Influence of surface anions on transport of quasi-one-dimensional surface electrons over helium in region of scattering by gas

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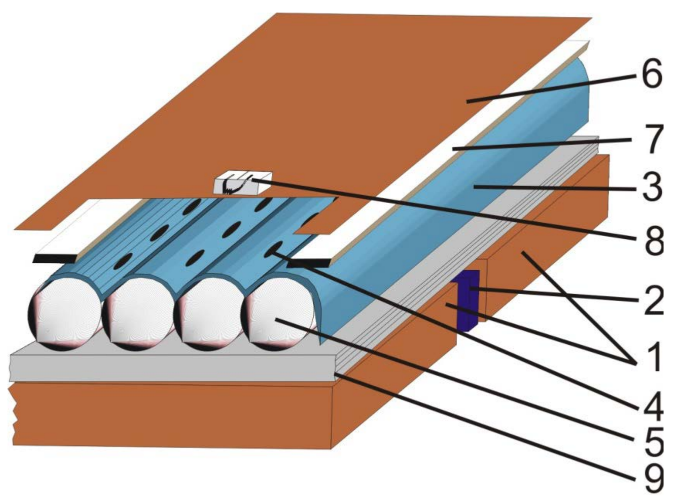
Abstract. Behavior of the surface electrons in conditions of restrict geometry attracts great attention of physicists because unusually phenomena. One-dimensional-system (1D) of particles is sensitive's to localization and the quantum effects. The simplest object for experimental study some phenomena is the surface electrons over layer liquid helium at different restricted conditions. In dense helium gas the electron forms over liquid helium state of a disk-shaped surface anion (self-localized electron, SA) with low mobility. From row experimental and theoretical data the SE-SA transition strongly depends on both the density gas phase and the structure and state of the substrate surface [1-3].

Aim is investigation by transport method the influence of SE/SA interaction on a conductivity jump in condition of topological semi-insulator .

Method

The Sommer-Tanner measurement conductance method is used which considers capacitive coupling of the measurement electrodes with the electron subsystem (sketch is bottom picture).

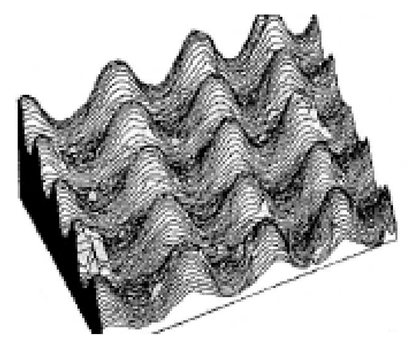
The experimental cell.

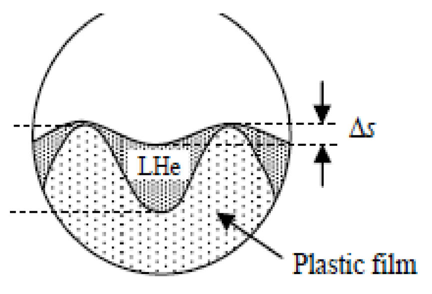


1 - measurement electrodes;
2 – screening stripe;
3 – He film;
4 – Q1D surface electrons:
5 – substrate ;
6 – upper electrode;
7 - guard ring;
8 – electron source (tungsten thread);
9 – Si-plate.

Setup and substrate

The linear electron channels formed over the tops of profiled substrate. It includes 25 segments of fibers with diameter of 220 μm (left picture) covered by plastic film of 70 μm thick and helium (on figure "the experimental sell").

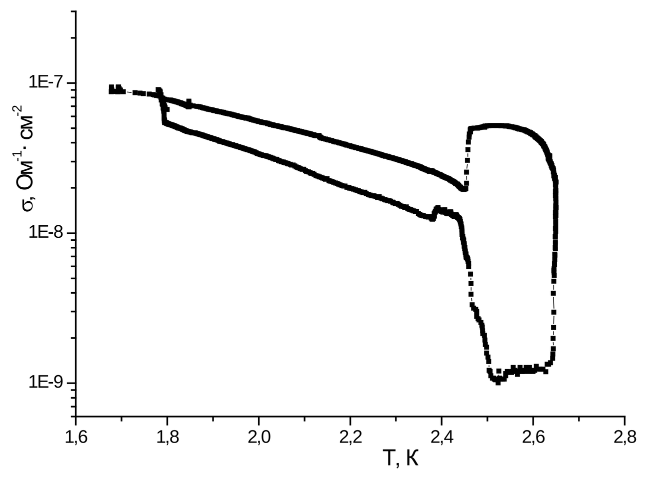


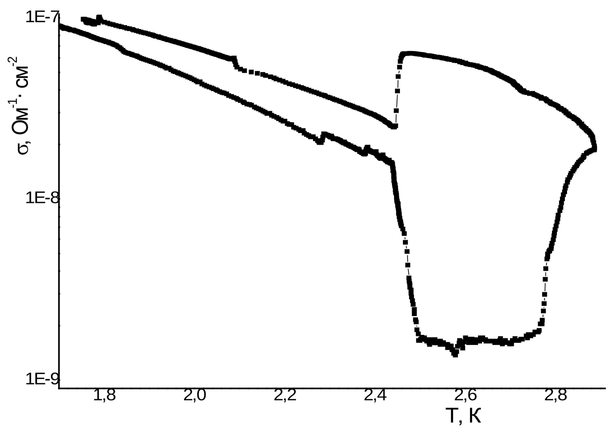


A inhomogeneities forming lattice of a wavelike micro-protrusions by step of 5x5 μm were on film (upper peactures). Composite substrate placed on Si-plate of 0.2 mm thick at a height of 4 mm above massive helium.

The results

The electron conductivity, σ **is** measured in the temperature range 1.7–3.0 K, where it is limited by interaction of electrons with helium atoms in a vapor.





The description of results

Under the monotonic increase in temperature, T (exponential increase in the density of vapor phase, n_g) the conductivity of SE decreases. However, in original experiments at T = 2.45 K an abrupt growth of σ is observed (~ 2.5 times). The further increase in T leads to the slowly decrease of σ and then to the substantial its decrease until a transition SE/SA. The electron density is $6{\bullet}10^8$ cm^{-2} (left graph). A fall in conductivity takes place at the higher value of T when the electron density is ~10^9 cm^{-2} (right graph). The reverse dependence σ vs T is characterized by low conductivity of the system up to T=2.45 K, and then there is the growth of σ by approximately an order of the magnitude almost to its initial value.

The main analytical relations on SE and SA transport over helium are

the mobility of SE in gas region is $\mu_g = 8e / (3\pi\hbar\sigma_s n_g \gamma)$;

the mobility of SA is $\mu_{SA} = 2\pi\hbar\alpha^{5/2} / (\eta m^{1/2} e^2 E_{eff}^3)$.

(Here e and m is charge and mass of free electron accordingly;
$\hbar$ is Plank's constant;
σ_s is the scattering section of electron on helium atom in gas at density, n_g,;
γ^{-1} is effective Bohr radius of electron over helium;
α and η is surface tension and viscosity of liquid helium accordingly;
E_{eff} is effective electric field).

Conclusion

The observed positive jump of conductivity at T ~ 2.45 K achieves value σ for SE on massive helium. Effect can be attributed to the topology of the electron configuration on the helium layer in particular by the specific interaction of the border surface electrons with the surface anions.

The motivation for similar research is in particular the search of quantum dots for a quantum computer. To solving this problem the further experimental studies are needed.

References

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