Ballistic Nanodevices For Terahertz Data Processing
NANOTERA Project (IST-2001-32517)

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The objective of NANOTERA project is to investigate and develop alternative devices for future high frequency applications. The project intends to design, fabricate and characterise ballistic devices up to room temperature and up to millimetre wave frequencies in view of developing digital/analog electronic devices for THz data processing This study is divided in three main workpackages focused on simulation and design, fabrication, and characterization. The main achievements of the project are summarized the following.

A semiclassical 2D MC simulator has been tuned to physically model the ballistic nanodevices object of the NANOTERA project. Even if some of the analysed structures would require a 3D simulator, by introducing some simplifications and assumptions in the model, this simulator is able to reproduce most of the experimental behaviours observed at room temperature [1,2]. In Figure 1, we present simulation results on characteristic ballistic non-linear effect [3] on Three Terminal Branch Junction in push pull mode. In Figures 2 and 3, we present a MUX/DEMUX prototype. The current flow is controlled by a Schottky gate. The simulated intrinsic behaviour of such kind of device is given in Figure 4..

For the realization of ballistic passive and active device, an in depth study [4]was necessary for heterostructure optimization and for nanolithography process (resolutions in dimension and alignment in the order of ten nanometers).. The lithography step and low-damage process on transport properties are key issues. Our technological process was based mainly on negative tone e-beam resist (HSQ). DC behaviour was examined on simple passive devices (wire, crosses, TBJ…) to estimate what parameters led to ballistic behaviour at room temperature. Then active devices were realized by adding a Schottky gate. A good isolation between the gate and the channel was a key issue.

DC and microwave characterizations of ballistic devices were realized. These characterizations were used for determining microwave performance of ballistic device and frequency limitation related to parasitic elements. In figure 5, results on ballistic RF to DC conversion [5]are presented up to 94GHz and compared with microwave simulation. The main conclusion of the work is that new devices, based on ballistic electron transport and showing interesting properties at room temperature and millimetre waves were designed and fabricated successfully.

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[2] J. Mateos, B. G. Vasallo, D. Pardo, T. González, J. S. Galloo, S. Bollaert, Y. Roelens and A. Cappy, "Microscopic modelling of nonlinear transport in ballistic nanodevices," IEEE Trans. Electron Devices, vol. 50, pp. 1897-1905, 2003
[3] H. Q. Xu, "Electrical properties of three-terminal ballistic junctions," Appl. Phys. Lett., vol. 78, pp. 2064-2066, 2001
[4] JS Galloo, E. Pichonat, Y. Roelens, S. Bollaert, X. Wallart, A.Cappy « Technological process for fabrication of nanometric GaInAs/AlInAs ballistic devices » 13th NID Workshop, Athenes, 4-6 février 2004
[5] L. Bednarz, Rashmi, B. Hackens, H. Boutry, V. Bayot, I. Huynen, J.S. Galloo, Y. Roelens, S. Bollaert, E. Pichonat, A. Cappy, « Nanoscaled Double Y-branch junction operating at room temperature as RF to DC rectifier », Proceedings of the IEEE Nano 2004 Conference, Munich, August 17-19, 2004

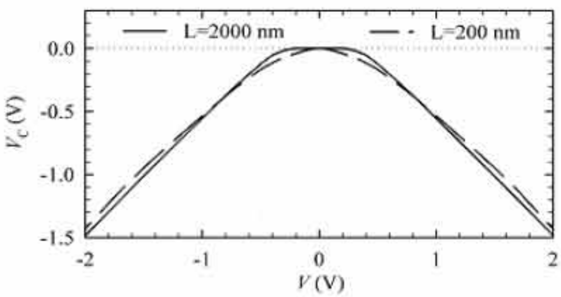


Figure1: V_C as a function of the applied voltage V when biasing in push-pull fashion $V=V_L=-V_R$ left and right branches of TBJs with different lengths: one ballistic (L=200 nm, dashed line) and one diffusive (L=2000 nm, solid line).

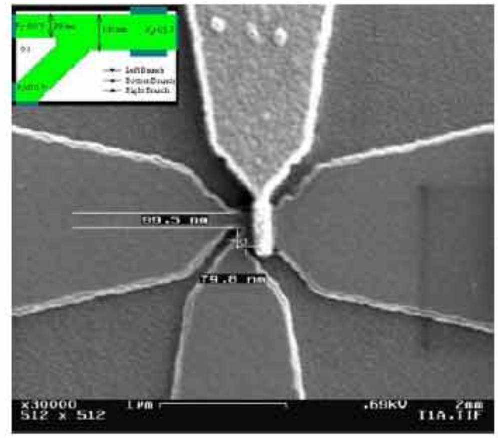


Figure 2: SEM image of the fabricated structure. Inset: simulated structure

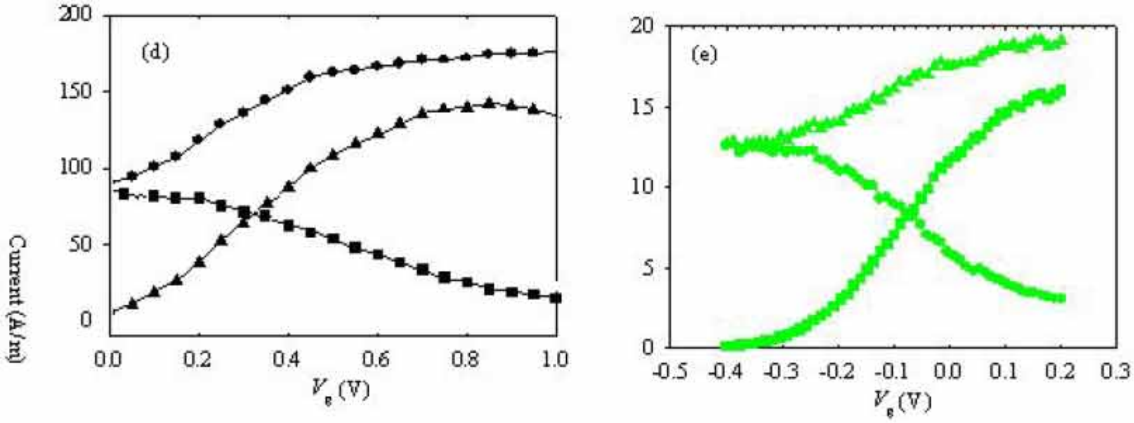
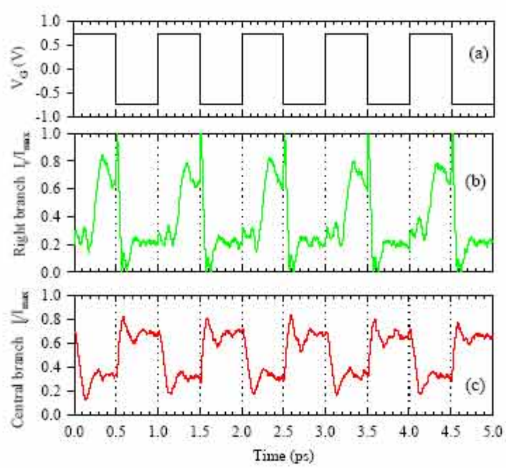


Figure 3: Current flowing through the three branches as a function of V_g for V_L=0 V and $V_B=V_R$=0.5 V (d) calculated in the simulated devices and (e) measured experimentally in the fabricated structure.



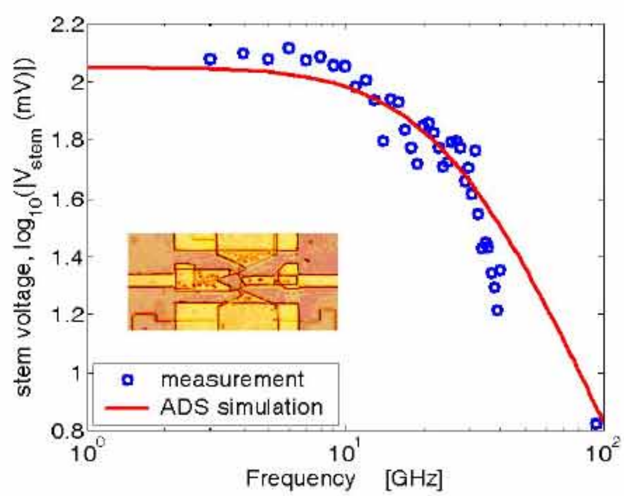


Figure 4: THz square signal applied to the gate and normalized response current in the (b) central and (c) right branches of the MUX/DEMUX.

Figure 5: RF-to-DC conversion (3-94 GHz) comparison between measurement and ADS simulation (-10 dbm power input)