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Conductance of Winding Wires

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INTRODUCTION

In the past years a strong attention has been focused on the optical and transport properties of semiconductor heterostructures due to the possibility of tailoring material parameters such as the electron effective mass, and the band gap, by changing the structure parameters.

Recent experimental results on $In_xGa_{1-x}As$ structures [1], [2] can not be explined in the framework of standard theoretical and simulative approach for the description of carrier transport in quantum wells. While the values of the experimental mobility can be fitted using existing theories [3], [4], [5] in terms of background impurities scattering and alloy disorder scattering, a variation with respect to the transport direction seems to be explained only by the different sourface roughness (SR) experimentally observed along two orthogonal lattice directions. However, according to the theory, its effect should be negligible.

Since the effect of the SR on the conductance may depend upon resonances and localized states, the traditional approach, based on the scattering perturbation theory, is questionable.

In order to get a better insight on the effect of the SR on the conductance, we have considered winding quantum wires (QWRs) and have computed the coherent transport characteristics by means of the Landauer approach and a numerical solution of the open-boundary two dimensional Schrödinger equation.

THE METHOD

The profile of the QWRs analyzed in the present work are shown in figures 1 and 2. The distance between the boundary walls of the simulated wires is constant since the roughness profile of the considered structures is mainly due to the profile of the substrate. The numerical approach we adopted is based on the Landauer formula and the needed transmission coefficient $T(E)$ is obtained from the solution of the two-dimensional Schrödinger equation for the winding wire 20 nm wide. The open-boundary Schrödinger equation is solved making use of the Quantum Transmitting Boundary Method [6]. In particular we are able to introduce in the model a realistic potential profile taken directly from the experiments [1], [2].

In this way we are able to calculate the transmission coefficient, the coherent component of the current flowing through the device and the ohmic conductance, without any free parameter.

RESULTS

From preliminary results, it turns out that for scpecific values of the carrier energy the winding profile of the wire can generate resonances as shown in fig.s 3 and 4. This explains the behavior transmission coefficient T(E) curve of fig. 5: for smooter winding the T(E) reaches the unity at lower energy. We belive that this effect can explain the different values of the mobilty mesured along two orthogonal lattice directions characterized by two different periodicities of the substrate SR.

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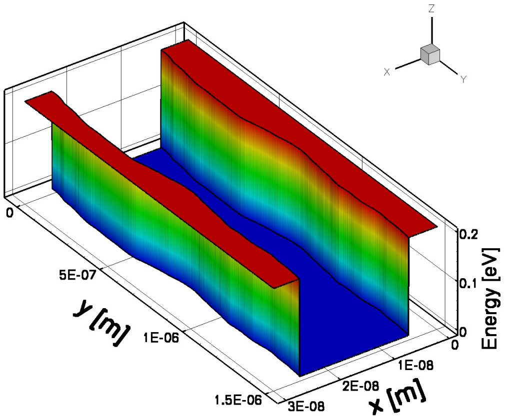

Fig. 1. This potential profile is characterized by a root mean square height of 2-3 nm and a periodicity of about 0.9±0.3 μm.

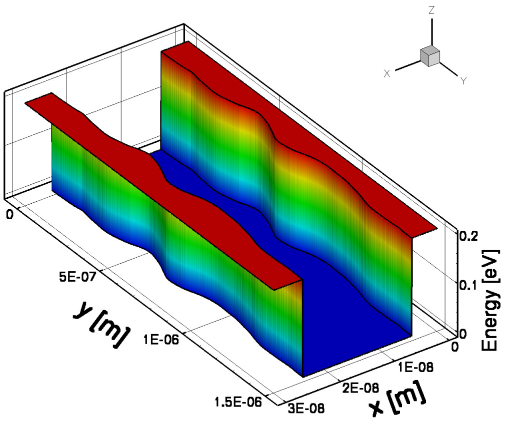

Fig. 2. This potential profile is characterized by a root mean square height of 2-3 nm and a periodicity of about 0.28±0.09 μm.

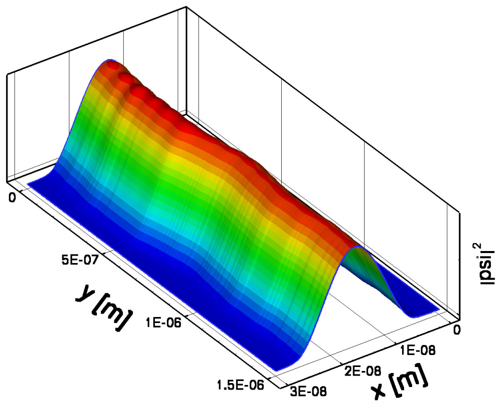

Fig. 3. Example of a scattering state of the system of fig. 1. The longitudinal energy of the incoming electrons is about 0.41 meV.

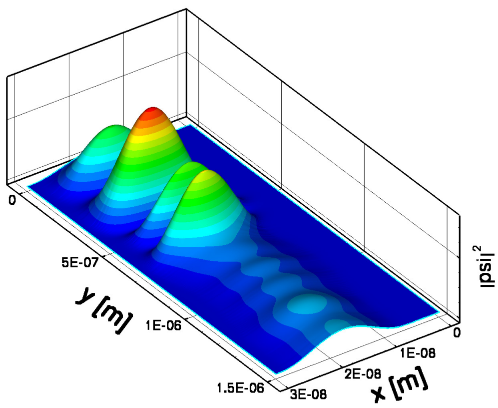

Fig. 4. Example of a scattering state of the system of fig. 2. The longitudinal energy of the incoming electrons is about 0.13 meV.

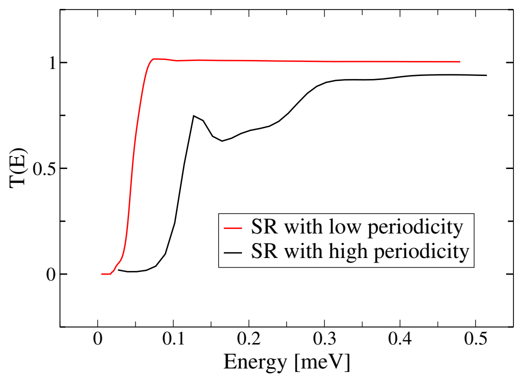

Fig. 5. Transmission coefficients as a fuction of the lognitudinal energy of the injected electron in the case of the two QWRs shown in figures 1 and 2.