Nanotechnology
Myths and Reality:
A Materials Perspective

Asst. Prof. E. Reynaud
Department of Mechanical Engineering
NSF-CHN/NCOE
UMass Lowell

OUTLINE

This talk is built around several case studies in nanotechnology first presented by undergraduates in the Mechanical Engineering Department at UMass Lowell as a **materials science class project**.

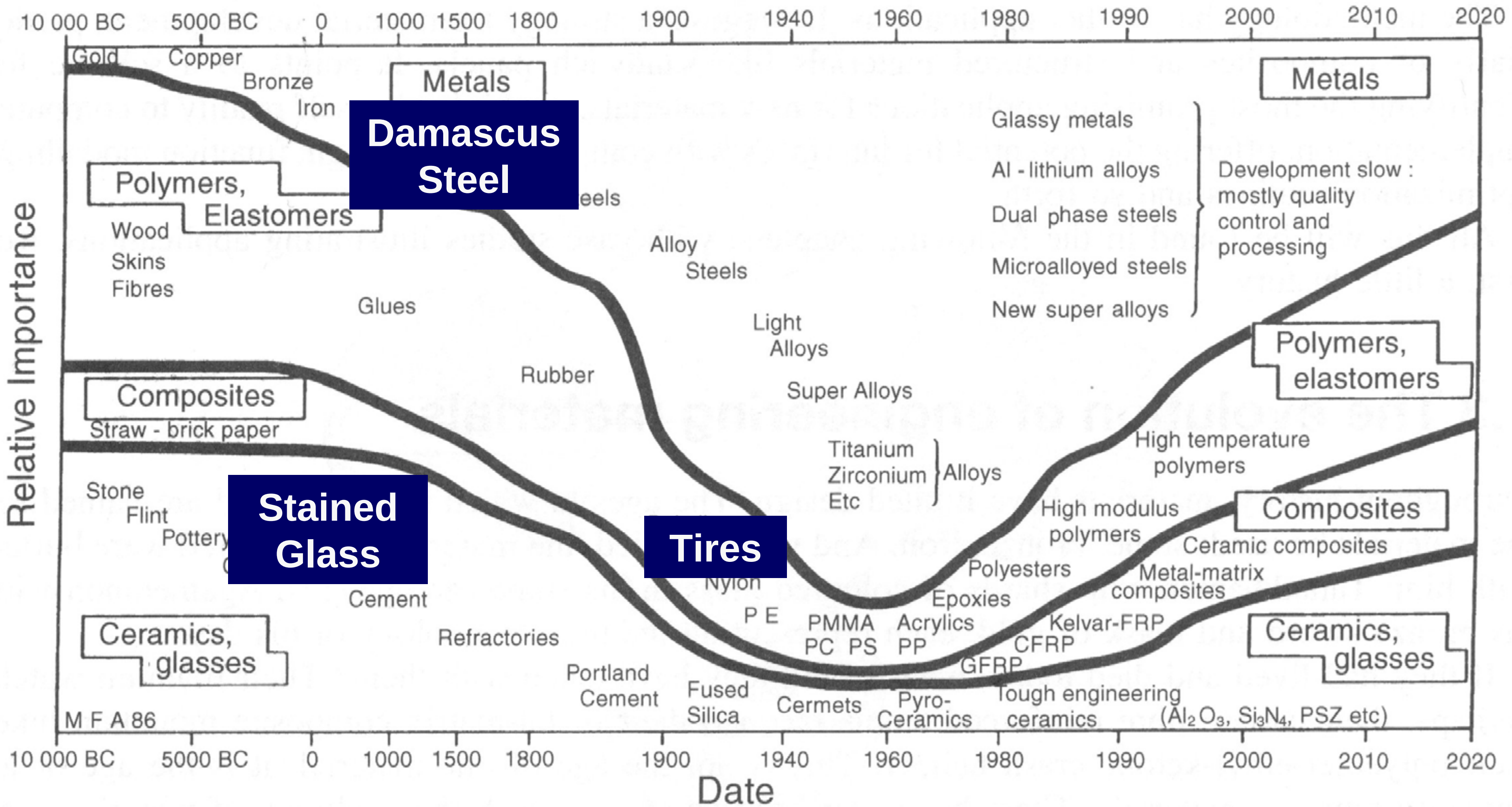
We will focus on three ideas encountered by the students during this assignment:

- The novelty of nanoparticles
- Nanotechnology in sport goods
- The nanotechnology-enabled space elevator

The novelty of nanomaterials

“Nanoparticles are new materials”

The novelty of nanomaterials



Materials Selection in Mechanical Design, M.F. Ashby, Butterworth Heinemann, 1999.

The novelty of nanomaterials

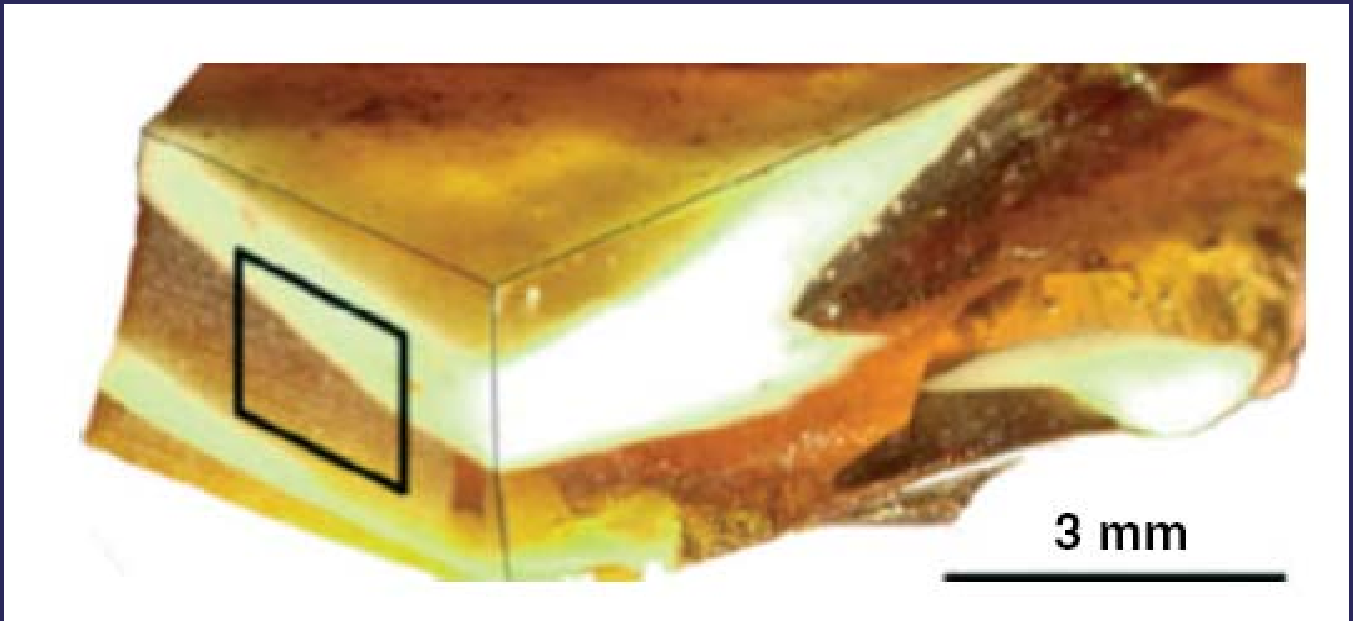
Illustration on Roman Glasses

Opalescence was caused by centuries of exposure to moisture.

A Roman maid prepares perfume. (University of Pennsylvania Museum)

http://www.archaeology.org/online/reviews/roman/index.html

The novelty of nanomaterials



This fragment of Roman Glass was found during an archaeological excavation at Bliesbruck–Reinheim (French–German border) . It was dated at **100–150 AD.**

This fragment was probably a piece of a **household plate** used to present fluids or solids, and was presented as a funeral gift.

P. Fredrickx, X-Ray Spectrom. 2004; ***33****: 326–333*

The novelty of nanomaterials

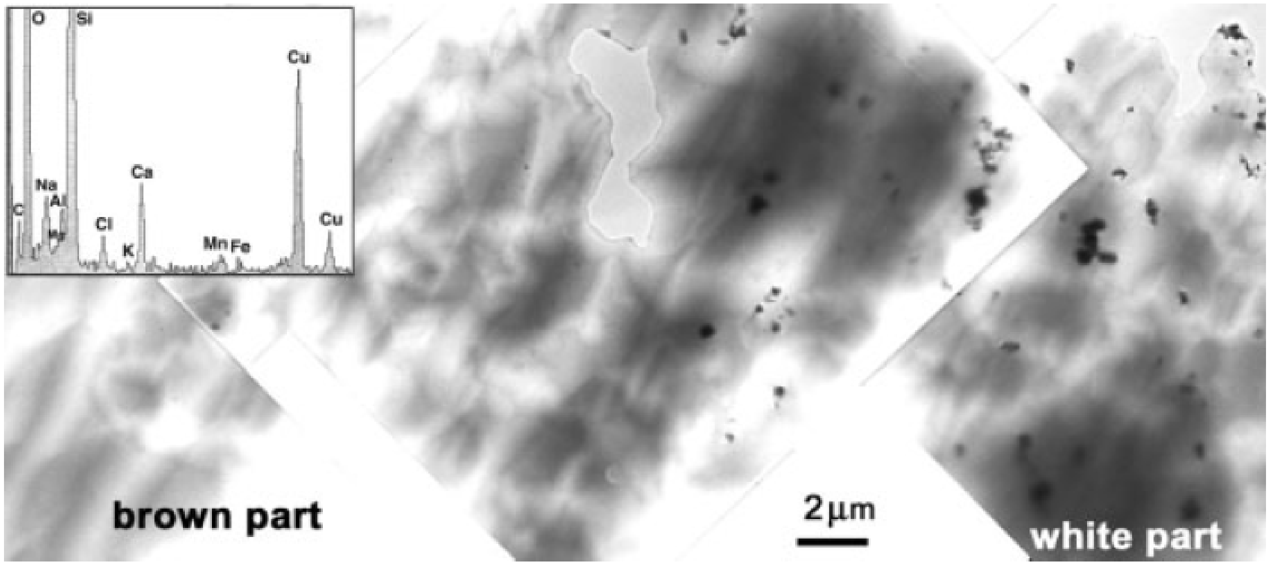
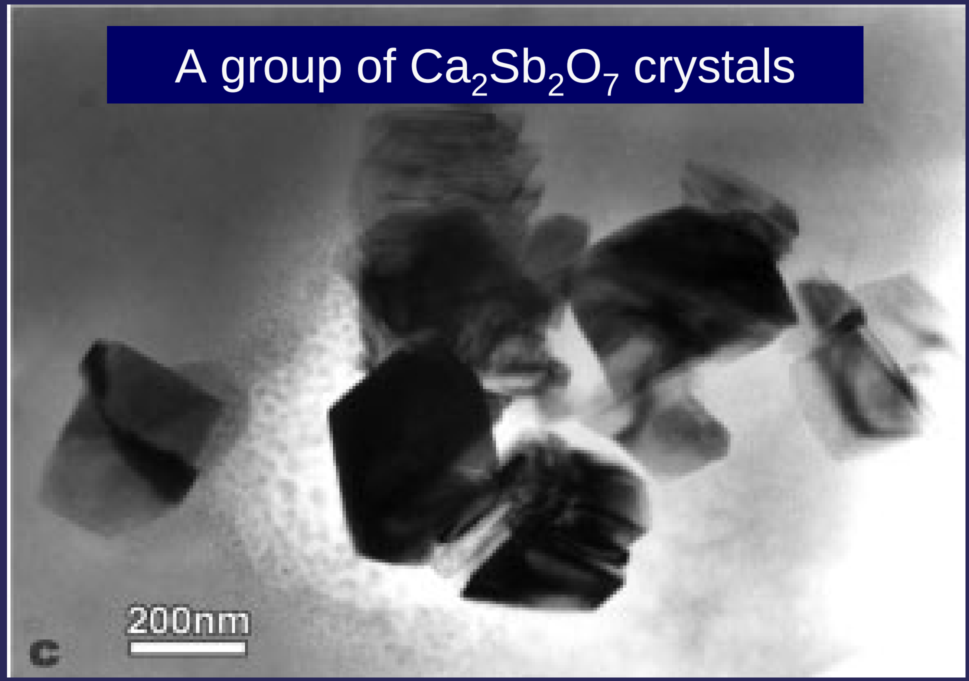


Figure 2. The interface between the brown coloured glass (left) and the white coloured glass (right). The white side obviously contains many small crystals, but the brown part seems empty at first sight. Inset: an EDX spectrum taken in the brown part with a broad beam. The average glass composition is shown, which is essentially the same as that found in the white glass matrix.

Since the basic glass composition of the white part and the brown part are very similar, it may be suggested that both colors were obtained starting from the same batch and that the white color was obtained starting from the brown color.

P. Fredrickx, X-Ray Spectrom. 2004; ***33****: 326–333*

The novelty of nanomaterials



A group of $Ca_2Sb_2O_7$ crystals

The Romans were using a mineral called ‘stibium’ Sb_2S_3 to give a gold-like color to silver or in cosmetics, according to their literature.

This mineral was certainly added to the brown glass batch. A reaction of Sb with the Ca in the glass matrix may have led to the observed $Ca_2Sb_2O_7$ nanocrystals.

Their **size** play a major role on the opaque white color of the material.

P. Fredrickx, X-Ray Spectrom. 2004; ***33****: 326–333*

The novelty of nanomaterials

Illustration on Damascus steel

Damascus steel is originally a steel used in Middle Eastern swordmaking from about 1100 to 1700 AD.

Damascus swords were described as extremely sharp and flexible, and were claimed to be able to cut through lesser quality European swords and even rock.

The exact technique used to create original Damascus steel is an on-going subject of investigation, and the name has seen a lot of abuse.

http://en.wikipedia.org/wiki/Image:DamaszenerKlinge.JPG

The novelty of nanomaterials

http://www.japanesechefsknife.com/KDSeries.html

http://www.hammersmithknives.com/images/raindrop.jpg

Three things are required to produce "true" Damascus steels:

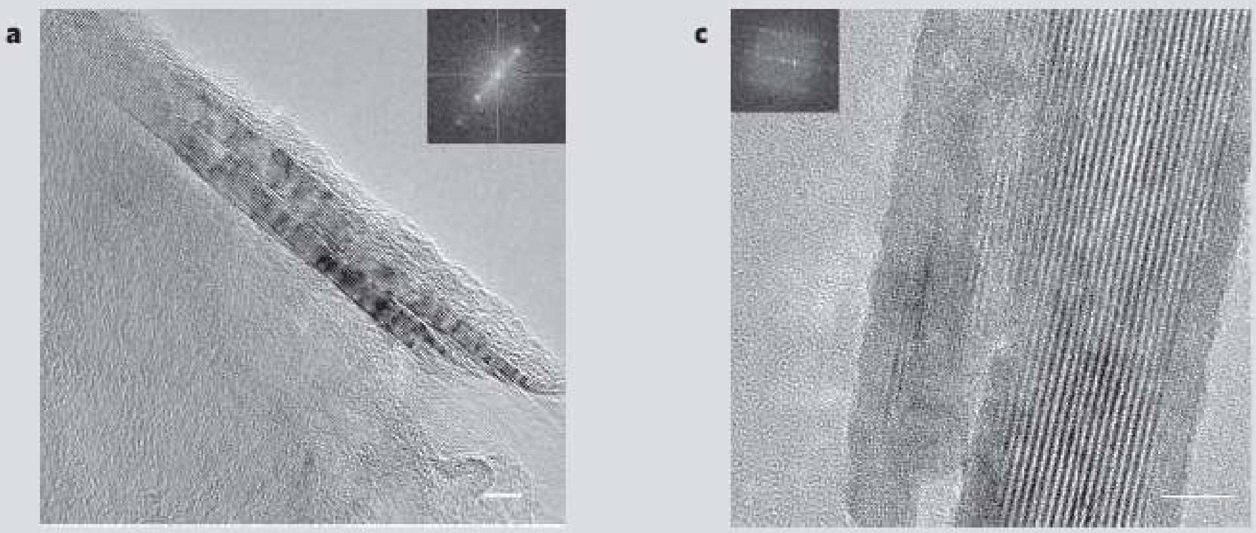
• The right combination of time/temperature firing during ingot making

• the proper thermomechanical sequencing during the forging process,

• and the right chemical composition (especially minor element additions, e.g. V).

http://www.tf.uni- kiel.de/matwis/ amat/ def_en/kap_5/advanced/t5_1_1.html

The novelty of nanomaterials



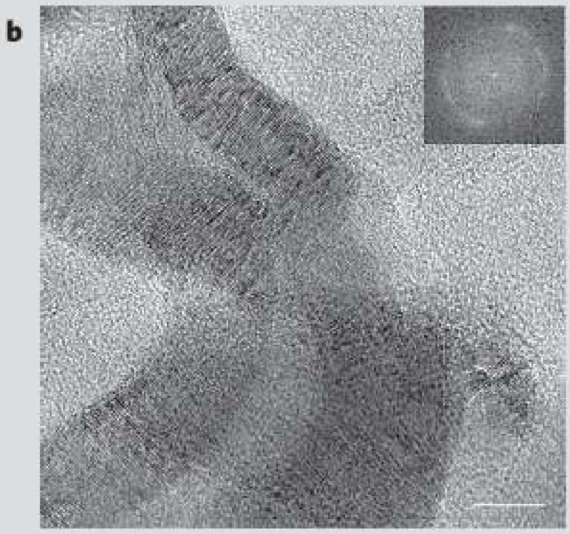


Figure 1 | High-resolution transmission electron microscopy images of carbon nanotubes in a genuine Damascus sabre after dissolution in hydrochloric acid. **a**, **b**, Multiwalled tubes with the characteristic layer distance $d \approx 0.34$ nm (ref. 12), as indicated by the Fourier transforms (see insets). Scale bars: 5 nm (**a**) and 10 nm (**b**). In **b**, the tubes are bent like a rope. **c**, Remnants of cementite nanowires encapsulated by carbon nanotubes, which prevent the wires from dissolving in acid. Scale bar, 5 nm. The fringe spacing of the wire is 0.635 nm, taken from the Fourier transform (inset), and is attributed to the (010) lattice planes of cementite.

M. Reibold et al., Nature, 444, 286.

The novelty of nanomaterials

Illustration on Tires

The novelty of nanomaterials

A pure latex (crosslinked hevea sap) is very soft, and has almost no existent abrasion resistance.

There is a need for adding at least 50% of its weight of a reinforcing agent that will give it the stiffness and the abrasion resistance required for holding the car to the road.

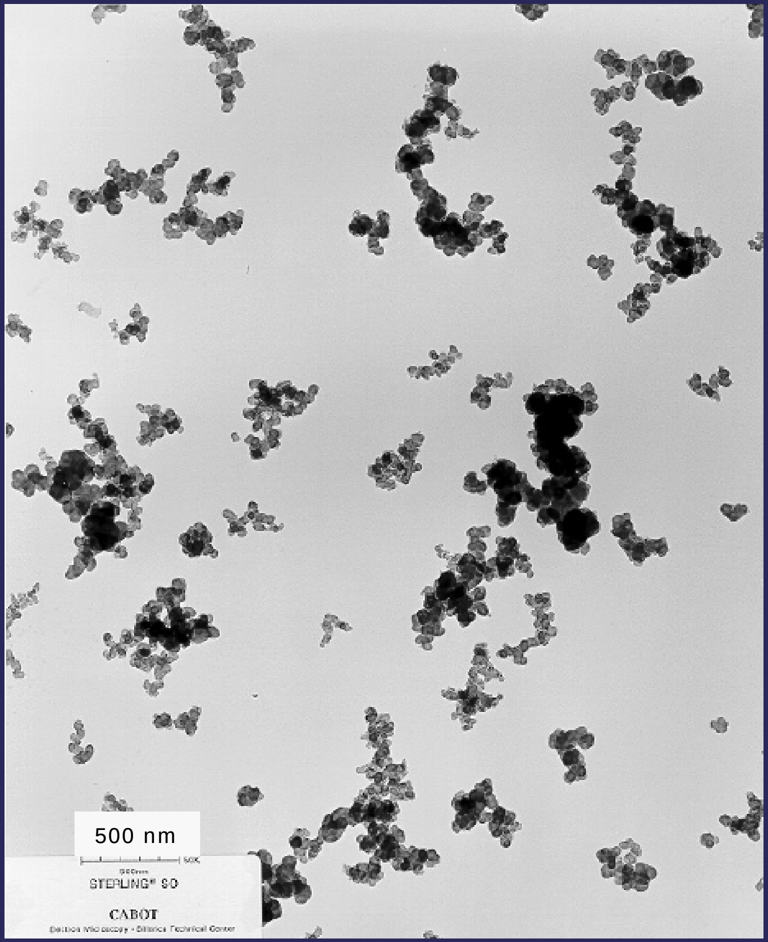
http://en.wikipedia.org/wiki/Image:Latex_dripping.JPG

The novelty of nanomaterials

Carbon blacks, a by-product of petroleum combustion, is added to rubber as a **reinforcing phase** in automobile tires.

Carbon blacks help also to conduct the heat away from the tread and belt area of the tire, and increase the tire life.

After 1915 carbon blacks became widely used as a reinforcing agent in the production of automobile tires

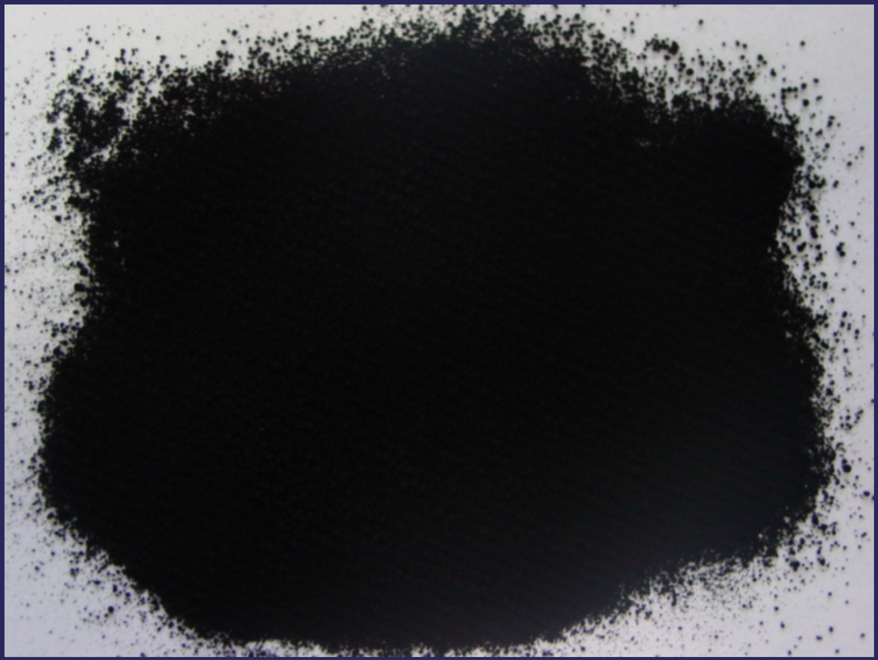


CARBON BLACKS

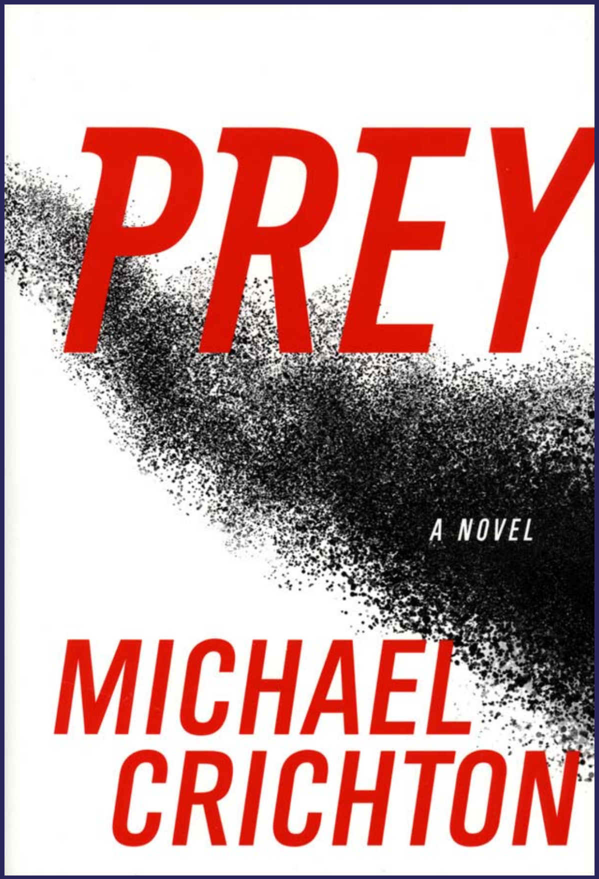
Cabot Corporation

http://en.wikipedia.org/wiki/Carbon_black

The novelty of nanomaterials

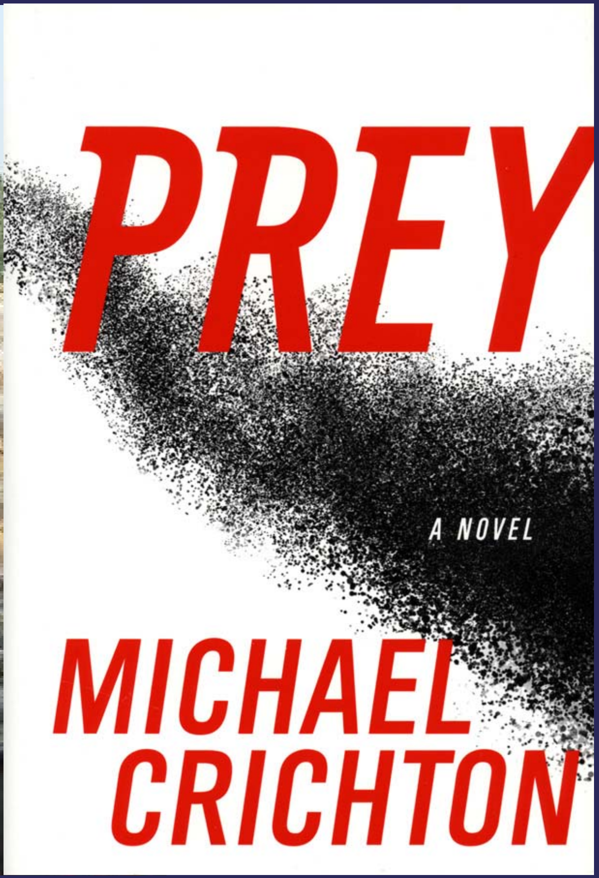


http://www.cusana.go.kr/upload/item/Dsc01457.jpg



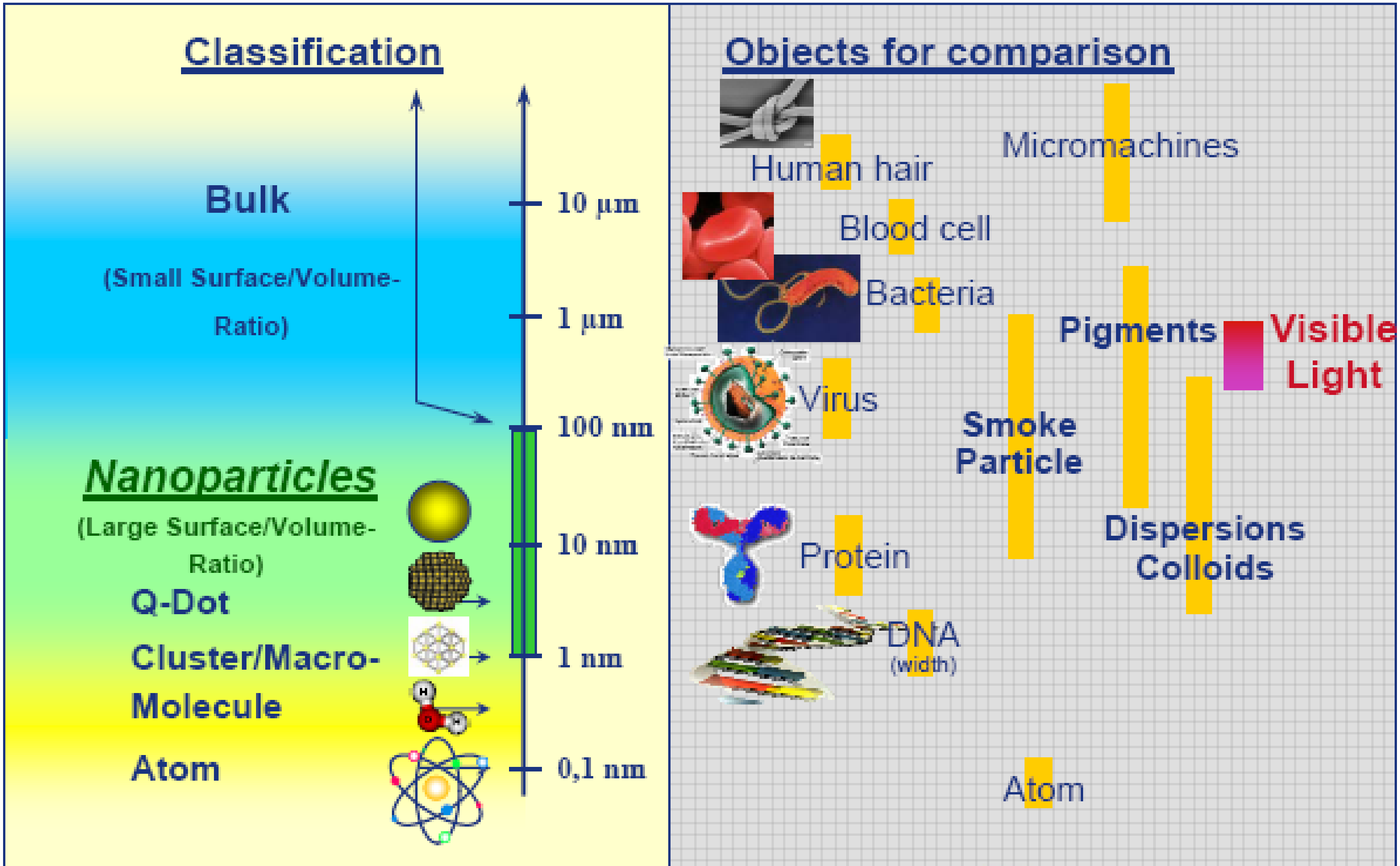
The novelty of nanomaterials

Although J. K. Wright, a Philadelphia ink maker, discovered the process of manufacturing carbon black in 1864, it was little used until improved technology in the twentieth century reduced the high cost of production.



http://img.alibaba.com/photo/10888540/Carbon_Black.jpg

The novelty of nanomaterials



Nanotechnology in Sport Goods

“CNT Baseball bats are so good!”

Nanotechnology in Sport Goods

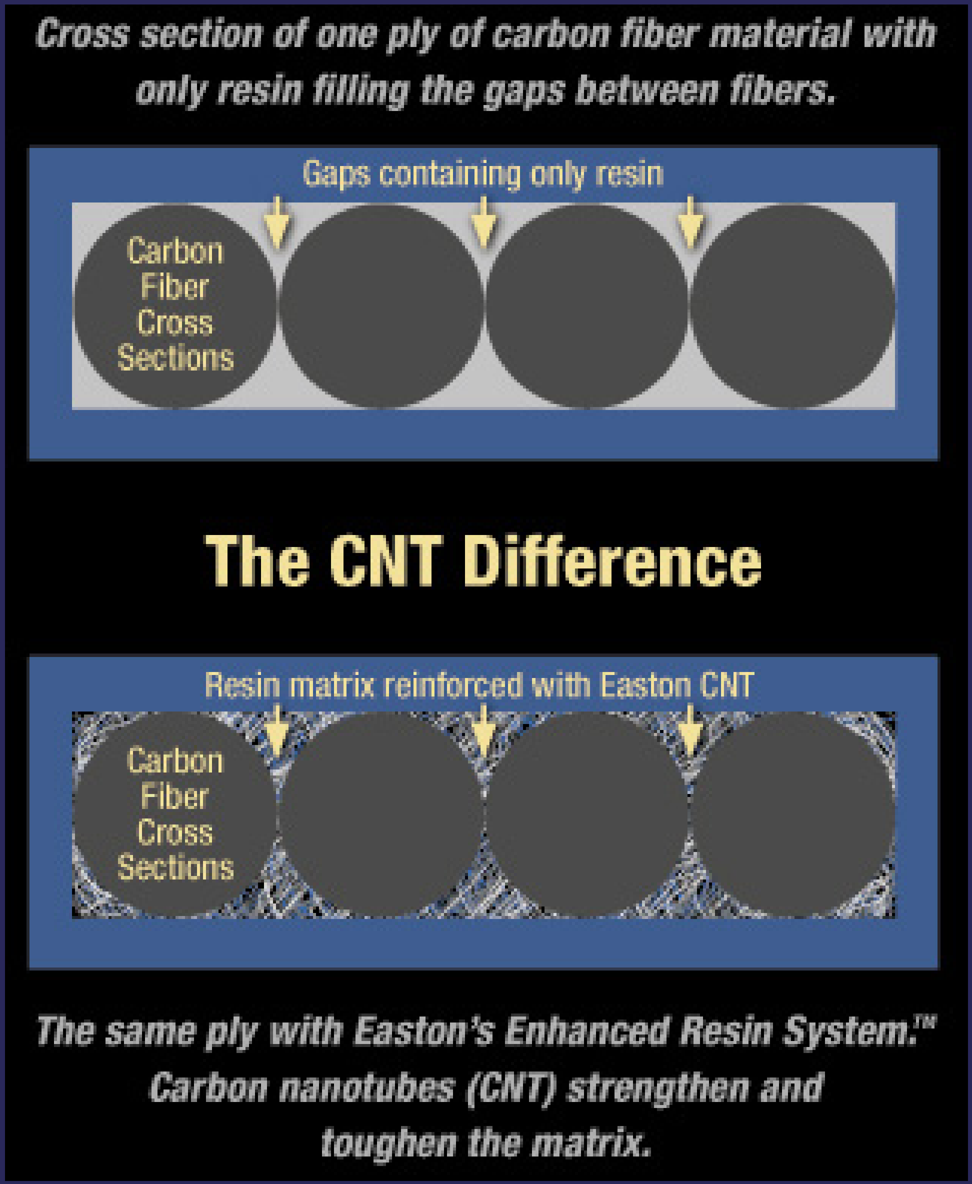
Nanotechnology in Sport Goods

Price : 289 USD
(from Overstock.com)

Weight : 850 grams

Currently 0.25 grams of purified SWNT cost 333 USD
Sigma-aldrich.com

Nanotechnology in Sport Goods



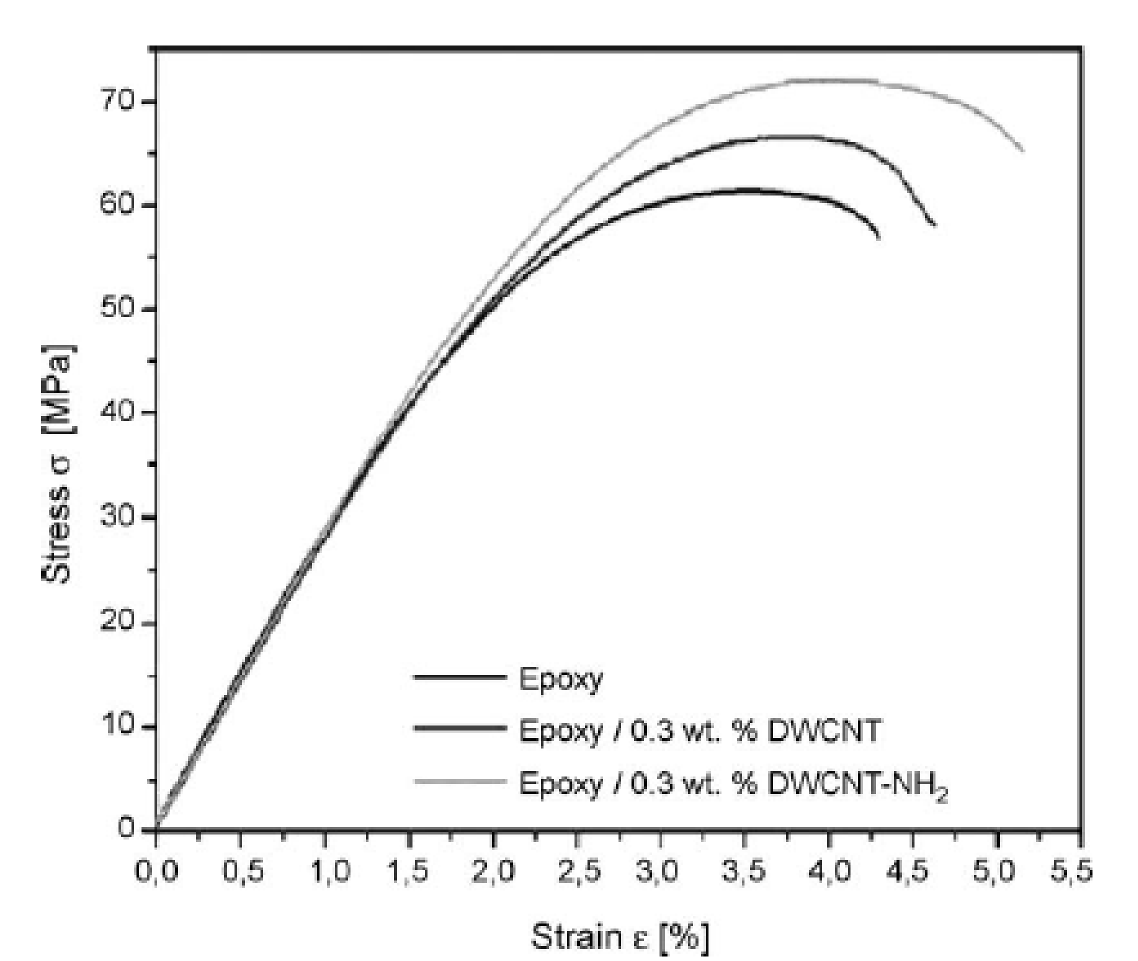
http://www.eastonbike.com/PRODUCTS/TECHNOLOGY/tech_cnt.html

In the best case scenario (all the price of a bat goes into buying the SWNTs), the Nanotubes only represent :

-0.03 wt% of the overall bat,

-and at the very best 0.1 wt% of the resin matrix.

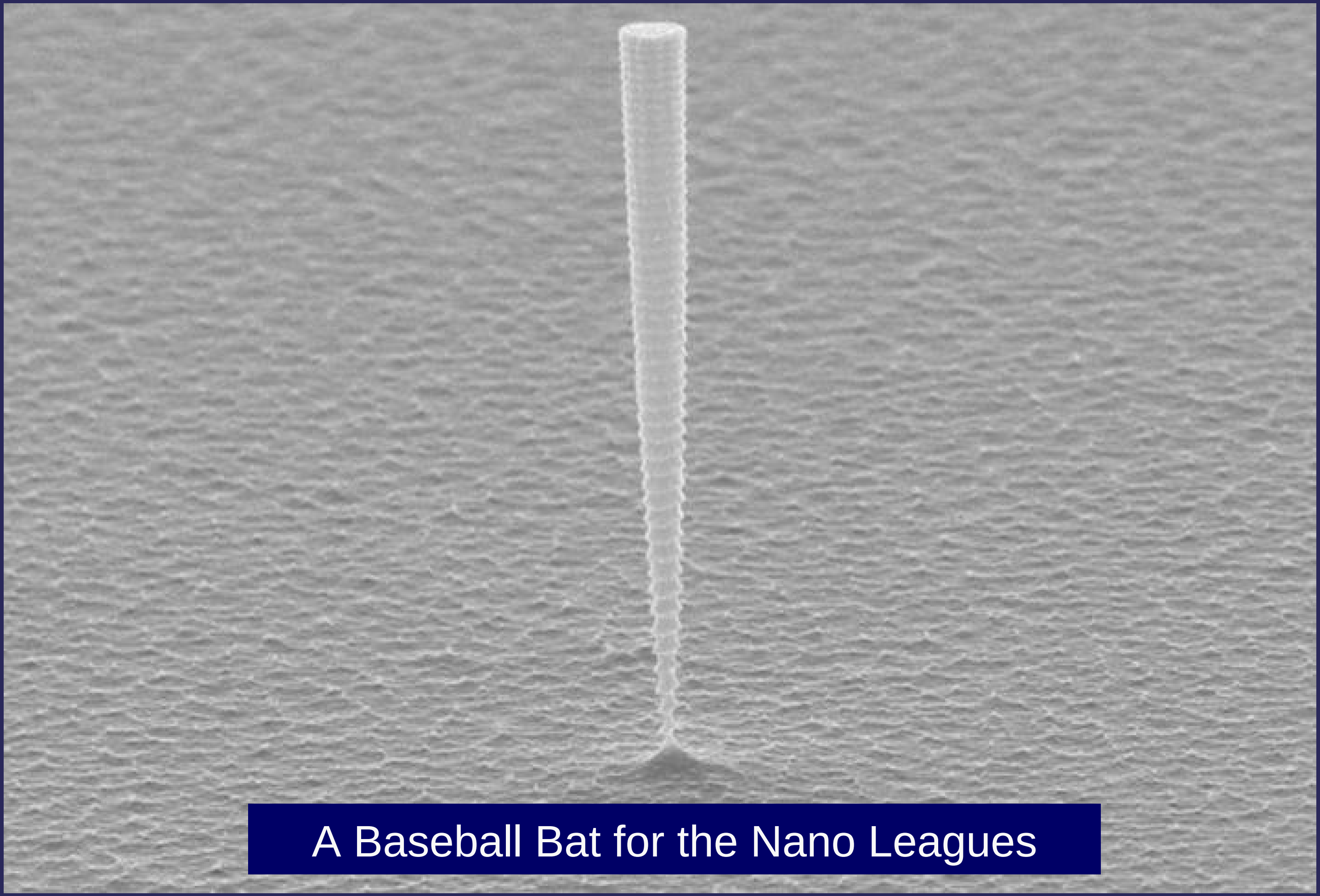
Nanotechnology in Sport Goods



Stress–strain curves of the neat epoxy and its nanocomposites containing 0.3 wt.% DWNTs and 0.3 wt.% DWCNT-NH2

Gojny et al., Compos. Sci. Technol. 65 (2005) 2300.

Nanotechnology in Sport Goods



Description:Tapered silicon pillar by Deep Reactive Ion Etching.
Magnification: (3"x4" image): 10,800x **Instrument**: Philips XL30 SEM
Submitted by: Keith Morton **Affiliation**: NSL, Princeton University

The nanotechnology-enabled space elevator

"In the applications of Carbon Nanotubes, there is:

- The space elevator, …."

The nanotechnology-enabled space elevator

David Smitherman of NASA has compiled plans for an elevator that could turn science fiction into reality.

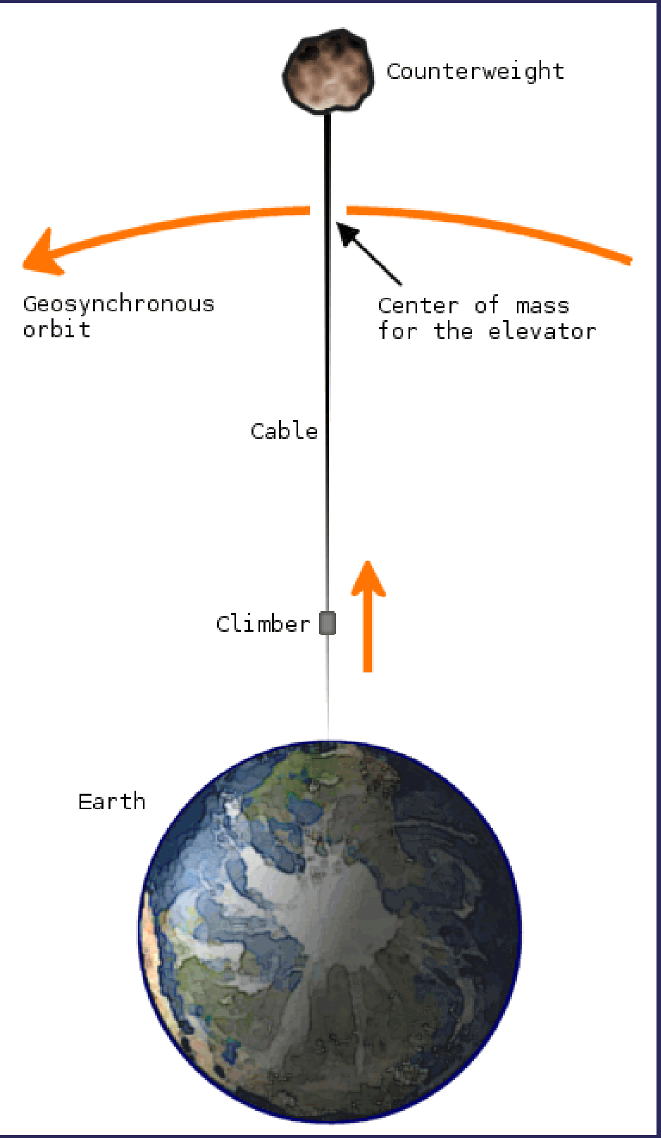
His publication, Space Elevators: An Advanced Earth-Space Infrastructure for the New Millenium, is based on findings from a space infrastructure conference held at the Marshall Space Flight Center in 1999.

http://science.nasa.gov/headlines/y2000/ast07sep_1.htm

The nanotechnology-enabled space elevator

A space elevator is essentially a long cable extending from our planet's surface into space with its center of mass at geostationary Earth orbit (GEO), 35,786 km in altitude.

Electromagnetic vehicles traveling along the cable could serve as a mass transportation system for moving people, payloads, and power between Earth and space.



http://en.wikipedia.org/wiki/Image:Space_elevator_structural_diagram.png

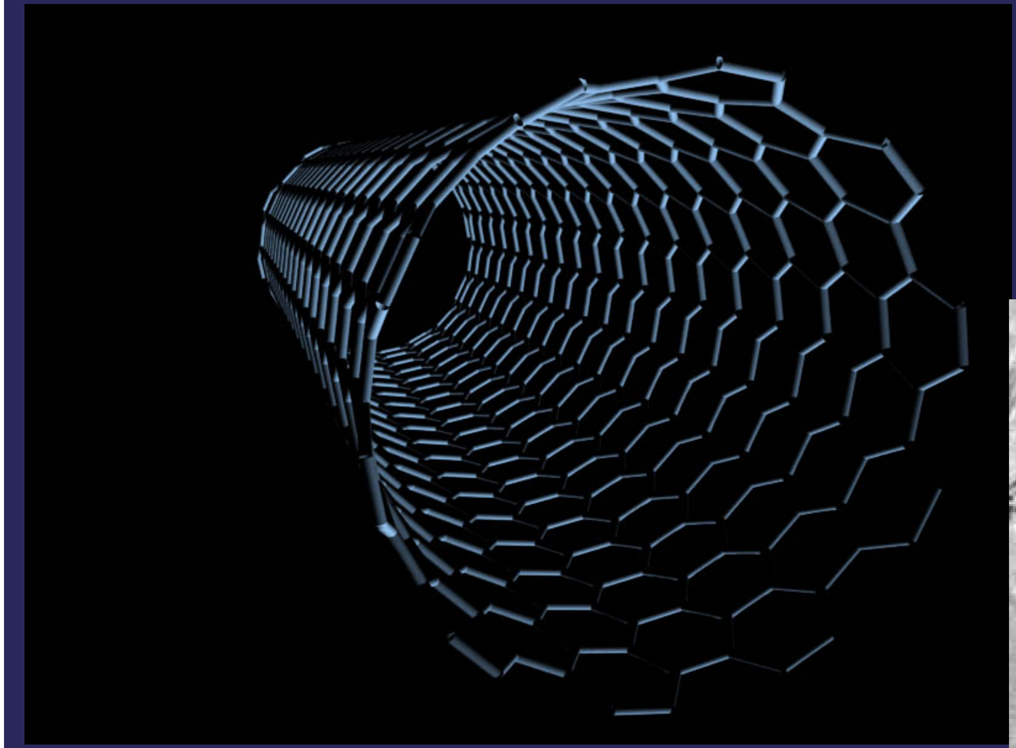
The nanotechnology-enabled space elevator

The cable must be made of a material with a huge tensile strength over density ratio (the stress a material can be subjected to without breaking, divided by its density).

Material	Target B.C. Edwards' calculations	Steel	Carbon or Glass Fiber	SWNT in epoxy [2000]
Tensile strength [GPa]	130 (Safety factor :2)	2	20	52

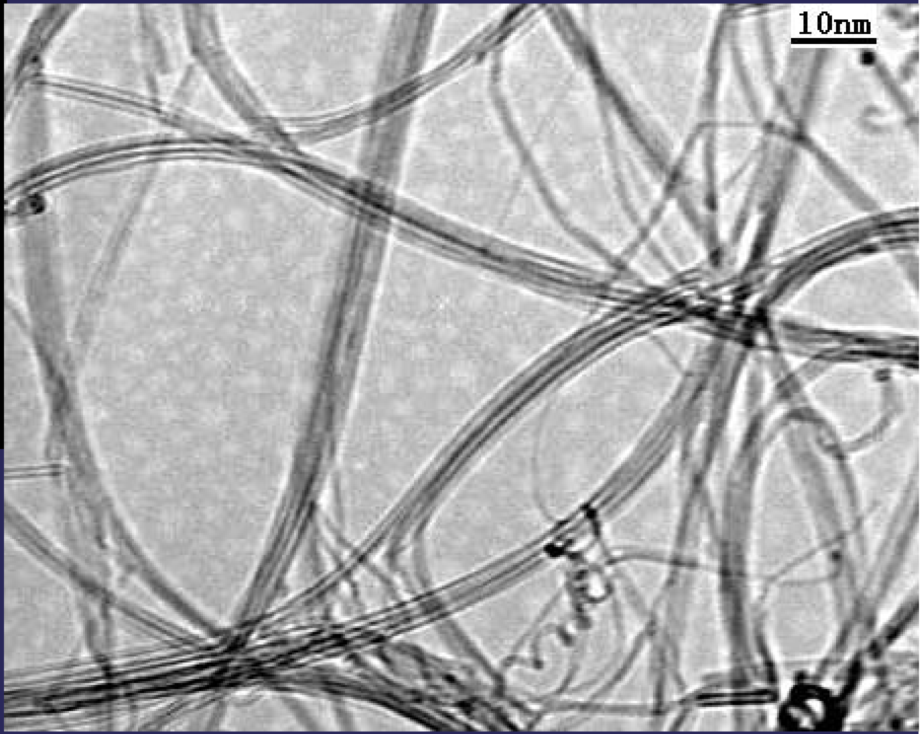
A space elevator can be made relatively economically feasible if a cable of required properties can be mass-produced at a reasonable price. The technology to spin regular VdW-bonded yarn from carbon nanotubes is just in its infancy: the first success in spinning a long yarn (meter long), as opposed to pieces of only a few centimeters, has been reported in March 2004.

The nanotechnology-enabled space elevator



Simulation of the armchair single wall nanotube.
The SWNT has a diameter ~ 1.4 nm. The simulated fragment is 4.5 nm long.

A Transmission Electron Micrograph of affordable Carbon Nanotubes



http://theory.physics.lehigh.edu

http://www.cheaptubesinc.com/images/swnt90.gif

The nanotechnology-enabled space elevator

Available online at www.sciencedirect.com

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Acta Materialia 55 (2007) 5269–5279

Acta MATERIALIA

www.elsevier.com/locate/actamat

The role of defects in the design of space elevator cable: From nanotube to megatube

Nicola M. Pugno *

Department of Structural Engineering and Geotechnics, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

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Abstract

Researchers are claiming that the feasibility of space elevator cable is now realistic, thanks to carbon nanotube technology, proposing its realization within a decade. However, the current view of basing the design of the megacable on the theoretical strength of a single carbon nanotube is naïve, as has recently been emphasized. In this paper 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. Nonasymptotic 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 megacable are reported, suggesting that it would need a taper ratio (for uniform stress) of about two orders of magnitude larger than currently proposed.

Keywords: Fracture; Scaling; Nanocomposite; Stress rupture; Toughness

THANK YOU!