P: ISSN NO.: 2394-0344 RNI No.UPBIL/2016/67980 VOL-2* ISSUE-7* October- 2017
E: ISSN NO.: 2455-0817 Remarking An Analisation

Magnetic Field Normal to the Plane of Electromagnetic Wave on the Surface of Nano Materials

Abstract

Oscillations are, generally speaking, the simple back and forth swings of an object as induced by the driving factor inside or outside, which can be found in nearly all the materials from the vast universe to the tiny molecules or even electrons. They are so usual and important in our living planet that can be well utilized and change our world. Among them, the electromagnetic (EM) oscillation has been paid great attentions. The origin of EM oscillation can trace back to the middle and later period of 19th century, at which time Maxwell predicted theoretically the existence of EM wave from the electron oscillations, and Hertz confirmed it experimentally. Then, it was realized that EM wave is always around world in the forms of visible or invisible light. Without delay, the applications of EM oscillation were widely exploited especially in the communication technology. From the Maxwell equation, one can obtain two solutions, which stand for the radiative and collective EM waves, respectively. However, the latter one, also named as Plasmon, does not attract enough attention until its extraordinary properties are discovered in recent years, which has formed a new subject of Plasmonics. The author has interest to study the surface properties of nano materials in presence of magnetic field.

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Introduction

From Hydodynamical equation, one can obtain two solutions, which stand for the radiative and collective EM waves, respectively. However, the latter one, also named as Plasmon, does not attract enough attention until its extraordinary properties are discovered in recent years, which has formed a new subject of Plasmonics. The author has interest to study the surface properties of nano materials in presence of magnetic field.

Review of Literature

The phenomenon related to Plasmon was firstly reported by Wood [1] in 1902, with the results of uneven distribution of light in a diffraction grating spectrum. However, he cannot give a plausible explanation for this so-called Wood's anomalies. After about 40 years, Fano [2] theoretically revealed in 1941 that the Wood's anomalies relied on the subsequently excited Sommerfeld's type EM waves with large tangential momentum on a metallic surface, which cannot be described by Rayleigh's approximation [3]. Nevertheless, these surface waves are very strongly damped in the transversal direction. On the other hand, in 1879, Crookes [4] reported firstly the fourth fundamental state of matter with the positive ions and negative electrons or ions coexisting, and he called it as "radiant matter". Then, Langmuir studied the oscillations in ionized gases and named the ionized state of matter as plasma [5]. Subsequently, he and Tonks [6] declared another important result that plasmas can sustain ion and electron oscillations and formed a dilatational wave of the electron 4 density. This wave is equivalent to Fano's which can be quantized as plasmas oscillations, i.e., Plasmons, with one resonant frequency of Plasmons existing in one bulk material. Based on amount of experimental and theoretical work on the origin and implications of characteristic energy losses experienced by fast electrons in passing through foils, Pines and Bohm suggested some of these energy losses are due to the excitation of Plasmon which was a collective behaviour [7-10], and found that the resonant frequency of Plasmon in bulk Plasma is (1) 1/2 2 0 0 ω ε = ne m/, where n and m are the electron density and mass respectively and 0 ε is permittivity of vacuum. From more detailed numerical calculations in 1957, Ritchie [11] found an anomalous energy loss happened both at and below the resonant frequency of Plasmon when an electron traversed the thin films, the cause of which was suggested to be depending on the interface of the materials. This suggestion was quickly confirmed experimentally by Powell and Swan [12]. Actually, the resonant frequency of Plasmon is determined by the restoring force that exerts on the mobile charges when they are displaced from equilibrium, for example by the nearby passage of an electron [12, 13]. Following the previous work, Stern and Ferrell studied the plasma oscillations of the degenerate electron gas related to the material surface and firstly named them as surface Plasmons (SPs) in 1960 [14]. Consequently, SPs are the collective oscillations of charges at the surface of Plasmonic materials. Owing to the heavy energy loss, Plasmon inside the materials evanesces severely, but fortunately, it can propagate quite a long distance along the surface [15].

Aim of the Study

The author has interest to investigate surface properties of nano materials in presence of external field which may be useful in all fields of science and technology for electronic devices. The author's aim at a basic understanding is not only surface properties of condensed materials and Graphene's but also magnetic effects on filtering properties of condensed materials in Medical Sciences, Bio-chemistry, Telecommunication, Optical and Electronic instruments and best of other applications in presence of magnetic fields.

Investigation of Properties of Nano Materials

The author considered a semiconductor-dielectric medium (taken as the Z=0 plane). The plane of propagation is the Y-Z plane and the magnetic field is in a direction normal to it, i.e., in the X-direction.

In this case, the components of the cyclotron frequency 'ω_c' will be:

$$\omega_{cx} = \omega_c\ ,\ \omega_{cy} = \omega_{cz} = 0$$

one can get:

(i) $$\varepsilon_{xx} = \varepsilon_L - \frac{\omega_p^{\ 2}}{\omega^2\left(\omega^2 - \omega_c^{\ 2}\right)}\left[\omega^2 - \omega_c^{\ 2}\right]$$

or $$\varepsilon_{xx} = \varepsilon_L - \frac{\omega_p^{\ 2}}{\omega^2}$$

(ii) $$\varepsilon_{yy} = \varepsilon_L - \frac{\omega_p^{\ 2}}{\omega^2\left(\omega^2 - \omega_c^{\ 2}\right)}\left[\omega^2 - 0\right]$$

or $$\varepsilon_{yy} = \varepsilon_L - \frac{\omega_p^{\ 2}}{\left(\omega^2 - \omega_c^{\ 2}\right)}$$

(iii) $$\varepsilon_{zz} = \varepsilon_L - \frac{\omega_p^{\ 2}}{\omega^2\left(\omega^2 - \omega_c^{\ 2}\right)}\left[\omega^2 - 0\right]$$

or $$\varepsilon_{zz} = \varepsilon_L - \frac{\omega_p^{\ 2}}{\left(\omega^2 - \omega_c^{\ 2}\right)}$$

(iv) $$\varepsilon_{yz} = 0 - \frac{\omega_p^{\ 2}}{\omega^2\left(\omega^2 - \omega_c^{\ 2}\right)}\left[0 - 0 + i\cdot 1\cdot\omega\cdot\omega_c\right]$$

or $$\varepsilon_{yz} = i\ \frac{\omega_p^{\ 2}}{\left(\omega^2 - \omega_c^{\ 2}\right)}\cdot\frac{\omega_c}{\omega}$$

(v)

$$\varepsilon_{zy} = 0 - \frac{\omega_p^{\ 2}}{\omega^2\left(\omega^2 - \omega_c^{\ 2}\right)}\left[0 - 0 + i\left(-1\right)\omega.\omega_c\right]$$

or $$\varepsilon_{zy} = i\,\frac{\omega_p^{\ 2}}{\left(\omega^2 - \omega_c^{\ 2}\right)}\,\frac{\omega_c}{\omega}$$

Therefore the non-zero components of the dielectric function are:

$$\varepsilon_{xx} = \varepsilon_L - \frac{\omega_p^{\ 2}}{\omega^2} \qquad \text{Unchanged}$$

$$\varepsilon_{yy} = \varepsilon_{zz} = \varepsilon_L - \frac{\omega_p^{\ 2}}{\omega^2 - \omega_c^{\ 2}}$$

$$\varepsilon_{yz} = -\varepsilon_{zy} = i\,\frac{\omega_c}{e}.\frac{\omega_p^{\ 2}}{\omega^2 - \omega_c^{\ 2}}$$

Substituting the above values in eqn. (1), it becomes:

$$\varepsilon_0 + \varepsilon_{zz}\left[1 - 0\right]^{1/2} - \frac{1}{2i}\left[2i\,\frac{\omega_c}{\omega}.\frac{\omega_p^{\ 2}}{\omega^2 - \omega_c^{\ 2}}\right] = 0$$

or $$\varepsilon_0 + \left(\varepsilon_L - \frac{\omega_p^{\ 2}}{\omega^2 - \omega_c^{\ 2}}\right) - \frac{\omega_c}{\omega}.\frac{\omega_p^{\ 2}}{\omega^2 - \omega_c^{\ 2}} = 0$$

or $$\left(\varepsilon_0 + \varepsilon_L\right) - \frac{\omega_p^{\ 2}}{\omega^2 - \omega_c^{\ 2}}\left[1 + \frac{\omega_c}{\omega}\right] = 0$$

or $$\left(\varepsilon_0 + \varepsilon_L\right) - \frac{\omega_p^{\ 2}}{\omega^2 - \omega_c^{\ 2}}\left(\frac{\omega + \omega_c}{\omega}\right) = 0$$

or $$\varepsilon_0 + \varepsilon_L - \frac{\omega_p^{\ 2}}{\omega\left(\omega - \omega_c\right)} = 0 \qquad (2)$$

Eqn. (2) gives the dispersion relation of the coupled surface modes for polar semiconductors of $\varepsilon_L\left(\omega\right)$, medium. This relation will describe the changes in the frequency of surface mode with the changes in the strength of the magnetic field.

In order to study the coupling between surface Plasmon and surface optical Phonon in the presence of magnetic field, the author proceed first to decouple the modes as the author did in the case of zero magnetic field. The uncoupled modes will be given as before. For surface Plasmon the background dielectric function is a constant and is given by:

$$\varepsilon_L = \frac{\varepsilon_0 + \varepsilon_\infty}{2}$$

For the surface optical Phonon the frequency ω=ω_s. Hence, for strongest coupling in eqn. (5.46), the author gets:

$$\varepsilon_0 + \varepsilon_L - \frac{\omega_p^{\,2}}{\omega_s\left(\omega_s - \omega'_c\right)} = 0$$

$$\text{or } \omega_s - \omega_c^{'} = -\frac{\omega_p^{\,2}}{\omega_s\left(1+\varepsilon_L\right)}$$

$$\text{or } \omega_c^{'} = \omega_s - \frac{\omega_p^{\,2}}{\omega_s\left(1+\varepsilon_L\right)} \quad (3)$$

(as $\varepsilon_0 = 1$ for vacuum)

To study the surface Plasmon optical phonon mode in the presence of magnetic field in the non-retarded limit the graph is plotted between ω_c/ω_t and ω/ω_t. The equation is used as:

$$\varepsilon_0 + \varepsilon_L - \frac{\omega_p^{\,2}}{\omega\left(\omega - \omega_c\right)} = 0$$

After simplification, it gives:

$$\omega = \left(\frac{\omega_p^2}{\varepsilon_0 + \varepsilon_L} + \frac{\omega_c^2}{4}\right)^{1/2} + \frac{\omega_c}{2}$$

Now applicable equation is:

$$\frac{\omega}{\omega_t} = \left\{\frac{\left(\omega_p/\omega_t\right)^2}{\varepsilon_0 + \varepsilon_L} + \frac{\left(\omega_c/\omega_t\right)^2}{4}\right\}^{1/2} + \frac{\omega_c/\omega_t}{2} \quad (4)$$

Chart for The Values of ε_0, ε_L and ω_p/ω_t

S.No.	Elements	ε_0	ε_∞	ε_L	ω_px10^{13}	ω_tx10^{13}	ω_p/ω_t
1	RbI	5.5	2.6	4.05	1.9	1.4	1.36
2	NaBr	6.4	2.6	4.5	3.9	2.5	1.56

Table 1: For ω/ω_t versus ω_c/ω_t for RbI

ω_c/ω_t	ω/ω_t
1.0	1.16609
1.5	1.619583
2.0	2.092555
2.5	2.575208
3.0	3.063226
3.5	3.554488
4.0	4.047847
4.5	4.542635
5.0	5.03844
5.5	5.534991
6.0	6.032107
6.5	6.529661
7.0	7.027559
7.5	7.525735

Fig. 1 Graph between ω/ω_t Versus ω_c/ω_t For Rbi In Presence of Magnetic Field

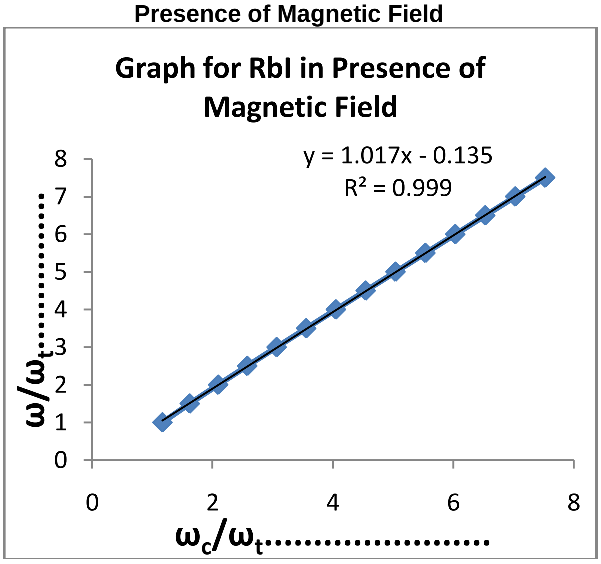
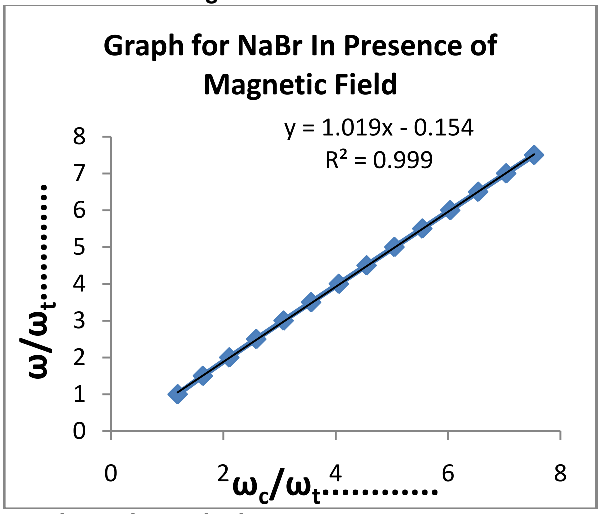


Fig.1.shows the variation of ω_c/ω_t versus ω/ω_t for constant value of ω_p/ω_t for RbI. It is seen from above fig.1 that the value of lattice vibration frequency ratio increases gradually with increasing the value of cyclotron frequency ratio. It is also seen that the graph is very smooth and linear for the condensed material RbI.

Table 2.: For ω/ω_t Versus ω_c/ω_t for NaBr

ω_c/ω_t	ω/ω_t
1.0	1.187943
1.5	1.636434
2.0	2.106014
2.5	2.586326
3.0	3.072662
3.5	3.562668
4.0	4.055059
4.5	4.549079
5.0	5.044261
5.5	5.540299
6.0	6.036983
6.5	6.534169
7.0	7.031751
7.5	7.529652

Fig.2 Graph between ω/ω_t versus ω_c/ω_t for NaBr in Presence of Magnetic Field



Results and Conclusion

Fig.1.shows the variation of ω_c/ω_t versus ω/ω_t for constant value of ω_p/ω_t for RbI. It is seen from above fig.1. that the value of lattice vibration frequency ratio increases gradually with increasing the value of cyclotron frequency ratio. It is also seen that the graph is very smooth and linear for the condensed material RbI. Fig.2. shows the variation of ω_c/ω_t versus ω/ω_t for constant value of ω_p/ω_t for NaBr. It is seen from above that the value of lattice vibration frequency ratio increases gradually with increasing the value of cyclotron frequency ratio. It is also seen linearity of the graph for the condensed material, i.e. NaBr is nearly equal to one. The variation of ω_c/ω_t versus ω/ω_t for constant value of ω_p/ω_t for RbI. It is seen from above fig that the value of lattice vibration frequency ratio increases gradually with increasing the value of cyclotron frequency ratio. It is also seen that the graph is smooth and nearly linear for the condensed material NaBr. Studies of semiconductors and substances are being done at Physics Department, New York City College of Technology of the City University of New York LCEPFL, Ecublens CH-1015, Switzerland, Phy. Rev. B, Vol. 49, No. 4, 15Jan 1994-11 TATA Institute of Fundamental Research Bombay.

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