Transformation of the Fermi Surface and Anisotropy Phenomena in 2D Hole Gas at GaAs/$Al_xGa_{1-x}As$ Heterointerface under Uniaxial Stress

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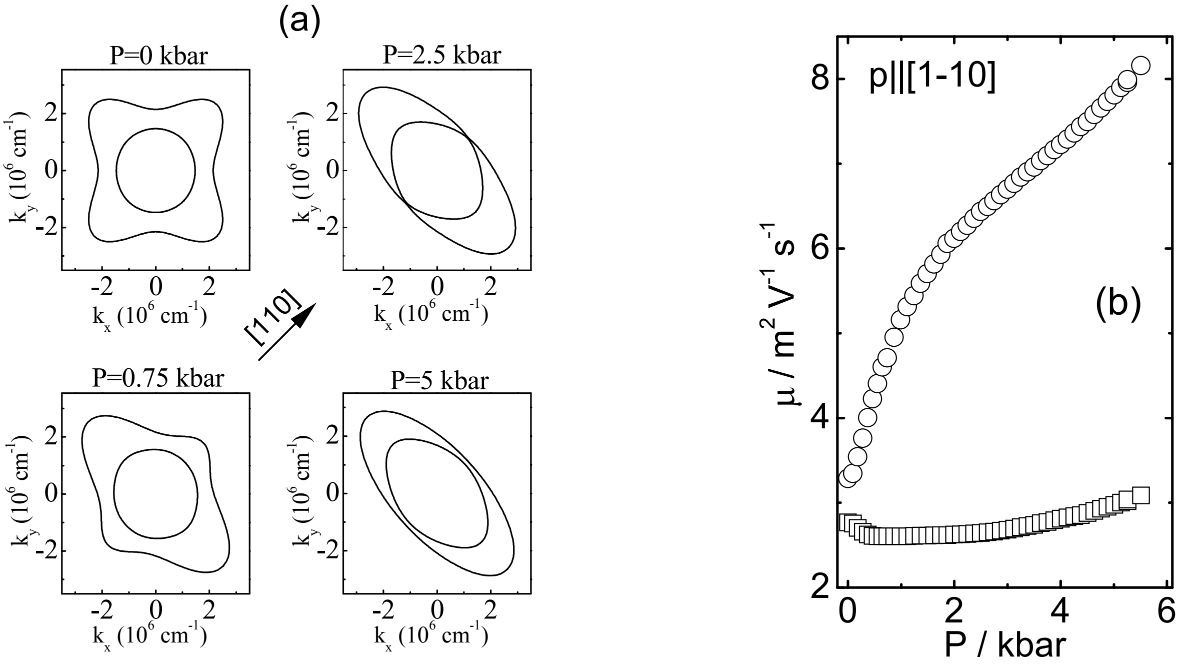
Strong anisotropy of the energy spectrum, transport, dynamic and optical properties of 2D hole gas at p-(001)GaAs/$Al_xGa_{1-x}As$ heterointerface induced by uniaxial stress has been detected both theoretically and experimentally. By numerical calculations the Fermi surface (FS) was found to become strongly anisotropic when in-plane uniaxial stress is applied. At relatively moderate uniaxial stress P about 2 kbar the Fermi surface in the both spin splitted subbands of the ground 2D hole state transforms into ellipsoids strongly elongated in the direction perpendicular to the applied stress (Fig. 1a). Under uniaxial compression along [110] direction (as well as along [1-10] direction) the FS dimension in the direction of compression decreases in the both subbands up to 2.5 kbar, when the both FS's touch each other in two points. Further increase of compression makes them again separated in k space. This transformation of the energy spectrum reveals in anisotropy of mobilities μ, experimentally obtained from resistivity, Hall effect and Shubnikov – de Haas oscillations measurements on p-(001)GaAs/$Al_xGa_{1-x}As$ samples uniaxially compressed in [110] and [1-10] directions. For example, at compressive stress P = 5 kbar along [1-10] direction mobility anisotropy $\mu_{[1-10]}/\mu_{[110]}$ shows more than 2.5 times increase in respect to the initial magnitude



(Fig. 1b).

Fig1: (a) Fermi surface of the two ground state heavy hole subbands in a p-(001)GaAs/$Al_{0.5}Ga_{0.5}As$ heterojunction (N_S=7.6·$10^{11}$$cm^{-2}$) at different uniaxial compression applied along [110] direction. (b) Dependence of the mobility in two perpendicular directions on external [1-10] uniaxial compression. Circles and squares are mobilities for the directions of transport current parallel and perpendicular to the compression respectively.

Anisotropic evolution of the FS represented on Fig. 1 (a) leads also to a magnetic breakdown (MB) between two spin splitted subbands. The probability of MB is very high in the region of pressure about 2,5 kBar when the two FS'es are very close to each other in [110] direction. MB reveals in a change of 2D hole dynamics. Fast Fourier Transform analysis shows in Shubnikov-de Haas oscillation spectrum the presence of combination frequencies and high harmonics of the two fundamental frequencies $F_{1,2} = \frac{cS_{1,2}}{e\hbar}$, where S_1 (S_2) is the area of the both quasiclassical 2D hole orbits.

Theoretical calculations of intersubband light absorption spectra in p-type $GaAs/Al_xGa_{1-x}As$ heterostructures show that uniaxial strain induced anisotropy of the energy spectrum and wave functions of 2D holes leads to the difference in absorption for different far-infrared light polarization. At nonzero pressure the absorption of light with polarization perpendicular to the direction of compression is smaller than the absorption of light with polarization parallel to the direction of compression for the most values of photon energy.

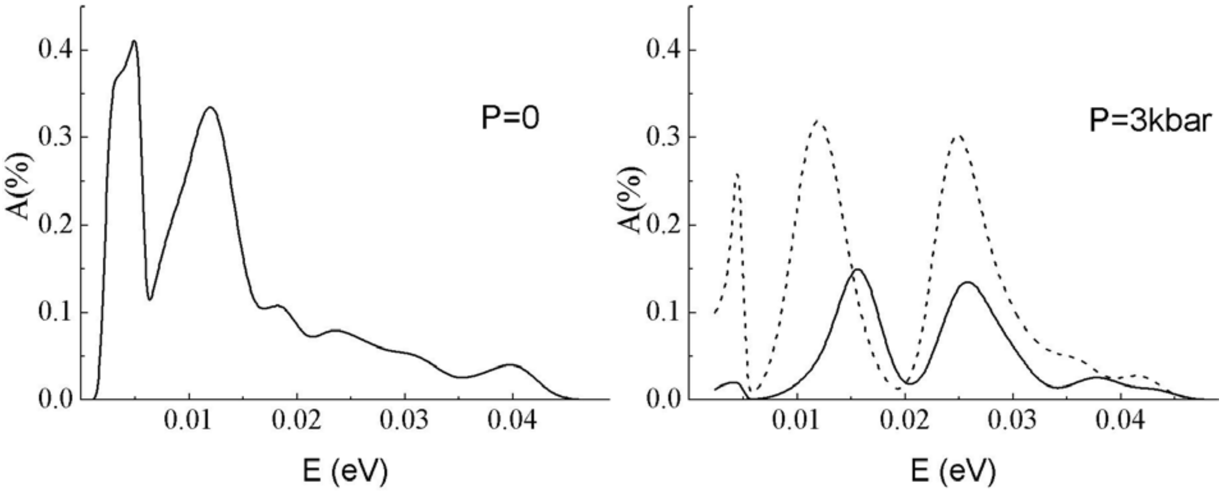


Fig2: Calculated light absorption spectra in a p-type (001)$GaAs/Al_{0.5}Ga_{0.5}As$ single heterojunction under uniaxial compression applied along [110] direction at P = 0 and P = 3 kbar. Solid and dashed lines correspond to the absorption of light with polarization perpendicular and parallel to the direction of applied compression respectively.

All the phenomena described above are qualitatively the same under uniaxial compression along [110], [1-10] and [100] directions and determined by the anisotropy change of the energy spectrum. In heterostructures under consideration anisotropy of the energy spectrum and connected phenomena under uniaxial stress are essential only for 2D holes and negligibly small in 2D electron system.

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