Functionalized Carbon Nanotubes A Key to Nanotechnology

Carbon nanotubes, a new 1D carbon material, were discovered around ten years ago. This new molecular form of carbon exhibits a series of fundamentally new and unexpected physical, mechanical and chemical properties and brought nanotubes into the position of one of the most promising tools in future nanotechnology. Depending on their structure, nanotubes can carry current with essentially no resistance, semiconducting tubes can be made switchable. Nanotubes can have implications for the fabrication of molecule-based electronic devices, nanotransistors and memory elements. Due to their extraordinary mechanical properties considerable interest is in the development of carbon composites for applications in automobile and aerospace industry.

Until now, the majority of the investigations on carbon nanotubes has been carried out with an insoluble form of solid state material and on undefined mixtures with different characteristics with respect to their properties. In this context, chemical functionalization will provide solubility to the tubes and transform them into processible material. Thus, functionalization of nanotubes becomes an essential prerequisite for potential nanotechnological applications and can be seen as a key to nanotechnology.

The European Research Structure

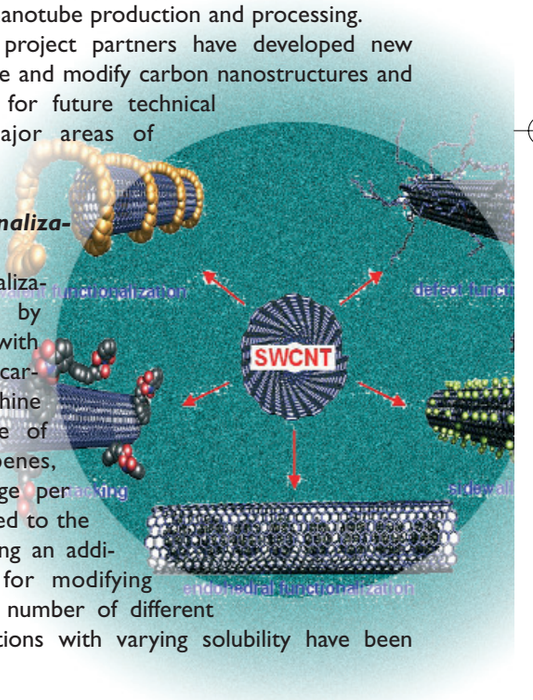
Nanotechnology is a global phenomenon, a large number of initiatives have already been established in order to create products based on nanotechnology.

At present, functionalization of carbon nanotubes CNTs represents a minute fraction of the total "nanotube job" only. Since the mid-nineties more than 5.500 papers on carbon nanotubes can be found. Starting with 139 papers in 1995, approximately 2600 scientific papers be published by the end of 2002. During the same period of time, from 0 papers in 1995, dealing with nanotube functionalization, the number increased to 107 by the middle of 2002

In its 4th FP programme from 1994 to 1998, the European Commission funded some 80 projects on nanotechnology. From about 300 RTN networks within the current 5th FP programme Improving Human Potential, more than 20 networks are involved in the research of nanotechnologies and nano-materials. From the total of 87 networks in the chemistry panel, four networks are strictly engaged with the chemistry of carbon nanotubes. FUNCARS, with nine participant groups in five European countries, is thematically concerned with the functionalization of carbon nanotubes.

Contributions to the ERA

Carbon nanotubes (CNTs) are related to three other carbon forms, the two-dimensional graphite, the three-dimensional diamond, and the spherical, soccer ball like fullerenes. Depending on their production, single-walled carbon nanotubes (SWCNTs) and multi-walled nanotubes (MWCNTs) are distinguished.
Speaking about functionalization of carbon nanotubes, between covalent and non-covalent functionalization, functionalization of sidewalls and defect sites, and exohedral and endohedral functionalization has to be distinguished.
Some European countries started heavily to invest in nanoscience and technology and promoted them to the European leaders in nanotube production and processing.
The nine European project partners have developed new routes to functionalize and modify carbon nanostructures and made them suitable for future technical applications. The major areas of innovations are:



- ***Covalent functionalization of CNTs***
  Chemical functionalization suc-ceeded by reacting SWCNTs with radicals, nitrenes, carbenes and azomethine ylides. In the case of nucleophilic carbenes, one negative charge per addend is transferred to the tube surface, offering an additional parameter for modifying tube properties. A number of different nanotube modifications with varying solubility have been synthesized.

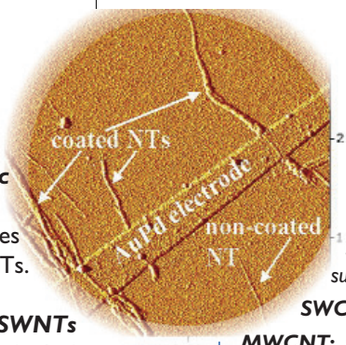
- ***Electrical attachment of functional groups onto CNTs***
  Electrochemical modification of SWCNTs was achieved by combining electrochemistry and nanolithography.

- ***Novel techniques of nanotubes' purification.***
  An advanced purification technique, based upon oxidation, ultrasonication, size exclusion chromatography and vacuum filtration was developed.

- ***Grafting of carbon nanotubes with organic polymers***
  Covalent grafting of organic polymers to nanotubes was achieved by reacting of polystyrene with SWCNTs.

- ***Incubation of biological macromolecules with SWNTs***
  A non-covalent functionalization of CNTs with biological macromolecules like nucleotides or proteins will promote the development of new bioelectronic nanomaterials. A helical organization of protein molecules with MWCNTs was observed.

- ***Hydrogen chemisorption on graphene surface***
  Hydrogen is chemisorbed to sp2 bonded carbon surface, causing long-range electronic effects, important for nanotube electronics.



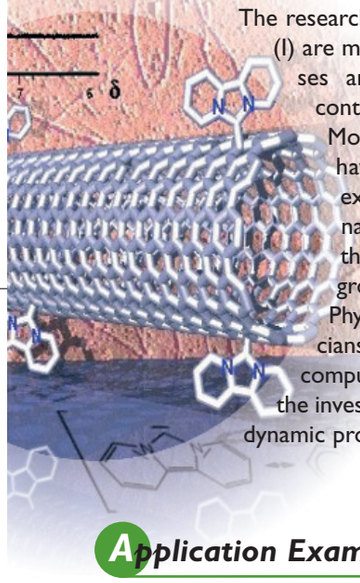
Glossary

CNT: *carbon nanotube, tubular carbon structure, consisting of a honeycomb arrayed surface*

SWCNT: *single-walled carbon nanotube*

MWCNT: *multi-walled carbon nanotube, concentrically arranged*

The Participation



The researcher teams of Erlangen (D) and Trieste (I) are most experienced in systematic syntheses and represent the leading chemical contributors to the network. The teams of Montpellier (F) and the MPI Stuttgart (D) have an internationally recognized expertise in the production of carbon nanotubes and supply the network with the research material. The Bologna (I) group together with the Vienna Material Physics group (A) comprise the theoreticians of the network, having experience in computer simulation and modelling, and in the investigation of spectral characteristics and dynamic properties of such systems.

Application Example

A new method of derivatization of an individual SWCNT, deposited on a Si/SiO_2 wafer, was developed in Stuttgart. UV activation of appropriate functional reagents yielded nitrenes, which could be attached to the carbon lattice of the tubes. These functionalities were employed subsequently to bind gold particles onto the tube surface improving the electrical contact properties.

The treatment of individual SWNTs, deposited on a Si/SiO_2 wafer, with H_2Se gas lead to the formation of Se nano-particles on the tubes. The Se particles, arranged along the tubes/thin bundles, were formed by site-selective oxidation or at oxidation defects and can be taken as a measure for determination of sidewall defects of carbon nanotubes.

Chemical Functionalization of Carbon Nanotubes

FUNCARS

Contract number: HPRN-CT-1999-00011

Start date: 1.04.2000 End date: 31.03.2003
Duration: 36 months
Project cost: 1 480 000 euros EC Funding: 1 480 000 euros

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Useful links

http://www.cordis.lu/nanotechnology/home.html
http://europa.eu.int/comm/research/fp6/mariecurieactions
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Release december 2002

KI-AC-02-012-EN-C