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POLARITON DISPERSION OF NANOCOMPOSITE BASED PIEZOELECTRIC CRYSTAL

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ABSTRACT- The dispersion relation and propagation of phonon-polariton modes in Al doped $BaTiO_3$metal nano composite system is studied by using Maxwell-Garnett approximation. The calculation of dispersion relation shows that four modes of propagation exist. By varying the filling factor, the propagation modes are analysed. It is found that the frequency of the top most mode decreases with the filling factor of the system. The interfacial mode in the polariton dispersion represents the transverse optical phonon frequency of $BaTiO_3$. The dispersion moves towards the higher wave vector region with concentration of metal nanoparticles. This tuning of polaritonic gap is used for various optical applications.

Key Words- [Phonon-Polariton; Piezo electric crystal; Nanocomposites; $BaTiO_3$]

1.INTRODUCTION

Polaritons are quasiparticles resulting from strong coupling of electromagnetic waves with an electric or magnetic dipole-carrying excitation[1, 2, 3]. Recently, there has been a lot of interest in the study of polaritons both in bulk and other superlattice system, which leads to various applications in the field of Research and Industrial sector. Nanocomposites are materials that incorporate particles into a matrix of standard material [4].The addition of nanoparticles in thePiezo electric crystal resultsdrastic changes in their properties that can include mechanical strength, toughness and electrical or thermal conductivity.

In this work, dielectric response of Al doped $BaTiO_3$metal nano composite system for various filling factor is studied using Maxwell-Garnett approximation. Hence, the dispersion relation of the phonon-polariton mode is studied.

2. THEORY

The dielectric function for bulk material is given by

$$\varepsilon(\omega) = \varepsilon_{\infty} + \frac{(\varepsilon_0 - \varepsilon_{\infty})\omega_{TO}^2}{\omega_{TO}^2 - \omega^2 - i\omega\gamma} \quad (1)$$

Where ω_{TO} is the frequency of the transverse optical phonons, ε_{∞} and ε_0 are the high frequency and static dielectric constants respectively. Here γ is the damping factor.

The bulk metallic dielectric permittivity with Drude approximation of the nanoparticles system can be expressed in the following way [5],

$$\varepsilon_m = \varepsilon_0 - \frac{\omega_p^2}{\omega(\omega + i\gamma)} \quad (2)$$

Whereω_p is a plasma frequency.

The dielectric function of the nanocomposite system (Al- $BaTiO_3$) by Maxwell-Garnet approximation [6]is given by,

$$\varepsilon_{eff} = \varepsilon(\omega)\frac{(2-f)\varepsilon_m(\omega)+f\varepsilon(\omega)}{f\varepsilon_m(\omega)+(2-f)\varepsilon(\omega)} \quad (3)$$

Where f is the filling factor of the nanoparticles.

The strong coupling between the electromagnetic wave and the phonon componentof piezoelectric crystal may generate the phonon-polariton. The dispersion relation for this system is given by,

$$\frac{c^2k^2}{\omega^2} = \varepsilon(\omega)\frac{(2-f)\varepsilon_m(\omega)+f\varepsilon(\omega)}{f\varepsilon\ (\omega)+(2-f)\varepsilon(\omega)} \quad (4)$$

Where c is the velocity of light,k is the wave vector and ω is the frequency.

3. RESULTS& DISCUSSIONS

The phonon-polariton dispersion for various filling factor of metal nanoparticles of AldopedBaTiO$_3$metal nano composite system is studied.Fig.1.shows the dispersion when the filling factor is equal to 1, the system is full of $BaTiO_3$.As in the Literature, it has two modes of propagation. When f=0, it consists of only metal nano particles and it is represented by the plasmonic behavior of Al as shown in Fig.2. The polariton dispersion when the filling factor is equal to 0.5 as shown in Fig.3.There are four modes of propagation. The lowest mode represents the conventional mode of propagation and ends with the transverse optical phonon frequency (ω_{TO}) of $BaTiO_3$when $k \rightarrow \infty$. The upper mode of propagation reflects the plasmon frequency ofAlin the order of 10^{15} Hz. The other conventional modes of propagation start with the longitudinal optical phonon frequency (ω_{LO}) of $BaTiO_3$. Another interfacial modepropagates at a constant frequency of $\omega_{TO}$of $BaTiO_3$.Fig.4. shows the polariton dispersion when the filling factor becomes 0.9.

It is found that the frequency of the topmost mode decreases with filling factor. There is no appreciable change in the other modes of propagation except the dispersion moves towards the higher wave vector region with the concentration of metal nano particles.

CONCLUSION

By varying the filling factor of the metal nano composite system, the effective dielectric constant and hence the behavior of phonon-polariton is discussed. It is concluded that the frequency of the upper mode increases with the concentration of metal nano particles. When the filling factor increases,the parameters shift towards lower wave vector region.

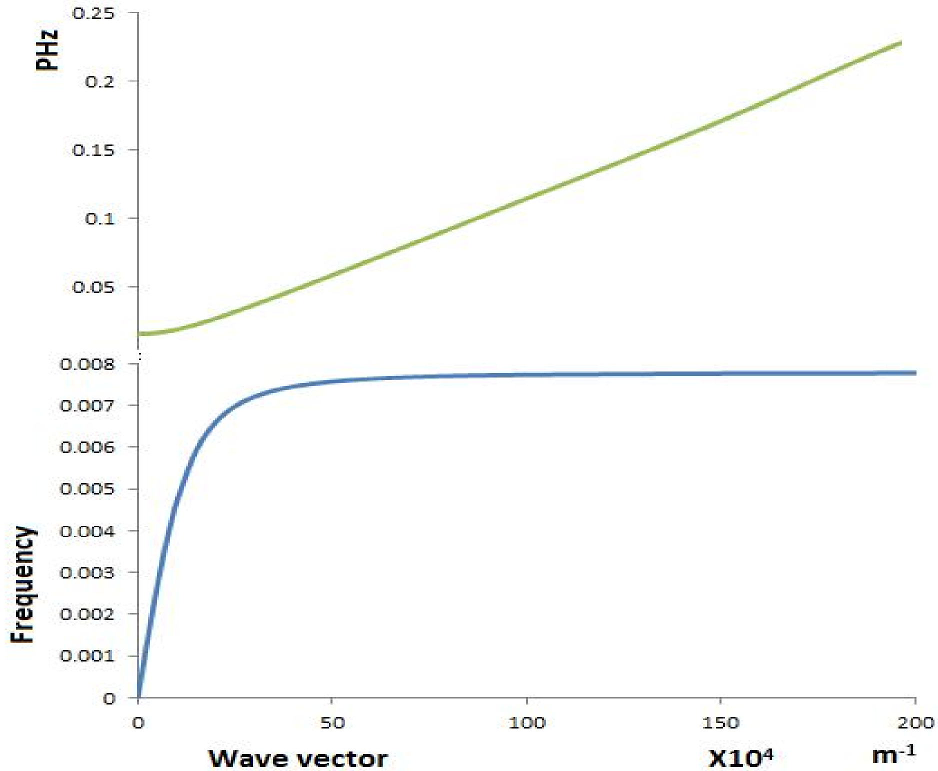

Figure 1- Polariton dispersion of the nanocomposite based Piezo electric crystal system with filling factor f=1.

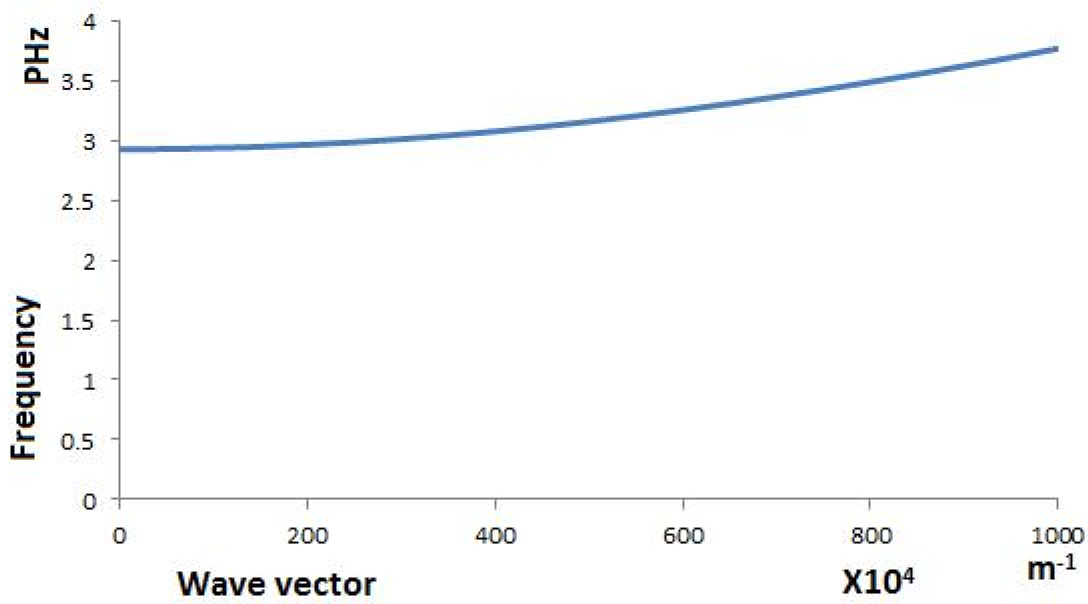

Figure 2- Polariton dispersion of the nanocomposite based Piezo electric crystal system with filling factor f=0.

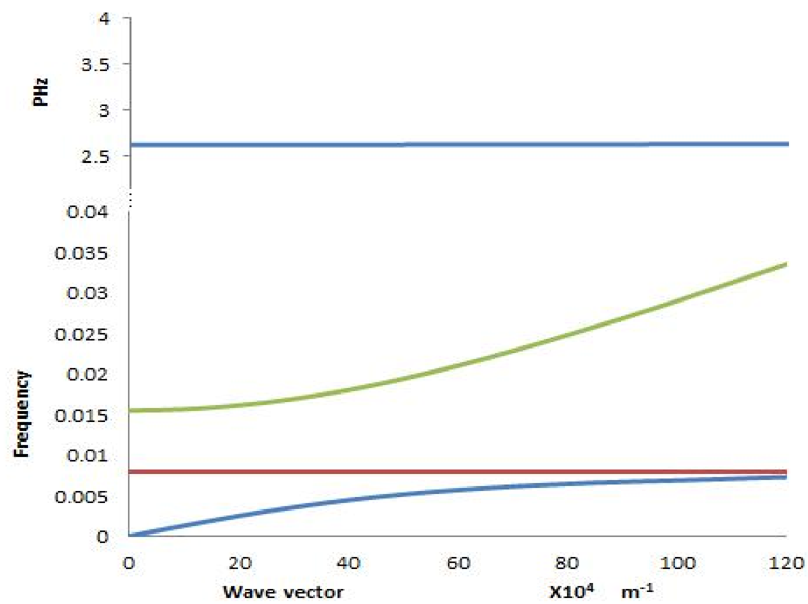

Figure 3- Polariton dispersion of the nanocomposite based Piezo electric crystal system with filling factor f=0.5

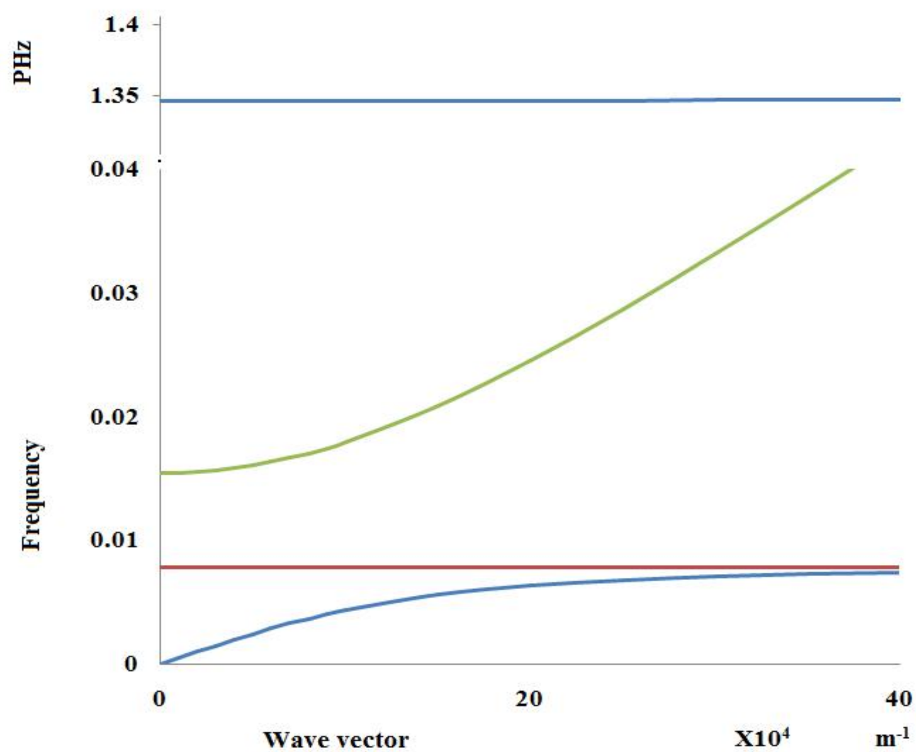

Figure 4- Polariton dispersion of the nanocomposite based Piezo electric crystal system with filling factor f=0.9

REFERENCE

[1]. D.L.Mills and E. Burstein, Rep. Prog. Phys. 37, 817 (1974).

[2]. Huang, Kun ,Lattice vibrations and optical waves in ioniccrystals, Nature 167: 779–780 (1951).

[3]. K.S. Joseph Wilson and K.Navaneethakrishnan, Mod. Phys. Let. B, 18(2/3), 105 (2004).

[4]. M. J. Kadhim*, A. K. Abdullah, I. A. Al-Ajaj, and A. S. Khalil, (IJAIEM) , 3, 1, (2014)

[5]. C.Kittel, Solid State Physics, John wiley& Sons, Eighth edition, 137(2005)

[6]. Stalmashonak, A ;Seifert, G; &Abdolvand,A, Ultra-Short Pulsed Laser Engineered Metal–Glass Nanocomposites, SpringerBriefs in Physics, 2-11,(2013)