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INFN - Laboratori Nazionali di Frascati

THE MAGIC WORLD OF NANOTECHNOLOGY

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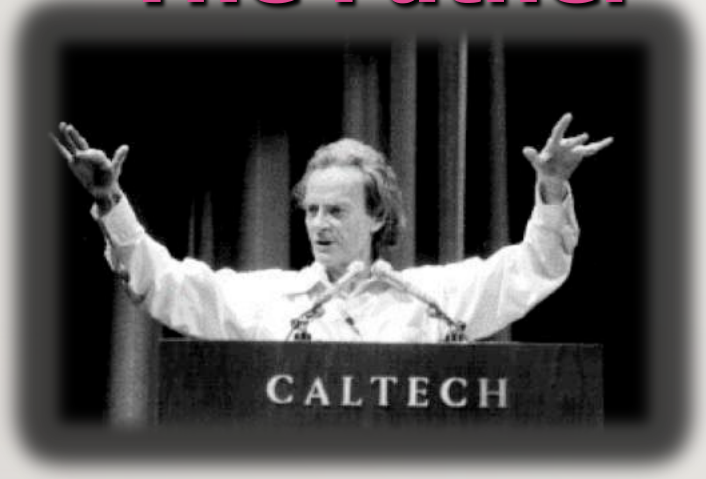
INSPYRE 2018 - INFN, FRASCATI NATIONAL LABORATORIES.

"The Father" of Nanotechnology



Richard Feynman's talk (*Nobel '65, in Physics*), December 29th 1959 at the annual meeting of the American Physical Society at the California Institute of Technology (Caltech) **"There's Plenty of Room at the Bottom", it** was first published in Caltech Engineering and Science, Volume 23:5, February 1960, pp 22-36.

to describe a field, in which little has been done, but in which an enormous amount can be done in principle.

This field is not quite the same as the others in that it will not tell us much of fundamental physics (in the sense of, "What are the strange particles?") but it is more like solid-state physics in the sense that it might tell us much of great interest about the strange phenomena that occur in complex situations.

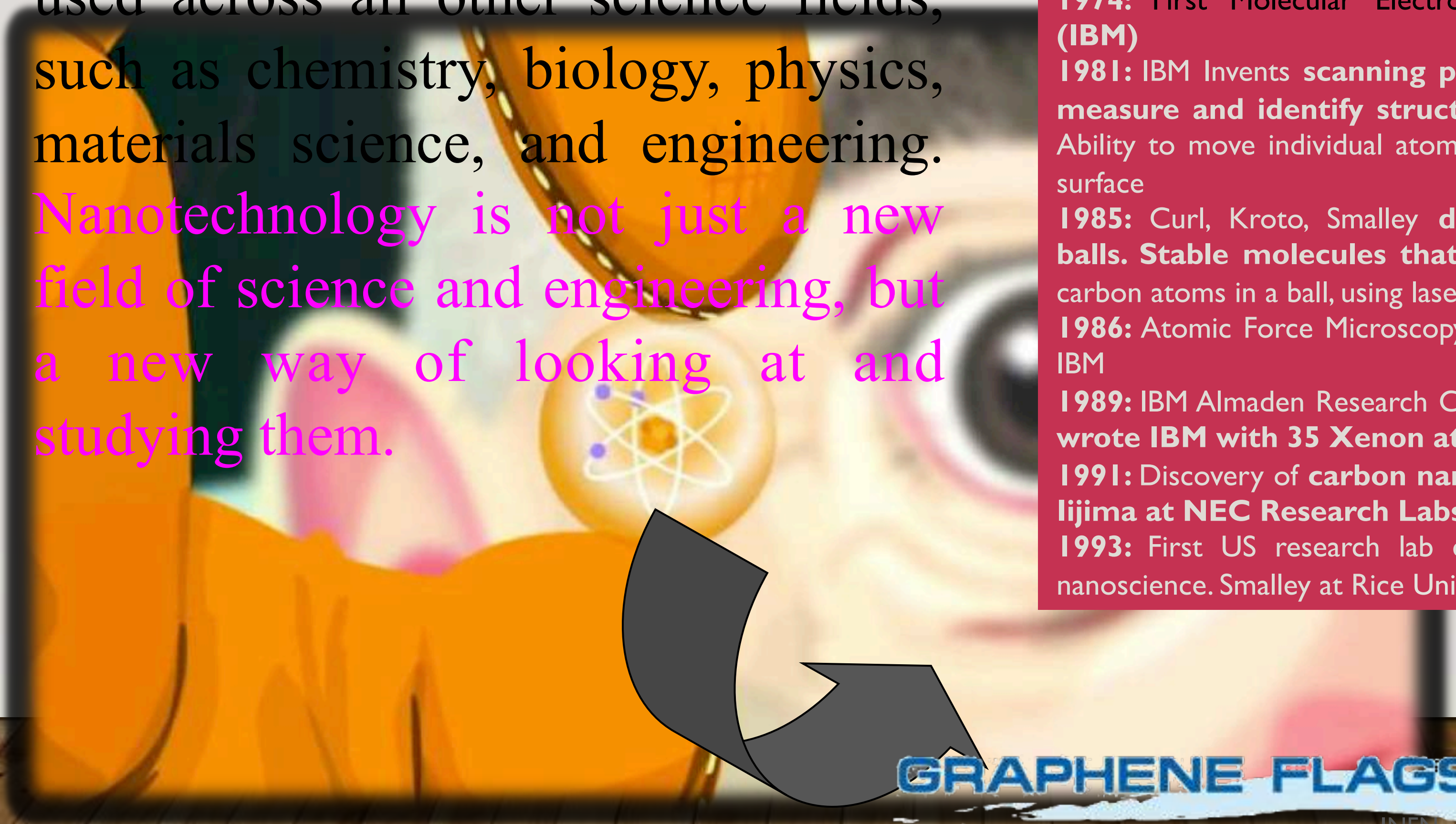
Furthermore, a point that is most important is that it would hav an enormous number of technical applications."

What is nanotechnolgy ?

<u>Nanoscience and nanotechnology</u> are the study and application of extremely small systems and can be used across all other science fields, such as chemistry, biology, physics, materials science, and engineering. Nanotechnology is not just a new field of science and engineering, but a new way of looking at and studying them.

<u>MILESTONES OF NANO-RESEARCH</u>:

1959: R. Feynman described a process in which scientists would be able to manipulate and control individual atoms and molecules
1974: First Molecular Electronic Device patent **(IBM)**
1981: IBM Invents **scanning probe microscope: measure and identify structures** at nano-scale. Ability to move individual atoms and molecules on surface
1985: Curl, Kroto, Smalley **discovered buckey balls. Stable molecules that** contain 50 to 500 carbon atoms in a ball, using laser vaporized carbon.
1986: Atomic Force Microscopy (AFM) Invented at IBM
1989: IBM Almaden Research Center : **D.M. Eigler wrote IBM with 35 Xenon atoms.**
1991: Discovery of **carbon nanotubes by Sumin Iijima at NEC Research Labs**
1993: First US research lab devoted entirely to nanoscience. Smalley at Rice University.



The first example of nanotechnology!?

The Lycurgus Cup
(IV sec. A.D.
at British Museum)

This extraordinary cup is the unique complete example of a very special type of glass, known as dichroic, which changes colour when held up to the light.

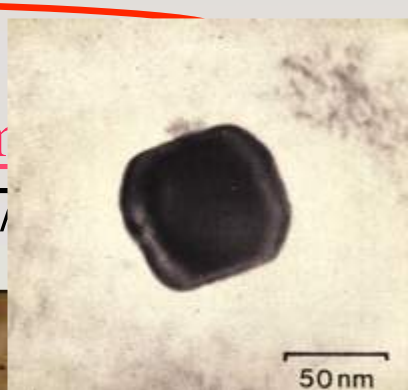
Riflection, Green Colour,

Trasmissin, Red Colour

Using transmission electron m

The particles are only about 7 across, an

embedded in the glass.



The relevance of the nanoscale

The bulk properties of materials often change dramatically when reduced to nanoscale dimensions.

This has to do with two main reasons:

Firstly, nanomaterials have a relatively **larger surface area** when compared to the same mass of material in bulk form.

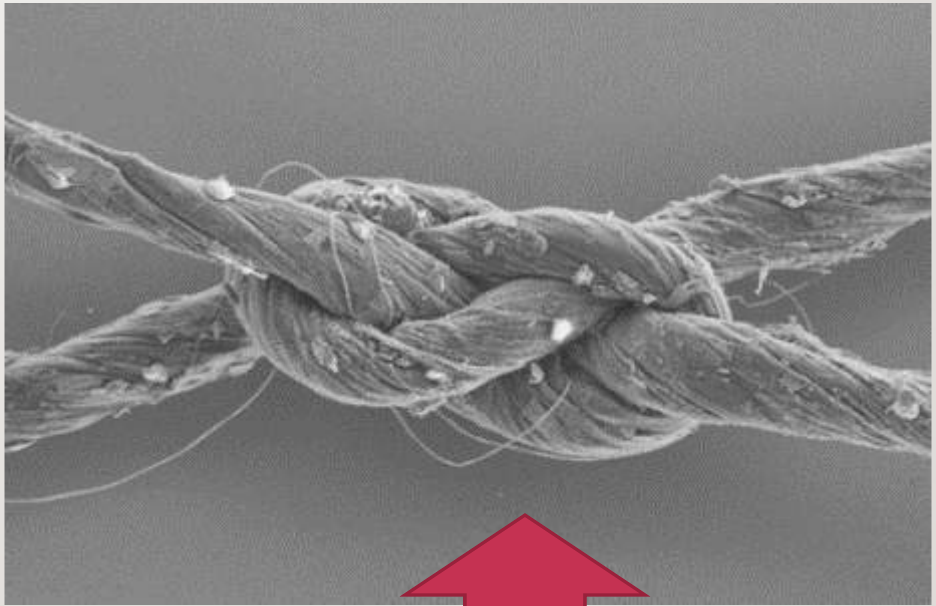
This can make materials more chemically reactive (in some cases materials that are inert in their larger form are reactive when produced in their nanoscale form), and affect their strength or electrical properties.

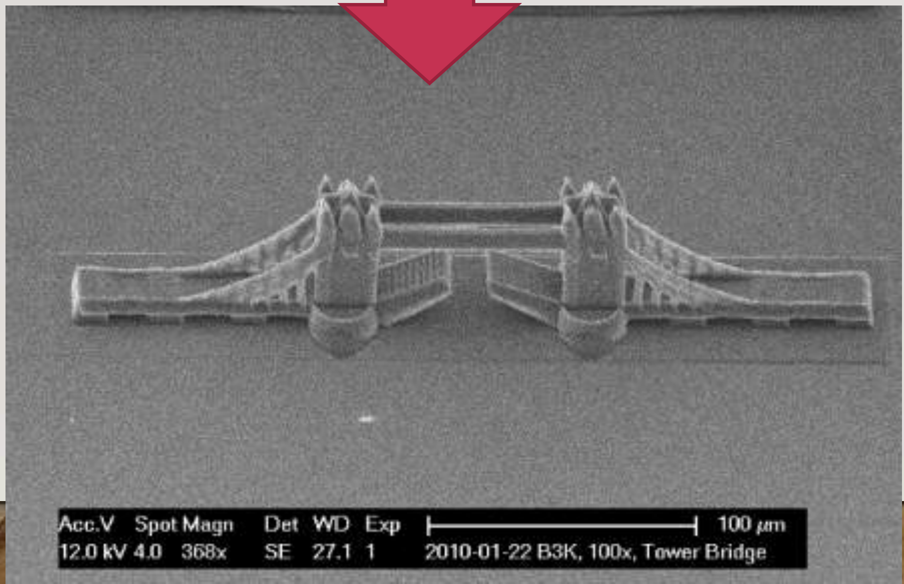
Secondly, **quantum effects** can begin to dominate the behavior of matter at the nanoscale – particularly at the lower end – affecting the optical, electrical and magnetic behavior of materials.

Materials can be produced that are nanoscale in one dimension (for example, very thin surface coatings), in two dimensions (for example, nanowires and nanotubes) or in all three dimensions (for example, nanoparticles and quantum dots).

GRAPHENE FLAGSHIP

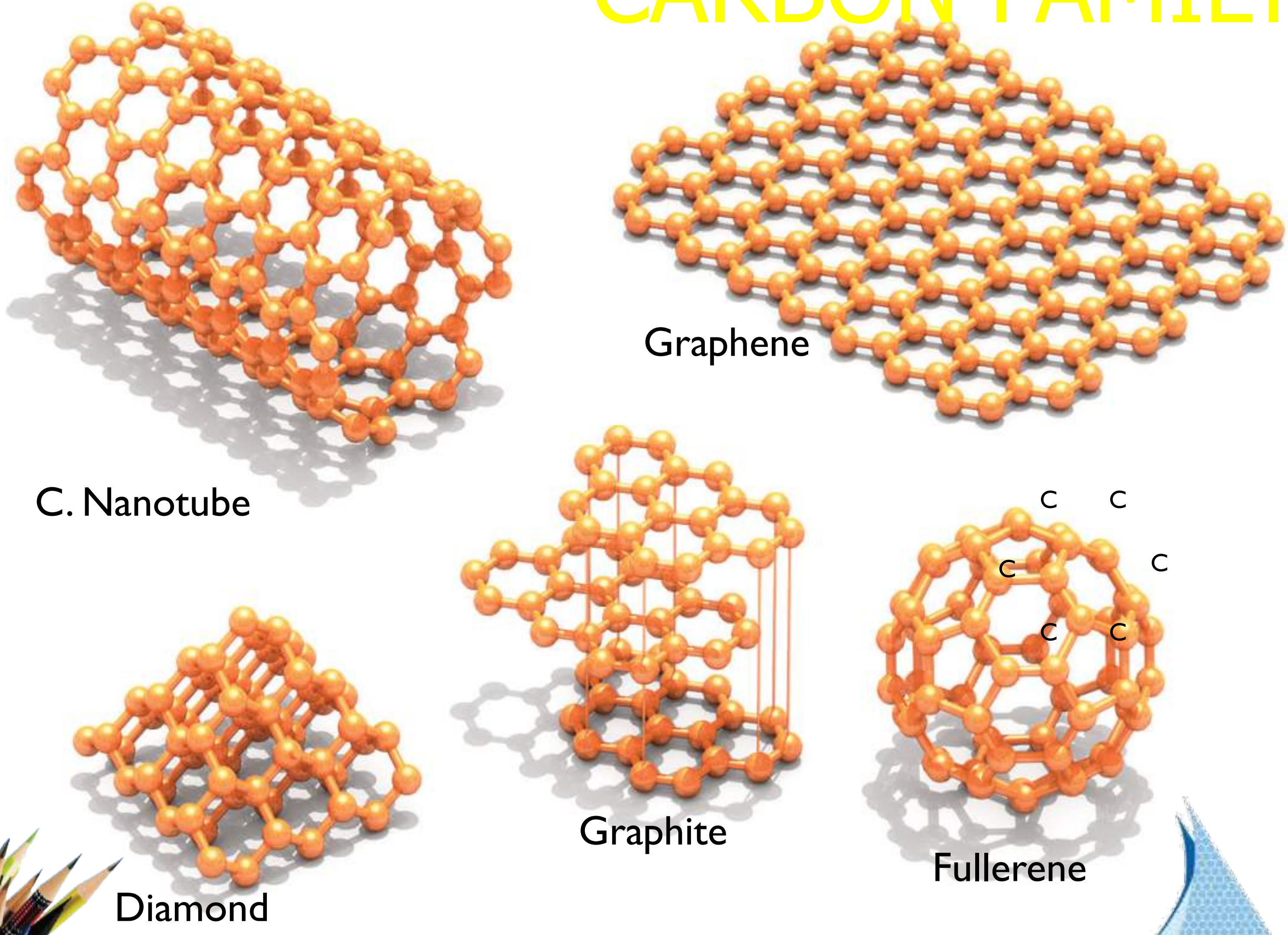
"Top – Down Bottom- Up"





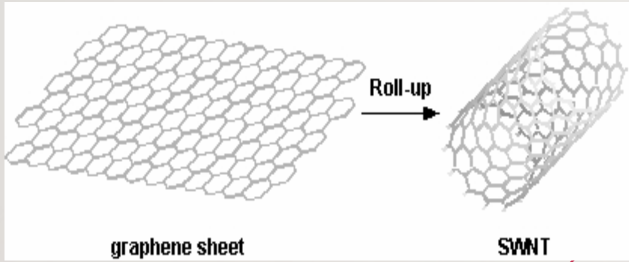
GRAPHENE FLAGSHIP

CARBON FAMILY

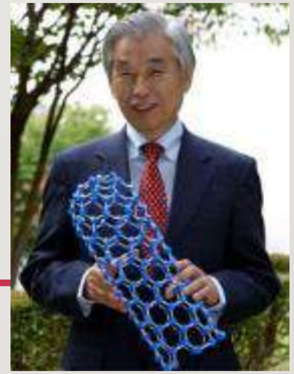


GRAPHENE FLAGSHIP

WHY CARBON NANOTUBES?

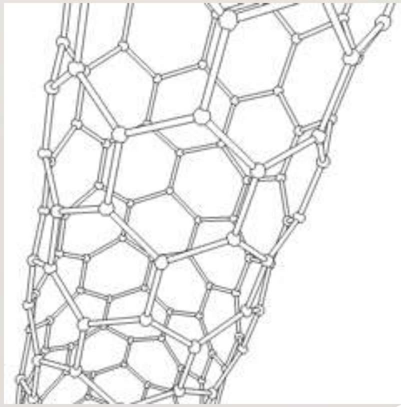


High aspect ratio (L/Φ) ⇒1D structure



High Young 's Modulus (around 1 Tpa)

High Tensile Strenght (90 - 150 Gpa).

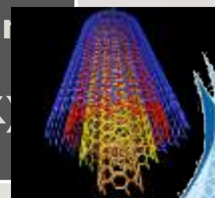


High current density (~ 10^9 A/cm^2) more than cupper!

No Joule effect!!!

It is 50000 times smaller than an human hair

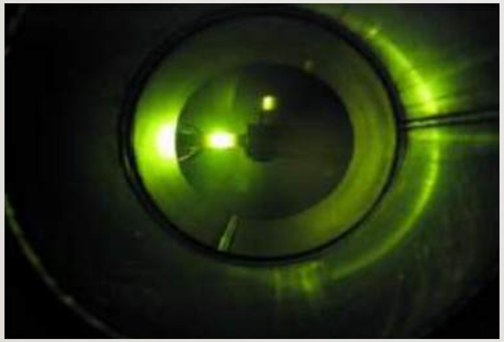
High thermal conductivity at room temperature (1800-6000W/m*K)



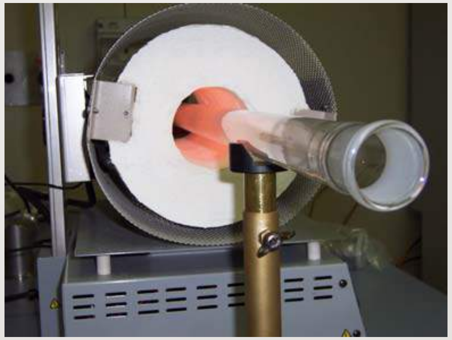
GRAPHENE FLAGSHIP

Frascati

Carbon Nanotubes

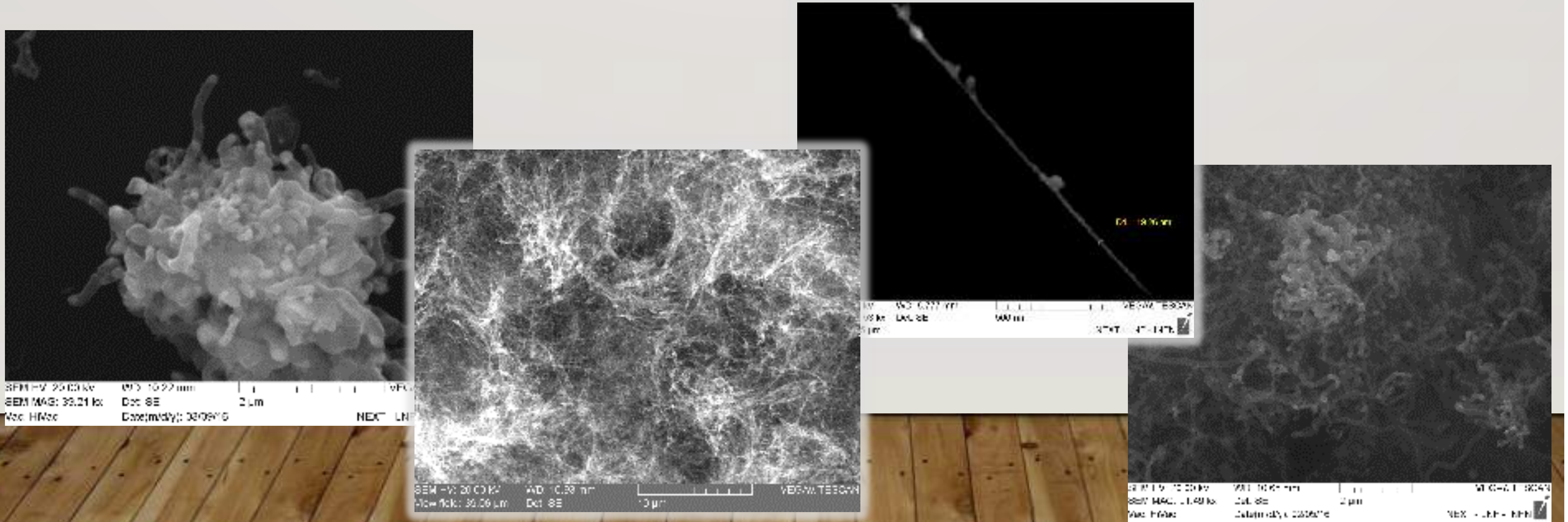


Arc Discharge



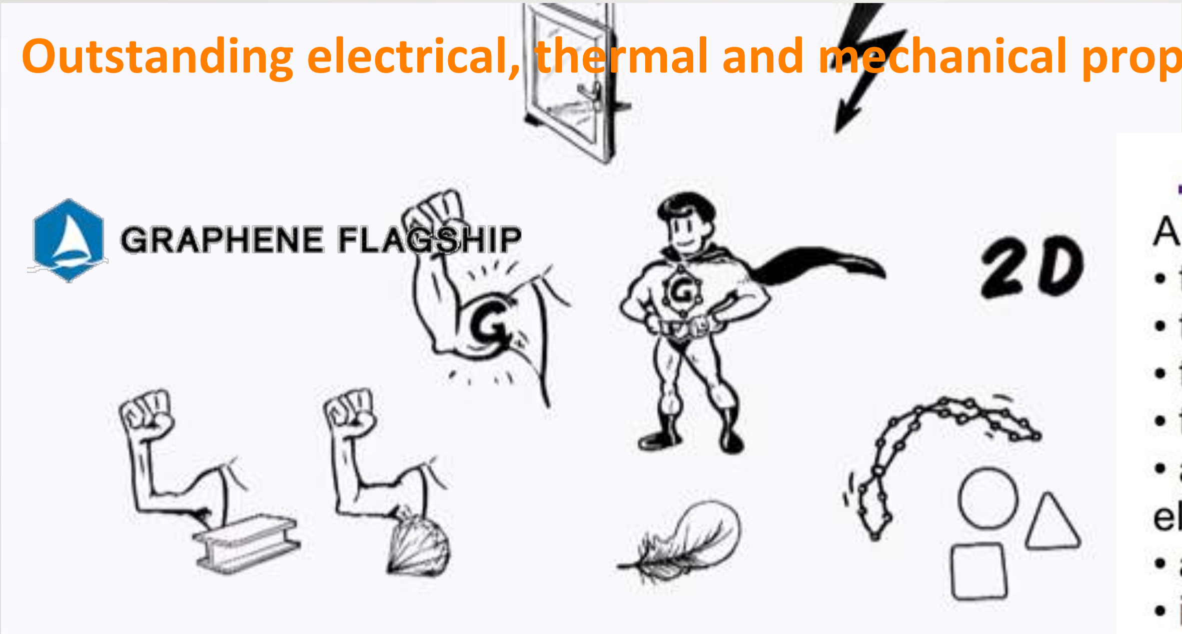
Chemical Vapour Deposition (CVD)

Hot filament - CVD



Graphene

Outstanding electrical, thermal and mechanical properties:



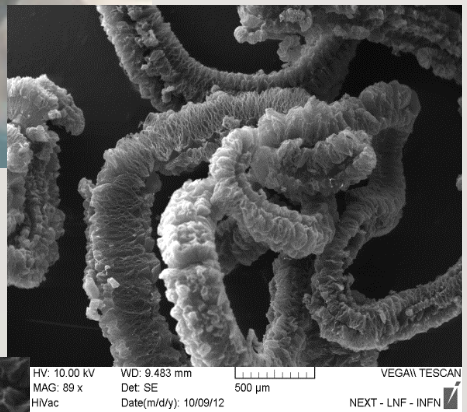
Graphene

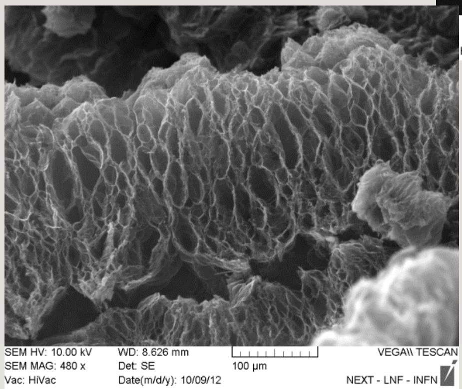
A single layer of graphene is
- the world's thinnest material
- the world's strongest material
- the world's stiffest material
- the world's best conductor of heat
- an excellent conductor of electricity (~Cu)
- almost transparent
- impermeable to helium

	Cu	CNT	GNR
Max current density [A/cm^2]	10^7	$> 10^9$	$>10^8$
Thermal conductivity [kW/mK]	0.38	$1.7 \div 5.8$	$3.0 \div 5.0$
Mean free path at 20 °C [nm]	40	$10^3 \div 25\text{x}10^3$	$\sim 10^3$
Temperature coefficient of the resistance [$10^{-3}K^{-1}$]	4	$-1.37 \div 1.1$	- 1.47
Tensile strength [GPa]	0.22	$11 \div 63$	--

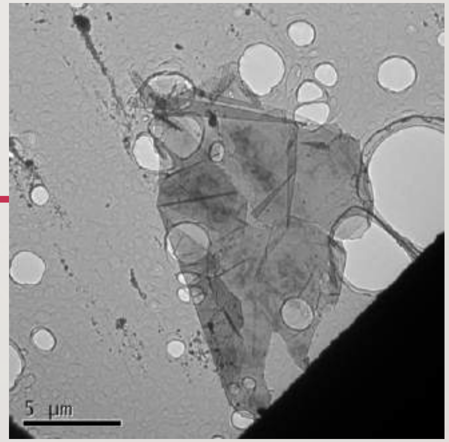
GRAPHENE FLAGSHIP

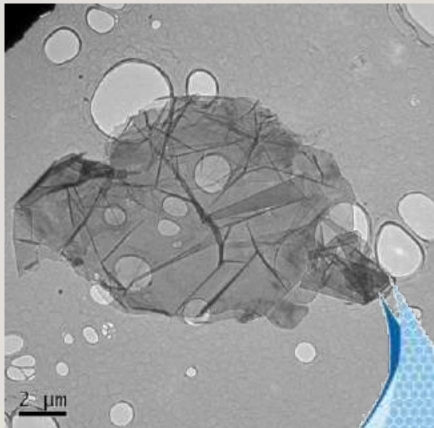
Graphene NanoPlates





Ultrasonic Bath



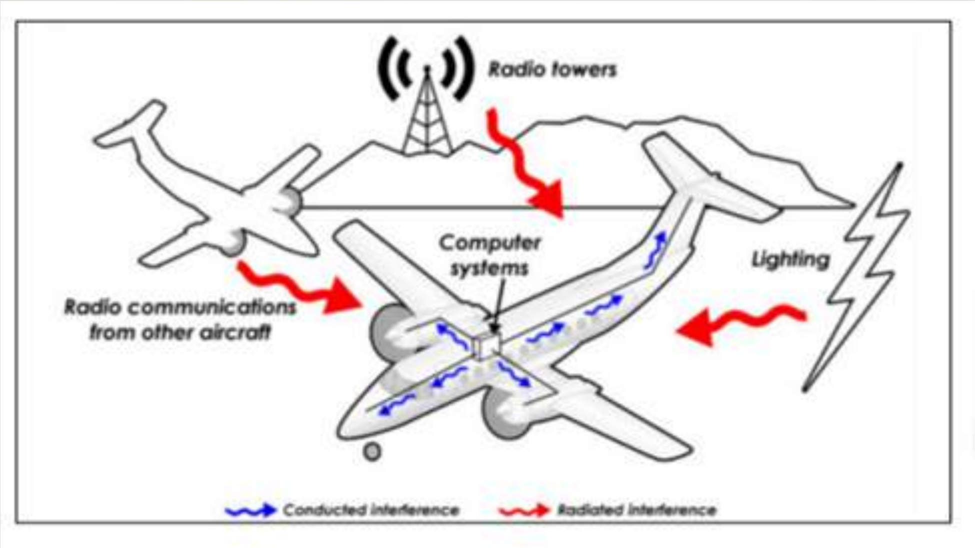


GRAPHENE FLAGSHIP

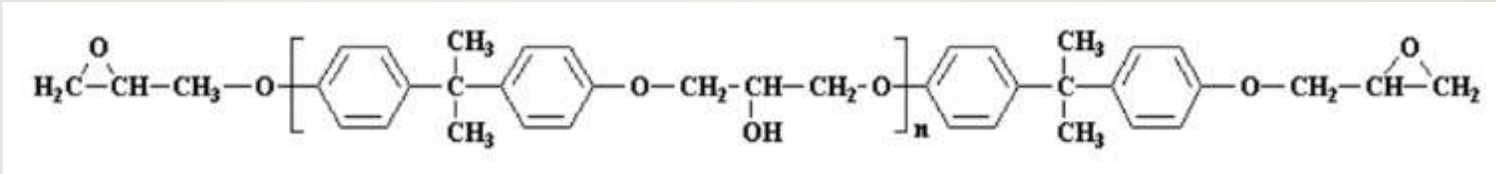
APPLICATIONS

- AEROSPACE
- ELECTRONICS
- ENVIRONMENT
- MEDICINE AND BIOLOGY

ELECTROMAGNETIC SHIELDING

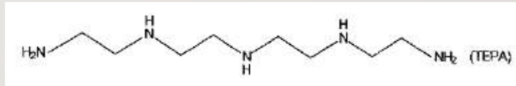


Epoxy Resin

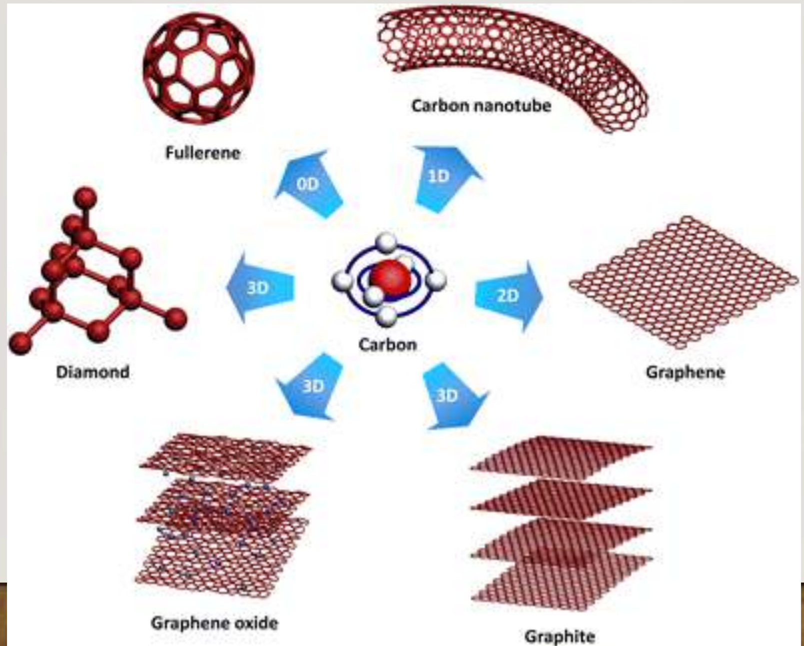


+

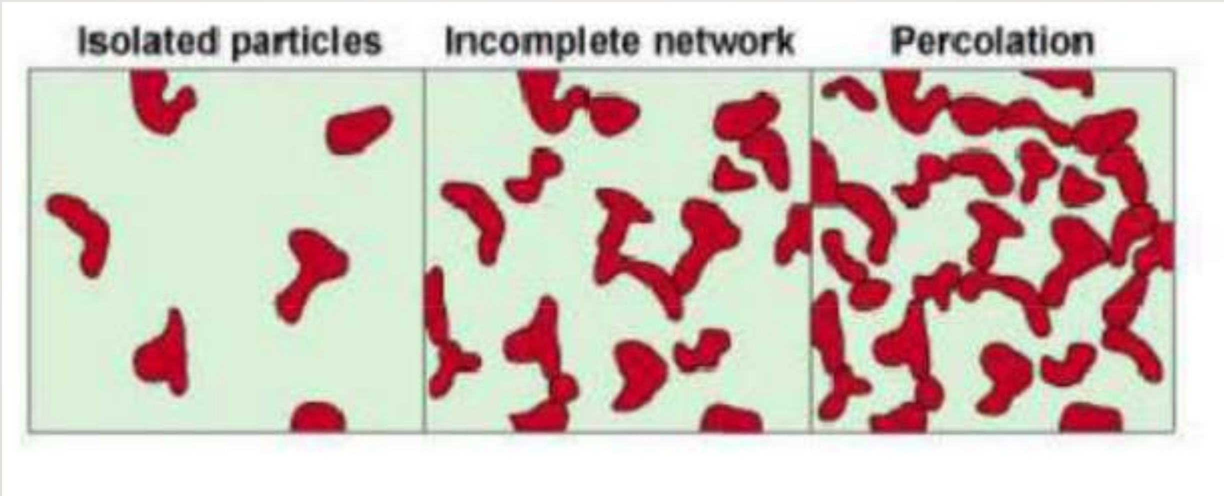
Curing agent

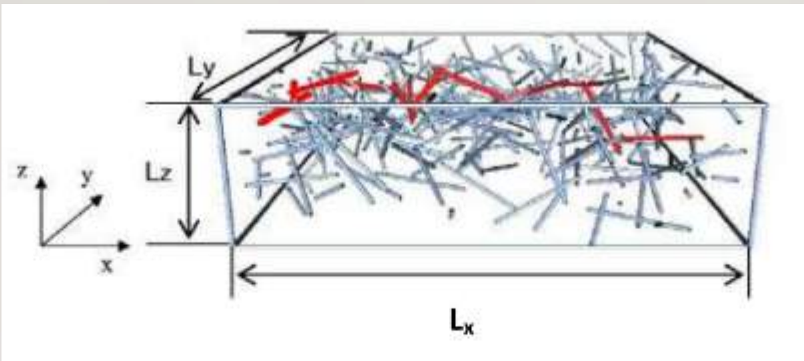


Carbon Nanostructures



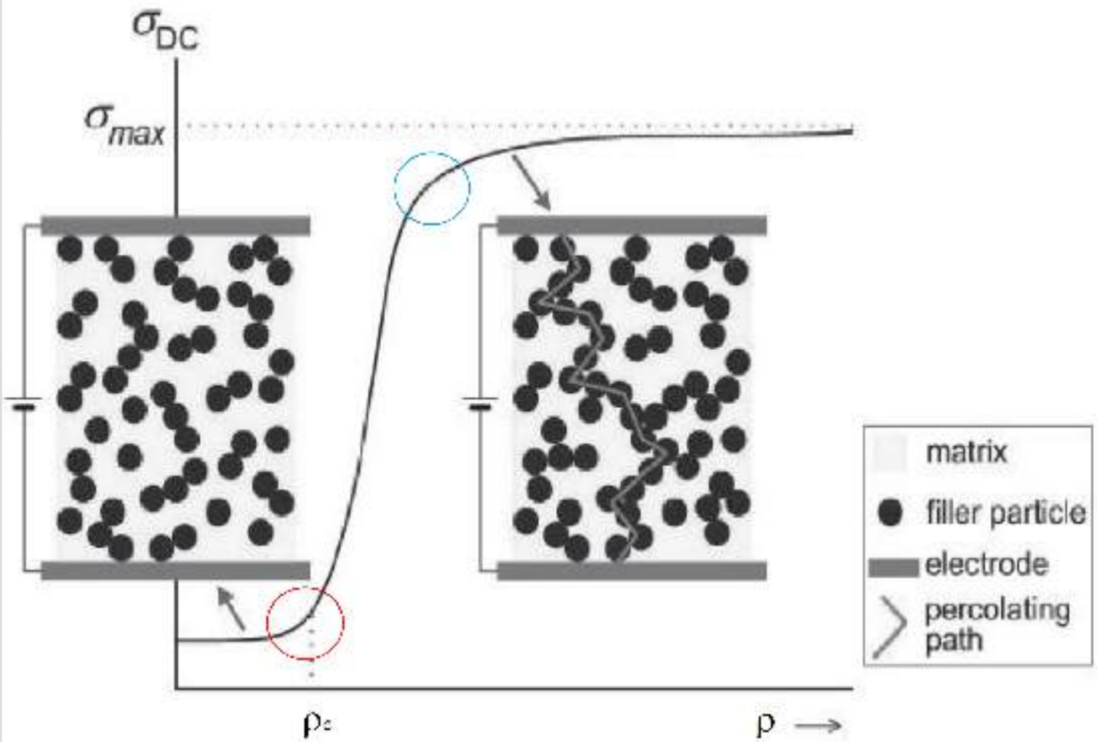
- SWCNT
- MWCNT
- Graphene Nanoplates (GNP)
- Thick Graphite (TG)
- Exfoliated Graphite (EG)



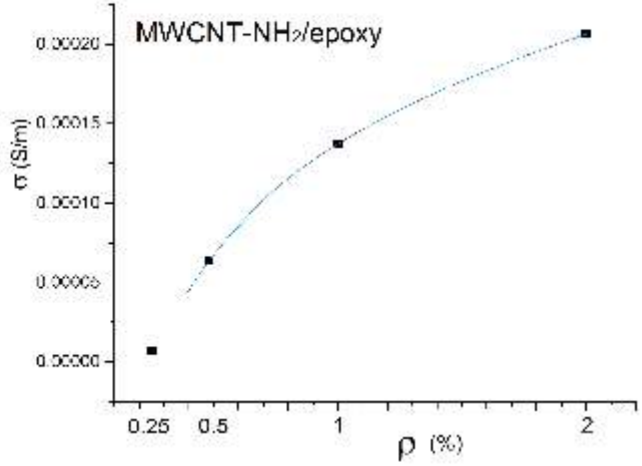


<u>Above percolation threshold</u>:

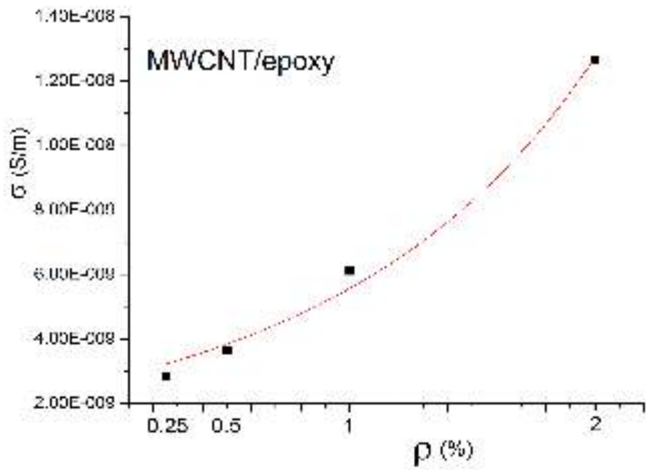
- Network
- Conductivity starts to occour



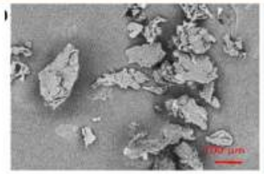
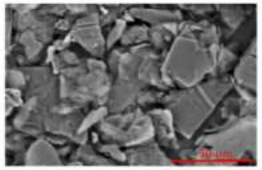
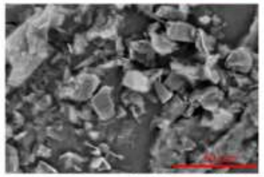
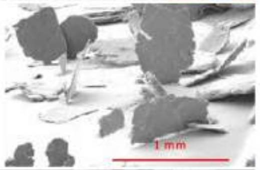
σ_{DC}
σ_{max}
matrix
filler particle
electrode
percolating path
ρ_c
$\rho \rightarrow$

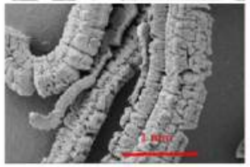
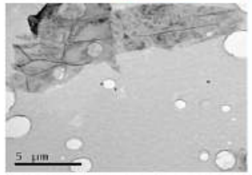
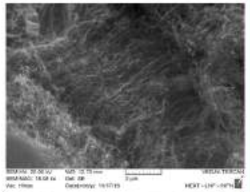
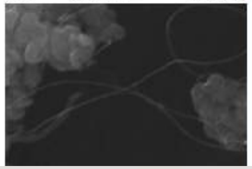


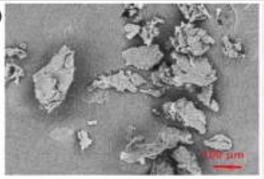
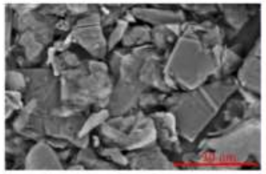
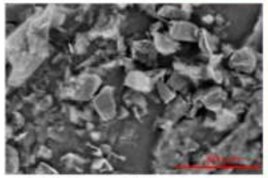
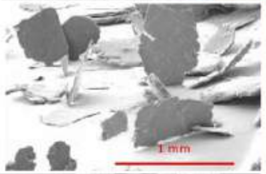
MWCNT-NH2/epoxy
0.00020
0.00015
0.00010
0.00005
0.00000
σ (S/m)
0.25
0.5
1
2
ρ (%)

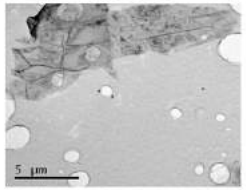
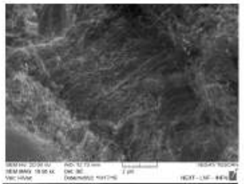
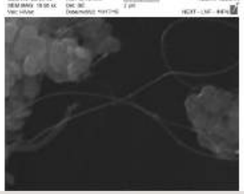


MWCNT/epoxy
1.40E-008
1.20E-008
1.00E-008
8.00E-009
6.00E-009
4.00E-009
2.00E-009
σ (S/m)
0.25
0.5
1
2
ρ (%)

Picture	Nanostructures	Threshold
	CG – Coarse graphite	100-200 μm
	MG – Medium graphite	44-75 μm
	FG – Fine graphite	15-44 μm
	NG – Natural graphite	500-700 μm

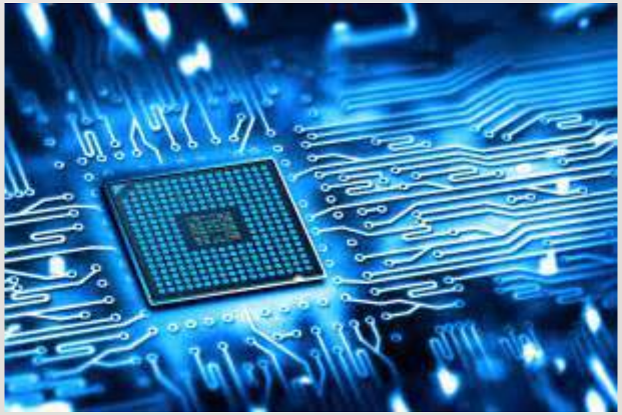
Picture	Nanostructures	Threshold
	EG – Exfoliated graphite	300-500 μm
	GNP – Graphene Nano Platelets	5-10 μm
	MWCNT – Multi Wall Carbon Nanotubes	2-10 μm
	MWCNT- NH_2 - Multi Wall Carbon Nanotubes, funzionalizzati con gruppi amminici	2-10 μm

Picture	Nanostructures	Threshold
	6 (CG)	26-36%
	6 (MG)	27-37%
	6 (FG)	28-38%
	10 (NG)	18-26%

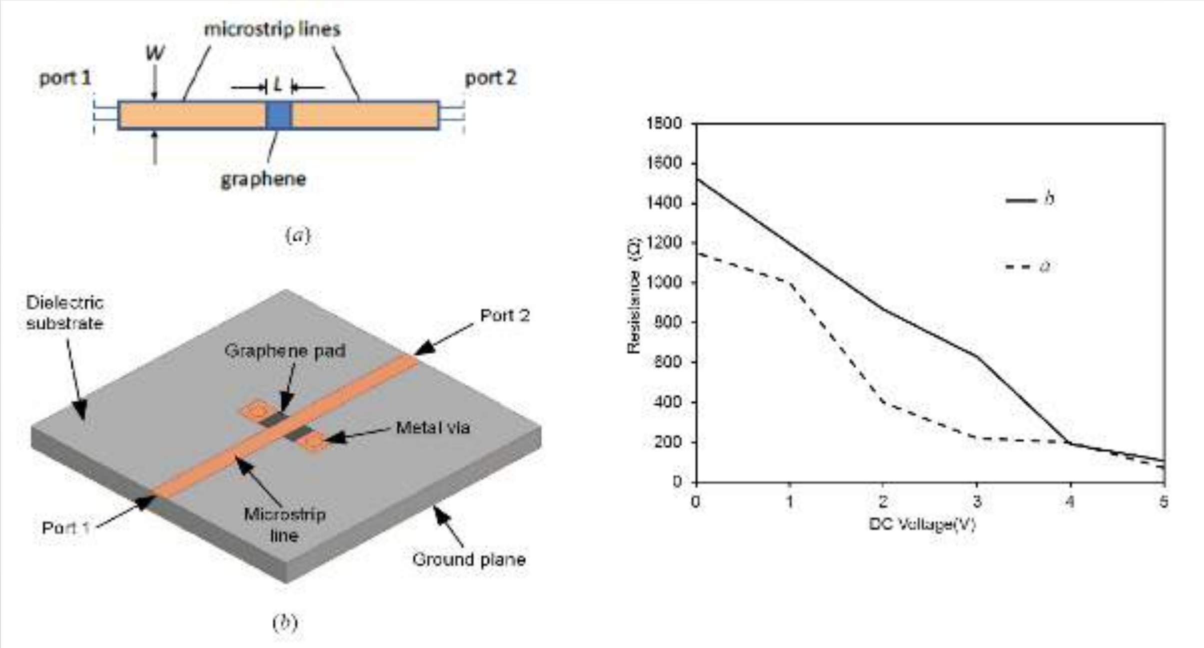
Picture	Nanostructures	Threshold
	20 (EG)	1-3%
	1000 (GNP)	1.5-2.5%
	2000 (MWCNT)	1-2.5%
	2000 ($MWCNT-NH_2$)	0.2%

APPLICATIONS

- AEROSPACE
- ELECTRONICS
- ENVIRONMENT
- MEDICINE AND BIOLOGY

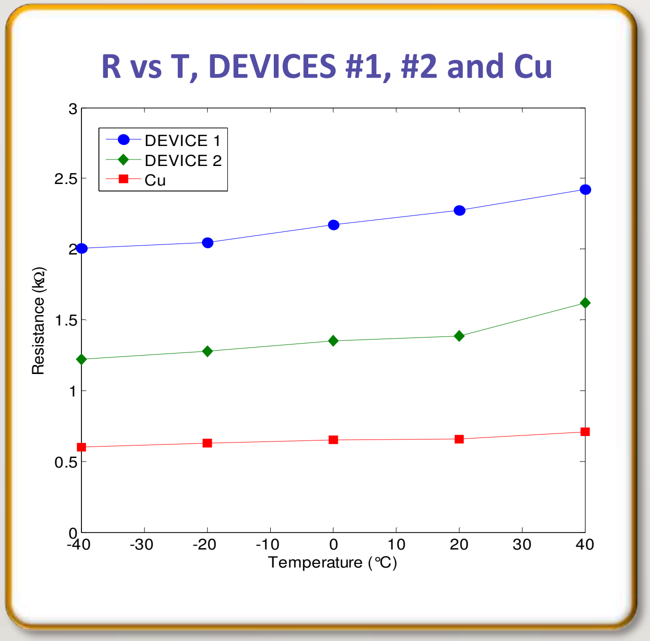


Innovative Tunable Microstrip Attenuators Based on Few-Layer Graphene Flakes



GNP thin film was used for a tunable attenuator device. The GNP patch was deposited in two configuration, first in the gap of a microstrip line and secondly, as a novel enhanced design, two graphene patches located between the main microstrip line and two metal vias. The results show for the first configuration a wide band functionality from DC to 20 GHz, with a tunability of 7 dB and minimum insertion loss of 5 dB, and for the second an operation in a frequency band of DC to 5 GHz, with 14 dB tunability and minimum insertion loss of 0.3 dB

Carbon interconnects with negative temperature coefficient of the resistance



Temperature Coefficient of the Resistance (TCR)

$$TCR(T_0) = \frac{1}{R}\frac{dR}{dT}\bigg|_{T=T_0}$$

Device	TCR @ 20 °C [mK^{-1}]
Device 1	3.1
Device 2	7.2
Copper (measured)	3.5
Copper (theoretical)	3.7

Good thermal stability around 20 °C (low TCR values)

Among many outstanding properties of carbon-based interconnects, it is of great interest for nanoelectronics applications, the possibility to have an electrical resistance almost insensitive to the temperature increase. This behavior has been theoretically predicted and experimentally proven for graphene nanoribbons, but only in controlled conditions, and for limited ranges of geometrical dimensions and temperature. We demonstrated the possibility of observing such a desirable behavior in graphene conductors, made by self-assembly of graphene flakes.

APPLICATIONS

- AEROSPACE
- ELECTRONICS
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APPLICATIONS

- AEROSPACE
- ELECTRONICS
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TOXICITY

INCUBATION WITH MWCNT

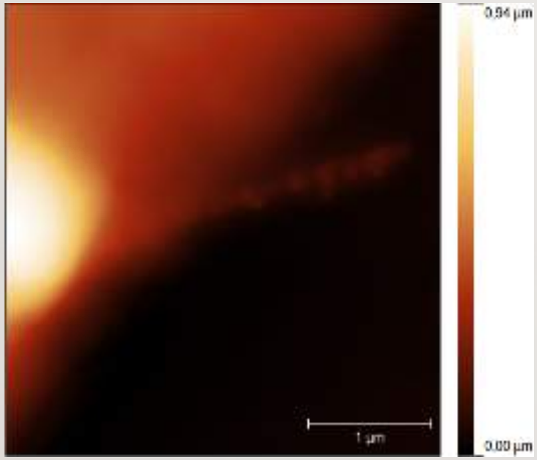
● MWCNT dispertion in H_2O by sonication for 15 minutes.

● MWCNT incubation at concentrations of 0.1mg/ml for 72h.

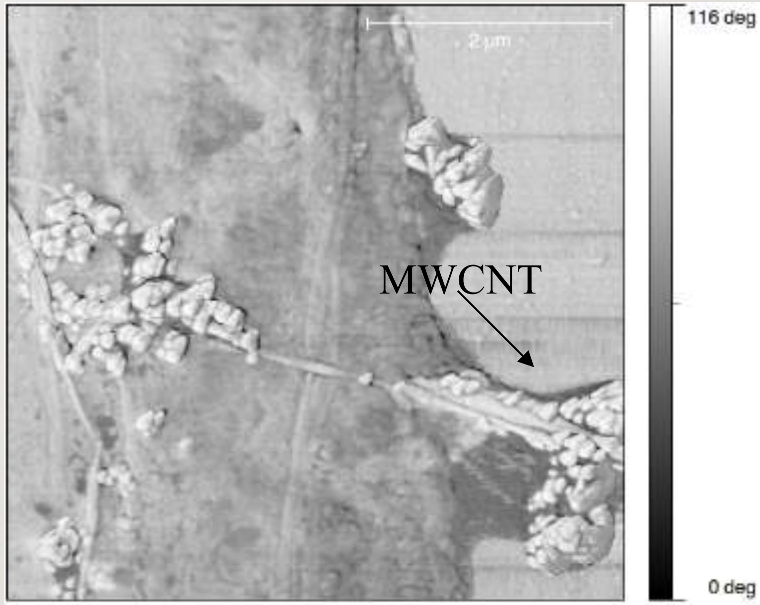
● Cells fixed with 4% paraformaldehyde and preserved in PBS solution.

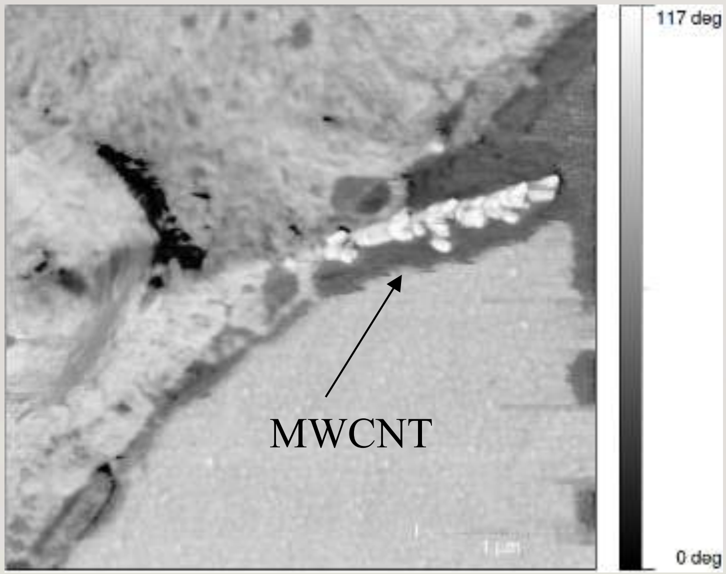
AFM PREPARATION

● Dishes washed three times with solution containing 0.1M glucose and NaCl with ratio of 2:1.



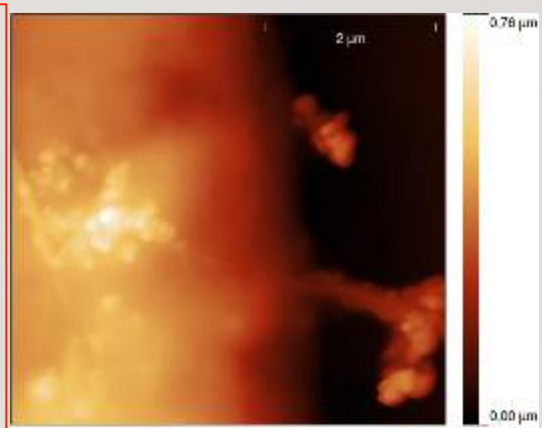
AFM in tapping mode
($A_S / A_0 \sim 0.86$)





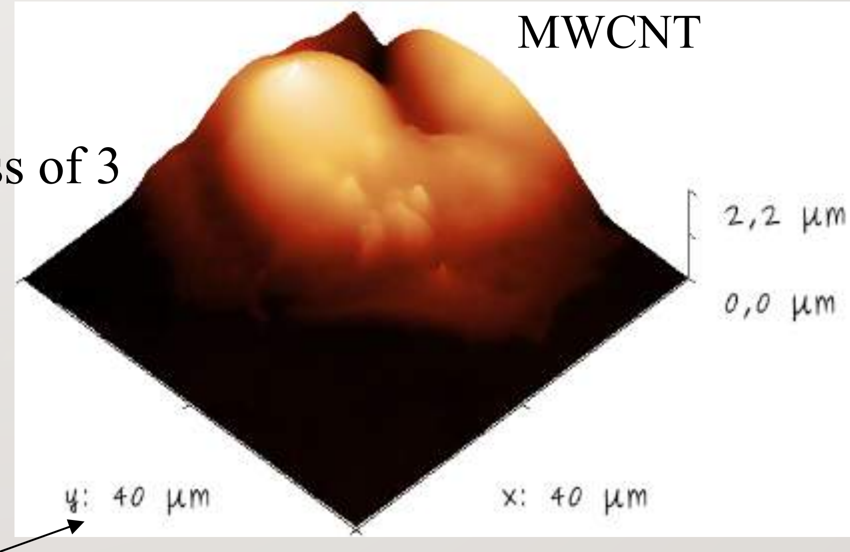
- PHASE SHIFT

different interaction tip-sample respect to cellular part.



TOXICITY - SURFACE MODIFICATION

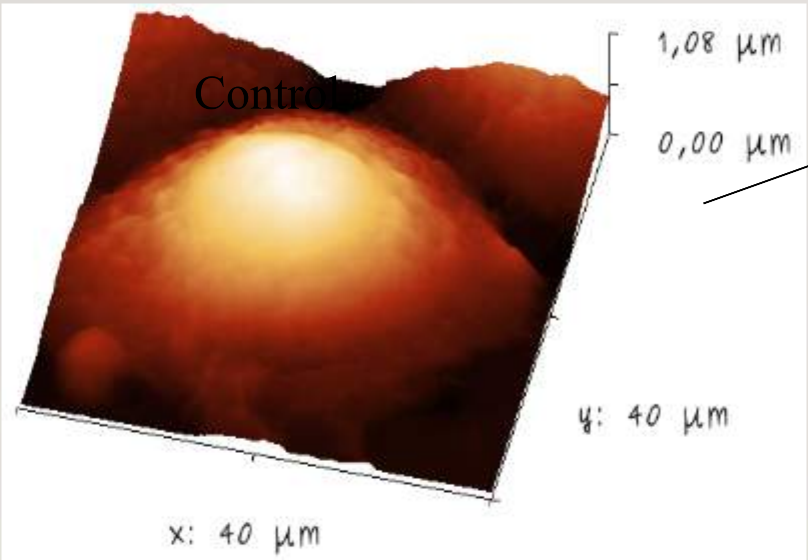
Treatment with MWCNT



- DECREASE in roughness of 3 times

- DECREASE of surface area of 3%

Control

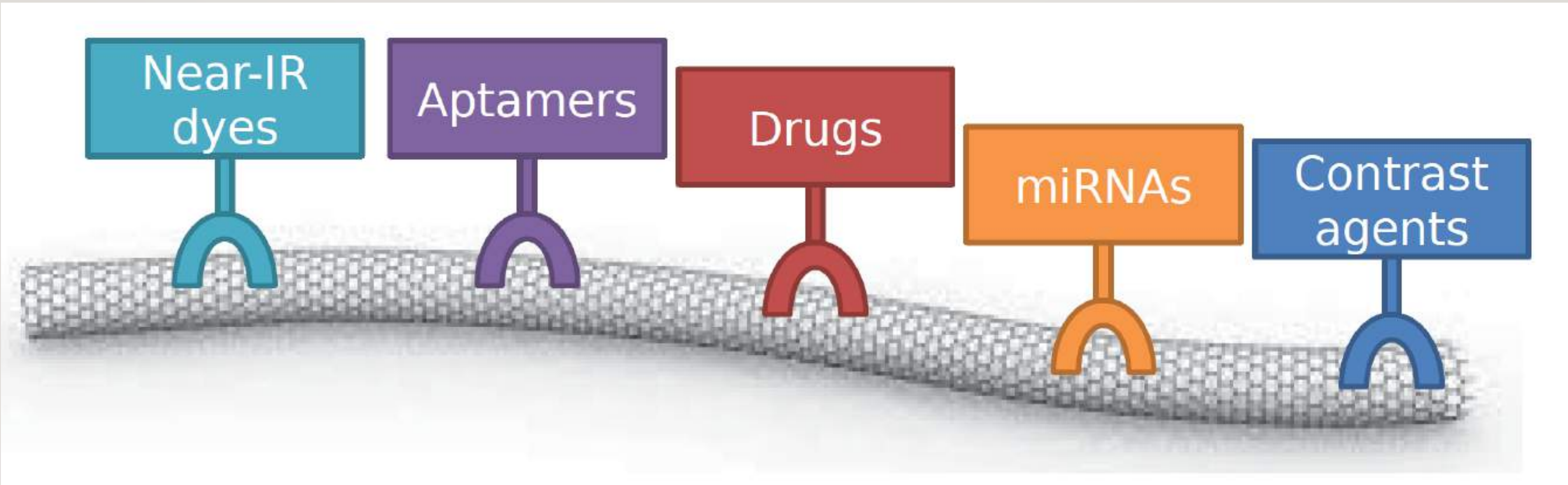


- The results are conserved in all frames examinated → Global property

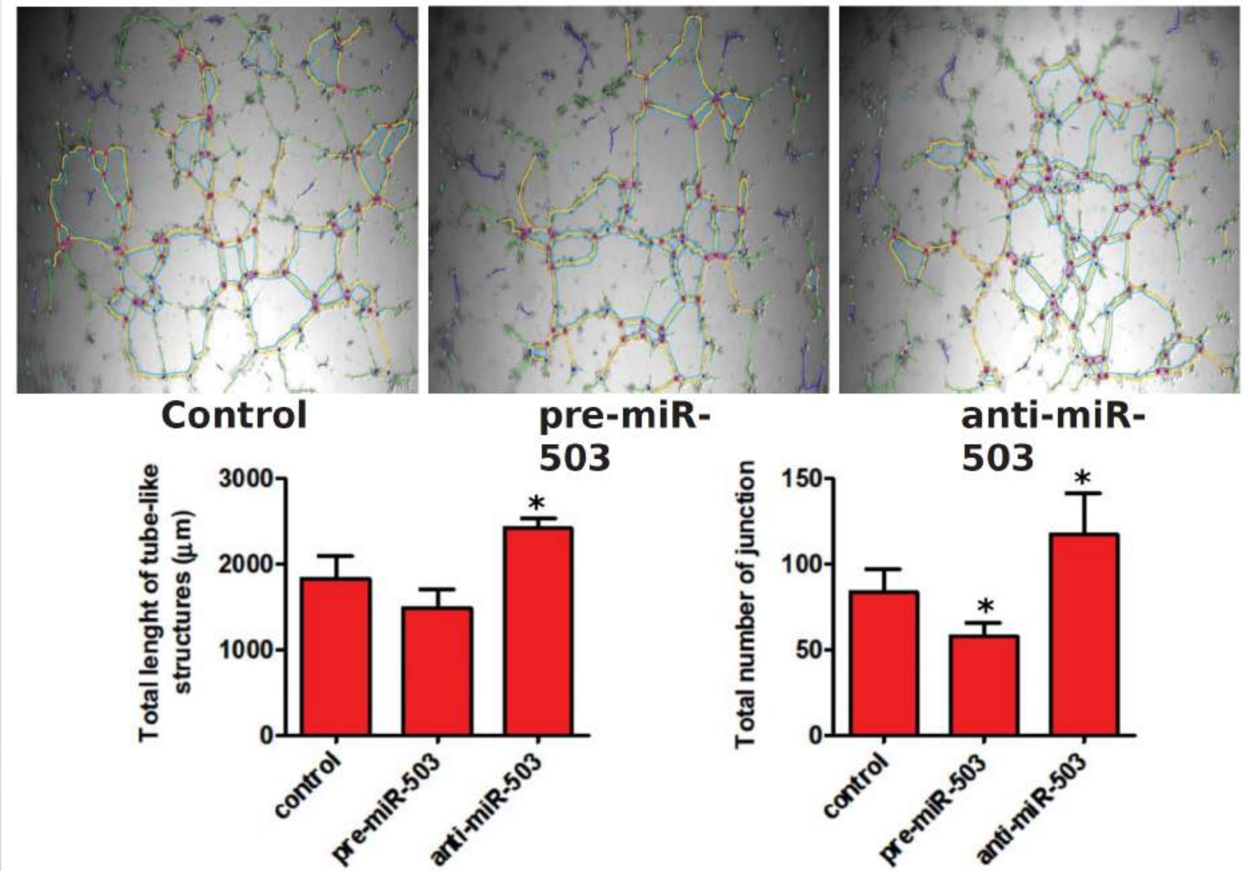
PEDIATRIC PULMONAY HYPERTENSION

Innovative therapeutic and diagnostic tool

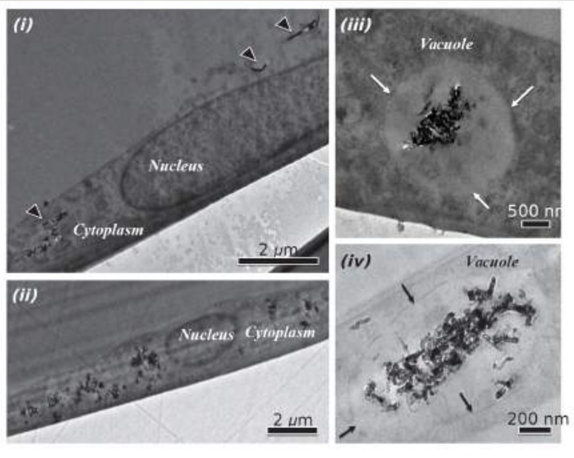
MicroRNA + Carbon Nanotubes



Formation of a vascular network



Intracellular localizzation




MOJOTIC FESTIVAL 12
you
谢谢
choukran
Asante
tighmmi
Danke
감사하십시오
gracias
thank
Merci
당신을
spasiba
grazie
ありがとう
obrigada
arigato