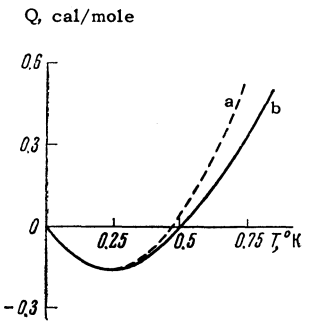

FIG. 2

$$I_\alpha = \int_0^\infty \frac{x^\alpha}{e^x/A + 1}\, dx, \quad A = e^{\mu/kT}.$$

In the solid phase, according to references 1 and 2, the spin orientation begins at temperatures considerably below those of the liquid phase. Consequently, we can write for the free energy $F^{II} = -RT \ln 2$. The thermal portion of the free energy, proportional to $RT(T/\Theta)^3$, we neglect since $T \ll \Theta$.

Solving (2) graphically, we find the connection between T_1 and $T_2(p)$. Knowing $T_2(p)$ from experiment,[6] it is possible to plot the p-T diagram (Fig. 1). In view of the fact that the entropy and specific heat of liquid He^3 are in better agreement with experiment for the spectrum (3b), the corresponding curve should fit better the transition from the liquid phase into the solid phase. As can be seen from Fig. 1, where the letters a and b correspond to spectra (3a) and (3b) respectively, the p-T diagram should have a minimum at $T \approx 0.5°K$ and $p \approx 30$ atmos.

The heat of melting is computed as $Q = T(S_l - S_S)$. Below 0.5°K the heat of melting is negative and reaches a maximum value at $T \approx 0.25°K$ (Fig. 2).*

In conclusion the author considers it his pleasant duty to thank Professor I. M. Lifshitz for suggesting the problem and for valuable advice.

*In the calculation of Q, no account was taken of the dependence of the entropy on the pressure.

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DISCRETE ENERGY LOSSES OF ELECTRONS IN SOLIDS AND YIELD OF SECONDARY ELECTRONS

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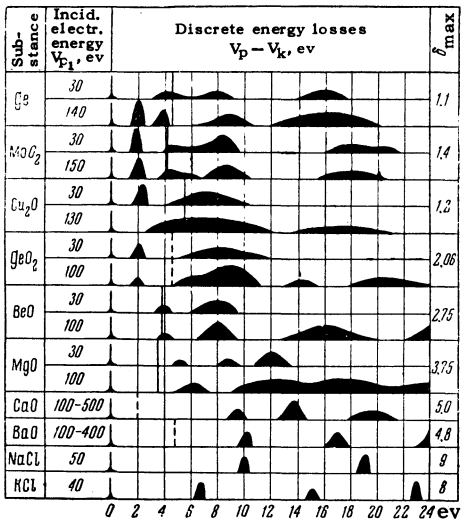
Submitted to JETP editor March 8, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **35**, 281-283 (July, 1958)

THE yield of secondary electrons in metals is small. This is explained by the interaction between the secondary electrons that move in the substance and the conduction electrons. As a result of this interaction, many secondary electrons reach the surface with an energy less than the work function in vacuum. The loss of secondary electrons in dielectrics and semiconductors should obviously be due to a different mechanism. As early as in 1939, Bruining and deBoer proposed that substances with high and low values of the secondary-emission coefficient δ have different arrangements of the energy bands.[1]

The electrons reflected after interaction in media, like the incident electrons, participate apparently in the formation of secondary electrons. If it is assumed that secondary electrons are produced by the incident and reflected electrons via the same mechanism, then investigations on the energy losses of the reflected electrons can be generalized to include the incident electrons.

Many investigations[2-6] have led to the conclusion that the discrete energy losses of the low-energy electrons incident on matter are due to the electron excitation by the crystal lattice and to their transition from the filled band to one of the allowed free bands located above the potential of vacuum. Such a loss mechanism is accompanied by the appearance of electrons with increased energies in media. Under favorable conditions, if the energy of an electron reaching the surface of the substance is greater than the work function, it can escape into the vacuum as a secondary electron.



It is interesting to compare the values of the discrete energy losses $V_p - V_k$ with the values of the work function $e\varphi$ and with the maximum value of the secondary-emission coefficient δ_{max} for a given substance. The table shows schematically the discrete energy losses of the incident electrons, obtained in our laboratory for many substances,[2,4-6] and also the value of $e\varphi$.[7] The last column shows the values of δ_{max} obtained with the same targets as used to determine the discrete energy losses. In the case of insulators, δ was measured with a balanced pulse curcuit developed in our laboratory.* The table includes also data on the discrete energy losses for CaO and BaO, taken from the work of Rudberg,[8] and for NaCl and KCl, taken from the work of Shul'man and Fridrikhov.[9] The work functions are represented by lines. In the absence of reliable data on the work function, the line is shown dotted. By comparing the relation between the values of $V_p - V_k$ and $e\varphi$ with the value of δ_{max} for various substances given in the table, we can separate these substances in three groups.

1. Substances for which all values of the discrete-loss energies are greater than $e\varphi$ have a large secondary-electron yield. These include MgO, CaO, BaO, NaCl, and KCl.

2. Substances for which the most intense discrete energy losses have values less than $e\varphi$. These have a low yield of secondary electrons and include Ge and MoO_2.

3. An intermediate group is characterized by the fact that, in addition to discrete losses with energy values greater than $e\varphi$, there exists also a more or less intense loss with an energy value less than $e\varphi$, occurring principally at low values of V_p. If the relative intensity of the discrete losses with energies less than $e\varphi$ is considerable, then δ_{max} is small (Cu_2O). If the indicated intensity is insignificant compared with the intensity of the discrete losses with energies greater than $e\varphi$, then δ_{max} can be comparatively large (GeO_2 and BeO).

The dependence of the yield of secondary electrons on the ratio of the values of $V_p - V_k$ and $e\varphi$, found for the above substances, can be explained as follows. The secondary electrons produced inside the substance can lose energy to excitation of the valence-band electrons only if their energy is not less than the minimum energy of the discrete losses. At lower values of the secondary-electron energy, the electrons can lose their energy only to interaction with the lattice vibrations, giving up very small batches of energy, on the order of kT, in each collision.

The secondary electrons produced in the substances of the first group can cover a relatively large distance before their energy is reduced by phonon losses to a value less than $e\varphi$. The secondary-electron yield will therefore be greater for substances of this group and δ_{max} occurs at large values of $V_{p\,(max)}$.

In substances of the second group, the secondary emission is produced only because electrons in the valence bands receive from the primary electrons energies $V_p - V_k$ greater than $e\varphi$. Since the intensity of such discrete losses is small, the number of corresponding secondary electrons is also small. In addition, the only electrons in this group capable of escape to the vacuum are those which have not had time to reduce their energy to a value of less than $e\varphi$ and which obviously occur only relatively close to the surface of the target. Therefore δ_{max} is small and $V_{p\,(max)}$ should be less than for the first group of substances.

Everything said above concerning the second group of substances is correct also for the intermediate group. The only difference is that the number of secondary electrons occurring in the substance and having energies $V_p - V_k > e\varphi$ will be greater, and the probability of their losing energy to the excitation of electrons from the valence band will be less. Consequently, the values of δ_{max} can be greater for substances in the intermediate group than for substances in the second group.

We can thus conclude from the above comparison of the experimental data that the inter-band transitions play a substantial role in secondary

emission in insulators and semiconductors, and determine essentially the value of δ.

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Translated by J. G. Adashko
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ON THE DAMPING OF ELECTROMAGNETIC WAVES IN A PLASMA SITUATED IN A MAGNETIC FIELD

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Submitted to JETP editor April 11, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **35**, 283-284 (July, 1958)

THE damping of high frequency electromagnetic waves in a completely ionized plasma is usually determined by the frequency of collisions between electrons and ions[1] $\nu_{eff} = 2\sqrt{2\pi}\, e^4 n_0 L/m_e^{1/2} T^{3/2}$, where e is the charge, m_e the mass, n_0 the electron density, T the plasma temperature, and L the Coulomb logarithm. For high temperatures and low plasma densities, ν_{eff} is small. Under these conditions it may turn out that the damping of electromagnetic waves γ due to the existence of thermal motion of electrons is significant (this damping is similar to the well known[2] damping of longitudinal plasma oscillations. γ increases sharply when the frequency of the wave ω becomes close to the Larmor frequency ω_H of the electron or to a multiple of it ($\omega_H = eH_0/m_e c$, H_0 is the intensity of the external magnetic field).

Using the expressions obtained by Silenko and Stepanov[3] for the components of the dielectric permittivity tensor, we obtain for the damping coefficient $\gamma = \gamma_m$ for $\omega \approx m\omega_H$, $m = 1, 2, 3, \ldots$ the following expression:

$$\frac{\gamma_m}{\omega} = \sigma_m [\sin^2\theta n^4 - (1-v)(1+\cos^2\theta) n^2 + 2\left(1 - \frac{v}{1-u} + \frac{v\sqrt{u}}{1-u}\right)(1 - v - \sin^2\theta n^2)] \times [(2 - 3u - 3v + 4uv\cos^2\theta) n^4 + (4u + 8v - 2 - 6v^2 - 3uv - 3uv\cos^2\theta) n^2 - u - v(3 - 6v + 3v^2 - 2u)]^{-1}, \quad (1)$$

$$\sigma_m = \frac{\sqrt{\pi}\, m^{2m-2} \sin^{2m-2}\theta\, (u-1)\Omega^2}{2^{m+3/2} m! \,|\cos\theta|\, \omega_H^2} (\beta n)^{2m-3} e^{-z_m^2},$$

$$z_m = \frac{1 - m\omega_H/\omega}{\sqrt{2}\,\beta n \cos\theta},$$

where $n = kc/\omega$, $\mathbf{k}$ is the propagation vector, θ is the angle between $\mathbf{k}$ and $\mathbf{H}_0$,

$$u = (\omega_H/\omega)^2,\ v = (\Omega/\omega)^2,\ \Omega = (4\pi e^2 n_0/m_e)^{1/2},$$
$$\beta = v_T/c,\ v_T = (T/m_e)^{1/2}.$$

In deriving expression (1) it was assumed that

$$kv_T \ll \omega_H,\ \gamma_m \ll kv_T |\cos\theta|,\ |z_{1,2}| \gg 1.$$

The frequency ω is found from the equation

$$(1 - u - v + uv\cos^2\theta) n^4 - [2(1-v)^2 + u(v-2) + uv\cos^2\theta] n^2 + (1-v)[(1-v)^2 - u] = 0. \quad (2)$$

If it follows from (2) that $\omega \approx \omega_H, 2\omega_H$, with $|z_{1,2}| \sim 1$, then formula (1) is not valid for $\gamma_{1,2}$. In this case $\gamma_{1,2}/\omega \sim \beta n$ for values of θ which are not close to zero. However, the exact value of $\gamma_{1,2}$ for $|z_{1,2}| \sim 1$ may only be obtained numerically. For the case $\theta = 0$, the resonance $\omega = \omega_H$ which occurs for the extraordinary wave has been investigated by Silin.[4]

The damping (1) is determined by the interaction with the electromagnetic wave of those electrons, whose thermal velocity in the direction of H_0 is close to $(\omega - m\omega_H)/k\cos\theta$. For $n \gg 1$ formula (1) gives for γ_m the result obtained by Sitenko and Stepanov.[3]

For large T and small n_0, γ_m may be considerably larger than ν_{eff}. For example, let $n_0 \sim 10^8\,cm^{-3}$, $H_0 \sim 20$ gausses, $n \sim 1$, then $\gamma_{1,2}/\nu_{eff} \sim 10^6$ for $T \sim 10^{6\circ}K$. Far from resonance, γ is exponentially small and is usually much less than ν_{eff}.

In conclusion, I wish to express my sincere