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Acousto-electric wave instability in ion-implanted semiconductor plasmas

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Abstract. A comprehensive investigation of excitation of acousto-electric modes and novel properties introduced due to presence of negatively charged colloids in magnetized compensated piezoelectric semiconductor plasma is presented analytically. We derive a compact dispersion relation for the acousto-electric waves in colloids laden semiconductor plasma by employing multi-fluid balance equation. It is found that the presence of charged colloids not only modifies the wave spectrum but also alters the amplification characteristics even though colloidal particles, on account of their heavy masses, do not participate in wave propagation. The results of this investigation should be useful in understanding the characteristics of longitudinal acousto-electric wave in ion-implanted piezoelectric semiconductor plasmas whose main constituents are electrons, holes and negatively charged colloids, which are stationary in the background.

PACS. 72.50.+b Acoustoelectric effects – 72.30.+q High-frequency effects; plasma effects – 61.72.Ww Doping and impurity implantation in other materials – 82.70.Dd Colloids

1 Introduction

During the last decade, the study of dusty plasma has opened a new and fascinating research field. The formation of plasma crystal, modification of existing plasma mode spectrum and the existence of novel waves in dusty plasma have become the interest receiving areas of studies. An ordered structure of heavy charge particles was first theoretically predicted by Ikezi [1]. After Ikezi's predication, the dust Coulomb crystal formation has been demonstrated in a number of laboratory experiments. Recently, Otani et al. [2] have experimentally pointed out that in strongly coupled dusty plasma, under some specific physical conditions the particles have the ability to organize themselves in the form of ordered spatial structures to form a new "plasma crystal". Hence finds wide applications in studying physical processes in condensed matter such as melting and phase transitions as well, provides a strong motivation for investigating the collective properties in strongly coupled plasmas.

Since metals and semiconductors also contain large number of mobile charge carriers representing the system of plasma, which resembles the gaseous plasma regarding collective oscillations. But it is expected to be different in many respects like collision frequency, carrier mobility and the frequency of excited modes. Thus to study material properties a lot of researches have been reported on spectrum of linear and nonlinear waves in solid-state plasmas [3].

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The colloid formation of metal ions (such as Ag^+, Cu^+, Fe^+, etc.) by ion-implantation techniques in SiO_2 glasses has been carried out in a number of laboratory experiments [4–6]. The implantation of metal ions in the host material would modify its high magnetic coercivity, nonlinear optical properties etc. At low energy, chemical-binding effects on ion-ion and ion-target-atom interactions may explain the depth profiles of the implanted ions. These implanted metal ions are neutralized during the slowing down process and somehow agglomerate to form colloids. The observed distribution of the colloids are not ordered. However, if the colloids acquire charge under certain condition, a charge imbalance would be created inside the material and the material will show a variety of useful new properties that we can manipulate.

In this way, the presence of colloids in addition to mobile charge carriers present in semiconductors resembles the dusty gaseous plasma system. Though the role of dust particles in finding the new dust modes in gaseous plasma and plasma crystal formations have been studied extensively during last decade, but the study of these analogous phenomena in semiconductor plasmas remain untouched. Very recently, Salimullah et al. [7], first time predicted the possible Coulomb crystal formation in piezoelectric semiconductors. Ghosh and Thakur [8], by employing the multi-fluid balance equations for a colloids laden semiconductor plasmas whose main constituents are electrons, holes and negatively charged colloids, have reported a comprehensive investigation of propagation of new longitudinal electro-kinetic modes and novel spectrum properties introduced due to presence of negatively charged colloids.

Due to larger mass of ions compared with the mass of electrons in gaseous dusty plasma system, depletion of electron densities may be almost complete. As a result, only low frequency perturbations are seen, when the electron inertia became negligible. In semiconductors, the charge carriers, electrons and holes have high number densities and comparable masses. Therefore, the electron density should be reduced by small amount and it is expected that low as well as high frequency perturbations can be excited in the so-called "colloids laden piezoelectric semiconductor plasmas". At low frequency, all the three carrier species participate, while at high frequency, only electrons and holes can respond and the dust remains stationary in the background.

The colloids present in the semiconductor plasma usually acquire negative charge due to high mobility of electrons in comparison to positively charged holes. As a result, the balance of charge is altered by the presence of colloids and a charge imbalance parameter δ comes into play. It is also worth mentioning here that charging of colloids causes depletion of species (electrons in this case) of higher mobility, however, the ratio of number density of the electrons to that of the holes cannot be, in general, less than the square root of the ratio of their effective masses [9] i.e.

$$\delta = \frac{n_{0e}}{n_{0h}} \geq \sqrt{\frac{m_e}{m_h}}.$$

The interaction between mobile carriers and acoustic vibrations is one of the fundamental interaction processes in solids. This interaction gives useful information regarding the band structure of the host medium. The amplification of sound waves by the application of dc electric field has been commercially exploited for the fabrications of delay-lines, acousto-electric amplifiers and oscillators etc. The underlying physics of sound wave amplification in piezoelectric semiconductors is as follow: a sound wave traveling through a piezoelectric medium produces an ac electric field. If the crystal is an insulator, the electric displacement may be set to zero and one finds that the electric field is either in phase or 180° out of phase with the strain. In an insulator the dielectric frequency is always zero, therefore the stress also is in phase with the strain. In a piezoelectric semiconductor the electric field causes currents to flow. These currents are responsible for accumulation of space charge which varies periodically in space through the lattice. Due to these current movements the electric field is now lags the strain and likewise the stress lags the strain. The major cause of sound wave attenuation may be the Joule heating due to these currents. The fraction of this periodic resultant (in the case of electron-hole plasma) space charge which is present as mobile carrier causes a periodic change in the effective conductivity of the medium. When a direct current is passed through the medium an ac field is produced which is proportional to the effective conductivity modulation. Under the proper conditions, the phase of the total ac field, i.e. the field due to the sound wave and the direct current passing through the medium with variable effective conductivity is such that the stress leads the strain and power is delivered to the travelling wave resulting to sound wave amplification in piezoelectric electron-hole plasma. Since the acoustic gain is dependent upon the effective conductivity being modulated, anything which increases/decreases the effective conductivity modulation, increases/decreases gain.

The properties of the medium and wave characteristics could be better explained if the dispersive and dissipative properties could be fully understood. The propagation of acousto-electric wave requires large, dense and possibly magnetized medium which is not easy to achieve in gaseous system due to confinement problem. Fortunately, these conditions can be easily met in semiconductor plasma and thus can provide a small-scale model for the large devices. To the best of our knowledge, no study has yet been reported on the influence of charge imbalance parameter on the dispersion and absorption characteristics of acousto-electric wave in magnetized colloids laden semiconductor plasma. Therefore, a study of longitudinal acousto-electric interactions in such medium is much needed for better understanding of wave spectrum.

Motivated by the works of Salimullah et al. [7] and Ghosh and Thakur [8], in the present paper, we have focused our attention on the dispersion and absorption characteristics of one of the fundamental interactions in semiconductors plasma i.e. acousto-electric wave in the colloids laden piezoelectric semiconductor plasma. The paper is organized in the following manner. In Section 2, we outline the basic equations describing acousto-electric wave propagation and derive a compact dispersion relation for acousto-electric wave in the colloids laden piezoelectric semiconductor plasma using multi-fluid plasma model. The dispersion relation reveals that the presence of charge imbalance due to colloids modifies the existing modes in the system. In Section 3, we present numerical appreciations of the results obtained and discussions. The important conclusions drawn from the study are listed in Section 4.

2 Theoretical formulation

In the present model, we have considered an ion-implanted magnetized semiconductor plasma system consisting of electrons, holes and immobile charged colloids. Both electrons and holes may be collected by the colloids, but since the electrons move more swiftly than the holes, we have considered that the colloids tend to acquire a net negative charge through the different electron-sticking processes. These charged colloids acts as a third species or foreign particles inside the medium, as a result, the balance of charge in the medium is altered by the presence of colloids creating a charge imbalance in the otherwise compensated medium. So that the condition for charge neutrality in a plasma in presence of negative charged colloids becomes

$$-en_{0e} + en_{0h} - z_d en_{0d} = 0 \quad (1)$$

where $n_{0e,h,d}$ is the concentration of electrons (with the charge $-e$), holes and colloids respectively. z_d is the number of electrons residing on to the colloids surface. The charge of colloids $-z_d e$ can vary significantly depending on plasmas parameters. For many complex plasmas, this charge is negative i.e. ($z_d > 0$) and large ($z_d \sim 10^2$–10^3) [10–12]. Thus because of neutrality condition (1) it is possible to have in such plasmas

$$n_{0e} \ll n_{0h}. \tag{2}$$

To study the modification in two-mode interactions i.e. acoustic and plasmon modes; let us consider a compensated piezoelectric semiconductor plasma sample of infinite extent in the presence of implanted immobile colloidal particles. The medium is subjected to a dc electric field (applied along the z-axis) and a magnetostatic field $\mathbf{B}_0$ applied in the x–z-plane making an angle θ with the z-axis. Under the influence of the dc electric field, electrons will acquire drift along $-z$-direction and holes will acquire drift along $+z$-direction. We have considered an acoustic wave to be propagating along the z-axis of the medium. Furthermore, we introduce a parameter $\delta = n_{0e}/n_{0h}$, which measures the charge imbalance in the plasma, with the remainder of the charge residing on the colloids, so that the total system is charge neutral. The average size of colloids is assumed to be less than the inter-grain distance, the electron Debye radius as well as the wavelength, so that they can be treated as point masses [13].

For the wave, we assume all variables to be of the form $\exp[i(\omega t - \kappa z)]$ in which (ω, κ) are the frequency and wave number of the wave. The wave equation in an elastic piezoelectric medium becomes

$$(-\rho\omega^2 + c\kappa^2)u_x = i\kappa\beta E_z, \tag{3}$$

where β is the piezoelectric coefficient of the medium and all other symbols have the usual meanings as given by Steele and Vural [14].

In deriving equation (3), we have assumed that the piezoelectric semiconductor under consideration has a cubic symmetry, which simplified the involved tensor components without diluting the physical significance of the problem under study. The sound wave is taken as a shear wave that propagates along z-axis, which is $\langle 011\rangle$ axis of the crystal. The lattice displacement $\mathbf{u}$ is taken along x-axis only, which is a $\langle 100\rangle$ axis. This geometry is appropriate to many piezoelectric compound semiconductor of III-V class.

In the present configuration the electrons and holes acquire perturbed motion in accordance with momentum balance equation and can be written as

$$\vartheta_{eZ} = i(e/m_e)E_{1Z}/F(\omega,\kappa), \tag{4}$$

and

$$\vartheta_{hZ} = -i(q/m_h)E_{1Z}/G(\omega,\kappa) \tag{5}$$

where

$$F(\omega,\kappa) = (\omega + \kappa\vartheta_{0e} - iv_e) - \frac{D_e v_e \kappa^2}{\omega + \kappa\vartheta_{0e}} + \frac{\omega_{ce}^2 \sin^2\theta(\omega + \kappa\vartheta_{0e} - iv_e)}{\omega_{ce}^2\cos^2\theta - (\omega + \kappa\vartheta_{0e} - iv_e)^2}, \tag{6}$$

and

$$G(\omega,\kappa) = (\omega - \kappa\vartheta_{0h} - iv_h) - \frac{D_h v_h \kappa^2}{\omega - \kappa\vartheta_{0h}} + \frac{\omega_{ch}^2 \sin^2\theta(\omega - \kappa\vartheta_{0h} - iv_h)}{\omega_{ch}^2\cos^2\theta - (\omega - \kappa\vartheta_{0h} - iv_h)^2}. \tag{7}$$

Here e and q are the charges on electrons and holes respectively. $\vartheta_{0e,0h}$ and $v_{e,h}$ are the drift velocities and momentum transfer collision frequencies of the electrons and holes respectively. $\omega_{ce} = eB_0/m_e$ and $\omega_{ch} = qB_0/m_h$ are the cyclotron frequencies of electrons and holes respectively. All other symbols have their usual meaning with subscripts e, h stand for electrons and holes respectively. Using equations (3) to (7) and the usual relations for the continuity and electrical displacement for a longitudinal wave, we get the dispersion relation for acousto-electric interaction in colloids laden semiconductor as

$$(\omega^2 - \kappa^2\vartheta_s^2)\left[1 - \omega_{ph}^2\left\{\frac{(\delta/m)}{(\omega + \kappa\vartheta_{0e})F(\omega,\kappa)} + \frac{1}{(\omega - \kappa\vartheta_{0h})G(\omega,\kappa)}\right\}\right] = K^2\kappa^2\vartheta_s^2 \tag{8}$$

where $K^2 = (\beta^2/c\varepsilon)$ is the dimensionless electromechanical coupling coefficient. The plasma frequency for holes is given as $\omega_{ph}^2 = q^2 n_{0h}/\varepsilon m_h$.

In absence of piezoelectricity ($\beta = 0$), the coupling parameters on R.H.S. of equation (8) vanishes and we get two independent modes as

$$\omega^2 - \kappa^2\vartheta_s^2 = 0, \tag{9a}$$

and

$$1 - \omega_{ph}^2\left\{\frac{(\delta/m)}{(\omega + \kappa\vartheta_{0e})F(\omega,\kappa)} + \frac{1}{(\omega - \kappa\vartheta_{0h})G(\omega,\kappa)}\right\} = 0. \tag{9b}$$

Equation (9a) is the usual sound mode propagating through an elastic medium and equation (9b) represents the electro-kinetic mode modified due to the presence of static charged colloids in the host material.

In the collision dominated regime ($\omega \ll v_e$, v_h and $\kappa\vartheta_{0e} \ll v_e$, $\kappa\vartheta_{0h} \ll v_h$) equation (8) is solved with the approximation $(\kappa\vartheta_s/\omega) = 1 + i\alpha$ [15], where the gain per radian α is $\ll 1$. For $\alpha > 0$ the acoustic wave would be of amplifying nature. Therefore, one gets from equation (8)

$$\alpha = \frac{\frac{1}{2}K^2\left(\frac{\omega_{Rh}}{\omega}\right)\frac{1}{\phi_h\gamma_h}\left[\left(\frac{\omega}{\omega_{De}}\right)^2\frac{1}{\phi_e^2}\left\{1 - \left(\frac{\delta}{m}\right)\left(\frac{\omega_{De}}{\omega_{Dh}}\right)^2\frac{v_h\phi_e\gamma_e}{v_e\phi_h\gamma_h}\right\} + \gamma_e^2\left\{1 - \left(\frac{\delta}{m}\right)\frac{v_h\phi_h\gamma_h}{v_e\phi_e\gamma_e}\right\}\right]}{(A)^2 + (B)^2} \tag{10}$$

where

$$A = \left[\frac{\omega}{\omega_{De}\phi_e} - \frac{\omega}{\omega_{Dh}\phi_h}\frac{\gamma_e}{\gamma_h} + \frac{\omega_{ph}^2(\delta/m)}{\omega v_e \phi_e} - \frac{\omega_{Rh}}{\omega\phi_h}\frac{\gamma_e}{\gamma_h}\right]$$

and

$$B = \left[\gamma_e + \frac{\omega^2}{\omega_{De}\omega_{Dh}\phi_e\phi_h\gamma_h} + \frac{\omega_{ph}^2(\delta/m)}{\omega_{Dh}v_e\phi_e\phi_h\gamma_h} + \frac{\omega_{Rh}}{\omega_{De}\phi_e\phi_h\gamma_h}\right]$$

in which $\omega_{De,h} = \vartheta_s^2/D_{e,h}$ is the electron and hole diffusion frequencies,

$$\gamma_{e,h} = \frac{\vartheta_{0e,h}}{\vartheta_s} \pm 1, \quad \omega_{Rh} = \frac{\omega_{ph}^2}{v_h},$$

$$\phi_{e,h} = \frac{1 + \left(\omega_{ce,h}^2/v_{e,h}^2\right)}{1 + \left(\omega_{ce,h}^2\cos^2\theta/v_{e,h}^2\right)}.$$

It can be infer from equation (10) that all the effects of the magnetic field appear in the interaction through the parameter $\phi_{e,h}$ only. To study the amplification characteristics ($\alpha > 1$) of wave, we shall discuss two different velocity regimes as follows.

2.1 When $\gamma_e > 0$ and $\gamma_h > 0$ i.e. $\vartheta_{0e} > \vartheta_s < \vartheta_{0h}$

In this velocity regime, α will be positive only when the expression within the square bracket of numerator of equation (10) is positive i.e. when

$$\delta < m\left[\left(\frac{\omega_{Dh}}{\omega_{De}}\right)^2 \frac{v_e\phi_h}{v_h\phi_e}\left|\frac{\gamma_h}{\gamma_e}\right|\right], \tag{11}$$

and

$$\delta < m\left[\frac{v_e\phi_e}{v_h\phi_h}\left|\frac{\gamma_e}{\gamma_h}\right|\right]. \tag{12}$$

If the above conditions are fulfilled the gain per radian will be

$$\alpha \approx \frac{\frac{1}{2}K^2\left(\frac{\omega_{Rh}}{\omega}\right)\frac{1}{\phi_h|\gamma_h|}\left[\left(\frac{\omega}{\omega_{De}}\right)^2\frac{1}{\phi_e^2} + |\gamma_e|^2\right]}{(A)^2 + (B)^2}. \tag{13}$$

where

$$A = \frac{\omega}{\omega_{De}\phi_e} - \frac{\omega}{\omega_{Dh}\phi_h}\left|\frac{\gamma_e}{\gamma_h}\right| + \frac{\omega_{ph}^2(\delta/m)}{\omega v_e\phi_e} - \frac{\omega_{Rh}}{\omega\phi_h}\left|\frac{\gamma_e}{\gamma_h}\right|$$

and

$$B = |\gamma_e| + \frac{\omega^2}{\omega_{Dh}\omega_{De}\phi_e\phi_h|\gamma_h|} + \frac{\omega_{ph}^2(\delta/m)}{\omega_{Dh}v_e\phi_e\phi_h|\gamma_h|} + \frac{\omega_{Rh}}{\omega_{De}\phi_e\phi_h|\gamma_h|}.$$

It may be inferred from above discussion that the amplifying nature of the acoustic wave will be very much decided by the value of charge imbalance parameter δ. Hence the presence of stationary charged colloids modified the wave spectrum effectively in this velocity regime.

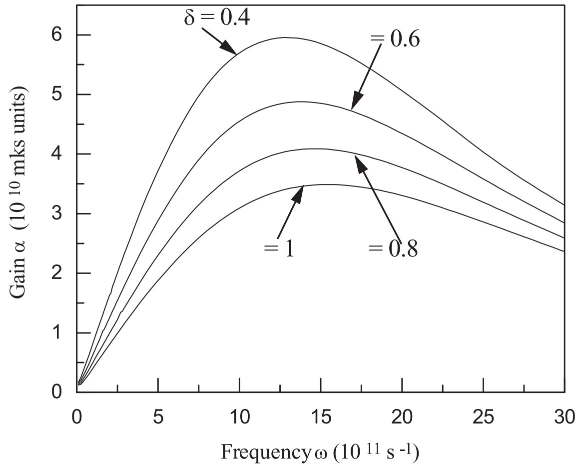

Fig. 1. Variation of gain α with wave frequency ω with δ as parameter.

2.2 When $\gamma_e > 0$ and $\gamma_h < 0$ i.e. $\vartheta_{0e} > \vartheta_s > \vartheta_{0h}$

In this velocity regime one will get decayed mode ($\alpha < 0$) always; hence of no interest here.

3 Result and discussions

The theoretical formulation presented in the preceding section is numerically analyzed here. The expression for gain per radian (α) derived for first case can be employed to study the amplification characteristics of the acoustic mode in the magnetized colloid laden piezoelectric semiconductor plasma. We have considered the case of a compensated semiconductor viz. InSb at 77 K. The parameters chosen are: $m_e = 0.014m_0$, $m_h = 0.40m_0$; m_0 being the free mass, $\varepsilon_L = 17.54$, $\beta = 0.054$ Cm^{-2}, $\rho = 5.8 \times 10^3$ kgm^{-3}, $n_{0e} = n_{0h} = 10^{24}$ m^{-3}, $v_e = 3.5 \times 10^{11}$ s^{-1} and $v_h = 4.4 \times 10^{11}$ s^{-1}. We have used equation (11) for the numerical calculations and the results are displayed in the form of curves in Figures 1–3.

Figure 1 illustrates the dependence of gain per radian (α) on wave frequency ω with δ as parameter. It is inferred from this figure that for all values of δ the gain per radian α follows the identical nature of variation with frequency ω. The gain per radian first increases with increase in frequency, achieves maximum value and then starts decreasing with increasing frequency. At higher frequencies, the wavelength of acoustic mode becomes smaller than the Debye length, so that the ac electric field produced by the acoustic mode will not be screened by the mobile charged particles. Since the screening is what actually produces the charge bunching, that bunching will be greatly reduced. In turn, the gain depends on the bunching, so that it too reduced at such high frequency. In the absence of colloidal particles, the plasma has equal number densities of electrons and holes ($\delta = 1$); the graph infer that the acoustic mode have lowest value of gain per radian. For $\delta = 1$, we found that at $\omega \approx 1.54 \times 10^{12}$ s^{-1} the maximum

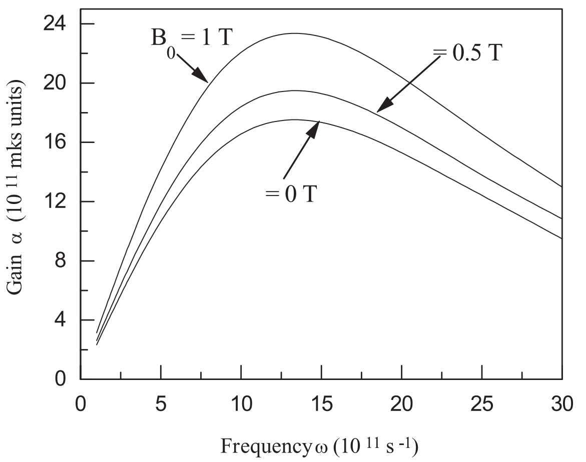

Fig. 2. Variation of gain α with wave frequency ω with magnetic field as parameter.

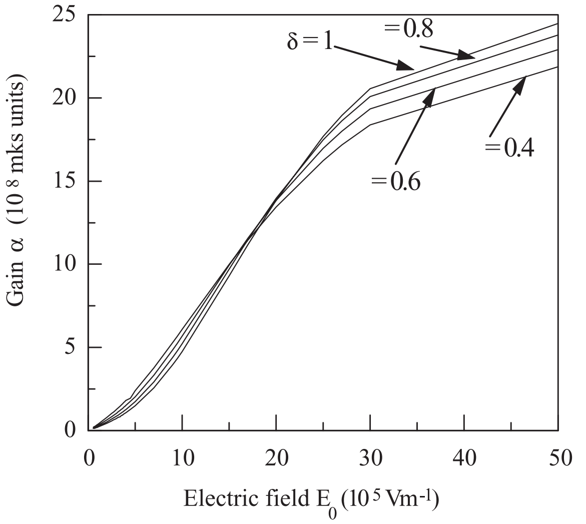

Fig. 3. Variation of gain α with electric field E_0 with δ as parameter.

value of $\alpha \approx 3.48 \times 10^{10}$ mks units is obtained. When colloidal particles are introduced some of the electrons due to their higher mobility stick on to them, and a charge imbalance ($\delta < 1$) is created in the plasma. As a result, the value of α gets significantly modified. It is seen that while nature of variation remains the same the value of α increases with the decrease in the value of δ. As δ decreases, the value of α_{max} increases and the frequency at which one gets maximum value of α is shifted towards lower frequency regime. Thus the result shows that charge imbalance increases the gain constant as well as bandwidth of the amplifier. This behaviour may be attributed to the partial compensation of the plasma medium characterized by $\delta < 1$ values. Decrement in the value of δ means decrement in the number of free electrons which are drifting in opposite direction to that of wave whereas the number of holes drifting along the wave propagation direction remains unaffected. Hence under the condition of charge imbalance in the plasma the amplification of the acoustical waves will be more pronounced since the charge carriers of opposite signs (holes) create the favourable effect in the interaction between acoustical and plasma waves.

Figure 2 displays the gain per radian α verses wave frequency ω graph with applied magnetic field B_0 as parameter. The nature of variation is as usual identical with that of Figure 1. It is found from this figure that the value of α increases with the increase in the value of magnetic field B_0. The value of α_{max} also increases with magnetic field; but the frequency ($\omega \approx 1.35 \times 10^{12}$ s^{-1}) at which α_{max} is achieved, remains unaffected by the presence of magnetic field. Hence magnetic field is also found to be favourable for acoustic wave amplification in ion-implanted semiconductor plasma. Authors have used a field geometry which ensures the drift of electron along negative z-direction and drift of hole along the positive z-direction parallel to the direction of acoustic wave propagation. It may be found from equations (4) and (5) that perturbed velocity of electrons decreases and that of holes in the direction of wave propagation increases with the increase in the value of ambient magnetic field. Hence the resultant perturbed velocity in the direction of sound wave propagation increases with the increase in magnetic field. This increase in resultant perturbed velocity is responsible for increase in the modulation of conductivity. As authors have already discussed in Section 1 that the gain is dependent upon the conductivity being modulated; anything, which increases the conductivity modulation increases the gain. Hence the essential reason for the enhancement of the growth rate due to the ambient magnetic field may be ascribed to the fact that the resultant perturbed velocity in the direction of wave propagation, which causes conductivity modulation, increases with the increment in ambient magnetic field. Previously Spector [16] reported that the amplification of longitudinal acoustic wave increases with cyclotron frequency ω_c upto $\omega_c < \omega_p$, the plasma frequency. In our case also $\omega_{ce} < \omega_{pe}$ and $\omega_{ch} < \omega_{ph}$ is satisfied and hence identical variation is justified. Similar results are also obtained by Lima and Miranda [17] for oblique propagation of acoustic wave.

The variation of acoustic gain per radian α with applied electric field E_0 with δ as parameter is depicted in Figure 3. It is seen that the value of α increases with the increase in electric field E_0 and then saturates out at higher values of E_0. It is noted that in the limit $0 < E_0 < 1.75 \times 10^6$ Vm^{-1}, one gets higher values of α by decreasing the value of δ whereas higher values of α may be obtained by increasing the value of δ when $E_0 > 1.75 \times 10^6$ Vm^{-1}.

4 Conclusions

We have shown that the amplification characteristics of the acoustic mode is strongly modified when a portion of the negative charge sticks on the colloidal particles in piezoelectric semiconductor plasma in presence of magnetic field. We have also found that as the portion of charge on colloidal particles increases, their role in the interaction becomes increasingly effective. The most important inferences that may be drawn from the above study are listed below:

(1) we get amplification of acoustic mode only when electrons and holes both drift faster than the acoustic wave velocity in a compensated semiconductor plasma;
(2) the charge imbalance increases the acoustic gain constant as well as bandwidth of the amplifier;
(3) the charge imbalance not only increases the value of acoustic gain per radian but also increases the maximum achievable value of α;
(4) the charge imbalance shifts the particular frequency towards lower side of the frequency spectrum at which one gets maximum gain.

Thus, a fundamental study of amplification characteristics of the acoustic waves in electron-hole plasma embedded with colloidal particles is important for understanding of waves and instabilities phenomena and can be put to various favourable applications.

It may be mentioned here that present theory provides a qualitative picture of modification in amplification characteristics of acoustic waves in magnetized electron-hole piezoelectric semiconductor plasma in presence of charged colloids. We have found favourable modification in acoustic mode spectrum. Thus, for the experimental verification of our theoretical idea, we propose to initiate a serious laboratory experimental effort.

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