Excitation of Polariton on the Surface of TlCl in Different Medium

Abstract

The surface Polariton strongly depend on the nature and geometry of the surface. The behaviour of surface can be studied with the help of dispersion relation for the case $\overline{K} > 0$ by using the Hydrodynamic method. It has been observed that the coupling length of wave vectors, wave radiative and non radiative nature of surface are wave vector dependent and the frequency of the coupled modes varies with the electronic concentration of the polar semi conducting medium. The author has also interest the study of Excitation of Polariton on the surface of TlCl in different medium.

Keywords: Polaritons, Plasmons, Hydrodynamical Model.

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Introduction

Surface waves and coupling between them several workers have made attempts to explain the surface enhanced Raman effect[1-2]. Super conductivity of high temperature[28] fractional quantum Hall effect[3] and several other effects[4] has been study. These studies have very wide applications in integrated optics and microelectronics[5]. Therefore, it was though of great interest to study of these surface plasmon phonon coupling[17-24].

In order to study the SP-SOP modes in a polar semiconductor with curved geometries one has to derive the dispersion relation. A survey of literature shows that generally people have derived the dispersion relation for curved geometries for the case $\overline{K} = 0$[6-9]. ($\overline{K}$ is the wave vector). The dispersion relation for SP-SOP modes of spherical polar semi conductor $\overline{K}$ >0 has been obtained as a particular case by using Bloch's hydrodynamic method [8-13].

Dispersion relation for SP-SOP modes has been studied theoretically in a number of geometries for polar semiconductor[7]. The spatial dispersion relation for SP-SOP modes of spherical polar semiconductor for K>0 has been derived by Bloch's hydrodynamical methods. Here the modified Bloch hydrodynamical equation has been used.

For a polar semiconductor the modified Block's hydrodynamic equation in the non-relativistic may be written as

$$m\frac{DV}{Dt} = e\phi - \overline{\nabla}\int_0^{n(r,t)} \frac{dP(n')}{n'} \quad (1)$$

$$\frac{\partial n}{\partial t} = -\overline{\nabla}.(n\overline{V}) \quad (2)$$

$$\nabla^2\phi = \frac{4\pi e}{\overline{\varepsilon}}\left[n(\overline{r},t) - N_+(\overline{r})\right] \quad (3)$$

The hydrodynamic pressure P is taken to be of Fermi type. The dielectric constant $\overline{\varepsilon}$ is the arithmetic mean of ε_0 (low frequency limit) and ε_∞ (high frequency limit) and it is the frequency-independent approximation is to the lattice dielectric function.

Now we can obtain the dispersion relation for the coupled SP-SOP modes by applying the hydrodynamic condition for the existence of surface waves, which says the normal component of the velocity $\overline{v}$ vanishes at the spherical boundary 'r = R.

$$\frac{e}{m}\left\{\frac{A_1}{Ka^2} i_1(Kr)\left[\left(\frac{p}{} \frac{\overline{\varepsilon}_1 I_1(pr)X_1(KR) - \varepsilon_2 KI_l(pR)X_1(KR)}{\varepsilon_2 I_l(KR)X_l(KR) - \varepsilon_1 I_l(KR)X_l(KR)}\right) + \frac{A_1 p}{\alpha^2} i_1(pR)\right]\right\} = \frac{\beta^2}{n_0} A_p I_l(pR)$$

the above equation may be written in a more simpler form as

$$\left[\frac{\dfrac{P\overline{\varepsilon}X_l(P)}{X_l(p)} - \dfrac{\varepsilon_2 KI_l(P)}{I_l(p)}}{\dfrac{\varepsilon_2 I_l(P)}{I_l(P)}\varepsilon_1 \dfrac{X_1(P)}{X_l(P)}}\right] = p^2\left(\frac{\omega^2}{\omega_p^2}\right) \quad (4)$$

where P = KR, $P'=pR$

we write above eq. (4) a more convenient from

$$(\bar{\varepsilon}A - \varepsilon_2 B)\omega_p^2 + (\varepsilon_2 C - \varepsilon_1 A)\omega^2 = 0 \quad (5)$$

where A, B and C are constants given by

$$A = \frac{X_{l-1}(\rho) - X_{l+1}(\rho)}{lX_{l-1}(\rho) + (l+1)X_{1+1}(\rho)} \quad (5a)$$

$$B = \frac{I_{l-1}(\rho) - I_{1+1}(\rho)}{lI_{(l-1)}\rho + (l+1)I_{l+1}(\rho)} \quad (5b)$$

$$C = \frac{I_{l-1}(\rho) - I_{1+1}(\rho)}{lI_{(1-1)}(\rho) + (l+1)I_{(1+1)}(\rho)} \quad (5c)$$

The equation (5) is the required general spatial dispersion relation of the coupled SP-SoP modes in a polar semiconducting sphere and it has been derived by the authors for the first time. The integer 'l' signifies the mode of ascillation. Modes *l* = 1,2,... correspond to dipole, quadrupoleetc, oscillation respectively. The *l* = 0 mode does not give any root for frequency '' and thus the solutions start with l = 1.

The spatial dispersion relation for the case $\bar{K} = 0$ can be obtained from equation (5) directly by substituting the value of constant A, B and C as $\bar{K} \to 0$, in the limit $\bar{K} \to 0$,the dispersion relation (5) reduces to

$$\frac{lI_{l-1}(\alpha R) + (l+1)I_{(l+1)}(\alpha R)}{lI_{l-1}(\alpha R)} = \frac{(2l+1)\varepsilon_2\omega_p^2}{[l\varepsilon_L + (l+1)\varepsilon_2]\omega^2 + [l(\varepsilon_2 - \bar{\varepsilon})]\omega_p^2} \quad (6)$$

Equation (6) is the dispersion relation for the coupled SP-SoP modes in a polar semiconducting sphere for the case $K = 0$,'ε_L' is the background dielectric function of the medium and 'E_2' is the dielectric constant of the binding medium. The dispersion relation (6) is the same which was derived by Srivastava and Tandon[7] for a polar semiconducting sphere, for the case $\bar{K} = 0$, using the Hydrodynamicalmethod. The dispersion relation[23] is the same which was derived by Barberan and Bausells[6] for metallic sphere.

In the hydrodynamic model, we use the local form of dielectric function which can be written as

$$\varepsilon_1 = \varepsilon_L - \frac{\omega_p^2}{\omega^2} \quad (7)$$

Where 'E_L' is the back-ground dielectric function of the polar semiconductor and given by[16]

$$\varepsilon_L = \frac{\varepsilon_\infty\omega^2 - \varepsilon_0\omega_t^2}{\omega^2 - \omega_t^2} \quad (8)$$

Equation (8) with the help of equation (7) gives

$$\varepsilon_1 = \frac{\varepsilon_\infty Y - \varepsilon_0}{Y-1} - \bar{\varepsilon}\frac{Z}{T} \quad (9)$$

where $Y = \frac{\omega^2}{\omega_t^2}$ and $Z = \frac{\omega_p^2}{\omega_t^2}$

Where the value of 'E_1' from equation (9) is substituted in the dispersion relation (5) and vacuum is taken as the binding medium we get the following equation

$$Y[Y^2 - (aZ + b)Y + aZ] = 0 \quad (10)$$

where $a = \frac{B - 2\bar{\varepsilon}A}{C - \varepsilon_\infty A}$, $b = \frac{C - \varepsilon_0 A}{C - \varepsilon_\infty A}$

The root Y = 0 of the equation (10) does not give any meaningful solution for frequency of the coupled modes. The frequencies of the coupled modes are thus given by the roots of the following quadratic equation.

$$Y^2 - (aZ + b)Y + aZ = 0) \quad (11)$$

The above equation is quadratic in Y thus for each mode 'l' it gives two coupled modes for the given values of the constants.

For the uncoupled SoP mode, S=0 or Z=0 then equation (11) gives,

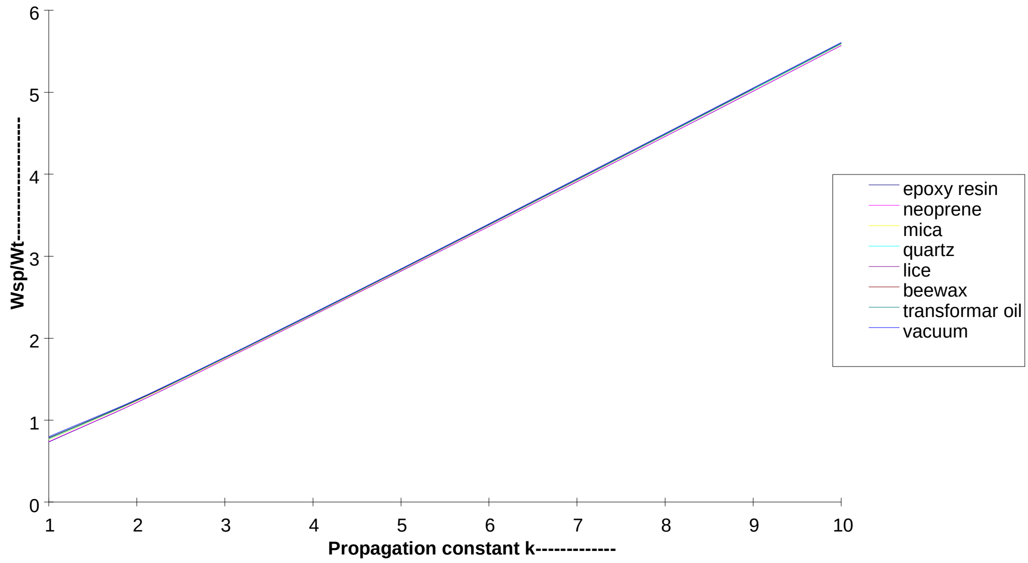
$$Y_{SOP} = \left(\frac{\omega_{SOP}}{\omega_t}\right)^2 = \left(\frac{C - \varepsilon_0 A}{C - \varepsilon_\infty A}\right)Z \quad (12)$$

or the uncoupled SP mode, $\varepsilon_1 = \bar{\varepsilon}$ the dispersion relation (5) then gives,

$$Y_{SP} = \left(\frac{\omega_{SP}}{\omega_t}\right)^2 = \left(\frac{B - 2\bar{\varepsilon}A}{C - \bar{\varepsilon}A}\right)Z \quad (13)$$

It is evident that the frequency of the uncoupled SP mode depends on the value of $Z = (\omega_{SP}/\omega_t)^2$ i.e. on the electronic concentration of the conducting materials TlCl

Graph for Wsp/Wt of TlCl



From the above figure we observe that the frequency of the upper mode varies linearly with the propagation constant in different dielectric medium. There are no major effect presence of different dielectric medium for short wavelength of incident electromagnetic wave but slight effect have been calculated for longer wavelength of incident em waves. It is also seen that behaviour of surface waves in vacuum is best in comparison to others. It is observed that the higher electronic concentrations the lower mode becomes like pure SoP mode and the upper mode like pure SP mode. The coupling between the SP and SOP modes is strongest when $_{SP=SOP}$ i.e. where the two uncoupled modes intersect. The strongest coupling is observed to occur at $_{wp/wt} \approx 1$ i.e. when $_{wp \approx wt.}$

A general spatial dispersion relation for coupled SP-SOP modes in polar semi conducting sphere has been derived using the Bloch's hydrodynamic method. The dispersion relation for the case $\overline{K}$ =0 has been derived as a particular case. It has been observed that the spatial effects are wave vector dependent. It has also been observed that the frequencies of coupled modes depend on the electronic concentration of the polar semiconducting medium. Pure SOP and SP mode like characters have been observed at higher electronic concentrations.

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