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ANALYSIS OF DIFFICULT EFFECTS BELONG TO QUANTUM PHYSICS ON THE BASIS OF INFORMATION TECHNOLOGIES

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ABSTRACT

In this work, the BP method was used and modeled on ICT in order to calculate the energy levels of electron in the KH for calculating polyaron effects, and the image of the compressive potential of the KH was considered parabolic. Because of the difficulty of solving the differential equation its solution is sometimes used by linear combinations of specific solutions which are obtained in strong and weak interaction regimes. When this method is applied to the volumetric polar semiconductors, the interpolation estimation of the energy of polaron state is obtained. In this case the correction due to the polaron effect occurs in the regime of a strong interaction impact in this condition the electron wave function is localized in the polarization field.

Keywords: Quantum, spectrum, electron, wave, atom, effect, orbit, cloud model, quantum physics, hydrogen atom, Schrödinger equation.

Energetic states density of electron gas which has quasi-two-dimensional-electron, is analytically and numerically analyzed with the account of non-parabolic dispersion. When the temperature rises, the energetic states density which the energy fluctuates, becomes smooth due to the surfaces is widened, and are nearly washed away at high temperatures.

INTRODUCTION

The study of electron or cavity properties in low-dimensional systems, such as *quantum dumps, quantum ropes and quantum dots* in semiconductors base, is one of the most actual problems of today [1].

It is known that the macroscopic characteristics of such structures are dependent on the energetic states density of the gas, and therefore, have an oscillatory nature, depending on the size of the structure. The cause of that is the spatial quantisation of the energy of the electricity carriers. As the size of the structure increases, the oscillation of the characteristics decreases and becomes like a quantitative crystal. Typically, these effects which are associated with quantisation of energy spectra are observed at low temperatures in semiconductor materials with high conductivity.

It is also known that as a result of disturbances in the structure, interaction among electro phonons or electrons, the spectrum of quasi particles can be complicated and the energy states density of the gas has complex nature and generally, may be depend on temperature $N(E,T)$ [2]. Only, in the ideal gas model and at low temperatures, the connection of the X3 to the energy has the simplest form: $N(E,0) \sim \sqrt{E}$

In the article [3] is shown that the connection of states density to the temperature $N(E,T)$ can be found by placing the GN functions in the row. The GN function is found by the differentiation of probability function of thermal excretion of electron $\rho(E,T)$ in the energetic state from one layer to another.

In the article [4], the connection of density of states to the temperature in the quantum magnetic fields is understood by placing $N(E,T)$ in a row according to the GN functions.

In the following, density of energetic states of electron gas which has quasi-two-dimensional electron is analytically and numerically analyzed taking into account the non-parabolic dispersion. It is shown that the connection of the density of fluctuating states to energy gradually decreases with increasing temperature. It is observed that the non-parabolic dispersion is shown at the wide temperature range.

Density of states

According to the theory of solid zones, the Schrodinger's equation is solved in the method of wave function of electron (cavity) and effective mass of energy spectrum of quasi-two-dimentional pit in the base of semiconductor heterostructure [1]. The following relationship is relevant for the wave vector

$$k^2 = k_\perp^2 + k_n^2, \quad k_\perp^2 = k_x^2 + k_y^2, \quad k_n = \frac{\pi n}{L}, \quad E_n = \frac{\hbar^2 \pi^2 n^2}{2m(0)L^2} = E_1 n^2 \quad (1)$$

Here, $m(0)$ - the effective mass at the bottom of the electron conductivity zone, L - the width of the cavity, $k_\perp$ - the wave vector of the electron in the plane of x, y, k_n - the z component of the wave vector. We describe the non-parabolic energy spectrum for electrons as follows [5]

$$\chi(E) = E(1+\alpha E + \beta E^2) = \frac{\hbar^2 k^2}{2m(0)} = \frac{\hbar^2\left(k_\perp^2 + k_n^2\right)}{2m(0)} \quad (2)$$

Here, α, β - the parameters illustrates the degree of non-parabolic degree of the dispersion. We use the full particle number equation in order to find the energetic states density of the electron gas (X3). It can be written as follows

$$N = s\frac{L_x L_y}{(2\pi)^2}\sum_{n=1}^{\infty}\int dk_x dk_y f(E) = s\frac{L_x L_y}{2\pi}\sum_{n=1}^{\infty}\int_0^{\infty} kdk f(E) = s\frac{L_x L_y}{4\pi}\sum_{n=1}^{\infty}\int_0^{\infty} dk_\perp^2 f(E) =$$

$$= s\frac{L_x L_y}{4\pi}\frac{2m(0)}{\hbar^2}\sum_{n=1}^{\infty}\int_0^{\infty} d\left(\frac{\hbar^2 k_\perp^2}{2m(0)}\right) f(E) = \frac{L_x L_y}{\pi}\frac{m(0)}{\hbar^2}\sum_{n=1}^{\infty}\int_0^{\infty}\frac{\partial\chi(E)}{\partial E} f(E)\Theta[\chi(E) - E_n]\, dE \quad (3)$$

Or

$$= \frac{L_x L_y}{\pi}\frac{m(0)}{\hbar^2}\sum_{n=1}^{\infty}\int_{\bar{E}_n}^{\infty}\frac{\partial\chi(E)}{\partial E} f(E)dE, \qquad \bar{E}_n \in \chi(E) \geq E_n. \quad (4)$$

Here $f(E)$ - the division function of Fermi-Dirak

$$f(E)=\frac{1}{e^{\frac{E-\mu}{T}}+1} \quad (5)$$

Let's express the concentration of electrons with X3 . The following can be written from (3):

$$n_{3D}=\frac{N}{L_x L_y L}=\frac{m(0)}{\pi\hbar^2 L}\sum_{n=1}^{\infty}\int_0^{\infty}\frac{\partial\chi(E)}{\partial E} f(E)\Theta[\chi(E)-E_n]\,dE=\int_0^{\infty}N(E)f(E)dE \quad (6)$$

We can get the formula for X3 here

$$N(E)=N_0\sum_{n=1}^{\infty}\frac{\partial\chi(E)}{\partial E}\Theta[\chi(E)-E_n], \qquad N_0=\frac{m(0)}{\pi\hbar^2 L} \quad (7)$$

$$\frac{\partial\chi(E)}{\partial E}=1+2\alpha E+3\beta E^2, \quad (8)$$

$$N(E)=N_0\sum_{n=1}^{\infty}(1+2\alpha E+3\beta E^2)\Theta[E(1+\alpha E+\beta E^2)-E_n] \quad (9)$$

In particular, if it is $\alpha=\beta=0$, the formula which is known to us, is created for the parabolic dispersion. [1]

$$N(E)=N_0\sum_{n=1}^{\infty}\Theta(E-E_n) \ . \quad (10)$$

We draw the graph of function $N(E)/N_0$ using the formula (9):
In this case we use values $E_1=0.01\,\text{eV}$ $\beta=0,\quad \alpha=-0.1,\ 0,\ 0.1\,\text{eV}^{-1}$.

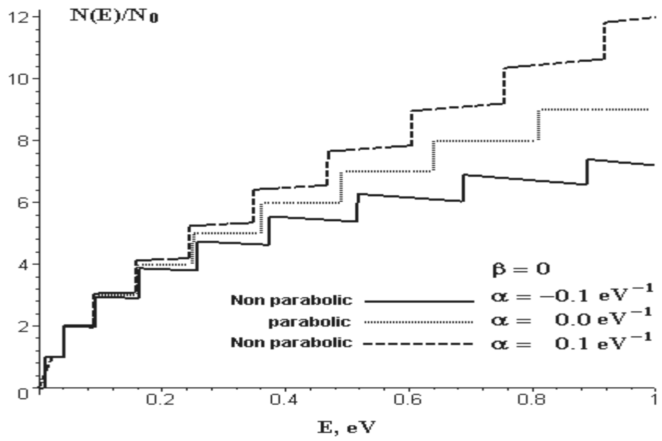

Figure 1. The connection of X3 to the energy: $E_1=0.01$ eV, $\beta=0,\quad \alpha=-0.1,\ 0,\ 0.1\,\text{eV}^{-1}$

As can be seen from Figure 1, the energy of quasi-two-dimensional electron gas is strongly dependent on the non-parabolic degree of the X3 spectrum. At the negative values of the non-parabolic parameter α , the two-dimensional electron gas is reduced than the X3 parabolic state. The steps in the chance of X3 are shifting to the high-energy sector. In this case, as the energy increases, the shift monotonously decreases. As the horizontal areas of the steps move towards the smaller X3, the greater the degree of non-parabolic degree - the greater the deviation.

At positive values of the non-parabolic parameter of α , the increase of the X3 is grown, increasing the energy more strongly shift upward.

Thermal expansion of surfaces. Dependence of X3 to the temperature

We express $N(E,T)$ with Fermi-Dirak function the derivation by energy $\partial f/\partial E$ in order to find the connection of X3 with temperature(9).

$$N(E,T)=\int_0^\infty N(E',0)\frac{\partial f(E',E,T)}{\partial E}dE' \quad (11)$$

Here,

$$f=\frac{1}{\exp((E'-E)/T)+1}$$

In this formula, the function $f(E)$ represents the filling probability of E discrete surface. In the case of thermodynamic equilibrium, the function $f(E)$ corresponds to the Fermi-Dirac function. Under unstable conditions, the view of the function $f(E)$ is determined by the Shockley-Reed Hall statistic, and the function GN is appropriate instead of expression $\partial f/\partial E$ [3,4]

$$N(E,T)=\int_0^\infty N(E',0)GN(E',E,T)dE', \qquad GN(E',E,T)=\frac{1}{T}\exp\left[\frac{E'-E}{T}-\exp\left(\frac{E'-E}{T}\right)\right] (12)$$

The filling of energy surfaces is represented by the Fermi-Dirac function in conditions which are close to thermodynamic equation. The derivation of this function by energy is symmetric function around $\partial f/\partial E$ - μ .

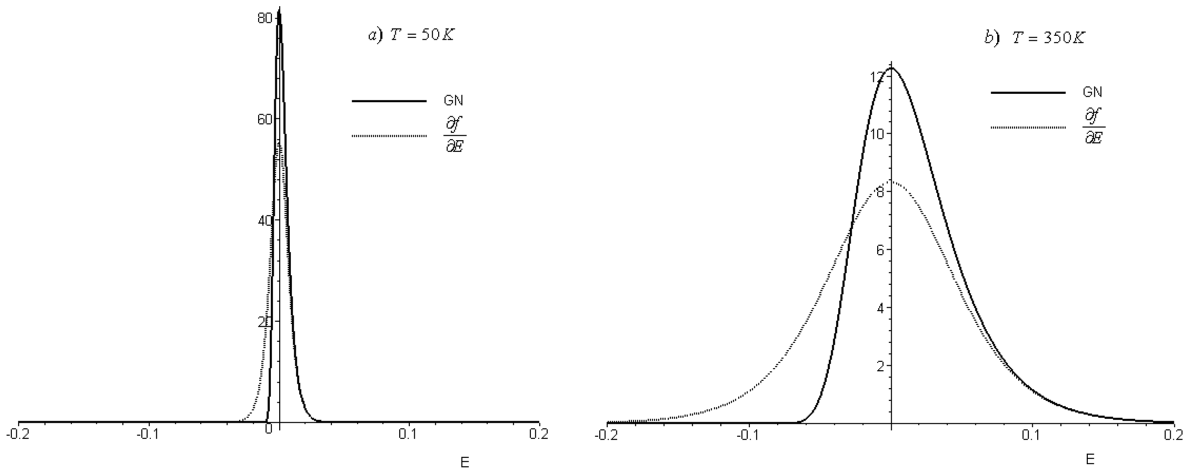

Figure 2. The graphs of GN and $\partial f/\partial E$ functions: temperature value: a) $T=50K$, and b) $T=350K$

We find the following by placing the expression (9) into (11)

$$N(E,T)=N_0\sum_{n=1}^{\infty}\int_0^{\infty}(1+2\alpha E'+3\beta E'^2)\Theta[E'(1+\alpha E'+\beta E'^2)-E_n]\frac{\partial f(E',E,T)}{\partial E}dE' \quad (13)$$

Let's analyze a simplified case $\beta=0$ in order to analyze the expression (13). In this case, the Heviside function $\Theta[E'(1+\alpha E')-E_n]$ limits the lower bound of integral from the point $\overline{E_n}$, the expression of this point is

$$\overline{E_n}=\frac{\sqrt{1+4\alpha E_n}-1}{2\alpha}\ .$$

We write the formula (13) as follows

$$N(E,T)=N_0\sum_{n=1}^{\infty}\int_{\overline{E_n}}^{\infty}(1+2\alpha E')\frac{\partial f(E',E,T)}{\partial E}dE'=-N_0\sum_{n=1}^{\infty}\int_{\overline{E_n}}^{\infty}(1+2\alpha E')\frac{\partial f(E',E,T)}{\partial E'}dE' \quad (14)$$

If we separate and integrate (14), we will give this result.

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