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Dynamical dielectric function of 2DEG in HgTe-based systems in random phase approximation formalism

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Studies of high frequency transport properties of HgTe quantum layers attract increasing interest in the last decade, as these materials are perspective for various detector applications, especially in THz region. These systems are characterized by strong nonparabolicity of localized electron energy spectra, like a graphene. Nevertheless, in contrast to graphene, their energy spectrum is not purely linear. Theory of screening in graphene in two-dimensional electron gas (2DEG) is well-established [1], allowing one to provide accurate numerical modeling of electron transport properties of graphene layers. However, dielectric function [1] is obtained for purely linear energy dispersion. In semi-metallic HgTe quantum wells, main scattering mechanisms are charged centers (e.q. charged impurities and holes) scattering, and longitudinal optical phonons scattering. First of this mechanisms relays on static screening in 2DEG, while second depends on the dynamic screening in it. Thus the problem of obtaining HgTe-specific dielectric function is open.

The Random-Phase Approximation (RPA) dielectric function $\varepsilon(\omega,q)$ for HgTe quantum well, which accounts for both nonparabolicity and nonlinearity of electron energy spectrum, was numerically calculated in this work. Simulation was based on two-dimensional Lindhard equation, it used numerically obtained dispersion equation for the considered quantum well. All modeling were provided for $Hg_{0.15}Cd_{0.85}Te$ / HgTe / $Hg_{0.15}Cd_{0.85}Te$ quantum well of 20 nm width for different temperatures, for arbitrary values of wave-vector and frequency.

It was found that for the case of static screening ($\omega = \mathbf{0}$), our dielectric function is similar to graphene one in the long-wavelength limit (in the case the electron scattering wave vector $\boldsymbol{q} \to \mathbf{0}$). However, at large values of $\mathbf{q}$, dielectric function for HgTe quantum well is several times smaller than the graphene one, which causes smaller dumping of large-angle scattering on charged centers and, as a result, smaller mobility.

In the case of dynamic screening, for the fixed frequency $\omega_{\mathbf{0}}$, there exists maxima on the dependence of $\varepsilon(\omega_0,q)$ on $\mathbf{q}$, both for graphene and HgTe dielectric functions. For graphene, this maximum growths to infinity. However, for HgTe dielectric function, this maxima is shifted to sufficiently smaller values of $\mathbf{q}$, while its height is finite, which affects scattering on longitudinal optical phonons in the well.

Considering the dependency of dielectric function on the frequency at fixed values of the wave-vector q, we can outline several important differences between graphene and HgTe dielectric functions. For graphene, there exists sharp maximum on the graph; also there exists minimum which is smoothed with increase of q. For HgTe screening function, such maximum on the graph is strongly damped, forming the plateau. The maximum value of this plateau is smaller than the peak value at the graphene graph; however, width of the plateau is sufficiently broader than the width of peak at graphene graph.

Obtained RPA dielectric function was applied to calculations of electron mobility in the considered QW, using the methodology [2]. Resulting mobilities were compared to those ones, obtained with the usage of graphene dielectric function.

1. *Hwang E. H., Das Sarma S.* Dielectric function, screening, and plasmons in two-dimensional graphene // Phys. Rev. B.-2007.-**75**.-P. 205418.
2. *Melezhik E. O., Gumenjuk-Sichevska J. V., Sizov F. F.* Modeling of electron energy spectra and mobilities in semi-metallic $Hg_{1-x}Cd_xTe$ quantum wells // Journal of Applied Physics.-2015.-**118**.-P. 194305.