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The NEGF Simulation of the RTD Bistability

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INTRODUCTION

It is well known that the current-voltage (I-V) curves of the resonant tunneling diodes (RTD) exhibit a characteristic plateau-like behavior and hysteresis. Response times approach terahertz frequencies. Hence, the RTD offer advantages for terahertz electronic devices and components. A proper and complete interpretation of the I-V curves is still a controversial issue. Some groups [1-2] utilized self-consistent solutions of the time-dependent Wigner function equation (WFE) for a GaAs-AlGaAs RTD. These simulations revealed intrinsic high-frequency oscillations in the tunneling current. Plateau-like behavior in the I-V curves were obtained from the time-average of the current oscillations. The results showed that the formation of the emitter quantum well (EQW) and the coupling of its quasi-bound state to the state in the main quantum well (MQW) is the physical mechanism responsible for both the hysteresis and the plateau-like behavior. The relaxation time affects the width of the hysteresis and if it is smaller than 200 fs, the hysteresis will disappear. WFE approach is very complex and time consuming. Other approach is based on the non-equilibrium Green's functions (NEGF). Other group [3] performed numerical calculations by the program NEMO based on the NEGF approach. They found that scattering in the emitter reduces hysteresis by broadening the quasi-bound state formed in the emitter as well. Nevertheless, the plateau region did not appear in their results.

EXPERIMENT AND SIMULATION

We simulated the same structure as in [1] and our AlAs-GaAs double barrier RTD grown by molecular beam epitaxy with two identical 3.4 nm AlAs barriers, 5.9nm GaAs well and 10 nm undoped GaAs spacer layers. We used the program Wingreen [4] based on the NEGF approach with the different values of scattering parameter "s". Our results in Fig.1 and Fig.4 show the dependence of the current peak position and the with of the hysteresis on the scattering rate. No plateau region appeared on the I-V curve in the contrast to the experimental data. The bistable region is produced by the different charge distribution in the both RTDs (see Fig.2 and Fig.5). The evolution of the electron charge distribution during the increasing bias is on the Fig.3. Experimental results to be further analyzed are shown in Fig.6.

CONCLUSION

We analyzed the reason why plateau region does not appear in the NEGF results. Full time-dependent Wigner-Poisson approach is able to retain necessary information about forming high frequency current oscillations and coupling of energy levels within EQW and MQW. On the other hand, NEGF approach implemented in Wingreen does not take into account a time evolution of such quantum effects and therefore is unable to involve plateau-like structure on I-V characteristics. Scattering rates have impact on the position and slope of hysteresis and therefore should be set appropriately.

ACKNOWLEDGEMENT

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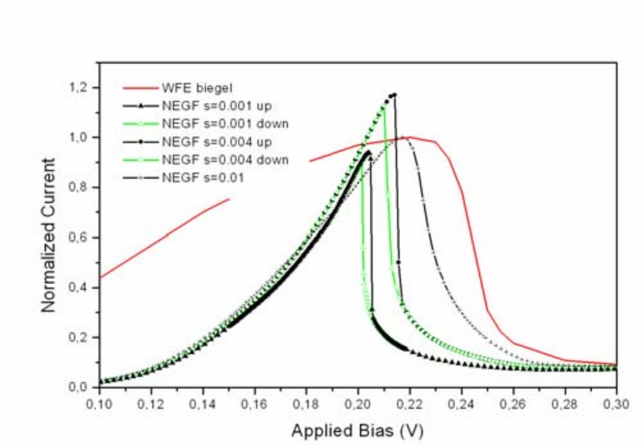

Fig. 1. I-V characteristics of RTD from [1] simulated by NEGF with different scattering parameter and WFE self-consistent time independent model [1]. (No hysteresis with s=0.01).

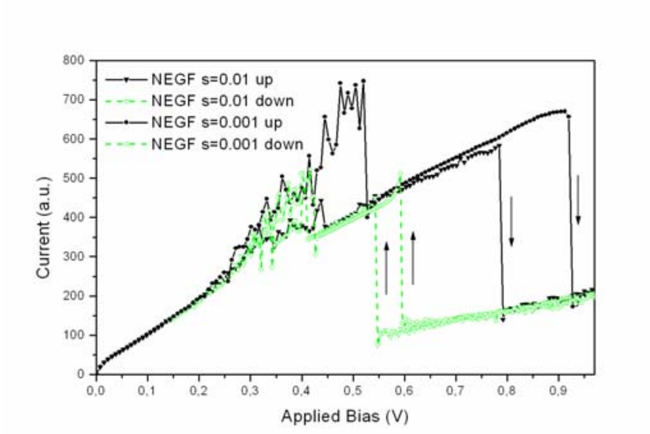

Fig. 4. I-V characteristics of GAAs/AlAs RTD simulated by NEGF with different scattering parameter.

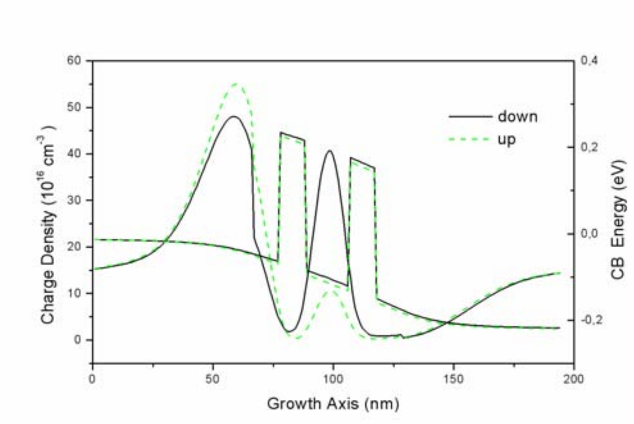

Fig. 2. Charge and potential distribution in RTD [1] in the bistable region at V=0.204V (NEGF simulation with s=0.001).

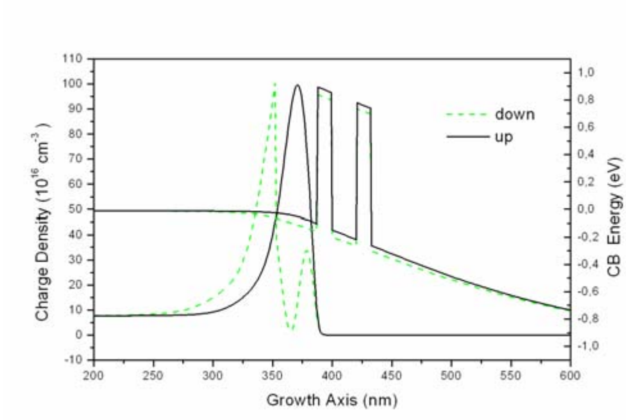

Fig. 5. Charge and potential distribution in GaAs/AlAs RTD [1] in the bistable region at V=0.88V (NEGF simulation with s=0.001).

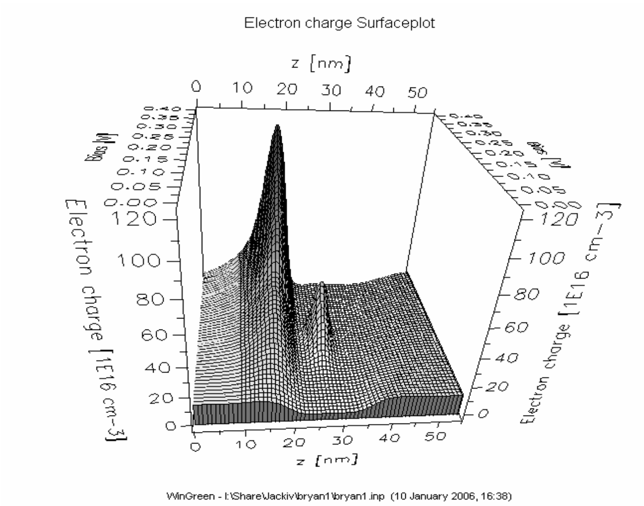

Fig. 3. Electron charge surface plot in RTD[1] (NEGF simulation with s=0.001).

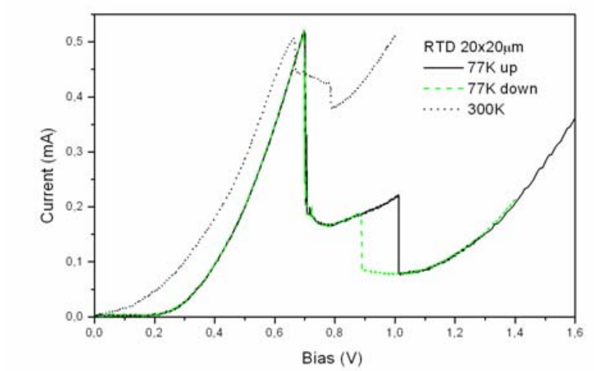

Fig. 6. Experimental I-V characteristics of the GaAs/AlAs RTD measured at the temperatures 300K and 77K.