Plasma-based growth and functionalization of CNT from first steps to technological applications

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Carbon nanotubes are important building blocks for novel applications in science and technology. They can be used for example for chemical or biological sensors as in connection microelectronics devices.

In this contribution we report about experiments performed in low-pressure capacitively coupled RF C_2H_4 in H_2 or NH_3 mixing gas plasma which is used to grow densely packed vertically aligned CNTs on different sets of substrates and catalysts.

For CNT growth, metal catalyst thin films (9 nm in thickness) were deposited at room temperature on different substrates by pulsed laser deposition. Films were then heated up to 550 – 700°C under vacuum and maintained in a hydrogen atmosphere during a period where the film morphology is transformed into nanoparticles. Depending on the catalyst/substrate nature the CNT morphology presents multi-walled graphene or bamboo-like structures [1].

Catalyst particles were especially studied at different steps of the CNT growth, before and during the first minutes by Near Edge X-ray Absorption Fine structure Spectroscopy (NEXAFS) and SEM. The chemical composition of metal carbides of the catalysts when immerged in plasma and their morphologies help the growth characteristic understanding.

The behaviour of atomic hydrogen by means of optical emission spectroscopy in different plasmas starting from hydrogen plasmas to different hydrogen/ ethylene mixtures is studied.

Important parameter for the future applications and development concerns the surface modification of these materials, which can result in controllable changes of their electronic or chemical properties. Of interest are here in particular nitrogen containing functional groups. We focus on first results dealing with the controlled functionalization of carbon nanotube (CNT) carpets by means of low temperature (nitrogen) containing plasmas. The effect of the plasma is analyzed by means of NEXAFS and X-ray photoelectron spectroscopy (XPS). Additional information about the effect of the plasma treatment on the surface properties of the materials are obtained by means of contact angle measurements.

Electrical and thermal characterization of carbon nanotube films has been achieved to determine their potential use in microelectronics devices [2].

[1] M. Gaillard, C. Boulmer-Leborgne, N. Semmar, E. Millon, A. Petit, Applied Surface Science 258 (2012), 9237-9241

[2] M.Gaillard, H.Mbitsi, A.Petit, E.Amin-Chalhoub, C.Boulmer-Leborgne, N.Semmar, E.Millon, J.Mathias, S.Kouassi, Journal of Vacuum Science & Technology B (Vol.29, Issue 4) 14 July 2011