Semiconducting carbon nanotubes as three-terminal devices

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In the last couple of years an enormous progress has been made in the field of carbon nanotube (CN) electronics. Particularly impressive are the improvements of carbon nanotube field-effect transistors (CNFETs) [1–3] since their first implementation in 1998 [4,5]. A key aspect has proven to be a deepened understanding of the device physics in these novel nano-devices. Since the actual contact area that creates source and drain in a CNFET is the interface between a three-dimensional (3D) metal and the one-dimensional (1D) semiconducting carbon nanotube, current injection into the nanotube channel is substantially different from a conventional metal oxide semiconductor field-effect transistor (MOSFET) [6]. The main difference is that in the case of a MOSFET current injection into the gate controlled area occurs from a doped part of the same semiconductor that forms also the channel while it is the injection from a metal in case of the CNFET. In general, the metal/semiconducting carbon nanotube transition region is characterized by the formation of a Schottky barrier (SB) of arbitrary height [7,8]. Interestingly, even if this barrier would be zero, the SB-CNFET behaves different from a MOSFET, i.e. tunneling from the source electrode still limits the current through the device [9,10]. It has been also found that the shape of this barrier is impacted by the size of the semiconductor. The smaller the semiconducting object, the thinner the Schottky barriers in a gated three-terminal device [6]. At the same time it has been experimentally verified that carbon nanotubes transistors operate in the ballistic regime even at room-temperature provided that their channel length does not exceed a couple of hundred nanometers [11–13]. Taking all these observations into account models have been developed to describe the performance of CNFETs and to make projections of the potential of nanotube transistors for future nanelectronic applications [14,6,15–17].

The current situation in the field and the work I will present is described by the exploration of novel device structures [18] inspired by recent simulations; It is aimed at a further improved understanding of the switching mechanism in semiconducting nano-devices [10,19] and the characterization of the high frequency performance of nano-transistors [20,21].

Most importantly, it is clear that the answers to the questions currently explored for carbon nanotubes will be of central interest not only for a carbon nanotube based electronics but for nano-applications in general.

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