Analysis of radiative and non-radiative properties of nanosize AgCl at resonance condition

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Abstract **- Polar semiconductor materials of few nanometers are expected to possess additional interesting electronic, mechanic and molecular properties. Specially in the beginning, all theoretical studies on carbon nanotube focused on the influence of the nearly one dimensional structure on molecular and electronic properties. In this article there is study of the physical structure, surface polaritons and absence of spatial dispersion effects in the case of surface phonon-polariton modes. Some interesting and important features of AgCl will also be studied on the basis of frequency-dependence of the lattice dielectric function which essentially affects, to various extents, all surface characterization of a semiconductor material. Here transmission of light and its coupling through the medium at surface is delt.**

IndexTerms**—polar semiconductors, dispersion relation, surface coupling.**

I. INTRODUCTION

Carbon nanotubes [1,2] have received much attention as functional materials [3]. The materials are synthesized via arc discharge [2], laser ablation [4], chemical vapor deposition [5], etc. The raw products usually contain impurities such as amorphous carbon, fullerenes, and catalytic metals. The impurities should be removed to utilize carbon nanotubes efficiently.

Most of the amorphous carbon and fullerenes are removed by gas phase oxidation [6]. Fullerenes can also be removed with toluene because they are soluble in the solvent [4]. Then the carbon nantubes are treated by acids such as HCl [6], HNO3 [7], and H2SO4–HNO3 mixtures [8] to remove catalytic metals and residual amorphous carbon. The carbon nanotubes are recovered by centrifugation or filtration after acid treatments. From the viewpoint of production engineering filtration is superior to centrifugation because the former can be easily scaled up. Filtration is also used to prepare thin carbon nanotube networks, which are used to prepare electric circuits [9] and gas sensors [10,11] by transferring to the surface of plastics, such as polydimethylsiloxane. Thin carbon nanotube films ‘‘buckypapers’’ are also prepared by filtration to use them as gas filters [12], electromechanical actuators [13] and electrodes of Li-ion batteries [14] and fuel cells [15]. The carbon nanotube networks are usually formed by vacuum filtration and the filtration characteristics are not studied in detail [12]. The dependence the internal structure of buckypapers on the different filtration conditions had been examined [16].

This analysis presents a detail of the radiative and non-radiative characteristics of AgCl compound applying conditions of resonance.

II. DERIVATION OF DISPERSION RELATION AND APPLYING IT TO FIND FILTRATION BEHAVIOUR

Coupled SP-SOP modes arise on the surface of material as a result of frequency and wave vector dependence of the dielectric surface function. The below equation

$$\left[\left(\bar{\varepsilon}(k\omega)-\left(\frac{\varepsilon_{\infty}(k\omega)\Omega^2-\varepsilon_0(k\omega)\frac{\omega_t^2}{\omega_p^2}}{\Omega^2-\frac{\omega_t^2}{\omega_p^2}}\right)\right)\right]\left(RZ_l\left(\delta kR\right)\right)' y_l(\alpha kR)$$
$$+\varepsilon_B(k\omega)\Omega^2(Ry_l(\alpha kR))' Z_l\left(\delta kR\right)-l^2X_l(\gamma kR)Z_l(\delta kR)\times$$
$$\left[\bar{\varepsilon}(k\omega)\varepsilon_B(k\omega)\right]=0 \tag{1}$$

and

$$\Omega^6\left(\frac{\omega_p}{\omega_t}\right)^2\varepsilon_\infty-\left[\varepsilon_0+\left\{\bar{\varepsilon}+(1+\varepsilon_\infty)k^2\right\}\left(\frac{\omega_p}{\omega_t}\right)^2\right]\Omega^4 + \left[\left\{(1+\varepsilon_0)+\bar{\varepsilon}\left(\frac{\omega_p}{\omega_t}\right)^2\right\}k^2+\bar{\varepsilon}\right]\Omega^2-\bar{\varepsilon}k^2=0 \quad (2)$$

may be reduced to obtained the dispersion relation for surface phonon-polariton modes, by neglecting the contribution due to plasma, i.e., by taking $\omega_P = 0$. It is clear that eq. (1) on being reduced will give the dispersion relation for surface phonon-polariton with spatial dispersion, and eq. (2) will give the dispersion relation without spatial dispersion.

Both equ. (1) and (2), on setting $\omega_P = 0$, then:

$$\varepsilon_B\varepsilon_\infty\omega^4-\left[\varepsilon_B\varepsilon_0+(\varepsilon_B+\varepsilon_\infty)k_1^2\right]\omega^2+(\varepsilon_B+\varepsilon_0)k_1^2=0 \quad (3)$$

This clearly indicates the absence of spatial dispersion effects in the case surface phonon-polariton modes.

If the bounding medium is vacuum (ε_B=1), the dispersion relation for surface phonon-polariton at polar semiconductor-vacuum interface is:

$$\varepsilon_\infty\omega^4-\left[\varepsilon_0+(1+\varepsilon_\infty)k_1^2\right]\omega^2+(1+\varepsilon_0)k_1^2=0 \quad (4)$$

When equ. (4) is plotted for carbon polar semiconductor, two coupled modes are obtained as shown in the fig. (2).

The uncoupled modes are given by equ ($\omega=\sqrt{\frac{(1+\varepsilon_0)}{(1+\varepsilon_\infty)}}$) and ($\omega=\sqrt{\frac{(1+\varepsilon_\infty)}{\varepsilon_\infty}}k_1$) are also plotted in the same figure (2) are similar to the curves obtained by other workers using Maxwell's equation method.

From fig. (2) It is clear that the lower coupled mode lies below the pure photon mode and is thus non-radiative, whereas the upper mode is radiative. The bound, non-radiative lower coupled mode propagates for a certain range of frequency. It tends towards the uncoupled surface phonon frequency given by eq. ($\omega=\sqrt{\frac{(1+\varepsilon_0)}{(1+\varepsilon_\infty)}}$), i.e. ω=1.09 for InAs, for high values of wave-vector $\bar{k}_1$. On the low wave vector side, the bound non-radiative mode exists up to frequency ω=1.0, below which it merges with the pure photon mode and becomes radiative. Thus, the bound, non-radiative surface polariton mode exists for the frequency range ω=1.0 to ω=1.09.

The upper mode tends to the pure photon mode even for low value of wave vector $\bar{k}_1$. For very small values of wave vector, it tends towards the pure surface optical phonon frequency. The mixed phonon-photon character is most prominent in the region where the uncoupled modes cross. The existence of bound, non-radiative surface phonon-polariton mode for a certain range of frequencies and the radiative mode for the other, can be well explained on the basis of frequency-dependence of the lattice dielectric function $\varepsilon_L(\omega)$.

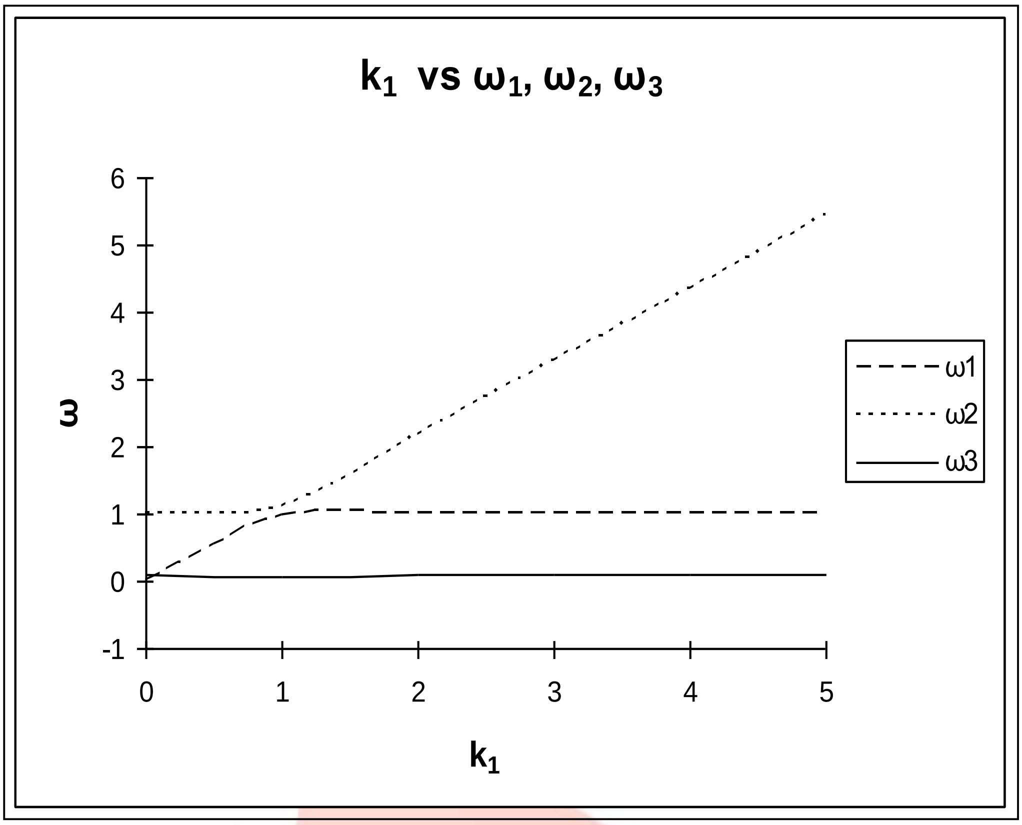

Fig. 1

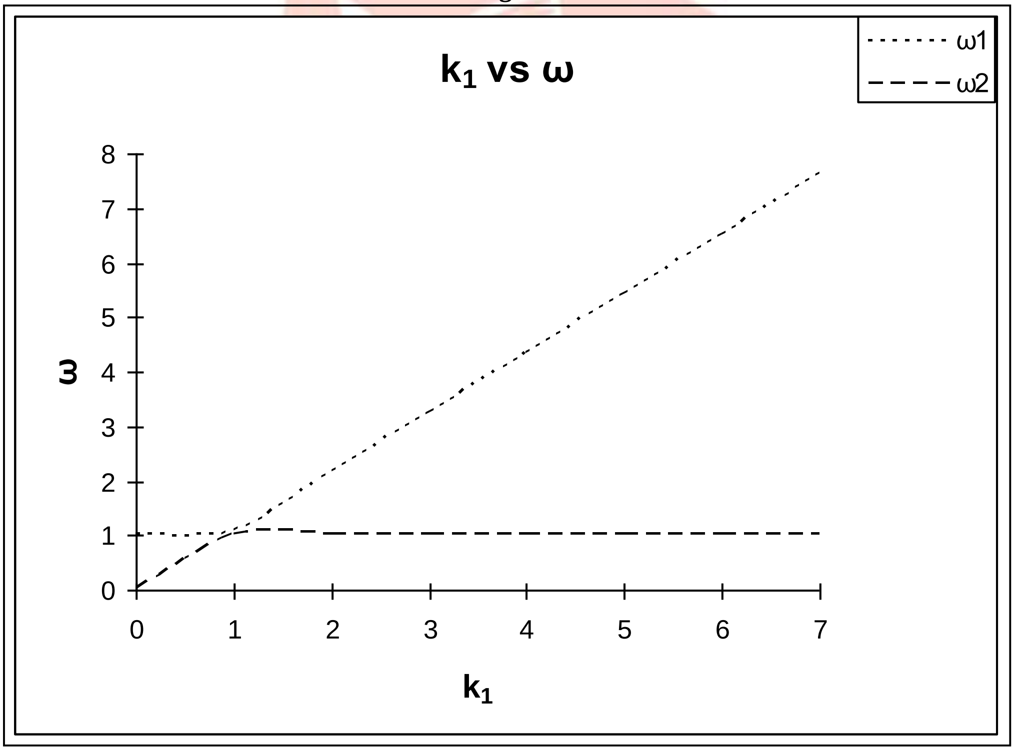

Fig. 2

III. RESULT

Result for fig. 1 and fig. 2 is the coupling length is 6.28571, which is same for both figure.

Table for Ω and k of AgCl

K	Ω1	Ω2	Ω3
10	0.6688	1.04124	10.3841
20	0.667365	1.0366	22.2711

30	0.66709	4.4182	32.401
40	0.6669	2.5045	44.7246
50	0.66695	1.0355	25.4498

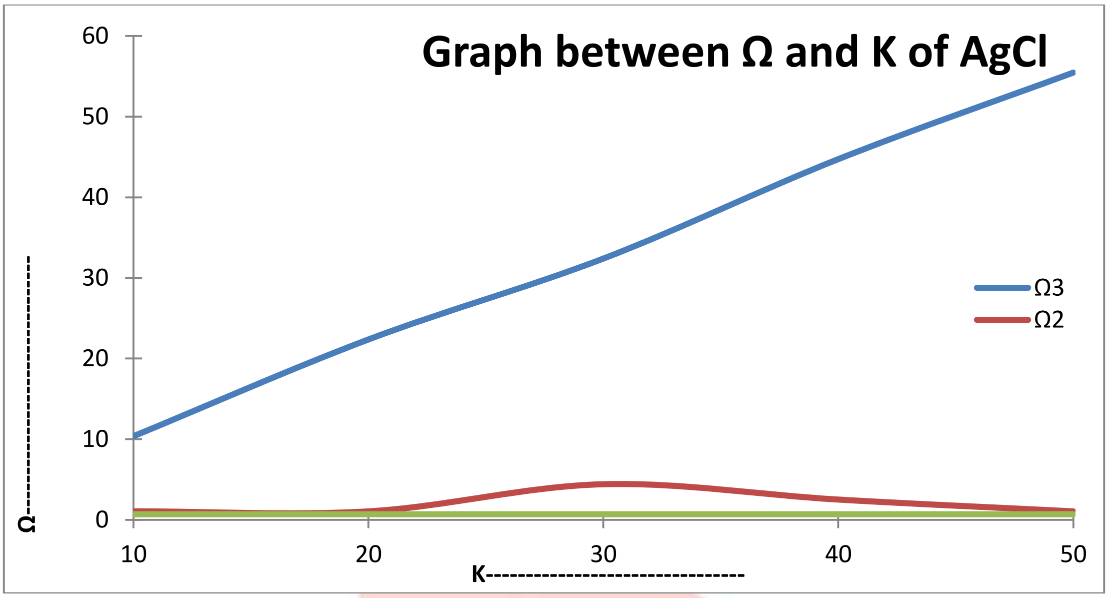

Fig. 3

IV. CONCLUSION

A study of above figure 3 shows that for high value of wave vector, the coupled surface polariton mode tends to constant values Ω = 10.3841 and Ω = 1.04124 for AgCl. At these frequency n^2 →infinite and ε(π). This is a condition of resonance, and at these points, the incident E.M. wave frequency matches exactly with the frequencies of coupled surface polariton mode. As a result, the total incident E.M. energy is propagated along the surface as surface polariton waves and no light is reflected or transmitted through the medium at all. The condition of n^2 >1 and ε(π) implies the existence and hence no transmission of light through the medium. For the frequencies for which ε(π) lies between '0'and '10', n^2→infinite and hence the refractive index 'n' becomes imaginary for these frequencies therefore all the incident energy is reflected back into surrounding medium. For ε(π) n^2<1, and the condition for the radiative Brewster mode is satisfied. This condition is satisfied for frequency region between π =10.3841 and π = 55.4498, π =1.04124 and π =1.0355, π =0.6688 and π =0.66695 respectively. For these frequencies, the incident energy can be filtered or transmitted through the medium. Thus, it is clear that as a result of the simultaneous existence of surface plasmon and surface optical phonon, which lead to coupled surface Plasmon–phonon–polariton modes, the polar semiconductor medium act as a band pass filter and as a high pass filter for incident EM waves.

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REFERENCES

[1] S. Iijima, Helical microtubules of graphitic carbon, Nature, 354 (1991) 56–58.
[2] T.W. Ebbesen and P.M. Ajayan, Large-scale synthesis of carbon nanotubes, Nature, 358 (1992) 220–222.
[3] R.H. Baughman, A.A. Zakhidov, and W.A. de Heer Carbon nanotubes – the route toward applications, Science, 297 (2002) 787–792.
[4] K.B. Shelimov, R.O. Esenaliev, A.G. Rinzler, C.B. Huffman, and R.E. Smalley, Purification of single-wall carbon nanotubes by ultrasonically assisted filtration, Chem. Phys. Lett., 282 (1998) 429–434.
[5] A. Srivastava, O.N. Srivastava, S. Talapatra, R. Vajtai, and P.M. Ajayan, Carbon nanotube filters, Nat. Mater., 3 (2004) 610–614.
[6] Z. Shi, Y. Lian, F. Liao, X. Zhou, Z. Gu, Y. Zhang, and S. Iijima, Purification of single-wall carbon nanotubes, Solid State Commun., 112 (1999) 35–37.
[7] A.C. Dillon, T. Gennett, K.M. Jones, J.L. Alleman, P.A. Parilla, and M.J. Heben, A simple and complete purification of singlewalled carbon nanotube materials, Adv. Mater., 11 (1999) 1354–1358.
[8] S. Fogden, R. Verdejo, B. Cottam, and M. Shaffer, Purification of single walled carbon nanotubes: The problem with oxidation debris, Chem. Phys. Lett., 460 (2008) 162–167.
[9] C. Lim, D.H. Min, and S.B. Lee, Direct patterning of carbon nanotube network devices by selective vacuum filtration, Appl.

Phys. Lett., 91 (2007) 243117.
[10] A. Modi, N. Koratkar, E. Lass, B. Wei, and P.M. Ajayan, Miniaturized gas ionization sensors using carbon nanotubes, Nature, 424 (2003) 171–174.
[11] S. Chopra, K. McGuire, N. Gothard, A.M. Rao, and A. Pham, Selective gas detection using a carbon nanotube sensor, Appl. Phys. Lett., 83 (2003) 2280.
[12] R. Smajda, A. Kukovecz, Z. Ko´nya, and I. Kiricsi, Structure and gas permeability of multi-wall carbon nanotube buckypapers, Carbon, 45 (2007) 1176-1184.
[13] D. Suppiger, S. Busato, and P. Ermanni, Characterization of single-walled carbon nanotube mats and their performance as electromechanical actuators, Carbon, 46 (2008) 1085–1090.
[14] S.H. Ng, J. Wang, Z.P. Guo, J. Chen, G.X. Wang, and H.K. Liu, Single wall carbon nanotube paper as anode for lithium-ion battery, Electrochim. Acta, 51 (2005) 23–28.
[15] W. Li, C. Liang, J. Qiu, W. Zhou, H. Han, Z. Wei, G. Sun, and Q. Xin, Carbon nanotubes as support for cathode catalyst of a direct methanol fuel cell, Carbon, 40 (2002) 791–794.
[16] Takaaki Tanaka, Filtration characteristics of carbon nanotubes and preparation of buckypapers, 2010, Desalination Publications 1944-3994/1944-3986.