Features of formation and studying quantum-dimensional structures on surface electrons over helium

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Introduction. The modern nano technology gives both the new glance on row physical effects the quantum/size structures (QSSs) and the possibility using structures in nano electronic. The electron layer over or under the smooth surface forms two dimensional (2D) structure. The substrate properties modulation either one or two direction can performed by periodical inhomogeneities and that lets designed the quantum wire (QW) or the quantum dot (QD) accordingly [1]. The quantum effects are observed at next conditions $E_{n+1} - E_n > k{\cdot}T$ and $E_{n+1} - E_n > h/\tau = h{\cdot}e/(m{\cdot}\mu)$ (T is temperature; τ is the electron relaxation time ; μ is the electron mobility. The surface electrons (SEs) over helium related to QSSs and is good artificial model.

The quantum-mehanical description

The QSS quantum parameters gives Schrödinger equation, $\hat{H}\psi(r) = E\psi(r)$, in potential well, U (here $\hat{H} = -(\hbar^2/2m)\Delta + U$ is Hamiltonian, E is the energy and $\psi(r)$ is wave function). For 2D system with rectangular potential the quantum energy spectrum is $(\pi^2 \hbar^2 n^2)/(2mL^2)$ (n = 1; 2; ….). The parabolic potential $U(r) = m\omega^2 r^2/2$ lead to a harmonic quantum spectrum $(l+1/2)\hbar\omega$ (l=1; 2; 3; …..).

SE over helium localized in shallow potential well $U(z) = e^2/z$ and distanced from substrate because weak polarization of He.The normal substrate motion is quantized by a "soft" hydrogen-like spectrum. The quantum parameters 2DSE can be estimated from relations: $p\,z = \hbar$ and $2p^2/2m = (Q_d\, e^2)/z$, then $E_l = Q_d^{\,2}{\cdot}R / l^2$, $z = (4\pi\varepsilon_o/Q_d)(\hbar^2/me^2)$ (here R is Ridberg's constant).The helium polarization parameter is Q_d = 0.007, so E_1 = 8 K and z = 7,6 nm. The motion SE along limited by scattering on both the atoms in gas and the ripplons.

For modulation of substrate properties under He can be use the cylinder or the sphere inhomogeneities:**1D** or **0D** electron system at the parabolic potential.

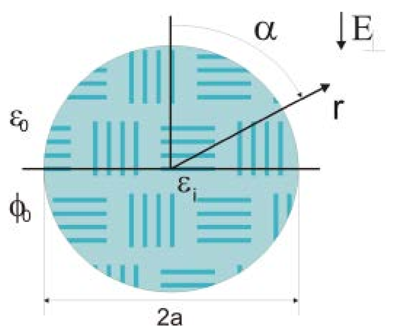
1D. The wave function here is $$\psi(y) = \pi^{-1/4} y_0^{-1/2} \exp\left(-\frac{y^2}{2y_0^2}\right)$$ $$y_0^2 = h/(2\pi\, m\, \omega_0)$$ is the electron localization size

and energy spectrum is $E_n = (n+1/2)\hbar\omega + h^2k^2/2m$

0D. The wave function is same at isotropy of the parabolic potential well. The harmonic energy spectrum is $E_n = (n+1/2)\hbar\omega$.

The electrostatic problem in uniform electric field: cylinder or sphere ($\Delta\varphi = 0$ where Δ is laplassian, φ is potential).

Cylinder (section) – 1D model.



$$\frac{r}{M}\frac{d}{dr}\left(r\cdot\frac{dM}{dr}\right) + \frac{1}{N}\frac{d^2N}{d\alpha^2} = 0$$

$$\varepsilon_i\left(\frac{\partial\varphi_i}{\partial r}\right)_{r=a} = \varepsilon_e\left(\frac{\partial\varphi_e}{\partial r}\right)_{r=a}$$

$$\varphi_i = -E_\perp\frac{2\varepsilon_i}{\varepsilon_i+\varepsilon_e}\cdot r\cdot\cos\alpha + \varphi_0 \qquad E_i = -\frac{d\varphi_i}{dx} = E_\perp\frac{2\varepsilon_i}{\varepsilon_i+\varepsilon_e}$$

Sphere – 0D model.

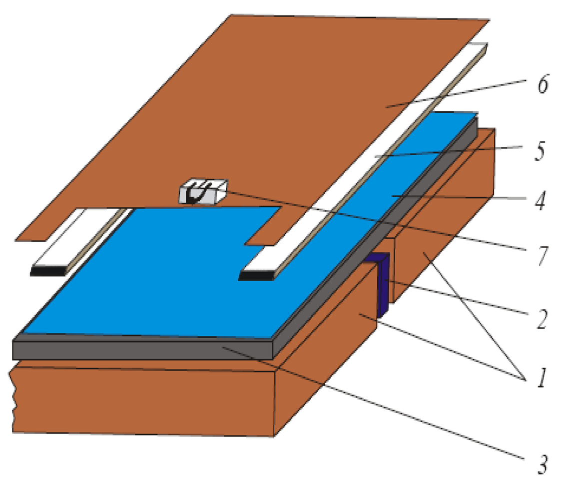
$$\frac{1}{M}\frac{d}{dr}\left(r^2\cdot\frac{dM}{dr}\right) + \frac{1}{N\sin\alpha}\frac{d}{d\alpha}\left(\sin\alpha\frac{dN}{d\alpha}\right) = 0$$

$$\varphi_i = -E_\perp\frac{3\varepsilon_i}{\varepsilon_i+\varepsilon_e}\cdot r\cdot\cos\alpha + \varphi_0 \qquad E_i = E_\perp\frac{3\varepsilon_i}{\varepsilon_i+\varepsilon_e}$$

Notice. 1. At large dielectric constant cylinder the electric field on border is $E_{1d} = 2E_\perp$ and for sphere this value is $E_{0d} = 3E_\perp$.
2. Because the function [cos] is even the electric potential is the parabolic function near top of border.

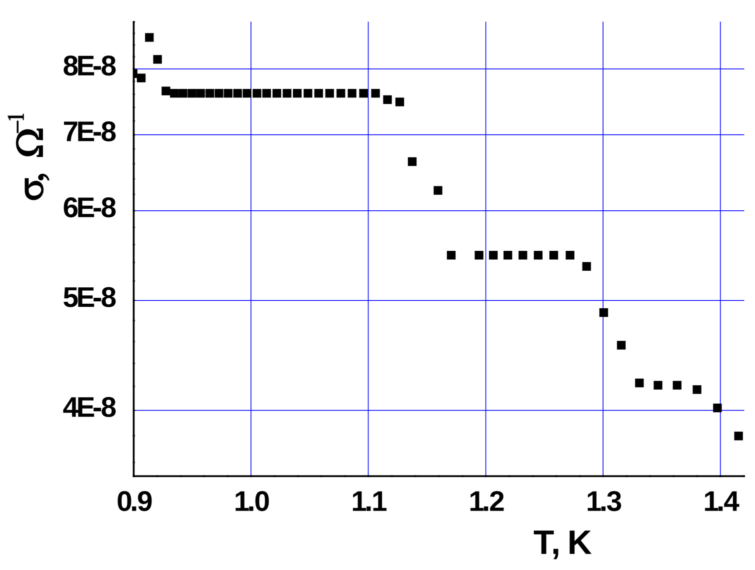
The study by transport method QSSs-SEs and examples.

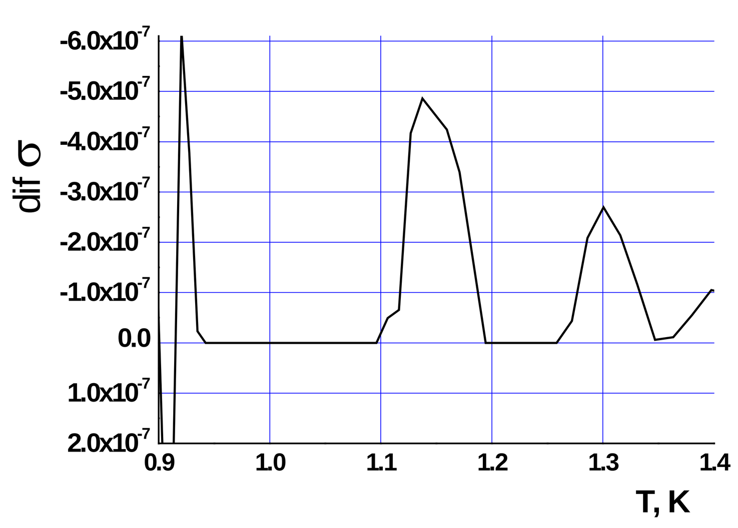
The QSSs features can be study either spectroscopy or simplest and enough exactly **transport method** [3,4]. The essence of method is analyzing the conductance electron system coupled capacitivelly with the measuring electrodes.



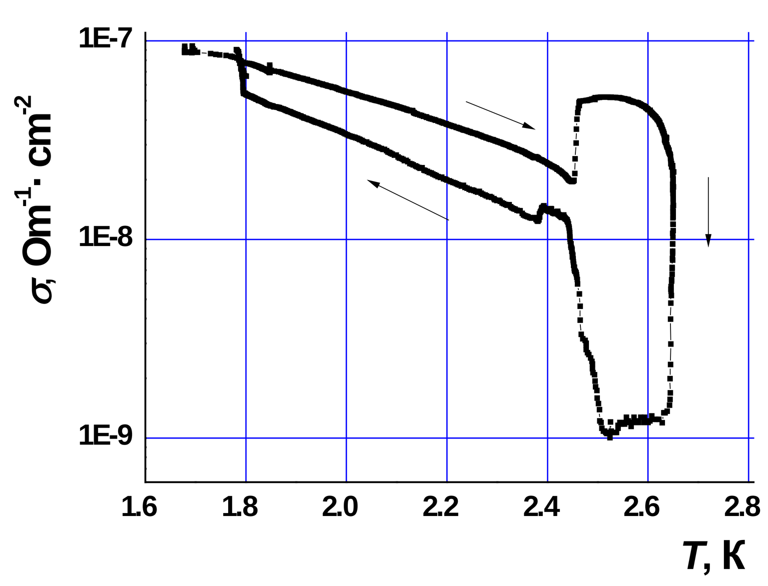
Here 1-2— the measurement electrodes, 3— dielectric substrate, 4— helium film, 5— guard electrode, 6—upper electrode, 7—heat filament.

1D. Conductance SE and its differential at substrate charged.





0D. SE conductivity with surface anions



Conclusion. For 2DSE a hydrogen-like spectrum takes a place. From Schrödinger equation at parabolic potential take a place for **1DSE and 0DSE** appropriate wave function and the harmonic energy spectrum. Modulation the substrate properties either one or two direction using dielectric fibers or spheres lead correspondently to potential like parabolic cylinder or the rotation paraboloid, parameters which is defined from electrostatic task. The potential is definited the appropriate electric field over the inhomogeneity tops. So, take a place forming either QW or QD with SEs. Investigate features these systems can performed by the simplest transport method. The results like quantized conductivity of 1D system and unusually jump in conductivity for 0D. So this transport method is convenient for the anomalies study in QSS. Different features QSS-SE considers the zone theory [5].

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