# TECHNOLOGICAL APPLICATIONS OF NANOPARTICLES

Monica Distaso



# OPTOELECTRONIC PROPERTIES OF NANOCRYSTALS

Optical transitions in semiconductors

Absorption of metallic nanocrystals (Au NCs)





## QUANTUM CONFINEMENT



the charge carrier motion is restricted to a small material volume

N(E)

# **MAGNETIC PROPERTIES OF NCs**

## **MAGNETIC FIELD**

#### BULK: Multidomain





NANOCRYSTALS: Single domain



Nanostructured ferromagnetic materials behave as single magnetic domain whose magnetization can be easily influenced by thermal fluctuations of the local environment, depending on the particle size and on a variety of surface effects.



Once the synthesis is stopped by lowering the reaction temperature, a surfactant coating layer around the NCs remains tightly bound to their surface and guarantees their full solubility in a variety of organic solvents.





# SELF CLEANING GLASSES



#### photocatalytic process

In the photocatalytic process, UV light from the sun energizes the SunClean self-cleaning glass to help slowly break down and loosen dirt and other organic material. Since UV light is abundant even an cloudy days or in shaded areas, this process works non-stop throughout the day.



#### hydrophilic process

The coating's hydrophilic property makes water droplets spread out, or sheet, across the surface of the gloss. Because of this, when rain or a light spray of water hits the window, the water helps to more effectively rinse away loosened dirt. This sheeting action, which works throughout the day and night, helps the window dry quickly with minimal spotting and streaking.

## NANOMATERIALS IN EVERY-DAY LIFE



DOCKERS<sup>®</sup> Pleated Go Khakı™ with Stain Defender™

<u>DOCKERS</u><sup>®</sup> Short Sleeve Basketweave Cole Shirt with Stain Defender™



Blousecoals





#### Elbeco Police Uniform (Nano-Dry)



Eddle Bauer Khakis / Lee Jeans (NanoCareTH)

Franz Ziener GmbH & Co.'s Oberammergau Ski Jackets



Ambush Smith's Techlite Sunglasses





Plenitude Revitalift Antiwrinkle Cream

Kodak's EasyShare LS633 Zoom Digital Camera



NuCelle SunSense Cerax Nanowax, SPF 30 Sunscreen Ski Wax



Nancsphere's Verigene<sup>TM</sup> ID Platform



NTera's NanoChromics<sup>Th</sup>

OT

Smart Windows



Sketch of the mechanism responsible for the reversible wettability changes of the films made of the OLAC-capped TiO2 nanorods.



## NASA Nanotechnology Roadmap

	С	APA	BILIT	Y	
	Molti-For Molti-For Right Strength Materials (>10, OPa)	rotional Materials Reusable Lamoth Vehicle (20% less mass, 20% less noise)	Revolutionary Aircraft Concepts (89% loss mass) 20% less emission, 25% increased range)	Autonomous Spacecraft (40% loss mass) Bio-Inspired Materia and Processes	Adaptive Self-Repairing Space Nissions
Materials	Increasing leve • Single-walled nanotube fibers	Is of system desi • Nanotube composites	gn and integration <ul> <li>Integral         <ul> <li>Integral             thermal/shape             control</li> </ul> </li> </ul>	• Smart "skin" materials	<ul> <li>Biomimetic material systems</li> </ul>
Electronics/ computing	Low-Power CNT electronic components	<ul> <li>Molecular computing/data storage</li> </ul>	<ul> <li>Faultradiation tolerant electronics</li> </ul>	<ul> <li>Nano electronic "brain" for space Exploration</li> </ul>	Biological computing
Sensors, s/c components	<ul> <li>in-space nanoprobes</li> </ul>	<ul> <li>Nano flight system components</li> </ul>	Quantum     navigation     sensors	<ul> <li>Integrated nanosensor systema</li> </ul>	・NEMS flight systems 復 1 µW
200	2 200	14 20	06 20	11 20	) 16



# What Is All the Fuss About Nanotechnology?





Nanotechnology influences almost every facet of every day life such as security and medicine. BUT, IS IT POSSIBLE TO USE NANOTECHNOLOGIES FOR BENEFIT PEOPLE, ESPECIALLY IN DEVELOPING COUNTRIES?

## TOP 10 APPLICATIONS OF NANOTECHNOLOGY FOR DEVELOPING COUNTRIES

- 1. Energy storage, production and conversion
- 2. Agricultural productivity enhancement
- 3. Water treatment and remediation
- 4. Disease diagnosis and screening
- 5. Drug delivery systems
- 6. Food processing and storage
- 7. Air pollution remediation
- 8. Construction
- 9. Health monitoring
- 10. Vector and pest detection and control

## AGRICULTURAL PRODUCTIVITY ENHANCEMENT

Nanoporous zeolites for slowrelease and efficient dosage of water and fertilizers for plants, and of nutrients and drugs for livestock

Nanocapsules for herbicide delivery

Nanosensors for soil quality and for plant health monitoring

Nanomagnets for removal of soil contaminants







## AGRICULTUR AND WATER

- Nanomembranes for water purification, desalination, and detoxification
- Nanosensors for the detection of contaminants and pathogens
- Nanoporous zeolites, nanoporous polymers, and attapulgite clays for water purification
- Magnetic nanoparticles for water treatment and remediation
- TiO<sub>2</sub> nanoparticles for the catalytic degradation of water pollutants

# FOOD PROCESSING AND STORAGE

 Nanocomposites for plastic film coatings used in food packaging

 Antimicrobial nanoemulsions for applications in decontamination of food equipment, packaging, or food

 Nanotechnology-based antigen detecting biosensors for identification of pathogen contamination

# AIR POLLUTION AND REMEDIATION 1907:

"Who should do science? People who don't like to live in crowded environments, people who like to go to the high mountains to enjoy the fresh air, to be in harmony with nature." – Albert Einstein

# 1994:

"Is this still the role of scientists? Isn't their role today more about cleaning the polluted cities than escaping to the mountains?" – Ilya Prigogine, (Nobel Prize in Chemistry, 1977)

# AIR POLLUTION AND REMEDIATION



# ENERGY STORAGE, PRODUCTION AND CONVERSION

CHALLENGES: ✓ 1.7 – 2 BILLION PEOPLE IN THE WORLD, HAVE NO ACCESS TO ELECTRICITY;

✓ ONE THIRD OF THE WORLD'S
 POPULATION RELIES PRIMARLY ON
 TRADITIONAL, NON-RENAWABLE,
 CONTAMINATING FUELS;

✓ THE RICHEST PEOPLE IN THE WORLD USE NEARLY 25 TIMES AS MUCH ENERGY PER PERSON AS THE POOREST PEOPLE



## **Urgent Need for an Alternate Source of Fuel**



John F. Bookout (President of Shell USA) ,"Two Centuries of Fossil Fuel Energy" International Geological Congress, Washington DC; July 10,1985. Episodes, vol 12, 257-262 (1989). R.E. Smalley *MRS Bulletin* 30, 412-417 (2005) J. Rifkin, *The Hydrogen Economy* (Tarcher, New York, 2002). Why hydrogen?

- Highest energy per unit mass for any material (2860 kcal/kg)
- Abundant
- No pollution

## SOLUTIONS

 Novel hydrogen storage systems based on carbon nanotubes and other lightweight nanomaterials

 Photovoltaic cells and organic light-emitting devices based on quantum dots

 Carbon nanotubes in composite film coatings for solar cells

 Nanocatalysts for hydrogen generation

Hybrid protein-polymer
 biomimetic membranes



# **CDC for H<sub>2</sub> Storage**

A hydrogen fuel cell (internal combustion engine) car will require 4 (8) kg or 225 (450) liters of hydrogen to travel 400 km.

Note: DOE target is system target and will include the density of accessories depending on the materials requirement



Volume of 4 kg of hydrogen stored in different ways

L. Schlapbach and A.Zuttel, Nature, 2001, v.,414, p. 353



**Metal Organic Framework** 

# "Nano" Challenges in Fuel cells



R.V. Hull, L. Li, Y. Xing and C.C. Chusuei, Chem. Mater., 18, 1780-1788 (2006).

### Nanotechnology push:

- •Carbon support research
  - Nanotubes
  - •Graphitic carbons
  - Novel nanocarbons
- •Catalyst particle size minimization - surface area maximization
- Hydrogen storage

# **Photovoltaics**

- Capture larger spectrum of solar energy
- By 2035 photovoltaics could produce about 10 percent of the world's electricity
- Play a major role in reducing carbon dioxide emissions
- Nanomaterials used: Nanodots and Nanorods



http://www.physorg.com http://www.konarkatech.com



## HEALTH, DISEASE DIAGNOSIS AND SCREENING





# **DRUG DELIVERY**







# **BIOCONJUGATION METHODS**



Chan, W.C.W. et al. Biomedical Photonics Handbook 2003, 58/1-58/14



## BIOLOGICAL APPLICATION IN CANCER THERAPY



Nanoparticle drug delivery Ref. The Engineer, 30 May-12 June 2003, p 15

## **DEVELOPMENT OF MULTIFUNCTIONAL TOOLS FOR in vivo APPLICATIONS**



#### **MAGNETIC AND FLUORESCENT SYSTEM: GENERAL CONSIDERATIONS**



#### **PERFORMANCE: MAGNETIC AND FLUORESCENT PROPERTIES**

Depending on the choice of the components of the system

## BIOCOMPABILITY

Depending for the application in vivo or in vitro

## PREPARATION OF FLUORESCENT-MAGNETIC HYBRID NANOSTRUCTURES: STATE OF THE ART



## **ENCAPSULATION**

Gaponik N., *Langmuir*, 2004. 20 (1449) Yoon T.J., *Small*, 2006. 2 (209)



## **DIRECT REACTION**

Kircher M.F., *Cancer Research*, 2003. 63 (8122) Veiseh O., *Nano Letters*, 2005. 5 (1003)



## **INORGANIC SYNTHESIS**

Gu H.W., J. Am. Chem. Soc., 2004. 126 (5664) Wang D.S., Nano Letters, 2004. 4 (409)

## Mesoporous Silica Beads Embedded with Semiconductor Quantum Dots and Iron Oxide Nanocrystals

PREPARATION





# Cytoplasma accumulation confirmed also by TEM



# Membrane localization confirmed also by TEM



## Superparamagnetic Fe2O3 Beads-CdSe/ZnS Quantum Dots Core-Shell Nanocomposite Particles for Cell Separation



#### Polymer coated γ-Fe2O3 beads (purchased from Indicia Biotech, France)



#### Nano Lett., Vol. 4, No. 3, 2004

#### **Covalent attachment of anticycline E to the luminescent/magnetic particle**



fluorescence (a) and transmission (b) microscopy images of anticycline E labeled luminescent/magnetic nanoparticles bound to MCF-7 breast cancer cells. Nano Lett., Vol. 4, No. 3, 2004



# **Traditional View: Increasing Pore Size Increases Specific Capacitance**



Power ~

Ideal pore size

## Are nanoparticles harmful?

• Evidence exists that nanoparticles may be toxic to biological systems.

• When ordinary materials are made into nanoparticles they tend to be more chemically reactive.

• Particles may be able to gain entry into the body via a number of routes: skin, lungs etc.

"The places where [diverse scientific] activity is high, where many scientists are interacting, where there are outstanding people...those are the circumstances that are going to pay off the most."

- Charles H. Townes (Nobel Prize in Physics, 1964)



# The GUYS of VIA PANISPERNA

## PHOTOGRAFER: BRUNO PONTECORVO



## MISSING: ETTORE MAIORANA



otografia di Ettore Majorana tratta dalla tessera universitaria datata 3 nevembre 1923.

# Good luck for your PhD by The GUYS of VIA MOREGO 30!!!

# Nanocrystalline Solar Cells: The Materials

## Materials:

- 1. (2) F-SnO<sub>2</sub>glass slides
- 2. Iodine and Potassium Iodide
- 3. Mortar/Pestle
- 4. Air Gun
- 5. Surfactant (Triton X 100 or Detergent)
- 6. Colloidal Titanium Dioxide Powder
- 7. Nitric Acid
- 8. Blackberries, raspberries, green citrus leaves etc.
- 9. Masking Tape
- 10. Tweezers
- 11. Filter paper
- 12. Binder Clips
- 13. Various glassware
- 14. Multi-meter



- Catalysis
- Micro-/nano-electronics & optical devices
- optics, ultrafast optical
- switches
- data storage (magnetic, optical)
- Analytical analysis
- Sensors
- Monitoring toxic chemicals
- Energy storage and conversion
- Fuel cells
- Nanocrystal assemblies drastically expands the range of applications
- Collective optical or magnetic properties due to long-range dipolar interactions