Can Photons Affect the Elastic Constants in Heavily Doped Nano Wires?

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Abstract Effect of strong photo excitation on the elastic constant (EC) in extremely degenerate Nano-Wires (NW) forming Gaussian band tails has been investigated by deriving a fundamental carrier statistics formula using NWs of Heavily Doped (HD) n-InSb, n-InAs, $Hg_{1-x}Cd_xTe$ and $In_{1-x}Ga_xAs_yP_{1-y\ y}$ lattice matched to InP as examples. We observe that ΔC_{44} becomes invariant of the film thickness under the condition of relatively low values of the quantum thickness, indicating a very sharp fall at a particular value of the nano thickness manifesting the quantum size effect, in EC. The EC increases with decreasing light intensity, wavelength and alloy composition where the rate of change depends on the values of the band constants respectively. The EC can be experimentally determined by using the corresponding the experimental values of the thermo electric power.

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Since the inception of solid state physics, the importance of band structure in determining the physical properties of different materials under various physical conditions is well known. In this paper we wish to study the influence of energetic photon on the EC in extremely degenerate NW on the basis of the Hamiltonian and perturbation theory together with the heavy mathematical techniques of Quantum Mechanics in this context. With the advent of technologically important nano materials, the EC has been investigated under different conditions of reduced dimensions in the literature by the group of Ghatak et al. [1–12] and few others [13, 14]. In what follows, we study the EC under strong photon field in heavily doped nano wires taking the examples as stated in the abstract.

The electron energy (E) versus electron wave vector relation in Quantum Wires (QW) of heavily doped III–V and optoelectronics materials in the presence of energetic photons assumes the

$$(\hbar N_z/L_z)^2 + (\hbar N_y/L_y)^2 + (\hbar k_x)^2 = [M_e f_1/5] \tag{1}$$

where the notations mean as usual and f_1 is a complex function of electron energy, scattering potential and incident photon wavelength. From (1) the corresponding density of states per sub band can be expressed as

$$f_2 = \frac{g_v M_c}{5\pi\hbar} f_1' [\frac{M_c f_1}{5} - \{\hbar N_z/L_z)^2 + (\hbar N_y/L_y)^2\}]^{-1/2} \tag{2}$$

The linear electron density under the condition of extreme carrier degeneracy assumes the form

$$N_{1D} = \frac{2g_v}{\pi\hbar} \, Real\, part\, of \sum_{n_y=1}^{n_{y\max}} \sum_{n_z=1}^{n_{z\max}} [\frac{M_c f_1}{5} - \{\hbar N_z/L_z)^2 + (\hbar N_y/L_y)^2\}]^{1/2} \bigg|_{E=E_{Fll}} \tag{3}$$

where E_{Fll} is the Fermi energy under the present constrained conditions.

The EC can be expressed as

$$\Delta C_{44} = \frac{-G_0^2}{9} Real\, part\, of [\frac{\partial N_{1D}}{\partial (E_{Fll} - E_{Sub-band})}] \tag{4}$$

Suggested relationship for experimentally determining ΔC_{44} from experimental values of corresponding Thermoelectric power (G)

$$\Delta C_{44} = \left[\frac{-N_{1D}(G_0)^2 |e| G}{(3\pi^2 k_B^2 T)} \right] \tag{5}$$

Therefore, by using (5) we can investigate ΔC_{44}.

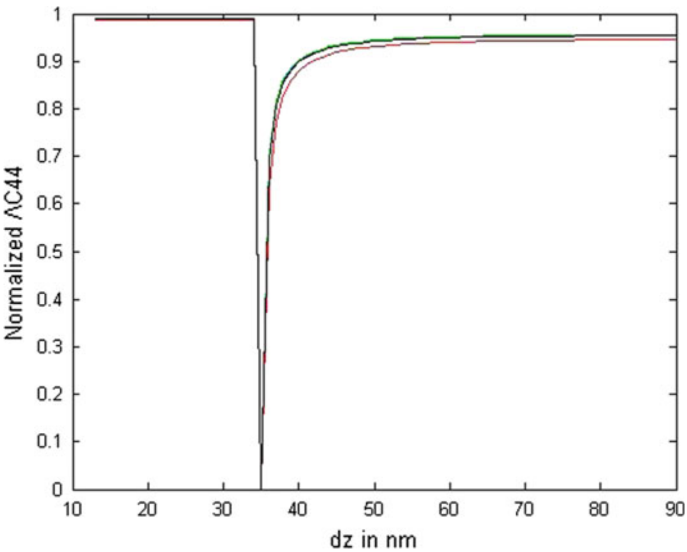

Fig. 1 The influence of quantum size effect on ΔC_{44} in the presence of intense photo excitation for all the highly degenerate Nano Wires as stated in the abstract

It appears from Fig. 1 that in HD Nano Wires the ΔC_{44} becomes invariant of the film thickness for the small value of film thickness, exhibits sharp fall at a particular value of thickness manifesting the quantum size effects in ΔC_{44} in Nano Wires and again increases rapidly with increasing thickness. Figure 2 shows the spiky oscillatory variation of ΔC_{44} with the electron statistics per unit length. The oscillatory variation occurs when the Fermi energy for the present system touches the edge of the sub-band energy. Figure 3 shows that the light intensity attenuates the ΔC_{44} which decreases as intensity increases although the amount of attenuation is different for different materials. Figure 4 shows that the influence of wave length on the ΔC_{44} decreases as with the increment of wave length of the external photo excitation for the whole range of wave lengths. Finally, from Fig. 5 we observed that with the decrement of alloy composition, the ΔC_{44} enhances.

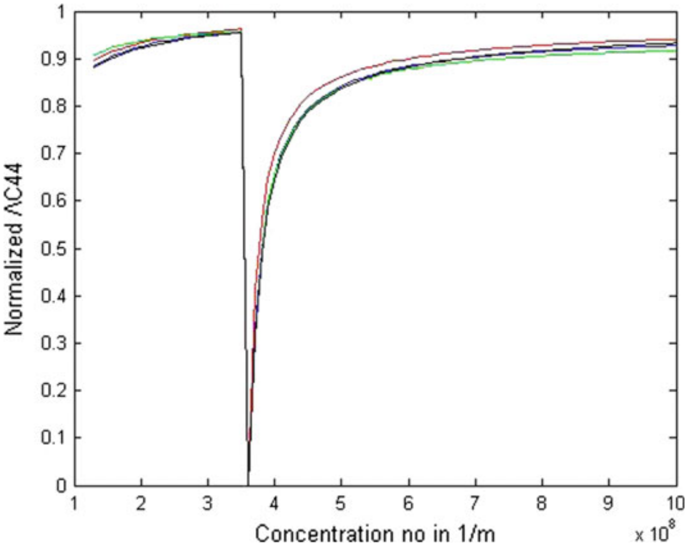

Fig. 2 The dependence of ΔC_{44} on carrier degeneracy in the presence of intense photo excitation for all the highly degenerate Nano Wires as stated in the abstract

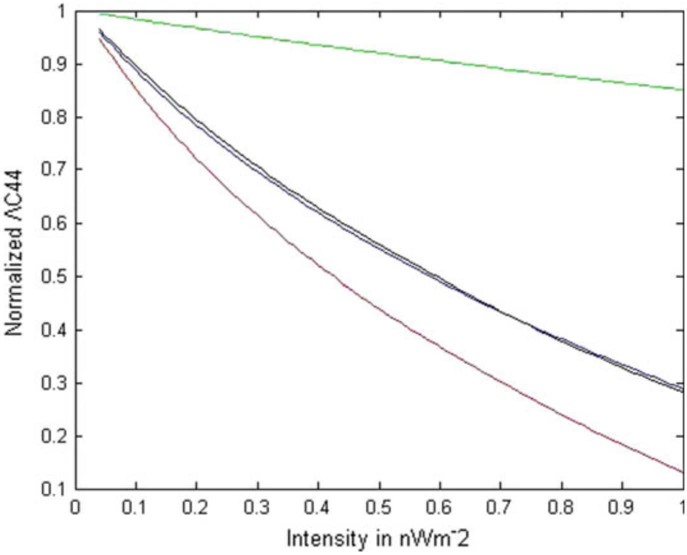

Fig. 3 The dependence of ΔC_{44} on intensity of photo excitation for all the highly degenerate Nano Wires as stated in the abstract

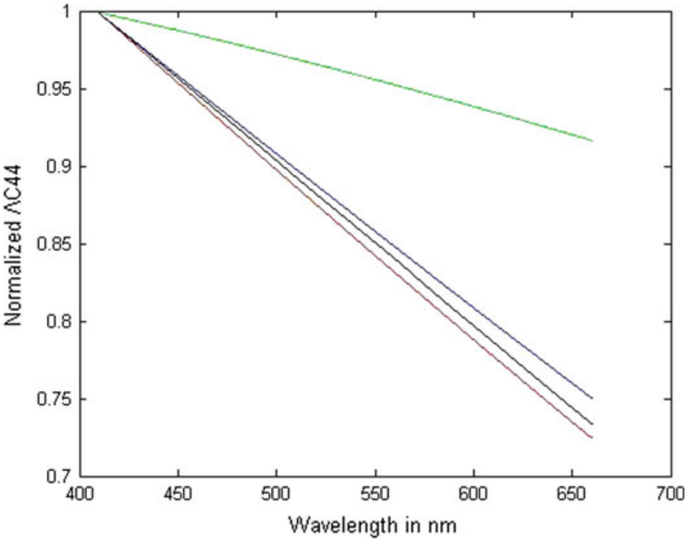

Fig. 4 The dependence of ΔC_{44} on wavelength of photo excitation for all the highly degenerate Nano Wires as stated in the abstract

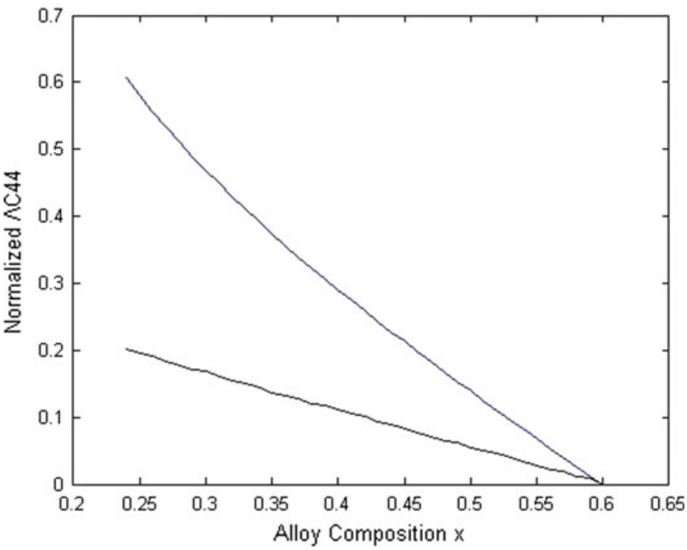

Fig. 5 The dependence of ΔC_{44} on wavelength of photo excitation for all the highly degenerate Nano Wires as stated in the abstract

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