WMH (IMS/RFIC) Monday 08:00 – 17:00 BCEC Room 152

Radio-Frequency Applications of Nanotechnology: Towards a New Generation of Extremely Integrated Devices and Systems

Full-day workshop reviewed by MTT-15, MTT-20, MTT-23.

Organizer(s):

Luca Pierantoni, Università Politecnica delle Marche, Ancona, Italy.
Fabio Coccetti, LAAS-CNRS, Toulouse, France.
Manos M. Tentzeris, Georgia Institute of Technology, Atlanta, GA, USA; IMS TPC.

The goal of this workshop is to present research activities on high-performance nanodevices for RF applications, showing the potential offered by emerging nano-scale materials. The latter include carbon nanotubes and graphene nanoribbons that exhibit unique electro-mechanical properties. The topics cover issues from production technology to recent advances in modelling. We describe the development of nano-components such as gas sensors, resonators, nano-antennas arrays, high-frequency interconnects, nano-electro-mechanical switches, nano-plasmonic structures, carbon based transistors and molecular devices for RF nanoelectronics. We focus on experimental techniques for the growing, assembling, positioning, contacting and broadband characterization of nanostructures, thus highlighting recent and emerging solutions. We introduce novel numerical techniques aimed at describing the coupling of Maxwell's equations with those governing the quantum transport.

Speakers:

1.Fabio Coccetti, LAAS-CNRS, Toulouse, France
"CNT Based Devices for Sensing and Communication Applications"

Carbon nanotubes are endowed of impressive mechanical and electrical properties. These properties can be used to implement either novel or more enhanced functionalities in the spectral range 100 MHz up to 1 THz. This contribution focuses on few representative devices which exploit these properties in order to explore application of nanotechnology into microwave and millimeter wave domain. More specifically two main area of interest will be targeted, sensing and communications. In this respect a couple of sensors will be presented, the first being a mass detector with a sensitivity of 1ng at room temperature, and a gas sensor working in a wide spectrum up to 100GHz which shows a phase shift of about 20° at 60 GHZ when exposed to nitrogen gas. In the area of devices for communication a resonator based on few millions CNT arrays with quality factor of around 900 and a negative differential resistance component based on suspended CNT over a trench in GaAs will be presented.

2. Trang T. Thai, Georgia Institute of Technology, Atlanta, GA, USA
"Carbon Nanotubes and Graphene Nano-Ribbons: Electrical Properties in Wireless Sensing Nodes"

Carbon nanotubes (CNTs) were found to have electrical properties highly sensitive to extremely small quantities of gases, such as ammonia, carbon dioxide, nitrogen oxide,

etc. at room temperatures with a very fast response time. Meanwhile, on the ground of theoretical analysis 2D graphene were predicted to have similar electrical properties to that of single walled CNTs (such as ballistic conduction). Therefore, graphene nano-ribbons (GNRs) are expected to share similar electrical characteristics, one of which is the gas sensing capability. The growth of graphene on Silicon Carbide (SiC) was initiated at De Heer's laboratory of Georgia Tech. Some success was achieved along with the capability of patterning in a process that was compatible to the existing semiconductor packaging technology, thus allowing easy integration for such GNR-based sensors.In this presentaion, electrical properties of CNTs and GNRs will be explored with regards to sensing and also other RF applications.

3. Peter Burke, University of California, Irvine CA, USA
"Arrays of SWNT Devices for Analog RF: Overview of the Field"

For practical RF applications where it is necessary to maintain 50ohm matching impedance and currents 1mA, using arrays of SWNT is essential. Multiple methods have been utilized for obtaining aligned CNT arrays from both solubilized nanotubes in solution, such as dielectrophoresis, Langmuir-Blodgett technique, spin-on, droplet-drying self-assembly, as well as from as-grown CVD methods such as, single crystal quartz substrate alignment, gas flow, and electrical field alignment. Depending on the method, CNT packing densities of 20tubes/μm have been achieved. For rf-transistor and amplifier CNT devices applications, where it is crucial to have nearly all semiconducting-CNT, the solubilized CNT array-methods are favored because it is possible to sort and enrich SWNT in solution between the semiconducting or metallic variants. The alternative is to use as-grown SWNTs and selectively etch those that are metallic.

4. Luca Pierantoni, Università Politecnica delle Marche, Ancona, Italy
"Novel Frequency- and Time-Domain Techniques for the Combined Maxwell-Dirac Problem in the Characterization of Nanodevices"

Carbon nanostructures are considered as key materials for electronic, RF and optical applications. An accurate modeling of these new emerging materials, from the atomic- to the micro-scale, is crucial for understanding their behaviour, in view of their potentialities, from DC up to RF. The goal of the present work is the development of new full-wave numerical techniques, in the frequency- and time-domains, aimed at modeling the self-consistent coupling of Maxwell's equations, describing the electromagnetic dynamics, with the Schrödinger/Dirac equations that govern the characteristics of quantum transport in low dimensional carbon materials. We deal with a variety of problems: the dynamic response of charge carriers to electromagnetic fields, the effects of lattice discontinuities on quantum transport, detailed description of the metal to carbon contact, characterization of edge and boundary conditions

5. Pavel Kabos, National Institute of Standards and Technology, Boulder, CO, USA
"Broadband Characterization of High Impedance Nanoscale Systems"

Nanotechnology has anabled the development of a number of promising nanoscale devices that operate in the microwave regime between a few MHz and 100 GHz. One characteristic feature of such nanoscale system is their high DC resistivity and related high impedance load. The braodband measurement of these extreme impedances at high frequencies is challenging. Specifically, these extreme impedances are very far from the impedance of traditional microwave systems and test equipment that have impedance on the order of either impedance of a free space or the characteristic impedance of standard microwave vector analysers. In this talk we describe several strategies for addressing the chalenges related broadband measurements of high-impedance systems, in general, and nanoscale devices, in particular, at microwave frequencies. We also review techniques for broadband electrical characterization of carbon-nanotube-based and semiconducting-nanowire-based devices at microwave frequencies.

6. Paul Salet, Ecole Polytechnique Fédérale de Lausanne, Switzerland
"Carbon Nanotube Nano-Electro-Mechanical Switches"

This talk reports on recent progress in the research concerning Carbon nanotubes (CNTs) for applications in Radio-Frequency Nano-Electro-Mechanical-Systems (RF NEMS). Their unique electrical and mechanical properties makes them a very attractive material fro RF NEMS. More particularly we illustrate some basic device functions with CNTs such as NEM switches, NEM resonators and NEM capacitors. We show some possible approaches for their practical fabrication as well as some of the achieved device characteristics. It is demonstrated that one promising approach for RF NEMS is to use CNTs not as individual nano-objects but as a thin film layer that can be processed to realize suspended CNT membranes and tunable capacitors. The objectives and technical progress in the EC projects NANORF and VIACARBON are reported.

7. Paolo Lugli, Technische Universitaet Munich, Munich, Germany
"Molecular Devices for RF Nanoelectronics"

The field of molecular electronics has received considerable attention recently, as electronic functionalities have been achieved via molecular structures, either using single molecules or molecular films. In the former case, phenyl-based chains are the building element of diodes and memory cells. There, carrier transport can occur balistically, which might open the way for high frequency applications. Due to their intrinsically nanometer dimensions, contacting molecular structures pose great technological challenges. From the modeling point of view, novel quantum mechanical approaches have to be developed. Organic films on the other side are considerably less challenging from a synthetic point of view, but they are expected to provide reduce performance with respect to the single-molecule systems. The modeling and simulation of devices based on molecular films is also of reduced complexity and conventional tools can be used.

8. Erping Li, Singapore National Research Institute, A*STAR-IHPC, Singapore
"Coupling of Maxwell's and Schrödinger's Equations for Modeling of Nano-Plasmonic Structures"

Miniaturization of devices are challenges with the existing technologies. To deal with these challenges, a new research area, plasmonics in which the electromagnetic wave propagate through the interface between metal and dielectric. Plasmonics can be widely used for nanophotonics and nano-electronics, RF propagation at nano-regime, and biological sensing. In this presentation, we present an approach that couples Maxwell and Schrodinger's equations for nano-Plasmonics device investigations. The plasmonics based devices used for nano-interconnects and waveguides will be shown in this presentation.

9. Tomas Palacios, Massachusetts Institute of Technology, Cambridge, MA, USA
"Graphene RF Electronics"