2003

4th Round Table on

Micro / Nano Technologies for Space

ESA- ESTEC, Noordwijk – 20 / 22 May 2003

- High performance and multifunctionnal carbon nanotubes based materials -

NANOLEDGE

Expert in Carbon Nanotubes,
from their production to their integration
in high performance materials

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1. Introduction
2. High performance polymers :
   Electrostatic dissipation
   EMI shielding
3. Nanotubes based fiber
4. Actuation devices

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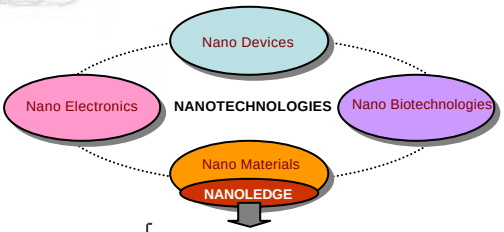
Nanotechnologies



High performance materials based on nanotubes

- Material reinforcement
- Conductive filler (thermal & electrical)
- Materials for energy devices (fuel cell, batteries...)
- Actuator

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A wonderful molecule

Single wall Carbon Nanotubes (CNT)

- **Tensile strength 50GPa**
- **Young's modulus 1TPa**
- **Electrical resistivity 10^{-4} ohm.cm**
- **Maximum current density 10^{13} A/cm²**
- **Thermal conductivity > 3000W/Km**
- **Field emission properties**
- **Expansion and contraction upon charge injection (~1%)**
- **Semi-conducting nanotubes**
- **Optical properties**
- **Photo-electrical properties**
- **Anisotropic material**
- **And so on**

A few nanometers
Single wall carbon nanotubes

A few tens of nanometers
Multi wall carbon nanotubes

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The stake

Nanotubes properties

Transfer nanoscale properties to macroscopic materials

Fiber

Bulk materials

Coatings

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Our Vision

« Nanoledge designs innovative, multifunctionnal and high performance materials taking advantage of Carbon Nanotubes unique properties.»

- **Design innovative materials** (Especially using the nanotubes based fiber)
- **Master chemistry of nanotubes**
- **Provide high quality nanotubes** (Industrial standards)

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High performance resins

- Carbon nanotubes have to be compatibilised before being inserted into composite matrix
- Nanoledge provides technologies to adapt the tubes:
  - Dispersion
    - Aqueous solvents : 3%wt of NT (With or without dispersant)
    - Organic solvents : 1%wt with dispersant in xylene, dichloroethylene, ethanol, NMP, DIMAC, toluene, other solvents following specifications
  - Fonctionnalization, derivatization

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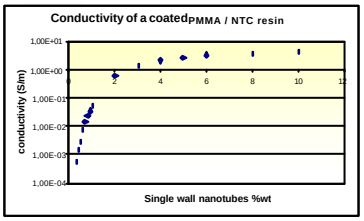
High performance resins

With less than 1% wt of SWNT, a lot of polymers become conductive



=> With small rates and very low density of nanotubes, these resins are very competitive in electrostatic dissipation

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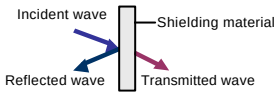
High performance resins

Electromagnetic shielding

(PMMA + nanotubes) coating :

- 5-15 %wt of nanotubes
- Thickness ~ 100 µm



Note : Nanotubes means raw product : 50%wt of nanotubes

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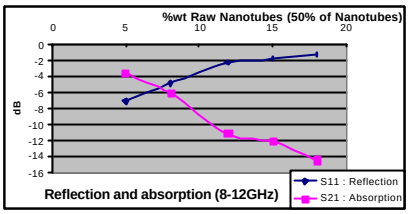
High performance resins

Electromagnetic shielding



Thermal conductivity of the coating is 10 times higher with 10%wt of SWNT

=> Multifunctionnal and light coatings for electromagnetic shielding

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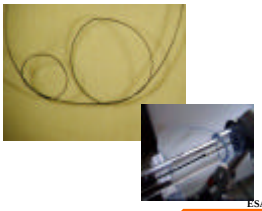
Carbon nanotubes based microfiber

- The PCS process : a patented process for nanoparticles based fiber
- The only production process allowing a ratio of nanotubes higher than 50%wt in the microfiber



⇒ The first 100% carbon nanotubes microfiber

⇒ A good way to insert nanotubes into polymers

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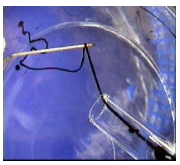
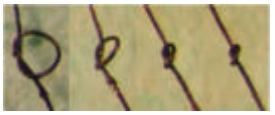
Characteristics of the actual microfiber

- Tensile Modulus : 60 GPA
  Tensile strength: 400 MPa
- Knot strength (flexibility) : 100%
- Very low density (<1.3)
- Diameter from 8 to 100 microns

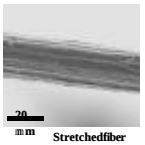




- Excellent thermal conductivity
- High specific surface

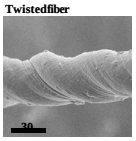
Characteristics of the actual microfiber (cont'd)

- From 60% to 100%wt of carbon nanotubes in the microfiber (different polymers)



Stretchedfiber

Twistedfiber



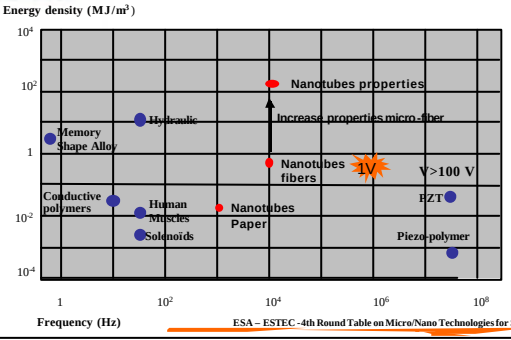
- Excellent Carbon nanotubes orientation in the microfiber in regard to the fiber axis : +/-10°
- Electrical resistivity: from 10e-4 to 10e1 ohm.cm-1 (Excellent current density)

Actuation device

- Nanoledge develops actuation device
- This actuation device is based on the carbon nanotube based microfiber
- Carbon nanotubes based actuator is placed in an electrolyte solution : Diameter = 40 µm, length = 30 cm
- Low voltage : **+/- 1 Volt** (applied at the top of the fiber)
- Stress generation : **20 MPa**
- Deformation : **from 0.5% to 1 %**
- Work per cycle : **0.3 J/cm3**

=> A high potential actuation device for micro and macro applications

Actuation device



Conclusion

- Nanotubes allow to design high performance and light materials
- Nanotubes based actuator devices shows very promising properties
- Nanotubes production will be industrialised => prices will be competitive

=> Nanotubes : a commercial, technical and industrial reality

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