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Shot Noise in Resonant Tunneling Structures Using Non-Equilibrium Green's Function Calculation

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INTRODUCTION

The non-equilibrium Green's function (NEGF) method has been applied to simulate the electronic transport in nano-hetero semiconductor devices such as the resonant tunneling structures (RTS). Any quantity characterizing the transport are calculated once a self-consistent solution of the Poisson and transport equations is achieved. Particularly, the characteristics of shot noise have been extracted using two different formulas, one derived from the scattering method[1] and another one from the master equation[2]. The result has confirmed the experimental data and shown the complicated behavior of charges in such structure.

BASICS OF METHOD

To simulate transport in nano-hetero semiconductor devices it is convenient to use the NEGF method. The heart of the formalism is a system of four Green's functions which completely describe the system including both the electronic structure and the statistical properties.

The equations to be solved for calculating the transport in devices are formally

$$\rho(\mathbf{r}) = -i\frac{e}{\pi}\int dE G^{<}(\mathbf{r},\mathbf{r},E) \qquad (1)$$

$$\nabla[\epsilon\nabla U] = (\rho+\rho_0), \qquad (2)$$

where ρ, ρ_0 are the charge densities of carriers and the bath, respectively; $G^{<}$ is one of the four functions, refered to as the lesser-Green function; and U is the electrostatic energy. Of course one needs more equations for the other Green's functions to compute $G^{<}$. To solve these equations our technique is to consider them as a single one and to use the Newton-Raphson method to reduce the computation time.

NUMERICAL RESULTS

Once the self-consistent solution is achieved, any desired quantity is computed (all concerned formulas are given Ref.[3]). We present four figures providing the transport information for a specific RTS, denoted as S[3/5/3] meaning that the thicknesses of both barriers and the well are 3 nm and 5 nm, respectively. Fig.1 is the conduction band at different values of bias. Fig.2 shows the I-V characteristics at two temperatures. The evolution of the resonant level is shown in that of the transmission coefficient plotted in Fig.3. The last figure presents the sub-poisonian (the inset) and super-poissonian noise extracted from our calculation according to the noise expressions used. The super-poissonian noise in the negative differential conductance (NDC) regime is in agrement with experimental data. The results suggest that the transport is essentially controlled by coherent tunneling under low bias and by sequential tunneling near and beyond resonance.

ACKNOWLEDGMENT

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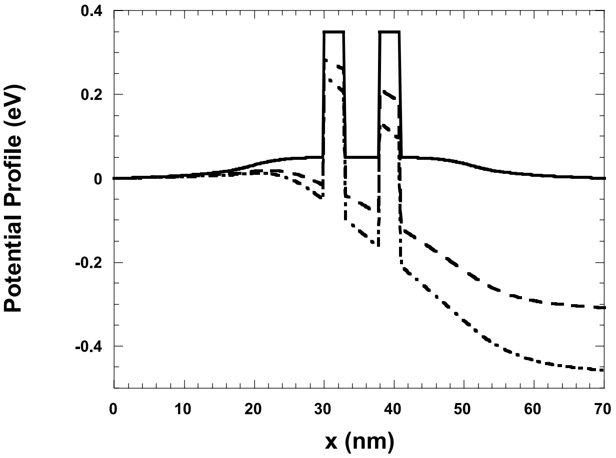

Fig. 1. Conduction band plotted at 0V(solid line), 0.31V (close to the resonance, dashed line), and 0.46V (above the resonance, dot-dashed line). Temperature: 300K.

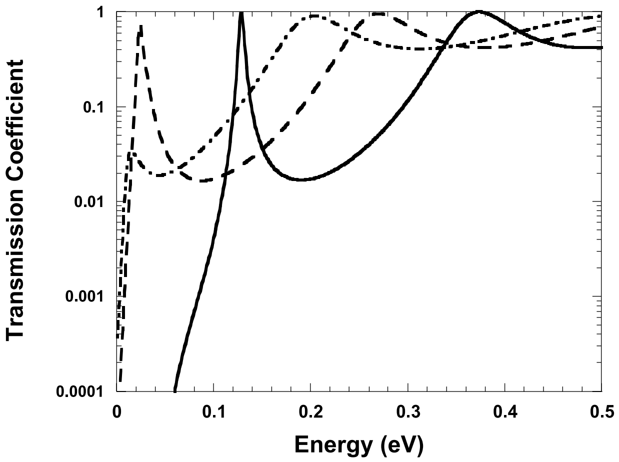

Fig. 3. The transmission evolution versus energy at different bias: 0V (solid line), 0.31V (dashed line), and 0.46V (dot-dashed line) (in the logarithmic scale).

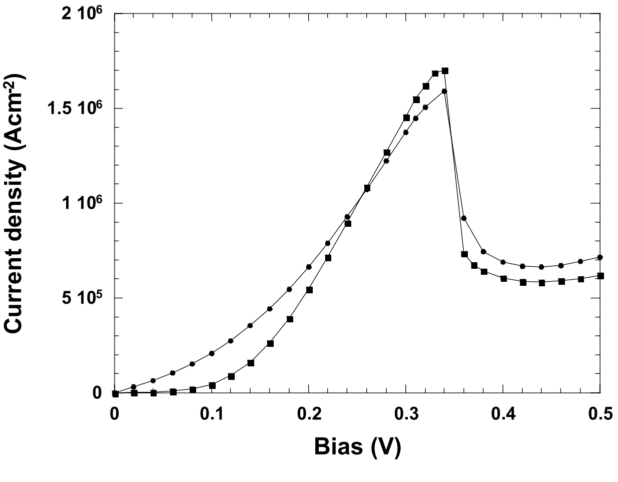

Fig. 2. The temperature effect on the current: 300K (circle) and 77K (square).

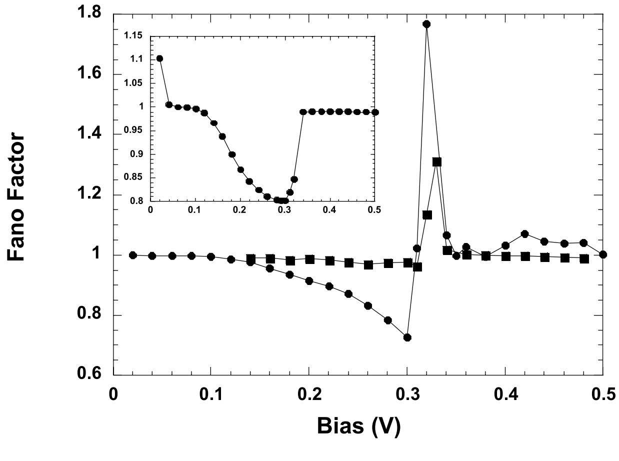

Fig. 4. The dominance of Fano factor in the NDC regime of current is reproduced at T=300K (square) and 77K (circle) using the Iannaconne's formula. The inset shows the Fano factor calculated from the Buttiker's formalism for the structure S[3/5/3] at 77K.