Strategies towards the fabrication of C nanotube-based systems: material preparation and device assembling

M.L.Terranova[*a], V. Sessa[*a], A. Fiori[*a], S. Orlanducci[*a], E. Tamburri[*a], F. Toschi[*a],
M. Rossi[*b]

[*] **Interdisciplinary Micro and NAno-structured Systems laboratory (MINAS)**
[a] **Dip. Scienze e Tecnologie Chimiche, Univ. of Rome "Tor Vergata" – Via della Ricerca Scientifica, 00133, Roma, Italy**
[b] **Dip. Energetica, University of Rome "La Sapienza" – Via Scarpa 16, Roma, Italy**

Carbon nanotubes represent nowadays one of the most important items for emerging nanotechnologies, and significant efforts are presently directed at optimizing the synthesis approaches and at developing systems made by different components mixed at the nanometer scale . In this context we are focusing the research to the production of nanotube materials for the following applications:

-Field emission devices
-Photovoltaic
-Strain sensing
-Thermal management
-Gas sensing

For every applications is required a material properly designed in terms of organization, chemical and physical properties and integrability with conventional synthetic approach.

In our laboratories two approaches are used to produce single-wall carbon nanotube (SWCNTs) systems suitable for technological applications. One approach employs Chemical Vapour Deposition (CVD) techniques for the realization of deposits with pre-definite architectures also on substrates with non conventional shapes (needles, wires) and on patterned surfaces. The second one relies on post-synthesis treatments suitable for production of organized nanotube aggregates.

CVD is a very efficient synthesis approach in view of the good control of deposit morphology, the capability of scaling the process and the full compatibility with semiconductor technology. Our synthesis process makes use of a HFCVD reactor specially modified by the introduction of a powder flowing cell which allows us to use solid carbonaceous species as precursors [1]. We successfully exploited controlled variations of synthesis parameters such as time, powder flux orientation and intensity of hydrogen flux and managed to control tubes' orientations and bundles' dimensions [2,3]. Moreover our synthesis processes are able to obtain selected area growth of SWCNTs on flat substrate and growth on micro-wire substrates.

For field emission applications an exact control of SWCNTs growth sites and of bundles density is strongly required. . Our nanotube deposits proved to be very efficient and highly reproducible emitters , able to follow a Fowler-Nordheim law . Studies of the field emission properties , performed on a series of samples with different morphologies , evidenced the influence of the nanotube morphologies on the field emission behaviour. These results are presently being used for the realization of a SWCNT-based triode device [4].

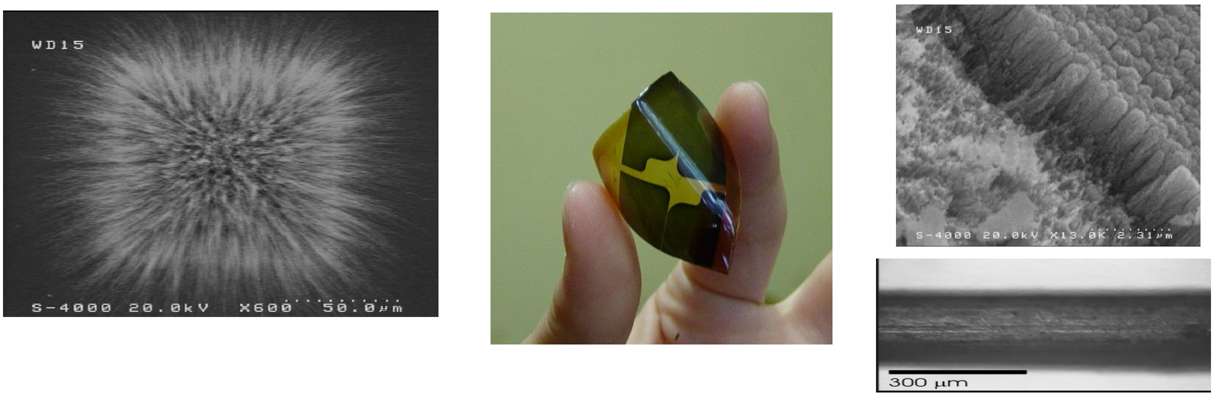
For some application the capability to move and order SWCNTs in controlled way during post-synthesis steps (purification and/or functionalization) is a very important task. In our laboratory electrophoresis and dielectrophoretic techniques are successfully used to put SWCNTs in specific location and/or in designed way. For example we realized homogeneous coating of nanotubes on metal micro wire used as electrochemical microprobes.

The dielectrophoretic process is used also during the preparation of nanotube-based gas sensors, whose response strongly depends on the organization of the nanotubes arrays . The SWCNTs alignment onto a multifinger electrode surface used as the gas sensing element [5] allows the detection of ppm or ppb gas concentrations at room temperature. Moreover the time response of our SWCNT sensor device, in term of adsorption and desorption, is dramatically accelerated applying a proper voltage to a back gate contact.

In order to create materials which can be easily processed for several advanced applications and which can have a low manufacturing cost , we are investigating the integration of nanotubes with polymeric matrices to form nanocomposites with novel or improved mechanical, thermal and electrical properties. In this context several classes of polymers are being investigated and different composite synthesis techniques are presently adopted. The classes of polymers range from the Conducting Polymers (such as polythiophene, polyaniline, polypirrole), the Thermoplastic Polymers (such as polystyrene, nylons) up to the Thermally Conductive Polymers (such as silicones, epoxy resins). In order to improve the nanotubes dispersion into the polymeric matrices, the SWCNTs are subjected to a series of chemical–physical treatments for purification and functionalization. In this way it is possible to produce a wide set of polymer/carbon nanotubes composites systems which include electrochemically deposited and spin coated films, fibres, pastes and free-standing plastic layers. In our labs we are presently testing this innovative class of materials for the fabrication of flexible plastic electrodes, pressure sensing devices based on piezoresistive effects [6], photovoltaic cells, and packaging for thermal management applications.

Morphological and structural characterizations of the nanostructures and nanomaterials are routinely performed by Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), Raman and UV/Vis Spectroscopy. Functional characterizations are carried out by electrical, thermal and electromechanical measurements [7].

This presentation will detail the morphological/structural properties of the produced nanomaterials as well as their integration in the devices .



Figure

Patterned growth of SWCNTs, a nanotube-polymer flexible device and SWCNTs deposited by CVD on a metal micro wire.

[1] S.Orlanducci, V. Sessa, M.L.Terranova, M. Rossi, D. Manno: *Chem.Phy.Lett.* **367**, 109-115, (2003)

[2] S. Orlanducci, A. Fiori, E. Tamburri, V. Sessa, M. L. Terranova, M. Rossi, *Crystal Research and Technology*, 40, 928 – 931, (2005)

[3] M.L.Terranova, V.Sessa, S.Orlanducci, A.Fiori, E.Tamburri and M.Rossi: Proceedings EUROCVD15 eds. A.Devi, H.Parala, M.L.Hitchman R.A.Fisher, M.D.Allendorf , 2005-09 , 340-347 (ECS, NJ, 2005)

[4] F. Brunetti, A. Di Carlo, R. Riccitelli, A. Reale, P. Regoliosi, M. Lucci, A. Fiori, M. L. Terranova, S. Orlanducci, V. Sessa, A. Ciorba, M. Rossi, M. Cirillo, V. Merlo, P. Lugli, C. Falessi, Proc. SPIE Vol. 5838, p. 154-161, Nanotechnology II; P. Lugli, L. B. Kish, J. Mateos; Eds (2005)

[5] M. Lucci, P. Regoliosi, A. Reale, A. Di Carlo, S. Orlanducci, E. Tamburri, M.L. Terranova, C. Di Natale, A. D'Amico, R. Paolesse, *Sensors and Actuators B: Chemical,* 111-112, 181-186 (2005)

[6] P. Regoliosi, F. Brunetti, A. Realea, A. Di Carlo, E. Tamburri, S. Orlanducci, M. L. Terranova, P. Lugli, Proc. SPIE Vol. 5838, p. 77-84, Nanotechnology II; P. Lugli, L. B. Kish, J. Mateos; Eds (2005)

[7] E.Tamburri, S.Orlanducci, M.L.Terranova, F.Valentini, G.Palleschi, A.Curulli, F.Brunetti, D.Passeri, A.Alippi and M.Rossi: *Carbon*, 43 (2005) 1213-1221