by $\Delta \approx \hbar^2/2ma^2$, where a is the film thickness. This should appear as an increase of the forbidden-band width with decrease of the film thickness.

This effect can obviously appear, for example, in the dependence of the red edge of the fundamental absorption on the film thickness or on temperature for a film of given thickness.

If we consider the simplest model of a film (a potential well with a flat bottom and infinitely high walls) the stepwise nature of the function of the density of states per unit energy interval will

correspond to the respective frequency dependence of the absorption coefficient.

[1] I. M. Lifshitz and A. M. Kosevich, Izv. AN SSSR, ser. fiz. **19**, 395 (1955), Columbia Tech. Transl. p. 353; see also I. M. Lifshitz and M. I. Kaganov, UFN **69**, 419 (1959), Soviet Phys. Uspekhi **2**, 831 (1960).

Translated by A. Tybulewicz
395

INFLUENCE OF HYDROSTATIC COMPRESSION ON THE SUPERCONDUCTING TRANSITION TEMPERATURE OF Nb_3Sn

B. G. LAZAREV, L. S. LAZAREVA, O. N. OVCHARENKO, and A. A. MATSAKOVA

Physico-technical Institute, Academy of Sciences, Ukr.S.S.R.

Submitted to JETP editor September 12, 1962

J. Exptl. Theoret. Phys. (U.S.S.R.) **43**, 2309-2310 (December, 1962)

IT has been found recently that ruthenium does not exhibit the isotopic effect: the superconducting transition temperature (T_c) is, within the experimental error, the same (0.493 ± 0.0015°K) for the ruthenium isotopes with mass numbers from M = 99 to M = 104.[1] Also, a very small isotopic effect has been observed for Nb_3Sn, for which T_c varies not as $M^{-1/2}$, as required by the electron phonon interaction mechanism, but as $M^{-1/12}$.[2]

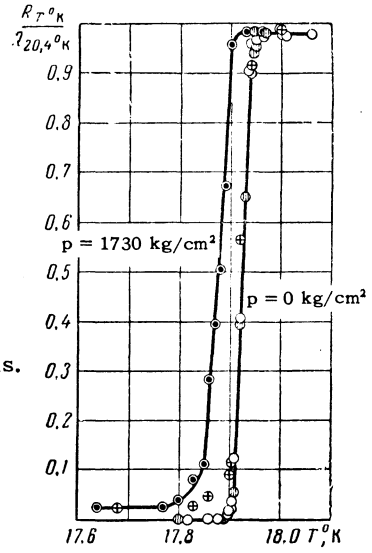
It was considered to be of very great interest to investigate the properties of such superconductors. We investigated one of these properties: the sensitivity to hydrostatic compression.

Samples of Nb_3Sn were prepared by diffusion growth of a film of this compound on the surface of a niobium wire (containing 99.5% niobium) immersed for this purpose in tin for several hours at about 1000°C.

A pressure of 1730 kg/cm^2 was produced by the ice technique described earlier.[3]

The figure shows the superconducting transition curves of Nb_3Sn with and without pressure. The transition temperature was reduced by the 1730 kg/cm^2 pressure by $(4.5 \pm 0.5) \times 10^{-2}$ deg, i.e., $\partial T_c/\partial p = -(2.5 \pm 0.3) \times 10^{-5}$ deg/atm.

Thus it is seen that the effect of pressure has the same sign (minus) as in the majority of superconductors, and its magnitude is close to the effect in such good superconductors as tin ($\partial T_c/\partial p = -4.6 \times 10^{-5}$ deg/atm)[4] or mercury (according to our measurements and published data[5] $\partial T_c/\partial p = -3.6 \times 10^{-5}$ deg/atm), for which T_c is nearly proportional to $M^{-1/2}$.



Superconducting transition in Nb_3Sn under pressure (dots with black centers) and without pressure (before application of pressure and after its removal); the latter case is represented by various symbols.

For these samples of Nb_3Sn we also determined the value of $(\partial H_c/\partial T)_{T_c} = -15.5 \times 10^3$ G/deg (this value agrees well with the results of Kunzler[6]).

The results obtained confirmed once again that Nb_3Sn is a superconductor of alloy type, i.e., the fields at the beginning of penetration into a superconductor and at the destruction of superconductivity are very different. The values of $\partial T_c/\partial p$ and $\partial H_c/\partial T$ (and hence also $\partial H_c/\partial p$) allow us to use the well-known thermodynamic relationships to obtain such quantities as, for example, the jumps in the thermal expansion coefficient ($\Delta\alpha$) and specific heat (ΔC) at the transition. Such estimates give grossly exaggerated values ($\Delta\alpha \approx 5 \times 10^{-4}$ deg^{-1}, $\Delta C \approx 100$ cal/deg) which probably indicates that the measured values of $\partial H_c/\partial T$ and $\partial T_c/\partial p$ refer to a very small part of the volume of Nb_3Sn. This agrees with measurements of other properties of this superconductor.[7,8] However, it is possible that the depth of penetration of the magnetic field in Nb_3Sn and similar superconductors may be very great.

[1] Geballe, Matthias, Hull, and Corenzwit, Phys. Rev. Lett. **6**, 275 (1961).

[2] G. E. Devlin and E. Corenzwit, Phys. Rev. **120**, 1964 (1960).

[3] L. S. Kan and B. G. Lazarev, JETP **14**, 440 (1944).