reflected wave can be neglected. As a result we readily obtain

$$\eta(d) = \left|\frac{E_1(d)}{H_0}\right|^2 = \left(\frac{9\sqrt{3}}{16}\,\frac{\omega^2}{cv}\,\delta^2\frac{N}{N_s}\,\frac{\Delta}{T}\right)^2 \mathrm{ch}^{-2}\frac{\Delta}{2T}\left|I(d)\right|^2. \qquad (6)$$

We shall use in the estimates the experimental law $\delta \sim \delta_0(1 - t^2)^{1/2}$, and the velocity v is conveniently expressed in terms of the correlation length $\xi_0 = 0.18\hbar v/kT_c$. For an indium film ($\delta = 6.4 \times 10^{-5}$ cm) of thickness $d = 5 \times 10^{-4}$ cm, on which radiation with wavelength $\lambda = 3$ cm is incident, we obtain $\eta \sim 10^{-11}$ (at $\Delta(0)/2T = 0.9$). An effect of this magnitude lends itself to observation[2].

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MANIFESTATION OF THE EXCITON MECHANISM IN THE CASE OF GRANULATED SUPERCONDUCTORS

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The exciton mechanism of superconductivity could, in our opinion, become manifest most clearly in the case of systems with planar geometry, i.e., for dielectric-metal-dielectric sandwiches and for layered chemical compounds (see [1] and the literature cited therein). There is no doubt, however, that it is quite difficult to attain an appreciable increase of the critical temperature T_c in the aforementioned cases. For sandwiches, the difficulties are connected with the need for making the metallic film extremely thin, even if we disregard the choice of a suitable dielectric [1, 2]. For layered compounds, the main problem is to introduce the necessary dielectric "layers" (e.g., by "intercalation"). The use of large molecules of the pyridine type [3] for such layers is not effective enough [3, 4]. On the other hand, the possibility of producing "layers" of the semiconductor type with the required exciton band has not yet been demonstrated.

In view of the foregoing, in the new experimental investigations [5 - 7], particular interest attaches to granulated superconductors, in which very

[2]) An effect connected with the expulsion of the excitations from the skin layer might exist also in a normal metal. The corresponding calculations are made very difficult by the nonlocality of the problem in the normal metal (in view of the absence of a Meissner current). This question was investigated in [4] only for the limiting case $\omega\tau \ll 1$, which is the inverse of the case considered above.

minute metallic particles (best in the form of flakes or strongly flattened disks) are situated in a suitable dielectric matrix. In this case, as already emphasized earlier [1], there is no need to produce a solid ultrathin film, and very extensive possibilities are apparently uncovered at the same time for the choice of the dielectric.

In [6], superconductivity was observed in the systems Cu-Ge, Au-Ge, and Ag-Ge, and it was assumed there that the superconductivity is due to the metallic phase of Ge (such a phase, which is stable at pressures $p > 115$ kbar, is actually superconducting with $T_c = 5.35°K$). A different explanation, however, is given in [7], and is connected precisely with the assumption of granulation and influence exerted on the Cu, Au, and Ag particles by the surrounding matrix of semiconducting Ge. Such a point of view is confirmed to a certain degree by experiments [5, 7] on the Al-Ge system. In this case the film is made granulated by different methods, and it is assumed for a number of reasons that the increase of T_c is connected with the presence of the dielectric.

There is no doubt that much progress in the understanding of the role of the exciton mechanism in the case of granulated superconductors can be attained only by means of new experiments. To interpret them, however, it is desirable to have at least approximate formulas that make it possible to estimate the effect exerted on T_c by different parameters, primarily the granule dimensions (in our opinion, the use for this purpose of the formula of [8] is not valid, for reasons indicated in [1, 9]).

For samples with dimensions that are small compared with the "coherence length," the effective interaction V_{eff} can be regarded as equal to the average interaction over the volume of the sample [10, 11]. Therefore, for a granule with a volume v we can put

$$V_{eff} = \frac{1}{v}\int V(\mathbf{r})\,d\mathbf{r} = \frac{V_b(v - v_s) + V_s v_s}{v}, \tag{1}$$

where on going to the last expression it is assumed that the interaction responsible for the appearance of the superconductivity in the "volume" of the granule is equal to V_b, while in the surface layer of the granule, with volume $v_s = Sa$, the corresponding interaction is equal to V_s; here S is the surface area of the granule and a is the characteristic depth to which the action of the dielectric extends.

We take V_b to be a phonon interaction and V_s an exciton interaction, and we therefore put

$$\left.\begin{aligned} g_b &= N(0)\,|V_b| \text{ for } \omega < \omega_{ph}, & g_b &= 0 \text{ for } \omega > \omega_{ph} \\ g_s &= N(0)\,|V_s| \text{ for } \omega < \Omega_e, & g_s &= 0 \text{ for } \omega > \Omega_e \end{aligned}\right\}. \tag{2}$$

Here N(0) is the density of states near the Fermi boundary for a metallic granule, $\omega_{ph} \sim k\Theta_D/\hbar$, Θ_D is the Debye temperature, and $\Omega_e = \sqrt{\varepsilon_0}\Omega \equiv k\Theta_e/\hbar$ is the characteristic exciton frequency (for details see [1]). Allowance for the Coulomb interaction, if it is suppressed to a sufficient degree (the condition $\ln(\omega_F/\omega_{ph}) \gg 1$, where $\hbar\omega_F = E_F$ is the Fermi energy in the metal), changes the picture little and, to a certain degree, it can be assumed that the Coulomb interaction has been taken into account when choosing the values of g_b and g_s.

Under the discussed conditions, in the weak-coupling approximation (see [1], formula (54)), we have

$$T_c \sim \Theta_D e^{-1/g}, \quad g = g_b(1-\xi) + \frac{g_s \xi}{1 - g_s \xi \ln(\Theta_e/\Theta_D)}, \quad \xi = \frac{v_s}{v}. \tag{3}$$

If

$$g_b g_s \xi (1-\xi) \ln\left(\frac{\Theta_e}{\Theta_D}\right) \ll g_b(1-\xi) + g_s \xi,$$

then

$$T_c \sim \Theta_D \left(\frac{\Theta_e}{\Theta_D}\right)^{\frac{g_s \xi}{g_b(1-\xi) + g_s \xi}} \exp\left\{-\frac{1}{g_b(1-\xi) + g_s \xi}\right\}. \tag{4}$$

For granules made of materials which are not superconducting in the bulky state, it is apparently necessary to put $g_b \le 0$. Obviously, at $g_b = 0$ we have

$$T_c \sim \Theta_e e^{-\frac{1}{g_s \xi}}. \tag{5}$$

For spherical granules of radius r, we have $\xi = 3a/r$; for granules in the form of flat discs of thickness 2d and characteristic radius $R \gg d$ the parameter is $\xi = a/d$. The use of discs (flakes) is preferable, for in this case one can hope to obtain not too small values of ξ (for a good metal the depth is $a \lesssim$ 3 - 5 Å) at not too small a volume of the granules. The latter is necessary to decrease the thermodynamic fluctuations and the possibility of disregarding the quantization of the electron levels in the granule. The role of the surface, and particularly the surface-connected contribution of the exciton mechanism, can hopefully be ascertained by varying the parameter ξ, with other conditions kept constant (of course, the changes of T_c will not be large so long as $\xi \ll 1$). In order for the exciton mechanism to be appreciable (i.e., for the parameter g_s to be sufficiently large), there should exist in the dielectric excitons with frequencies $\Omega_e \ll \omega_F$, which do not attenuate too strongly for the wave numbers $q \sim q_F$ ($\hbar q_F$ is the momentum on the Fermi boundary of the metal), and furthermore have as large an oscillator strength as possible [1]. It is quite difficult to satisfy these requirements, and Ge apparently does not satisfy them[1]. The latter casts some doubts on the interpretation of the data of [5 - 7] on the basis of the exciton mechanism and, what is more important, makes it possible to recommend urgently that the dielectric matrix in the granulated superconductors be made of different dielectrics (semiconductors) with distinct exciton bands lying much lower than the Fermi energy of the metal (in this connection, suitable values are $\hbar\Omega_e < 1 - 2$ eV, where Ω_e is the exciton frequency at $q \sim q_F$).

[1]The situation here, incidentally, is obscure, since the dielectric constant $\varepsilon = \varepsilon_1 + i\varepsilon_2$ of Ge depends in a rather complicated manner on the frequency ω (see, e.g., [12]), and the calculations of [1, 2, 9] were performed only for a much simpler model of the dielectric.

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