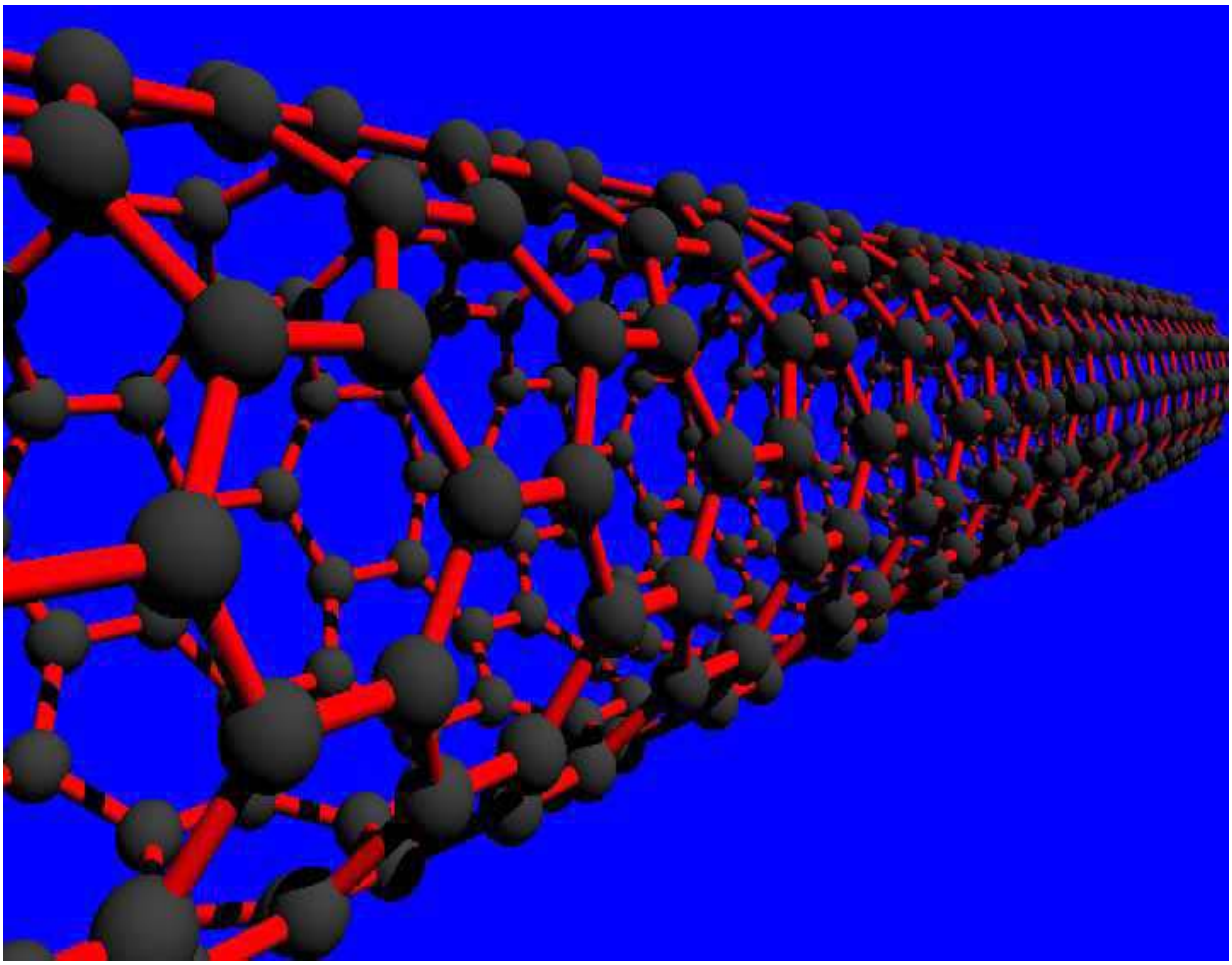
BOOK OF ABSTRACTS

Part II – Sunday Dec 7

CNT Fibers and Tether Design



Sun Dec 7, 2008: CNT fibres & tether design

9.00-09:45	Advances in synthesis of carbon nanotube materials and their application in manufacturing of CNT thread	Prof. Vesselin Shanov, University of Cincinnati
09.45-10.30	Production and mechanical properties of carbon nanotube nanocomposite fibers	Prof. Cècile Zakri, CRPP, University of Bordeaux
10.30-11.00	Coffee break	
11.00-11.30	Latest advancements on CNT plasma functionalization	Dr Jerôme Guillot, Dr. Patrick Choquet, CRP Gabriel Lippmann, Luxembourg
11.30-12:30	Direct-spinning of high performance fibres from single and double-walled carbon nanotubes	Dr. Marcelo Motta, Cambridge University
12.30-14.00	Lunch	
14.00-15.00	The role of defects in the design of a space elevator cable: From nanotube to megatube	Prof. Nicola Pugno, Polytechnic Institute Turin
15:00-15.30	The NASA tether strength competition – Review & prediction	Dr. Bryan Laubscher, Odysseus Industries
15.30-16.00	Coffee break	
16.00-16.30	Space Elevator Development Outlook: Focus Japan, Europe.	Dir.Akira Tsuchida, JAXA, Markus Klettner, ESW
16.30-17.00	Space Elevator Development Outlook: Focus USA	Dr. Brad Edwards, ESW Mr. John Winter, ESW
17.00-17.15	Final address	Dr. Brad Edwards, ESW Mr. Markus Klettner, ESW

9:00 – 09:45 Prof. Vesselin N. Shanov: ***Advances in synthesis of carbon nanotube materials and their application in manufacturing of CNT thread***

Prof. Vesselin Shanov, graduated with his masters in Electronic Materials from the Technological University of Sofia, Bulgaria, and a Ph. D. in Solid State Chemistry from the University of Regensburg, Germany, and Technological University of Sofia, Bulgaria. He has gained a vast amount of experience in a short time, serving as an associate professor at the Technological University of Sofia, a visiting professor at the Universities of Heidelberg, Regensburg and Cincinnati. Currently he is associate professor at the University of Cincinnati.

Dr. Shanov has international experience and engineering knowledge in the development of facilities and technologies for processing of nano-structured materials and thin films. He has also won several prestigious awards, including the Fulbright Award for Research and Teaching in USA, German Academic Foundation (DAAD) Grants, and the Bulgarian Patent Office Award for Distinguished Patent. His current research is focused on synthesis, processing, characterization, and application of nanostructured materials with emphasis on carbon nanotubes. His research, particularly his nano-science and engineering related studies have attracted attention from the scientific community: ***http://www.uc.edu/news/NR.asp?id=4811***,

Abstract:

ADVANCES IN SYNTHESIS OF CARBON NANOTUBE MATERIALS AND THEIR APPLICATION IN MANUFACTURING OF CNT THREAD

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The main obstacle to wider application of Carbon Nanotubes (CNTs) is their nature to grow in bundles resembling, "spaghetti" type morphology. UC researchers developed a novel catalyst for growing of aligned CNTs and succeeded to produce centimeter long carpets of this material.

This talk will focus on the latest results in catalytic synthesis of super long CNT arrays by CVD, achieved at the University of Cincinnati. The role of the catalyst design on the substrate surface and its impact on the length of the oriented carbon nanotubes will be revealed. Additionally, characterization of the arrays by ESEM, HRTEM, Micro-Raman Spectroscopy, and TGA will be discussed. The talk will also illustrate exiting applications of the CNT arrays related to their unique properties. Recent advances in the development of "Black Cotton™", which is centimeter long carbon nanotube (CNT) arrays grown on large substrates, will be presented. Applications of nanotechnology under development in our lab include spinning Black Cotton into threads and sheets and their electrical and mechanical characterization. These novel carbon nano-structures can be used to produce a new smart material with reinforcement, sensing, and actuation properties.

The talk will also present current research efforts to scale up the cultivated processes of synthesis and spinning the CNT arrays. The achievement of growing centimeter-long nanotube arrays provides hope that continuous growth of CNTs in the meter length range is possible. The array nanotubes mitigate the limitations of the powdered CNTs, and this is expected to open up new applications.

References

1. NSF Press Release: http://www.nsf.gov/news/news_summ.jsp?cntn_id=108992&org=NSF&from=news
2. Vesselin Shanov, Andrew Gorton, Yun Yeo-Heung, Mark J. Schulz, (patent pending), University of Cincinnati, UC 107-044 "*Catalyst and Method for Manufacturing Carbon Nanostructured Materials"*, 10/17/06.
3. Yun, Y., Shanov V., Tu, Y., Subramaniam S., and Schulz M. J., "*Growth Mechanism of Long Aligned Multiwall Carbon Nanotube Arrays by Water-Assisted Chemical Vapor Deposition*", J. Phys. Chem. B, 110, 23920, 2006
4. Vesselin Shanov, Atul Miskin, Sachin Jain, Peng He, Mark Schulz, "*Chapter 5. Advances in Chemical Vapor Deposition of Carbon Nanotubes*," in, "Nanoengineering of Structural, Functional, and Smart Materials," editors Mark J. Schulz, Ajit Kelkar, Mannur Sundaresan CRC Press, 1/06.
5. Vesselin Shanov, Yeo-Heung Yun, Mark J. Schulz, "Synthesis and Characterization of Carbon Nanotube Materials (Review)," *Journal of the University of Chemical Technology and Metallurgy,* 41, 4, 2006, 377-390.

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Notes /questions:

9.45 – 10.30 Prof. Cécile Zakri (CRPP): ***Production and mechanical properties of carbon nanotube nanocomposite fibers***

Prof. Cécile Zakri is a leading expert on CNT fiber production at Centre de Recherche Paul Pascal in Bordeaux. She is also a professor at Bordeaux University and has been Co-chair of ChemOnTubes 2008. Her research team received *Le Prix La Recherche* Award for synthesizing CNT fibers with exceptional properties.

Abstract:

PRODUCTION AND MECHANICAL PROPERTIES OF CARBON NANOTUBE NANOCOMPOSITE FIBERS

Pierre Miaudet, Maryse Maugey, Alain Derré, Philippe Poulin and Cécile Zakri

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We spin Carbon Nanotube (CNT) fibers by a coagulation process which consists in injecting a CNT dispersion in the co-flowing stream of a polyvinyl alcohol solution (PVA)[1]. The obtained fibers have a composite structure with large fraction of oriented CNTs and polymer. These fibers exhibit a very large strain to failure up to 450%. Their toughness, which is the energy needed to break the fibers, exceeds that of any other known materials. In order to increase the amount of energy that those fibers absorb at low strain, we also use hot drawing treatments, a concept inspired from textile technologies. This treatment yields a crystallinity increase of the PVA and an unprecedented degree of alignment of the CNTs. These structural modifications lead to markedly improved energy absorption at low strain, comparable or superior to industrial high performance fibers like Kevlar®, and make the fibers water resistant [2] .

Among other properties, these fibers also display a super strong shape memory effect, being able to retract like classical shape memory polymer but with a much higher stress recovery. Another amazing property is their temperature memory, which could be

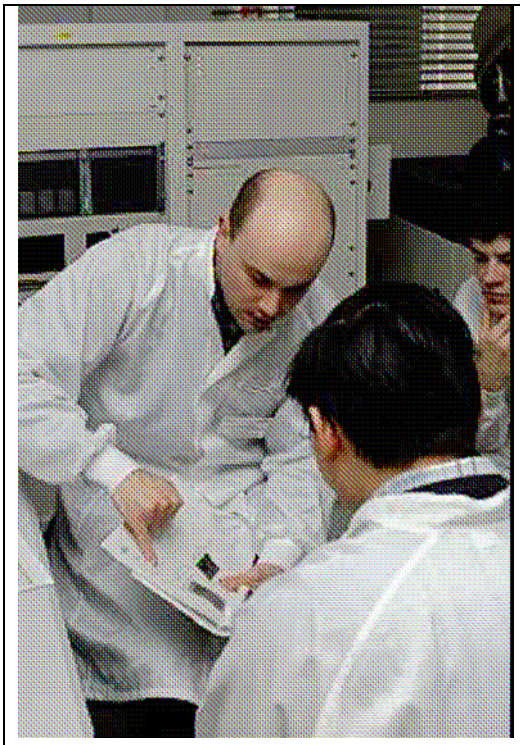
attributed to the intimate nano scale structure of the composite[3].

We believe that the properties described in this work can realistically validate in a near future the use of CNTs in textile applications and deployable aerospace and aircraft structures.

[1] B. Vigolo *et al*, Science, 2000, 290, 1331
[2] P. Miaudet *et al*, Nanoletters, 2005, 5, 2212-2215.
[3] P. Miaudet *et al*, Science, 2007, 318, 1294-1296.

Notes /questions :

11.00 – 11.30 Dr. Jerôme Guillot and Dr. Patrick Choquet (CRP Gabriel Lippmann): ***Functionalization of CNT***



Dr. Jerôme Guillot and **Dr. Patrick Choquet** are Researchers on CNT functionalisation at the Department for Science and Material Analysis (SAM) at the Public Research Centre Gabriel Lippmann in Belvaux, Luxembourg

Abstract:

Functionalization of Carbon Nanotubes with metallic nanoclusters for gas sensing applications

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Carbon Nanotubes (CNTs) have become one of the most intensely studied nanostructure and their inherent physical properties make them ideal supports for metal particles with a wide range of application in areas such as catalysis, nanoelectronic devices, sensors… This work focuses on the development of an electronic sensor based on nanotechnology: Carbon Nanotubes are randomly decorated with metallic nanoclusters in order to detect toxic gases with a high selectivity and sensitivity.
Numerical calculations have been performed to predict the charge transfert as well as the interactions of gold clusters with perfect CNTs and with surfaces containing defects. It appeared that interfacial properties can be tuned by chemical modification of the surface of the CNTs.

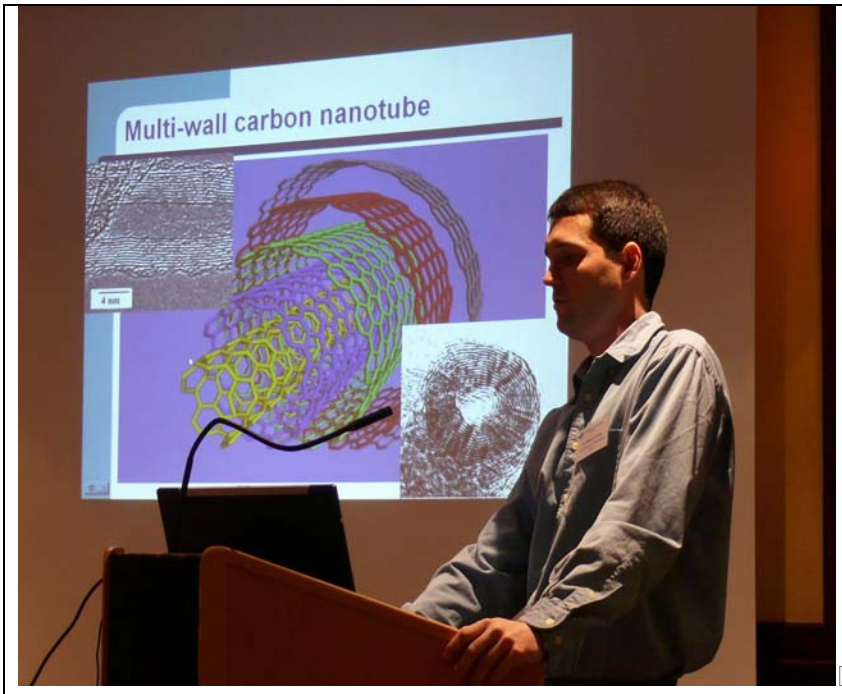
Multi Walled Carbon Nanotubes were then functionalized using two different deposition techniques: metal evaporation from high purity rods and an atmospheric plasma torch combined with metallic colloids solutions. The characterizations of the hybrids materials were carried out with High Resolution Transmission Electron Microcopy and X-ray Photoelectron Spectroscopy in order to study the influence of the treatment parameters on the samples morphology and their composition.

At last, sensors were designed and prepared from the functionalized CNTs. Their sensitivity towards different pollutant gases was tested too.

This work is funded by the EU Commission (Nano2hybrids, EC-STREP-033311).

Notes /questions:

11:30 – 12:30 Marcelo Motta (Cambridge University): ***Direct spinning of high performance fibres from single and double walled carbon nanotubes***



Dr. Marcello Motta is an expert on spinning high-performance continuous carbon nanotube fibers, the building blocks of a space elevator cable, at the Department of Materials Science of Cambridge University. Dr. Motta is also Chevening Technology Enterprise Fellow focussed on commercialisation of CNT fibers.

Abstract:
Individual single and double-walled carbon nanotubes are the strongest materials currently known, and thus are the most promising candidates to serve as building blocks for a new generation of high-performance fibres. However, their assembly into useful macroscopic forms with mechanical properties which reflect a significant proportion of those seen in the individual tubes, remains a well-defined challenge to materials processing.

At Cambridge University, we have recently introduced a method for the spinning of pure carbon nanotube fibres directly from the gas phase of a chemical vapour deposition reactor.[1] The major benefit of this process is the ability to continuously collect the pure and uniform nanotubes as a transparent thin-film or as a high-performance fibre. While the best strength (2.5 N/tex) and stiffness (160 N/tex) promise competition for established carbon fibres, the maximum energy absorbed at fracture (up to 100 J/g) is considerably higher.[2] When tested in small gauge lengths, and thus less sensitive to defects arisen from instabilities in the production line, these fibres show remarkable combination of tensile strengths (5-10 N/TEX), stiffness and toughness which makes them the strongest materials ever tested.[3] In this presentation I will show in detail how

these fibres are produced and discuss how their properties can still be significantly improved without the need to apply any extra additives or post-processing. These challenges will be set against the scaling-up plan already under development.

1. Li *et al*. *Science* 304, p.276-27, 2004.
2. Motta et al. Adv. Mater. 19, p.3721-26, 2007.
3. Koziol et al. Science 318,p.1892-95, 2007.

Notes / questions :

14.00 – 15.00 Prof. Nicola Pugno (Polytechnical Institute Turin): ***The role of defects in the design of a space elevator cable: From nanotube to megatube***

Prof. Nicola Pugno is Associate Professor of Structural Mechanics at the Department of Structural Engineering of the Politecnico di Torino. He is recognised internationally as a leading expert in the important field of Structural Mechanics and Strength of Materials.
In addition Prof. Pugno is "Leading Scientists of the World" laureate and has been collaborator of Nobel Laureate Prof. Kroto.

Abstract:
In this lecture the author will discuss his recent findings on the role of defects and related size-effects on the nanotube based space elevator mega cable design.

The role of thermodynamically unavoidable atomistic defects with different size and shape is quantified on brittle fracture, fatigue and elasticity, for nanotubes and nanotube bundles. Non-asymptotic regimes, elastic plasticity, rough cracks, finite domains and size effects are also discussed. The results are compared with atomistic simulations and nanotensile tests of carbon nanotubes. Key simple formulas for the design of a flaw-tolerant space elevator mega cable are reported, suggesting that it would need a taper ratio (for uniform stress) of about two orders of magnitude larger than currently proposed.

Notes / questions:

15.00-15.30 Dr. Bryan Laubscher (Odysseus Industries): ***The Spaceward/NASA Tether Strength Competition Review and Prediction***

Dr. Bryan Laubscher is Astrophysicist. He was a project leader at Los Alamos National Laboratory until 2008. Over the last 20 years he has carried out research and development in astrophysics, electromagnetic detection physics, space instrumentation, spacecraft, non-linear optics, laser technology, lidar and spectrometer development He is now with Odysseus Technologies focussing on the development of strong CNT threads.

Abstract:
In this presentation the importance of strength for the Space Elevator will be explained first. The ribbon remains the greatest challenge and its technology promises the greatest impact for our society. Then the past tether competitions will be summarized, focusing on the evolution of the teams participating in the competition. Finally predictions will be offered concerning the teams and competition held in the first quarter of 2009.

Notes / questions:

16:00 – 16:30 Akira Tsuchida (JAXA, JSEA, E-T-C), Markus Klettner (EuroSpaceward): ***Outlook on the Space Elevator development – Focus Japan, Europe***

Dir. Akira Tsuchida is JAXA Flight Director at Tsukuba Space Center of the Japanese experiment module 'Kibo' (Hope) of the International Space Station ISS and Member of the Board of the Japan Space Elevator Association. He led the first Japanese climber team E-T-C during the NASA beam power challenge in Salt Lake City in 2007.

Mr. Markus Klettner is Executive Director of EuroSpaceward. He received a MSc. degree in Space Management from the International Space University. In addition he owns a university degree in engineering and post-graduated in International Business Management. His MBA thesis in 1990 analysed the emerging commercial space market in Europe. During several years he edited the quarterly astronomical journal S.P.A.C.E at the House of Nature in Salzburg.

Abstract:

Japan: After the climber team E-T-C (a joint American-Japanese team) joined the 2007 NASA/Spaceward Space Elevator games at Salt Lake City Utah in 2007, the Space Elevator concept became popular in Japan. Also in 2007 the Japan Space Elevator Association (JSEA) was established and currently JSEA has over 120 members.

In his presentation, Mr. Akira Tsuchida, explains latest developments on the Space Elevator in Japan/Asia as follows:

(1) Space Elevator development plan by Japanese government
(2) 1st Space Elevator conference in Japan (JpSEC2008) results
(3) Plan of Space Elevator game in Japan in 2009

Europe: The presentation gives an outlook on possible future Space Elevator related ventures in Europe and highlights the role of EuroSpaceward to contribute its share to the global endeavour.

Notes /questions:

16:30 – 17:00 Dr. Brad Edwards, John Winter (all EuroSpaceward): ***Outlook on the Space Elevator Development – Focus USA***

Dr. Brad Edwards received his Ph.D. in Physics from the University of Wisconsin at Madison, USA, then spent ten years at Los Alamos National Laboratory developing space missions and advanced technology. His work at Los Alamos included building the world's first functional optical cryo-cooler, leading roles on several space missions, and developing advanced technology such as superconducting tunnel junctions.

However, Dr. Edwards is best known for his work developing the first viable designs for a space elevator. He is considered the father of the modern space elevator and is leading the effort to develop and build a space elevator. He is President of EuroSpaceward and Arthur C. Clark Award laureate.

John Winter has studied Political Science and Planetary Geology. He worked a number of years on State Dept. contracts and at the UN as a refugee expert and consultant. Currently he is coaching financial experts in the Grand Duchy and serves as Director PR of EuroSpaceward

Abstract:
The new incoming U.S. Administration is burdened with domestic financial and external diplomatic crisis which will make it difficult to achieve its own agenda within its first two years. It is certain the result will be bigger government with a focus on expanding social policies and bringing economic stability. The new Administration can be expected to work on projects multilaterally around the world that may support these goals. When possible, there will be efforts to think outside the box and "kill two birds with one stone". There will be more stress on the "public" in PPP (private public partnership). In science research and space policy, there will be a renewed stress on safety and reliability, adding to costs. But new programs will need to prove their worth and public benefit.

Dr. Brad Edwards and John Winter will assess the possible political fate of the ISS, the Space Shuttle as well as the "Return to the Moon" initiative under the new administration and how it may influence the Space Elevator endeavor.

Notes / questions: