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E: ISSN NO.: 2455-0817 *Remarking An Analisation*

Study of Szigeti Effective Charge on Polar Semiconductor Compounds

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Abstract

The frequency range that surface plasmonpolariton (SPP) mode exists is mainly limited by the metal material. With high permittivity dielectrics above metal surface, the SPP mode at high frequency has extremely large loss or can be cutoff, which limits the potential applications of SPP in the field of optical interconnection, active SPP devices and so on. To extend the frequency range of SPP mode, the surface mode guided by metal/dielectric multilayers meta-material has been studied based on the theory of electromagnetic field. It is demonstrated that surface mode not only could be supported by the meta-material but also extends the frequency to where conventional metal SPP cannot exist. Meanwhile, the characteristics of this surface mode, such as dispersion relation, frequency range, propagation loss and skin depth in metamaterial and dielectrics, are also studied. It is indicated that, by varying the structure parameters, the meta-material guided SPP mode presents its advantages and flexibility over traditional metal one. The author studied the new work in this field which is great advantages in the field of surface plasmons as Szigeti effective charge on polar semiconductors.

Keywords: Disperson Relation,Spp Modes, High Frequency,Dielectrics

Introduction

The author investigated Szigeti effective charge to study surface properties of polar semiconductors by using spatial dispersion relation and band pass filter of polar semiconductors. The effective charge is a measure of iconicity of polar semiconductors. Thus width of the band increases with increase in iconicity.

Aim of the study

These research papers contain new investigation in semiconductors and give relevant idea of surface properties of materials.

Review of Literature

Collective electronic excitations in metallic systems influence many physical and chemical phenomena, such as catalytic processes, epitaxy, charge transfers at interfaces, and dynamical processes [1–4] and, hence, they have been widely studied in recent years [5–11]. In particular, investigations on noble-metal surfaces are motivated by fundamental interest in understanding the electronic response of such systems. As a matter of fact, the jellium model, usually applied for describing screening properties in simple metals, is not realistic in this case as a consequence of the presence of localized d electrons[12]. Accordingly, several attempts have been undertaken in order to include band-structure effects in theoretical models [3, 13]. For Ag, the s–d polarization model correctly reproduces the main experimental findings. The excitation of surface plasmons (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[14] .

Szigeti effective charge on polar semiconductors

Now we consider the local theory approximation i.e. Kl <<1, where K is the wave vector and l is the electronic mean free path, the dielectric function for the polar semiconductor (medium I) is given by –

$$\varepsilon(\omega) = \varepsilon_L(\omega) - \frac{\omega_p^{\,2}}{\omega^2} \qquad (1)$$

where $\varepsilon_L(\omega) = \dfrac{\varepsilon_\infty \omega^2 - \varepsilon_0 \omega_t^2}{\omega^2 - \omega_t^2}$ (2)

which gives the background dielectric function of the lattice, ε_0 and ε_∞ corresponds to low frequency and high frequency dielectric constant respectively. $\omega_t$is the transverse optical phonon frequency and ω_p is the bulk plasma frequency for free charge carriers.In the case of metals $\varepsilon_L(\omega) = 1$ and in the case of non-polar crystals mode$\varepsilon_L(\omega) = \varepsilon_\infty$. This shows that the lattice dielectric function is constants for metals and non polar semiconductors, but it is frequency dependent for polar semiconductors. The eq. (1) can also be written as –

$$\varepsilon(\omega) = \varepsilon_\infty \left[1 + \frac{\Omega^2}{\omega_t^2 - \omega^2}\right] - \frac{\omega_p^2}{\omega^2} \qquad (3)$$

where $\Omega^2 = \dfrac{4\pi N E^{*2}}{\bar{m}\varepsilon_\infty}\left[\dfrac{\varepsilon_\infty + 2}{3}\right]^2$ (4)

$\bar{m}$ being the reduced mass of the ion pair, N the number of ions per unit cell and E^* is the Szigeti effective charge given as-

$$E^* = \left(\frac{\varepsilon_0 - \varepsilon_\infty}{4\pi}\right)^{1/2} (\bar{m} v_a)^{\frac{1}{2}} \left[\frac{3\omega_t}{\varepsilon_\infty + 2}\right] \qquad (5)$$

Where v_a is the volume of one unit cell.

Szigeti effective charge on filtering properties

The dielectric function can also be written as

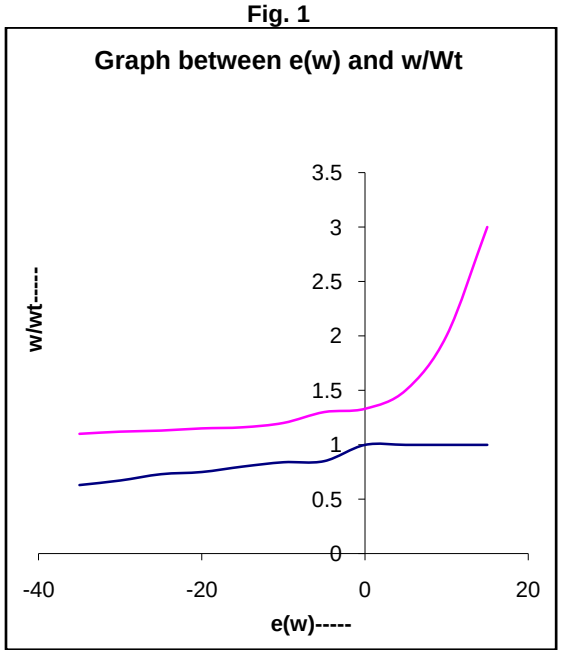
$$\varepsilon(\omega) = \varepsilon_\infty \left[\frac{(\omega/\omega_t)^2 - \varepsilon_0}{\omega^2/\omega_t^2 - 1}\right] - \frac{\omega_p^2/\omega_t^2}{\omega^2/\omega_t^2} \qquad (6)$$

We observe that there exist two coupling modes (surface phonon and surface optical phonons) from fig. (1) –

Table 1

Sl. No.	$\varepsilon(\omega)$	ω_-/ω_t	ω_+/ω_t
1	-35	0.630	1.10
2	-30	0.672	1.12
3	-25	0.730	1.13
4	-20	0.750	1.15
5	-15	0.800	1.16
6	-10	0.840	1.20
7	-5	0.850	1.30
8	0	1.000	1.33
9	5	1.000	1.50
10	10	1.000	2.00
11	15	1.000	3.00

Fig. 1



Here $\frac{\omega_+}{\omega_t}$ and $\frac{\omega_-}{\omega_t}$ are the roots of the eq. ε(ω) = 0. Then we get,

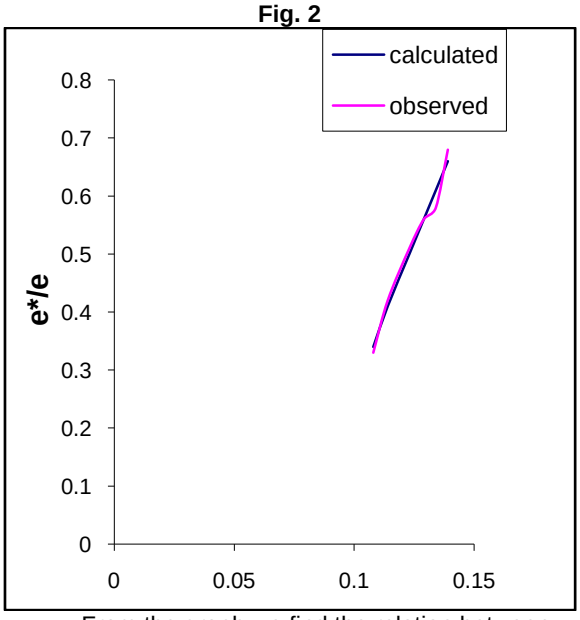
$$\left(\frac{\omega_\pm}{\omega_t}\right)^2 = \frac{1}{2}\left[\frac{\varepsilon_0}{\varepsilon_\infty} + \left[\frac{\omega_p}{\omega_t}\right]^2\right] \pm \left[\frac{1}{4}\left(\frac{\varepsilon_0}{\varepsilon_\infty} + \frac{1}{\varepsilon_\infty}\frac{\omega_p^2}{\omega_t^2}\right) - \frac{1}{\varepsilon_\infty}\left(\frac{\omega_p}{\omega_t}\right)^2\right]^{\frac{1}{2}} \qquad (7)$$

Thus the surface acts as a band pass filter. Again, there is no propagation when ε(ω) is negative. For $\frac{\omega}{\omega_t} > \frac{\omega_+}{\omega_t}$, the surface becomes transparent again acts as a high pass filter.

Sl. No	Compound	ε_0	ε_∞	$\bar{\Delta}$	e^*/e	
					Calculated	Observed
1	GaSb	16.1	14.4	0.108	0.34	0.33
2	InSb	17.7	15.6	0.114	0.41	0.42
3	GaAs	12.9	10.9	0.123	0.50	0.51
4	InAs	14.9	12.3	0.129	0.56	0.56
5	GaP	10.7	8.50	0.134	0.61	0.58
6	InP	12.4	9.60	0.139	0.66	0.68

Now from graph (1), we find band pass filter $\bar{\Delta} = (1 - \frac{\omega_-}{\omega_t})$ for the compounds GaSb, InSb, GaAs, InAs, GaP, and IP. The dielectric compound ε(ω) also depends upon Szigeti effective charge E*. The following table obtained.

Fig. 2



From the graph we find the relation between

$$\Delta = 0.074 + 0.0999\ {}^{e^*}/_{e} \qquad (8)$$

From above table it is observed that calculated e^* and observed are approximately same. The effective charge is a measure of iconicity of polar semiconductors. Thus width of the band increases with increase in iconicity.

Conclusion

Thus if there is more ionic character, band of allowed frequencies is wider and surface becomes high pass filter at a higher value of frequency ω.

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