# 1D polymer/CNT composite : elaboration and transport properties

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Multi-Walled Carbon Nanotubes (MWNTs) can be aligned directly during their synthesis, forming carpets and thus 1D anisotropic networks. Aerosol-assisted Catalytic Chemical Vapour Deposition (CCVD) process is, for instance, one technique used to produce aligned MWNTs[1,2]. Such aligned MWNTs can be impregnated in a polymer matrix, forming a 1D composite. Few papers[3,4] reports the preparation and the electrical property measurements of such composites. The conductivity is macroscopically measured by a two probe method, both along the axial direction of MWNTs and perpendicularly to this direction. The authors report interesting values of conductivities, in particular in the 1D direction, which are higher in comparison to conductivities measured on randomly oriented CNT composites[4]. However, little information is given in terms of conductivity contribution at the nanotube scale.

In this context, our motivation is to study the electrical properties of 1D composite materials taking into account their fabrication parameters. In this presentation, a particular attention will be paid to the physical-chemical analysis of the samples and the electrical property measurements at the nanoscale level.

1D composites are produced with a four step process : first, MWNT carpets are synthesized by an aerosol-assisted CCVD process on quartz substrates ; then the carpets are annealed at 2000°C under argon atmosphere[5] ; and then they are impregnated in an epoxy polymer matrix and cured ; finally they are polished in order to adjust the thickness of the composite.

At each step of the preparation process, the MWNTs and the composites are characterized. MWNT carpets are observed by Scanning Electron Microscopy (SEM) (Fig. 1.a) in order to measure their thickness (corresponding to the CNTs' length) and to qualitatively estimate their alignment. Some of the MWNT carpets are dispersed before and after the annealing operation in an ethanol solution and observed by Transmission Electron Microscopy (TEM) with the purpose of measuring their internal and external diameters by statistical analysis. Typically, MWNT carpets used in this study exhibit a thickness of 1 mm and MWNT external mean diameter is 50 nm. The surface of each side of the composite sample which has been mirror-polished, is observed by SEM (Fig. 1.b), showing that MWNTs sections are protruding. A statistical measurement of the protruding MWNTs gives an average density value of the tubes which is around $4.10^9$ MWNT/$cm^2$.
Atomic Force Microscope (AFM) equipped with a special Current-Sensing (CS) device has been used to analyse the composite surface at room temperature, which allows a simultaneous mapping of the topography (Fig. 2.a) and of the local resistivity of the surface. These combined measurements provide a clear identification of the MWNTs on the composite surface, supporting the information from the SEM observations (Fig. 2.b). They allow not only to calculate the MWNT density with a result consistent with the one provided by SEM, but also to measure how much the MWNTs protrude from the polymer, which is found to be around a few nanometres. The distribution of the resistivity along the composite surface is studied quantitatively. Statistical analysis of the resistivity clearly reveals the presence of MWNTs protruding from the surface. Low resistivity such as $10^4$ ohms has been measured in several areas of the composite surface. Some I/V spectroscopy curves were measured on different points of the surface ; they show two kinds of electrical behaviour when MWNTs are occurring in these areas : ohmic and non-ohmic ones. Some hypothesis of explanations will be given in order to explain the non-ohmic behaviour which is similar with previous measurements performed at the Laboratoire des Solides Irradiés on nano-objects[6] with the same geometry. Complementary AFM measurements are currently in progress in order to confirm such a non-ohmic behaviour at room temperature.

## References


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## Figures

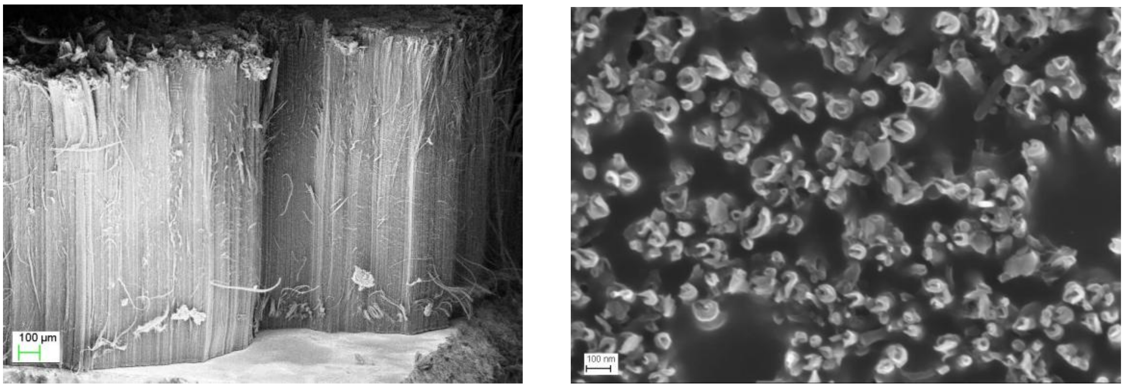


Fig 1 : SEM observations ((a) CNT carpet on quartz substrate ;
(b) CNT/Epoxy composite surface)

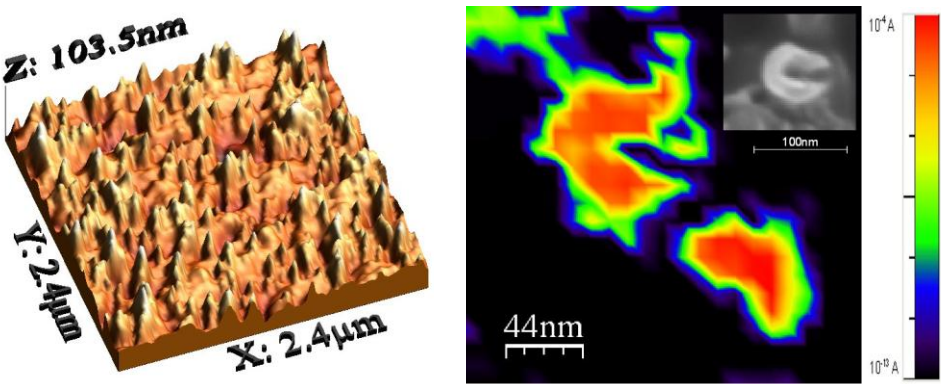


Fig 2 : AFM images ((a) 3D view of the surface topography ; (b) comparison between zoomed CS-AFM and zoomed SEM pictures on the upper inset)