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Influence of Depletion Transition Layers on Surface Polaritons in Semiconductor Films

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A theory of TM type surface polaritons in semiconductor films possessing depletion transition layer which electron concentration changes according to the law of hyperbolic cosine is built. The influence of dissipative as well as non-dissipative damping caused by plasma resonance in transition layer on dispersion properties of normal and tangential modes of surface polaritons is determined. It is shown that in the absence of dissipative damping two dispersion branches both for normal and tangential modes of surface polaritons exist, parted by a frequency gap. The account of dissipative damping leads to vanishing of the gap and the presence of a single dispersion branch both for normal and tangential modes of surface polaritons, wherein the damping of tangential mode exceeds considerably the damping of normal mode.

Surface polaritons in semiconductors with depleted transition regions were investigated in a number of works [1-8]. In these works different laws of electron concentration alteration $n(z)$ in the vicinity of semiconductor surface were considered. Thus, in the work [1] it was supposed that $n(z)$ changes linearly from the value n_s at the surface to n_b in the volume. In works [2-5] the dependence $n(z)$ of the exponential form was considered, and in the work [6] it was assumed that it has the form of smooth step. The most interesting result obtained in the works [5,6] was the existence of closed dispersion curves appearing in the frequency region higher than plasma frequency of the electrons on semiconductor surface. However, in these works collisionless damping of surface polaritons conditioned by their transformation into longitudinal plasma waves in the point of plasma resonance in which dielectric permeability of the semiconductor $\varepsilon(\omega, z)$ turns to zero was not taken into account. Collisionless damping of surface polaritons was evaluated approximately in earlier works [7,8] under the conditions of their propagation along a thin plasma layer and thin plasma cylinder. The solution of Maxwell's equations was found with help of the method of consequent approaches over small parameter equal to the ratio of transition region thickness by depth of surface polaritons field penetration into plasma.

In this work the dispersion properties of surface polaritons in semiconductor film with transition region are investigated with account of their collisional and collisionless damping. Dispersion equations are obtained by presentation of Maxwell's equations in the form of power series and were examinated numerically for the semiconductor film $n-InSb$ in a wide range of transition region thicknesses. It is shown that collisionless damping in thin films is rather essential and its account changes drastically the properties of normal and tangential modes of surface polaritons.

Let us consider inhomogeneous semiconductor film occupying volume $0 \le z \le L$ and bounded by a homogeneous dielectric with dielectric permeability ε_d. Along the axes X and Y the film is considered to be infinite. The electron concentration in the film is determined by following equation:

$$n(z) = n_b + (n_s - n_b)\frac{\cosh\left(z - \frac{L}{2}\right)/d}{\cosh L/2d}, \qquad (1)$$

in which d is the characteristic width of transition region near the film boundaries, n_s is electron concentration on the film boundaries $(z = 0, z = L)$, n_b is electron concentration in the film volume under the condition that the influence of transition region can be neglected $(d << L)$.

Electromagnetic properties of inhomogeneous semiconductor film in local approximation are described by dielectric permeability of the following form:

$$\varepsilon(\omega, z) = \varepsilon_b + \Delta\varepsilon \cosh\left(z - \frac{L}{2}\right)/d. \qquad (2)$$

Here

$$\varepsilon_b = \varepsilon_0\left(1 - \frac{\omega_{pb}^2}{\omega(\omega + i\nu)}\right), \qquad (3)$$

$$\Delta\varepsilon = -\varepsilon_0 \frac{\omega_{pb}^2}{\omega(\omega + i\nu)} \frac{g}{\cosh L/2d}, \qquad (4)$$

where $g = \dfrac{n_s - n_b}{n_b}$, $\omega_{pb}^2 = \dfrac{4\pi e^2 n_b}{m^* \varepsilon_0}$, e, ν and m^* are the charge, the effective collision frequency and effective electron mass. In the limit $L >> d$ equation (2) corresponds to exponential character of electron concentration alteration in the vicinity of film boundaries.

Let us consider TM waves propagating along the X axis with the frequency ω and wave vector k_x. If we present nonvanishing components of these waves in the form:

$$\{E_x, E_z, H_y\} = \{E_x(z), E_z(z), H_y(z)\} \times \times exp(i(k_x x - \omega t)) \qquad (5)$$

it follows from Maxwell's equations that magnetic field amplitude $H_y(z)$ satisfies the following ordinary differential equation of the second order [5,6]:

$$\frac{d^2 H_y(z)}{dz^2} - \frac{\varepsilon'(\omega, z)}{\varepsilon(\omega, z)} \frac{dH_y(z)}{dz} + \left[\frac{\omega^2}{c^2}\varepsilon(\omega, z) - k_x^2\right] H_y(z) = 0, \qquad (6)$$

where $\varepsilon'(\omega, z) \equiv \dfrac{d\varepsilon(\omega, z)}{dz}$

In dielectrics bordering on film with permeability ε_d magnetic field amplitude $H_y^d(z)$ has the form:

$$H_y^d(z) = \begin{cases} C_1 \exp(p_d z), & z < 0; \\ C_2 \exp(-p_d(z - L)), & z > L, \end{cases} \qquad (7)$$

where $p_d^2 = k_x^2 - \dfrac{\omega^2}{c^2}\varepsilon_d > 0$; $C_{1,2}$ are integration constants.

Following the works [5,6] we introduce a new variable $\upsilon = -\dfrac{\varepsilon(\omega, z)}{\varepsilon_b}$. Then the equation (6) becomes :

$$\upsilon\left[(1+\upsilon)^2 - \left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right]\frac{d^2 H_y}{d\upsilon^2} - \left[1+\upsilon - \left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right]\frac{dH_y}{d\upsilon} - \upsilon\left[\alpha^2 + q(1+\upsilon)\right]H_y = 0, \qquad (8)$$

where $\alpha = p_0 d$; $p_0^2 = k_x^2 - \dfrac{\omega^2}{c^2}\varepsilon_b$; $q = \dfrac{\omega^2}{c^2} d^2 \varepsilon_b$.

According to analytical theory of ordinary differential equations of the second order , differential equation (8) has singular points defined from the condition of vanishing of the coefficient by the second derivative $\dfrac{d^2 H_y}{d\upsilon^2}$, i.e.

$$\upsilon = 0; \qquad (9)$$

$$\left(1 + \upsilon + \frac{\Delta\varepsilon}{\varepsilon_b}\right)\left(1 + \upsilon - \frac{\Delta\varepsilon}{\varepsilon_b}\right) = 0. \qquad (10)$$

The equation (9) is equivalent to the condition $\varepsilon(\omega, z) = 0$ under which the plasma resonance in semiconductor film appears. The equation (10) is equivalent to the condition

$$1 + \upsilon + \frac{\Delta\varepsilon}{\varepsilon_b} = 0, \qquad (11)$$

as $1 + \upsilon = -\dfrac{\Delta\varepsilon}{\varepsilon_b}\cosh\left(z - \dfrac{L}{2}\right)\Big/ d$ and the second factor $1 + \upsilon - \dfrac{\Delta\varepsilon}{\varepsilon_b}$ does not turn to zero anywhere in the film. Equation (11) corresponds to turning to zero of the first derivative of dielectric permeability in the center of the film $\varepsilon'\left(\omega, \dfrac{L}{2}\right) = 0$. Thus, the equation (8) has two singular points: $\upsilon = 0$ and $\upsilon = -\dfrac{\Delta\varepsilon}{\varepsilon_b} - 1$. In the vicinity of the point $\upsilon = 0$ we search for the solution of the equation (8) in the following form:

$$H_y(\upsilon) = A_1 V_1(\upsilon) + A_2 V_2(\upsilon), \qquad (12)$$

where A_1 and A_2 are arbitrary constants, and expressions for two linearly independent solutions $V_1(\upsilon)$ and $V_2(\upsilon)$ are determined in the form of power series [9]:

$$V_1(\upsilon)=\upsilon^2\sum_{n=0}^{\infty}a_n\upsilon^n,$$
$$V_2(\upsilon)=\beta\ln\upsilon\, V_1(\upsilon)+\sum_{n=0}^{\infty}b_n\upsilon^n. \qquad (13)$$

Here $\beta=\frac{1}{2}(\alpha^2+q)\left[1-\left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right]^{-2}$.

Coefficients a_n and b_n are determined by following recurrent relations:

$$a_0=1; \qquad a_{-2}=a_{-1}=0; \qquad (14)$$
$$a_n=\frac{qa_{n-3}+a_{n-2}\left[q+\alpha^2-n(n-1)\right]-a_{n-1}(n+1)(2n-1)}{\left[1-\left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right]n(n+2)};$$
$$n\geq 1$$
$$b_0=1; \qquad b_1=b_2=0;$$

$$b_n=\frac{qb_{n-3}+b_{n-2}\left[\alpha^2+q-(n-2)(n-3)\right]-b_{n-1}(2n-5)(n-1)}{n(n-2)\left[1-\left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right]}-$$
$$\frac{2(n-1)\beta\left[1-\left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right]a_{n-2}-\beta(4n-7)a_{n-3}-\beta(2n-5)a_{n-4}}{n(n-2)\left[1-\left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right]}; \qquad n\geq 3.$$

Let us find the solution of the equation (8) in the vicinity of singular point $\upsilon=-\frac{\Delta\varepsilon}{\varepsilon_b}-1$.

In order to do this we introduce a new variable $w=1+\upsilon+\frac{\Delta\varepsilon}{\varepsilon_b}$. The differential equation (8) takes the following form:

$$w\left(w-2\frac{\Delta\varepsilon}{\varepsilon_b}\right)\left(w-1-\frac{\Delta\varepsilon}{\varepsilon_b}\right)\frac{d^2\mathrm{H}_y}{dw^2}-$$
$$-\left[w-\frac{\Delta\varepsilon}{\varepsilon_b}\left(1+\frac{\Delta\varepsilon}{\varepsilon_b}\right)\right]\frac{d\mathrm{H}_y}{dw}-$$
$$-\left(w-1-\frac{\Delta\varepsilon}{\varepsilon_b}\right)\left(\alpha^2+q\left(w-\frac{\Delta\varepsilon}{\varepsilon_b}\right)\right)\mathrm{H}_y=0. \qquad (15)$$

The solution of the equation (15) can be presented in a form:

$$H_y(w)=B_1W_1(w)+B_2W_2(w). \qquad (16)$$

Here B_1 and B_2 are arbitrary constants, and linearly independent solutions $W_1(w)$ and $W_2(w)$ are power series of the form $w^r\sum_{n=0}^{\infty}c_nw^n$, where c_n are determined by the expression

$$c_n=\frac{1}{D_1}\left\{c_{n-1}(r+n-1)\left[r+n-1+\right.\right.$$
$$\left.+3(r+n-2)\frac{\Delta\varepsilon}{\varepsilon_b}-\left(1+\frac{\Delta\varepsilon}{\varepsilon_b}\right)\left(\alpha^2-q\frac{\Delta\varepsilon}{\varepsilon_b}\right)\right]\times$$
$$\left.\times c_{n-2}\left[\alpha^2-q\left(1+2\frac{\Delta\varepsilon}{\varepsilon_b}\right)-(r+n-2)(r+n-3)\right]+qc_{n-3}\right\};$$
$$c_{-2}=c_{-1}=0; \quad c_0=1; \quad n\geq 1; \qquad (17)$$

We use here the notation

$$D_1=\frac{\Delta\varepsilon}{\varepsilon_b}\left(1+\frac{\Delta\varepsilon}{\varepsilon_b}\right)(r+n)(2r+2n-1),$$

and r takes two values $r=0$ and $r=1/2$ for solutions $W_1(w)$ and $W_2(w)$, correspondingly.

Convergence radia of series $V_1(\upsilon)$, $V_2(\upsilon)$, $W_1(w)$, and $W_2(w)$ are determined from the condition $|\upsilon|,|w|<\min[1;|w-\upsilon|]$.

Assume the point $z=0$ is an ordinary point of the differential equation (8), that is $\upsilon(0)=\upsilon_s \neq 0$ and $w(0)=w_s \neq 0$. Then the solution of the equation (8) can be presented in the form of linear combination of two power series over new variable $u=\frac{\upsilon-\upsilon_s}{R}$, where R is radius of convergence of these series equal to $R=\min\left[|\upsilon_s|,\left|1+\upsilon_s+\frac{\Delta\varepsilon}{\varepsilon_b}\right|\right]$

If we denote these series as $U_1(u)$ and $U_2(u)$, we obtain for each of them the following expression:

$$U_{1,2}(u)=\sum_{n=0}^{\infty} d_n u^n, \qquad (18)$$

where

$$d_n=\frac{1}{D_2}\left\{Rd_{n-1}\left\{\left(1+\upsilon_s-\left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right)(m-1)-(n-1)(n-2)\left[(1+\upsilon_s)(1+3\upsilon_s)-\left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right]\right\}+\right.$$
$$+R^2d_{n-2}\{\upsilon_s(\alpha^2+q+q\upsilon_s)+(n-2)[1-(n-3)(2+3\upsilon_s)]\}+$$
$$\left.+R^3d_{n-3}\{\alpha^2+q+2q\upsilon_s-(n-4)(n-3)\}+R^4qd_{n-4}\right\},$$
$$d_{-2}=d_{-1}=0;\ n\geq 2; \qquad (19)$$
$$D_2=n(n-1)\upsilon_s\left[(1+\upsilon_s)^2-\left(\frac{\Delta\varepsilon}{\varepsilon_b}\right)^2\right]$$

For the power series $U_1(u)$ we believe $d_0=1,\ d_1=0,$ for the power series $U_2(u)-d_0=0,\ d_1=1.$

As the film is symmetric about the plane $z=\frac{L}{2}$, two modes of surface polaritons exist in it, i.e. normal and tangential modes with symmetric and antisymmetric distribution of electromagnetic field over the film thickness. For the normal mode of surface polaritons $\frac{dH_y\left(\frac{L}{2}\right)}{dz}=0$, for tangential- $H_y\left(\frac{L}{2}\right)=0$

As the point $z=\frac{L}{2}$ corresponds to the point $w=0$, electromagnetic field distribution in the vicinity of film center is described by the solution (16). It is necessary to assume $B_2=0$ for the normal mode and $B_1=0$ for the tangential mode in the equation (16).

The point $\upsilon=-\frac{\Delta\varepsilon}{\varepsilon_b}-1$ $(w=0)$ is singular point of differential equation (8) irrespective to frequency region considered. The point $\upsilon=0$ (in assumption that $\nu=0$) can exist in transition regions of semiconductor film in frequency area between ω_{ps} and ω_{pb}, which we name resonance frequency. Here $\omega_{ps}=\sqrt{\frac{4\pi e^2 n_s}{m^*\varepsilon_0}}$ is plasma frequency of electrons at the boundaries of inhomogeneous film. Therefore, in non-resonant frequency regions, where $\omega<\omega_{ps}$, dispersion equation for surface polaritons in semiconductor film can be obtained using only equations (16) and (18), if we consider tangential components of electric and magnetic fields to be continuous on the film boundary $z=0$ and at some inner point of semiconductor (matching point) z_m, placed at the intersection of series convergence areas $U_1(u), U_2(u), W_1(w), W_2(w)$. The result is as follows:

$$\frac{p_d}{\varepsilon_d}=-\frac{\upsilon_z'(0)\,W(w_m)U_{1u}'(u_m)-W_\omega'(w_m)U_1(u_m)R}{R\varepsilon_s\,W(w_m)U_{2u}'(u_m)-W_\omega'(w_m)U_2(u_m)R} \qquad (20)$$

In the equation (20) it is necessary to assume $W=W_1$ for the normal modes of surface polaritons and $W = W_2$ for the tangential modes. The prime indicates the derivative over the variable, which is shown by the additional lower index of corresponding functions;

$$u_m = \frac{\upsilon_m - \upsilon_s}{R}, \quad w_m = 1 + \upsilon_m + \frac{\Delta\varepsilon}{\varepsilon_b},$$

$$\upsilon_m = -\frac{\varepsilon(\omega, z_m)}{\varepsilon_b}, \quad \varepsilon_s = \varepsilon(\omega, 0).$$

In resonance frequency region $\omega_{ps} < \omega < \omega_{pb}$, in which the solution (12) must be taken into consideration, we assume that point $z = 0$ belongs to series convergence area $V_1(\upsilon)$ and $V_2(\upsilon)$, i.e. $|\upsilon_s| < \min\left[1, \left|1 + \frac{\Delta\varepsilon}{\varepsilon_b}\right|\right]$. Then dispersion equation for surface polaritons can be obtained, using only equations (12) and (18). Therefore, we have:

$$\frac{\frac{p_d}{\varepsilon_d} V_1(\upsilon_s) - \frac{\upsilon_z'(0)}{\varepsilon_s} V_{1\upsilon}'(\upsilon_s)}{\frac{p_d}{\varepsilon_d} V_2(\upsilon_s) - \frac{\upsilon_z'(0)}{\varepsilon_s} V_{2\upsilon}'(\upsilon_s)} = \frac{V_{1\upsilon}'(\upsilon_m) - \frac{W_w'(w_m)}{W(w_m)} V_1(\upsilon_m)}{V_{2\upsilon}'(\upsilon_m) - \frac{W_w'(w_m)}{W(w_m)} V_2(\upsilon_m)}, \qquad (21)$$

where $W = W_1$ for normal modes of surface polaritons, and $W = W_2$ for tangential ones.

Dispersion equations (20) and (21) were investigated numerically. For the convenience of consideration dimensionless variables

$$\varsigma = \frac{ck_x}{\omega_{pb}}; \; \xi = \frac{\omega}{\omega_{pb}}; \; b = \frac{L\omega_{pb}}{c}; \; a = \frac{d\omega_{pb}}{c}$$

were introduced. All the calculations were made for doping semiconductor of type *InSb* with parameters $\varepsilon_0 = 16$, $g = -0{,}1536$, which corresponds to $\xi_s = \frac{\omega_{ps}}{\omega_{pb}} = 0{,}92$ [11,13]. It was supposed that semiconductor film has a boundary with dielectric having permeability $\varepsilon_d = 2$.

In Fig.1 dispersion curves for normal (symbol *N*) and tangential (symbol *T*) modes of surface polaritons in inhomogeneous film without dissipation ($\nu = 0$) are presented for the case when dimensionless thickness of semiconductor film $b = 0{,}3$ and dimensionless thickness of transition region $a = 0{,}1$. Dash line $\xi = \xi_s$ is the boundary of two frequency regions: the nonresonant $\xi < \xi_s$, in which $\upsilon \neq 0$ and resonant $\xi > \xi_s$, in which the point $\upsilon = 0$ exists near the surface of semiconductor film. In resonance area nondissipative damping of surface polaritons causes the fact that dimensionless wave number $\varsigma = \varsigma' + i\varsigma''$ is complex. The real part of wave number $\varsigma'(\xi)$ (curves N' and T') and the imaginary part of wave number ς'' (curves N'' and T'') are shown. In the figure it is demonstrated that relation $\varsigma'(\xi)$ are not closed. They begin at line ξ_s, and function $\varsigma'(\xi)$ is nonmonotonous for normal modes (curve N') and it is monotonous for tangential modes (curve T'). Besides, for normal mode of surface polaritons the imaginary part of wave number ς'' (curve N'') is less than the real part ς' (curve N') and it is a monotonically decreasing function of ξ. However, for tangential mode both of relations T' and T'' are monotonically increasing functions of ξ. Within the whole area of frequencies considered the condition $\varsigma''(\xi) > \varsigma'(\xi)$ is satisfied, i.e. this mode is a high-damping one in resonance frequency area even in the absence of collisions.

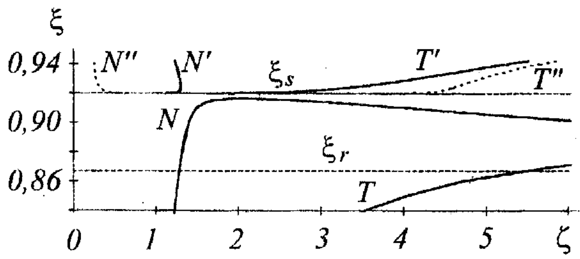

Fig.1. *Dispersion curves for normal (N) and tangential (T) modes of surface polaritons in inhomogeneous semiconductor film in the absence of damping ($\nu = 0$) in dimensionless values (definitions see in the text) ς, ξ for $a = 0{,}1$; $b = 0{,}3$; $g = -0{,}1536$; $\varepsilon_0 = 16$, $\varepsilon_d = 2$. In resonance area $\xi > \xi_s$ the curves labelled by one prime present the relation $\varsigma'(\xi)$, the ones labelled by two primes present the relation $\varsigma''(\xi)$ for normal and tangential modes. Dash line $\xi = \xi_s$ corresponds to plasma frequency of electrons on the surface of semiconductor film, and dash line $\xi = \xi_r$ corresponds to limit frequency of surface polaritons in homogeneous film with the concentration n_s.*

Thus, the values of collisionless damping for tangential and normal modes of surface polaritons in resonance area differ essentially.

In non-resonance area the dispersion curve of the normal mode N behaves in a conventional way: if ς is increased, the frequency also increases and achieves the maximum. If $\varsigma \to \infty$ it tends to the limit frequency of surface polaritons

$$\xi_r = \sqrt{\frac{\varepsilon_0}{\varepsilon_0 + \varepsilon_d}(1+g)}.$$

The figure shows that the tangential mode of surface polaritons (curve T)in non-resonance area is more smooth than the normal one, and if $\varsigma \to \infty$ it tends to the frequency ξ_r from below. It is worth noting that for each of the modes a forbidden frequency region (a gap) exists in non-resonant area in the vicinity of the frequency ξ_s.

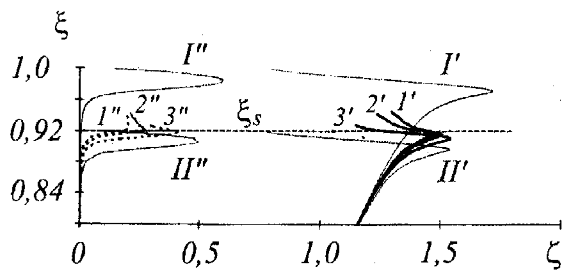

Fig.2. *Dispersion curves for normal modes of surface polaritons in inhomogeneous semiconductor film with account of dissipative damping* $\nu = 0.01$ *for* $b = 0.3$ *and for three values of the parameter a:* $a = 0,08$ *(index 1),* $a = 0,1$ *(index 2) and* $a = 0,15$ *(index 3). The curve with index I corresponds to the relations* $\varsigma'(\xi)$ *(solid lines), and the curves with index II correspond to the relation* $\varsigma''(\xi)$ *(dash lines). Long dash lines correspond to normal modes of surface polaritons in homogeneous film with electron concentration* n_b *(curves I' and I'') and* n_s *(curves II' and II'').*

Fig.2 presents the dispersion of surface polaritons normal modes, taking into account the final dissipative damping $\nu = 0.01$ for $b = 0,3$ and for three values of dimensionless parameter a: $a = 0,08$ (curves $1'$ and $1''$), $a = 0,1$ (curves $2'$ and $2''$) and $a = 0,15$ (curves $3'$ and $3''$). For the comparison in this figure dispersion curves of normal mode of surface polaritons in homogeneous semiconductor film with electron concentration n_s (index I) and n_b (index II) are presented. Here, as well as in the Fig.1, the relation $\varsigma'(\xi)$ is labelled by one prime and the relation $\varsigma''(\xi)$ is labelled by two primes. It can be seen that account of the dissipative damping of normal modes of surface polaritons is most important in non-resonance area, where dispersion curves experience the most deformation. As a result, the forbidden frequency area vanishes, and dispersion curves in resonance and non-resonance area go from one to the other continuously. On the dispersion curves of normal modes $1' - 3'$ turning points exist, increase of a leads to their shift to the lower frequency region. It should be noted that damping of normal modes remains low ($\varsigma'' < \varsigma'$) and achieves its maximum in the vicinity of the frequency ξ_s, that points to the dominating character of dissipative damping. It is essential that with the increase of a while b remains unchanged, damping of normal modes increases. The break points of branches $1', 1'', 2', 2'', 3'$ and $3''$ are connected with the fact that at higher frequencies the region of applicability of dispersion equation (21) is violated.

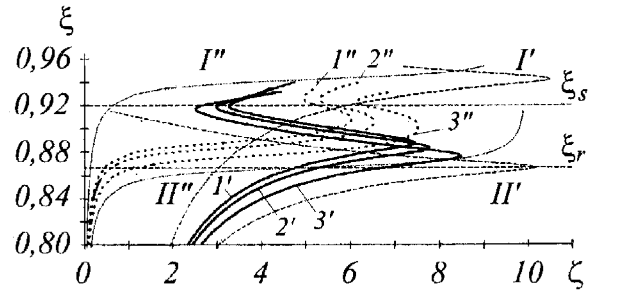

Fig.3. *Dispersion curves for tangential modes of surface polaritons in inhomogeneous semiconductor film in the presence of dissipative damping* $\nu = 0,01$ *for* $b = 0,3$ *and for three values of a :* $a = 0,08$ *(index 1),* $a = 0,1$ *(index 2) and* $a = 0,15$ *(index 3). The curves with index I correspond to the relations* $\varsigma'(\xi)$ *(solid lines), and curves with index II correspond to the relations* $\varsigma''(\xi)$ *(dash lines). Long dash lines correspond to tangential modes of surface polaritons in homogeneous film with electron concentration* n_b *(curves I' and I'') and* n_s *(curves II' and II'').*

In Fig.3 dispersion curves of tangential modes of surface polaritons for the same values of a and b as for the Fig.2, taking into account dissipative damping $\nu = 0,01$ are shown. It can be seen that a consideration of dissipative damping leads to vanishing the gap in frequency spectrum of tangential modes of surface polaritons. But, as propagation of polaritons is possible under the condition $\varsigma''(\xi) < \varsigma'(\xi)$, tangential modes of surface polaritons in inhomogeneous film exist only in non-resonance area, lying considerably lower the frequency ξ_r. Increase a while b remains unchanged leads to increase of tangential mode damping and decrease of their phase velocity. The turning points in the relations $\varsigma'(\xi)$ of tangential modes lie in the frequency interval $\xi_s > \xi > \xi_r$, and they are located lower than turning points for normal modes.

Thus, taking into consideration dissipative and non-dissipative damping of normal and tangential modes of surface polaritons in thin semiconductor film with depletion transition layers leads to considerable change of their dispersion properties. The investigated particularities of surface polaritons propagation can be used in contactless diagnostics of physical properties of real semiconductor films, in which the concentration of electrons near the surface is inhomogeneous as a result of various technological processes, such as diffusion, ion implantation, etching or influence of electromagnetic fields.

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Влияние обедненных переходных слоев на поверхностные поляритоны в полупроводниковых пленках

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Построена теория поверхностных поляритонов ТМ типа в полупроводниковых пленках, имеющих обедненные переходные области, в которых концентрация электронов меняется по закону гиперболического косинуса. Определено влияние диссипативного, а также недиссипативного затухания, обусловленного плазменным резонансом в переходных областях, на дисперсионные свойства нормальных (N) и тангенциальных (T) мод поверхностных поляритонов. Показано, что в отсутствие диссипативного затухания как для N, так и для T мод существуют две дисперсионные ветви, разделенные щелью по частоте. Учет диссипативного затухания приводит к исчезновению щели и наличию лишь одной дисперсионной ветви для обеих мод. При этом затухание T моды значительно превосходит затухание N моды.

Вплив збіднених перехідних шарів на поверхневі поляритони у напівпровідникових плівках

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Побудовано теорію поверхневих поляритонів ТМ типу у напівпровідникових плівках, в яких концентрація електронів змінюється за законом гіперболічного косинуса. Визначено вплив дисипативного, а також недисипативного згасання, яке зумовлене плазмовим резонансом у перехідних областях, на дисперсійні властивості нормальних (N) і тангенціальних (T) мод поверхневих поляритонів. Показано, що у відсутності дисипативного згасання як для N, так і для T мод існують дві дисперсійні гілки, розділені по частоті. Урахування дисипативного згасання веде до зникнення щілини та наявності лише однієї дисперсійної гілки для обох мод. При цьому згасання T моди значно перевищує згасання N моди.