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Study of Voigte Constant on Surface of Compound GaSb

Abstract

The excitation of surface Plasmon (SP) has been investigated using many spectroscopic techniques such as electron energy loss spectroscopy (EELS), optical absorption and transmission, photoemission and inverse photoemission, surface-enhanced Raman spectroscopy, scanning tunneling spectroscopy (STS), and energy-filtered low-energy electron microscopy. While silver was extensively investigated, by contrast gold systems, such as semi-infinite media, thin films, quantum wires, and nanoparticles have attracted relevant interest only in recent years as a consequence of the discovery that Au is a selective catalyst for a variety of important chemical reactions .The author investigated new surface properties to introduce Voigte constant in dispersion relation and studied surface properties of GaSb and effect of magnetic field in this paper.

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Introduction

The author shall discuss the effect of D.C. magnetic field on coupling of Plasmon-Phonons and Polaritons. Surface Plasmon waves in the presence of D.C. magnetic field is called magnetic plasmon surface wave in spherical surface of polar semiconductor. There are two cases [1] when D.C. magnetic field is parallel to x axis and [2] when D.C. magnetic field is parallel to plane of propagations. Here we shall investigate the dependence of surface plasmon frequency on the orientation and strength of an applied D.C. magnetic field in non retardation limit, or short wavelength limi and also study of Voigte constant on surface of compound GaSb.

Aim of the Study

There is new investigation to study the properties of polar semiconductors which will be applicable in future science to develop new devices in technology.

Review of Literature

Plasma-wall interactions in low-temperature plasmas are usually considered with respect to electric currents and heat flux to the wall, sputtering, ion implantation, deposition, secondary electron emission and surface reactions, to mention the most important aspects. In contrast, the forces that plasmas exert on walls have never been a major topic. This contribution aims at a demonstration, that the forces related to plasma-wall interactions are experimentally accessible with some effort.

Recently, calorimetric probes have increasingly been applied for plasma diagnostics[1–5]. Here, the corresponding integral is a third moment of the (three-dimensional) velocity distribution function; however, additional contributions, for example from chemical reactions, condensation and film deposition, evaporation and sputtering, heat conduction, and radiation, may play an important role. In laboratory at the University of Kiel, many scientists are currently working on experiments for the study of plasma sheaths by means of a combination of electrostatic, calorimetric and force measuring techniques. Those investigations aim at a better understanding of gas heating by a plasma [6–10], the momentum transfer from ions to the neutral gas in the presence of electric fields [11, 12] and of plasma sheaths in case of single and multiple ion species plasmas [13–17].There have been derived dispersion relation for three mode coupling in presence of magnetic field.

D.C. Magnetic Field on Dispersion Relation of Three Modecouplings

We shall discuss the effect of D.C. magnetic field on coupling of Plasmon-Phonons and Polaritons. Surface Plasmon waves in the presence of D.C. magnetic field is called magnetic plasmon surface wave in spherical surface of polar semiconductor. There are two cases 1. When D.C.

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magnetic field is parallel to x axis and 2. When D.C. magnetic field is parallel to plane of propagations. Here we shall investigate the dependence of surface plasmon frequency on the orientation and strength of an applied D.C. magnetic field in non retardation limit, or short wavelength limit.

According to the local field theory, the dielectric functions of a solid depend on the frequency w and propagation constant k and are denoted as $\varepsilon_1(k\omega)$. The D.C. magnetic field can be written as:-

$$B = (\bar{B}_x^0, \bar{B}_y^0, \bar{B}_z^0) \qquad (1)$$

And without the loss of generality we can write the propagation vector as :-

$$(\bar{0}, \bar{k}_y, \bar{k}_z) \qquad (2)$$

$$\varepsilon_{ij} = \varepsilon_L \partial_{ij} - \bar{\varepsilon}\frac{\omega_p^{\ 2}}{\omega^2(\omega^2 - \omega_c^{\ 2})}\left[\omega^2\partial_{ij} - \omega_{ci}.\omega_{cj} \pm i\partial_{ijk}.\omega_{ck}\right]$$

Where $\omega_p^{\ 2} = \dfrac{4\pi n_o e^2}{\bar{\varepsilon} m^*}$

ε_L=background dielectric functions of the non-local k dependence dielectric function which is given by:-

$$\varepsilon_L(k\omega) = 1 + \frac{4\pi e^2}{k^2}\sum_k \frac{f_0(k) - f_0(k - \bar{k})}{\varepsilon(k + \bar{k}) - \varepsilon(k) - h(\omega)} \qquad (3)$$

$$\omega_c = \frac{e}{cm^*}B$$

Here ω_c is cyclotron frequency.

δijk= kronical delta function.

As magnetic field is applied along Z-direction, we have

$$\omega_{cZ} = \omega_C \text{ and } \omega_{cx} = \omega_{cy} = 0 \quad \text{then}$$

$$\bar{\varepsilon}(\omega) = \varepsilon_L - \bar{\varepsilon}\,\frac{\omega_p^{\ 2}}{(\omega^2 - \omega_c^{\ 2})} \qquad (4)$$

$$\varepsilon_L = \frac{\varepsilon_\infty\omega^2 - \varepsilon_0\omega_t^{\ 2}}{\omega^2 - \omega_t^{\ 2}} \qquad (5)$$

If the bounding medium is ε_B then from the dispersion relation of three mode coupling we get

$$R\varepsilon_L Y'\left[\bar{\varepsilon}_1 - \varepsilon_L\Omega^2 X(rZ)' + \partial^2(RX)'Z\right] - l(l+1)XYZ\left[\varepsilon_B(\omega)\bar{\varepsilon}_1(\omega)\right] = 0 \qquad (6)$$

From equation (5) ε_L is put in equation (6), we get-

$$R\left(\frac{\varepsilon_\infty\omega^2 - \varepsilon_0\omega_t^{\ 2}}{\omega^2 - \omega_t^{\ 2}}\right)y'\left[\left\{\bar{\varepsilon}_1 - \left(\frac{\varepsilon_\infty\omega^2 - \varepsilon_0\omega_t^{\ 2}}{\omega^2 - \omega_t^{\ 2}}\right)\Omega^2\right\}X(RZ)' + \partial^2(RX)'Z\right] - l(l+l)XYZ\left[\varepsilon_B(\omega)\bar{\varepsilon}_1(\omega)\right] = 0$$

And simplifying we get-

$$R\left(\varepsilon_\infty\omega^2 - \varepsilon_0\omega_t^{\ 2}\right)\left[\left\{\left(\frac{\varepsilon_\infty\omega^2 - \varepsilon_0\omega_t^{\ 2}}{\omega^2 - \omega_t^{\ 2}}\right) - \bar{\varepsilon}\,\frac{\omega_p^{\ 2}}{\omega^2 - \omega_c^{\ 2}}\right\}\left(\omega^2 - \omega_t^{\ 2}\right) - \left(\varepsilon_\infty\omega^2 - \varepsilon_0\omega_t^{\ 2}\right)\Omega^2\right]XY'Z'$$
$$-R^2\left[\varepsilon_\infty\omega^2 - \varepsilon_0\omega_t^{\ 2}\right]\partial^2 XY'Z' - l(l+1)\left(\omega^2 - \omega_t^{\ 2}\right)^2$$
$$\varepsilon_B\left[\left\{\left(\frac{\varepsilon_\infty\omega^2 - \varepsilon_0\omega_t^{\ 2}}{\omega^2 - \omega_t^{\ 2}}\right) - \bar{\varepsilon}\,\frac{\omega_p^{\ 2}}{\omega^2 - \omega_c^{\ 2}}\right\}\right]XY'Z' = 0 \qquad (7)$$

Now, let us assume that ${}^{\omega_c}/_{\omega_t}$=M, N=$\omega_p/\omega_t$ and p=w/wt (7)

Putting the values of wc/wt, wp/wt and w/wt in equation (7), we get-

$$R^2\left(\varepsilon_\infty P^2 - \varepsilon_0\right)\left[\left\{\left(\frac{\varepsilon_\infty P - \varepsilon_0}{P^2 - 1}\right) - \bar{\varepsilon}\,\frac{N^2}{p^2 - M^2}\right\}\left(P^2 - 1\right) - \left(\varepsilon_\infty P^2 - \varepsilon_0\right)\Omega^2\right]XY'Z'$$
$$-R^2\left[\varepsilon_\infty P^2 - \varepsilon_0\right]\partial^2 XY'Z' - l(l+l)\varepsilon_B XY'Z\left[\left(\frac{\varepsilon_\infty P - \varepsilon_0}{P^2 - 1}\right) - \bar{\varepsilon}\,\frac{P^2}{p^2 - M^2}\right] = 0 \qquad (8)$$

Or

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$$R^2\left(1-M^2\right)XY'Z'\left[\varepsilon_\infty{}^2p^8-\left\{2\varepsilon_\infty\varepsilon_0+\varepsilon_\infty{}^2\left(m+1\right)\right\}\right]P^6$$
$$+\left\{\varepsilon_0{}^2+2\left(M^2+1\right)\varepsilon_0\varepsilon_{\infty\infty}-M^2\varepsilon_\infty{}^2\right\}P^4$$
$$-R^2\left[\varepsilon_\infty P^2-\varepsilon_0\right]\partial^2XY'Z'-l(l+l)\varepsilon_BXY'Z\left[\left(\frac{\varepsilon_\infty P-\varepsilon_0}{P^2-1}\right)-\bar{\varepsilon}\frac{P^2}{p^2-M^2}\right]=0$$

$$R^2\left(1-M^2\right)XY'Z'\left[\varepsilon_\infty{}^2p^8-\left\{2\varepsilon_\infty\varepsilon_0+\varepsilon_\infty{}^2\left(m+1\right)\right\}\right]P^6$$
$$+\left\{\varepsilon_0{}^2+2\left(M^2+1\right)\varepsilon_0\varepsilon_{\infty\infty}-M^2\varepsilon_\infty{}^2\right\}P^4$$
$$-\left[2\varepsilon_\infty\varepsilon_0m^2+P^2\varepsilon_\infty{}^2\left(m+1\right)+\varepsilon_o^2m^2\right]$$

$$-R^2\bar{\varepsilon}N^2XY'Z'\left\{\varepsilon_\infty{}^2p^8-\left\{(2\varepsilon_\infty+\varepsilon_0)P^4+(2\varepsilon_0-\varepsilon_\infty)P^2+\varepsilon_0\right\}\right\}$$
$$+R^2\left[\varepsilon_\infty{}^2p^8-\left\{\varepsilon_0+\varepsilon_\infty\left(m^2+1\right)\right\}\right]P^4+\left\{\varepsilon_\alpha+\varepsilon_0\left(m^2+1\right)\right\}P^2-m^2\varepsilon_0]\partial^2X'Y'Z$$
$$-l(l+l)\varepsilon_BXY'Z\left[\varepsilon_\infty p^4-\left\{\varepsilon_0+\varepsilon_\infty M^2\right\}P^2+\varepsilon_oM^2\right]+l(l+1)\varepsilon_BXY'Z\varepsilon(P^4-P^2)=0 \quad (9)$$

Or

$$AP^8+BP^6+CP^4+DP^2+e=0$$

Where A= $\left\{\varepsilon_0^2R^2(1-\Omega^2)xy'Z\right\}$ (10)

B= $[\left\{R^2(1-\Omega^2)xy'z'\right\}\left\{2\varepsilon_\infty\varepsilon_0+\varepsilon_0^2(m^2+1)\right\}-R^2\bar{\varepsilon}N^2XY'Z'\varepsilon_\infty+R^2\partial^2X'Y'Z\varepsilon_\infty]$ (11)

$$C=\begin{array}{l}[\left\{R^2(1-\Omega^2)XY'Z'\right\}\left\{\varepsilon_\infty{}^2M^2+\varepsilon_\infty(m^2+1)+\varepsilon_0^2\varepsilon_0\right\}+R^2\bar{\varepsilon}N^2XY'Z'(2\varepsilon_0-\varepsilon_\infty)\\+R^2\partial^2X'Y'Z\left\{(m^2+1)\varepsilon_0+\varepsilon_\infty\right\}-l(l+1)\varepsilon_BXY'Z+l(l+1)\varepsilon_Bxy'Z\varepsilon]\end{array} \quad (12)$$

$$D=\begin{array}{l}R^2(1-\Omega^2)XY'Z'\left\{\varepsilon_\infty{}^2M^2+2\varepsilon_0\varepsilon_\infty(m^2+1)+\varepsilon_0^2\right\}+R^2\bar{\varepsilon}N^2XY'Z'(2\varepsilon_\infty+\varepsilon_0)\\-R^2\partial^2X'Y'Z\left\{(m^2+1)\varepsilon_\infty+\varepsilon_0\right\}-l(l+1)\varepsilon_B\varepsilon_\infty XY'Z+l(l+1)\varepsilon_BXY'Z\bar{\varepsilon}]\end{array} \quad (13)$$

$$E=\begin{array}{l}R^2(1-\Omega^2)XY'Z'm^2\varepsilon^2-R^2\bar{\varepsilon}N^2XY'Z'\varepsilon_0\\-R^2\partial^2X'Y'Zm^2\varepsilon_0-l(l+1)\varepsilon_BXY'Z\varepsilon M^2]\end{array} \quad (14)$$

Hence equation (14) in the required dispersion relation of magneto Plasmon –Phonon and Polaritons in the polar spherical semiconductor for k≠0, in presence of d.c. magnetic field. Now we shall study the characteristic of above equation under certain conditions.

Now consider R→ infinity, Ω →1 and Z', x'→0, then above equation (14) become as-

$$P^4+\frac{D}{C}P^2+\frac{e}{C}=0 \quad (15)$$

And after putting the value of PM & M and A, B, C, D, in equation (15), we get-

$$\left[\omega^4-\left\{\left(\frac{\varepsilon_0\omega_t{}^2+\omega_p^2}{\varepsilon_\infty}+\omega_c^2\right)\omega^2+(\varepsilon\omega_c{}^2+\omega_p^2)\omega_t{}^2/\varepsilon_\infty\right\}\right]=0 \quad (16)$$

We find that above equation is quadratic in ω. we have already said that ωt are the roots of equation ε_{zz}=0. This gives the condition for the existence of surface mode i.e. the above equation gives-

$$\omega_{+-}^2 = \frac{1}{2}\left\{\left(\frac{\varepsilon_0\omega_t^{\,2}+\omega_p^2}{\varepsilon_\infty}+\omega_c^2\right)\omega^2 + \left(\frac{\varepsilon_\infty\omega_t^{\,2}+\omega_p^2}{\varepsilon_\infty}+\omega_c^2\right)^2 - 4\left(\frac{\varepsilon_0\omega_c^{\,2}+\omega_p^2}{\varepsilon_\infty}\omega_t^2\right)\right\} \tag{17}$$

Dividing above equation (17) by square of ωt, we get

$$x_{\pm}^2 = \frac{1}{2}\left[\frac{-\varepsilon_0+\left(\omega_p/\omega_t\right)^2}{\varepsilon_\infty}+\frac{\omega_c^2}{\omega_t^2}\right] \pm \frac{1}{2}\left[\left\{\frac{\varepsilon+\left(\omega_p/\omega_t\right)^2}{\varepsilon_\infty}+\frac{\omega_c^2}{\omega_t^2}\right\}\right]^2$$

$$+4\left\{\frac{\varepsilon_0\left(\dfrac{\omega_e}{\omega_t}\right)^2+\left(\dfrac{\omega_p}{\omega_t}\right)^2}{\varepsilon_\infty}\right\}\Bigg]^{1/2} \tag{18}$$

Now let us assume that

$$x = \left(\frac{\omega}{\omega_t}\right), x_+ = \left(\frac{\omega_+}{\omega_t}\right), x_- = \left(\frac{\omega_-}{\omega_t}\right) \tag{19}$$

Now when a d.c. magnetic field is applied in x-direction on the polar semiconductor of spherical surface, under condition R→ infinity, then the Voigt constant be given by-

$$\varepsilon_v = \frac{\varepsilon_{zz}^2+\varepsilon_{zy}^2}{\varepsilon_{zz}} \tag{20}$$

Now

$$\varepsilon_{zz} = -\frac{\left(\omega_c/\omega_t\right)^2}{x^2}\left[\frac{\left(\omega_p/\omega_t\right)^4}{\left[x^2-\left(\omega_c/\omega_t\right)^2\right]^2}\right] \tag{21}$$

$$\varepsilon_{yz} = -\frac{\left(\omega_c/\omega_t\right)^2}{x^2}\left[\frac{\left(\omega_p/\omega_t\right)^4}{\left[x^2-\left(\omega_c/\omega_t\right)^2\right]^2}\right] \tag{22}$$

With the help of equation we get-

$$\varepsilon_v x^2 = -\frac{1}{[x^2-\left(\omega_e/\omega_t\right)^2]}$$

$$\left[\frac{\varepsilon_\infty\left(x^2-x_+^2\right)(x^2-x_-^2)x^2}{\left[x^2-1\right]^2} - \left[x^2-1\right]\frac{\left(\omega_e/\omega_t\right)^2\left(\omega_e/\omega_t\right)^2}{\varepsilon_\infty\left(x^2-x_+^2\right)\left(x^2-x_-^2\right)}\right] \tag{23}$$

Now consider for compound GaSb

$$\varepsilon_0 = 16.1, \varepsilon_B = 14.4, \omega_p/\omega_t = 3, \omega_c/\omega_t = 0.525$$

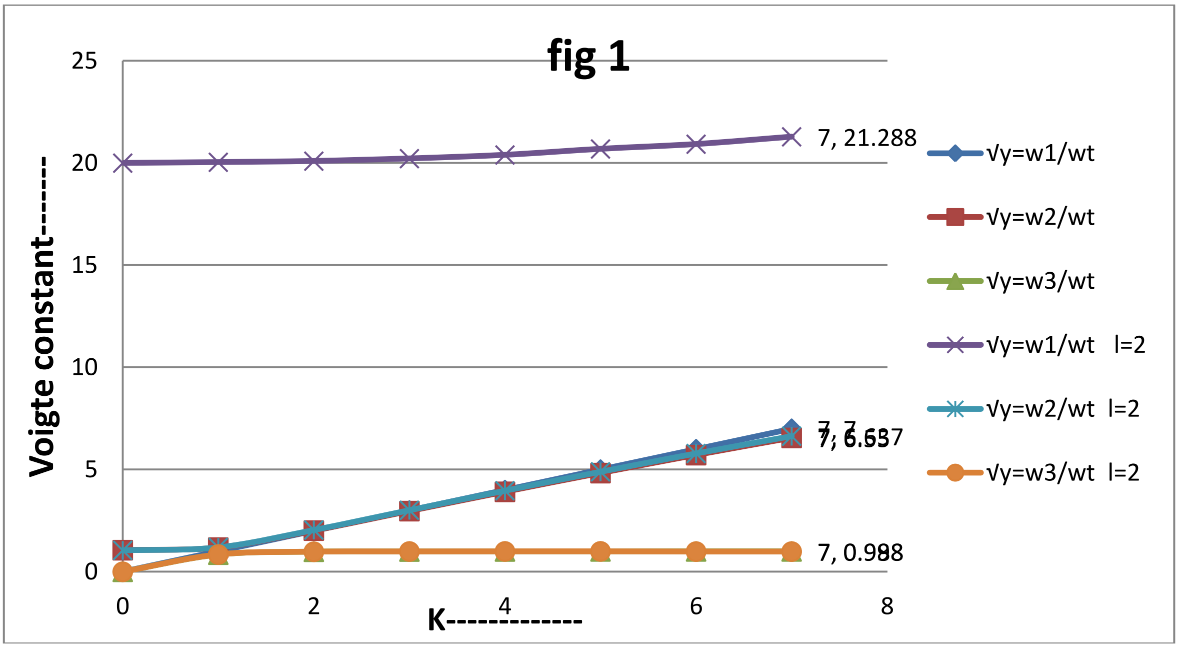
$$x_{+-}^2 = 1.00032778 \pm 0.292538031$$

$$x_+^2 = 0.716789747$$

$$x_-^2 = 0.846634364$$

Table
The values of Voigte constant for different values of k.

	Il=1			l=2		
√z=(wp/wt)	√y=w1/wt	√y=w2/wt	√y=w3/wt	√y=w1/wt	√y=w2/wt	√y=w3/wt
0	20.000	1.057	0	20.000	1.049	0
1	20.023	1.183	0.838	20.042	1.192	0.844
2	20.094	2.015	0.980	20.097	2.044	0.980
3	20.215	2.969	0.992	20.221	3.012	0.992
4	20.387	3.912	0.995	20.398	3.968	0.995
5	20.614	4.829	0.997	20.692	4.894	0.997
6	20.900	5.710	0.998	20.927	5.789	0.988
7	20.250	6.550	0.998	21.288	6.637	0.988



Conclusions

1. With the help of above fig. (1), we observe that for frequency below ω=ω-ε is larger and negative but $\left(\frac{\omega}{\omega_t{}^2}\right)$ is always positive. It means that ε_v is negative, thus surface mode would exist. Thus if $\alpha_1{}^2(q^2-\varepsilon v\omega)$ is positive but $q_z{}^2$ will be negative. Thus, there is no propagation of wave through the surface .for the region below w=w_; ε_v is large and positive and so $\alpha_1{}^2$ is negative and $q_{z1}{}^2$ is positive. Thus in this region no surface modes exist and wave propagates through the surface.
2. The region below ω=ω_and w=w+ and also be taken w=wt and, there are regions of no propagation where the surface mode exist and also portion of propagation where the surface mode do not exist. It is interested to note that number of region of propagation of waves has increased with the application of d.c. magnetic field, parallel to x-axis in the retardation effect. Thus, the surface acts as a band pass filter with an increased number of bonds.
3. Also, we observe that w>w+ the surface acts as a high pass filter because frequency above this value are allowed to propagate and ε_v=+ and $\alpha_i{}^2$ is negative, thus no surface mode exist in this region.

There are some new features which were not seen in the absence of a d.c. magnetic field and it proves to be very useful tool in theoretical and experimental study of surfaces in the presence of a d.c. magnetic field. In the present work we have considered a polar spherical semiconductor .we have also studied the effect of a d.c. magnetic field on the coupling of three surface modes (plasmons, phonons and polaritons) in spherical polar semiconductor for k≠0.

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