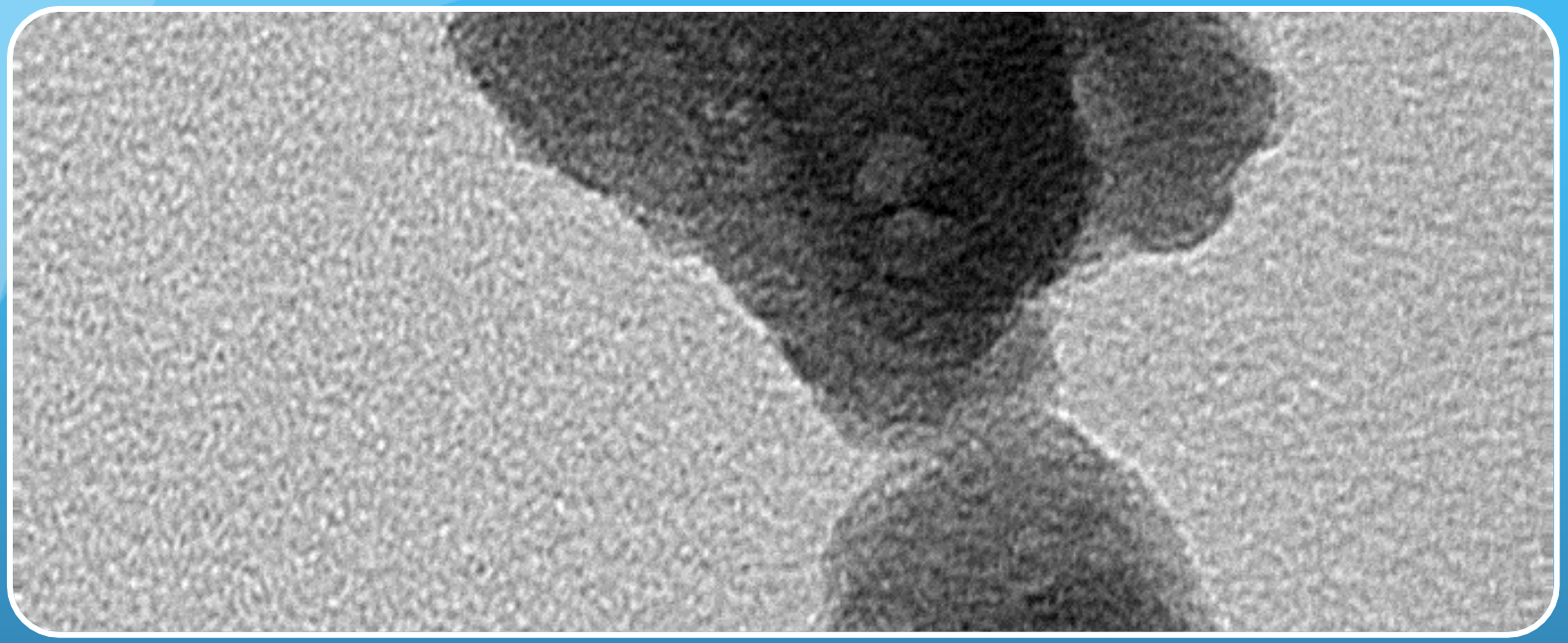


Engineering Aspects of Nanosafety

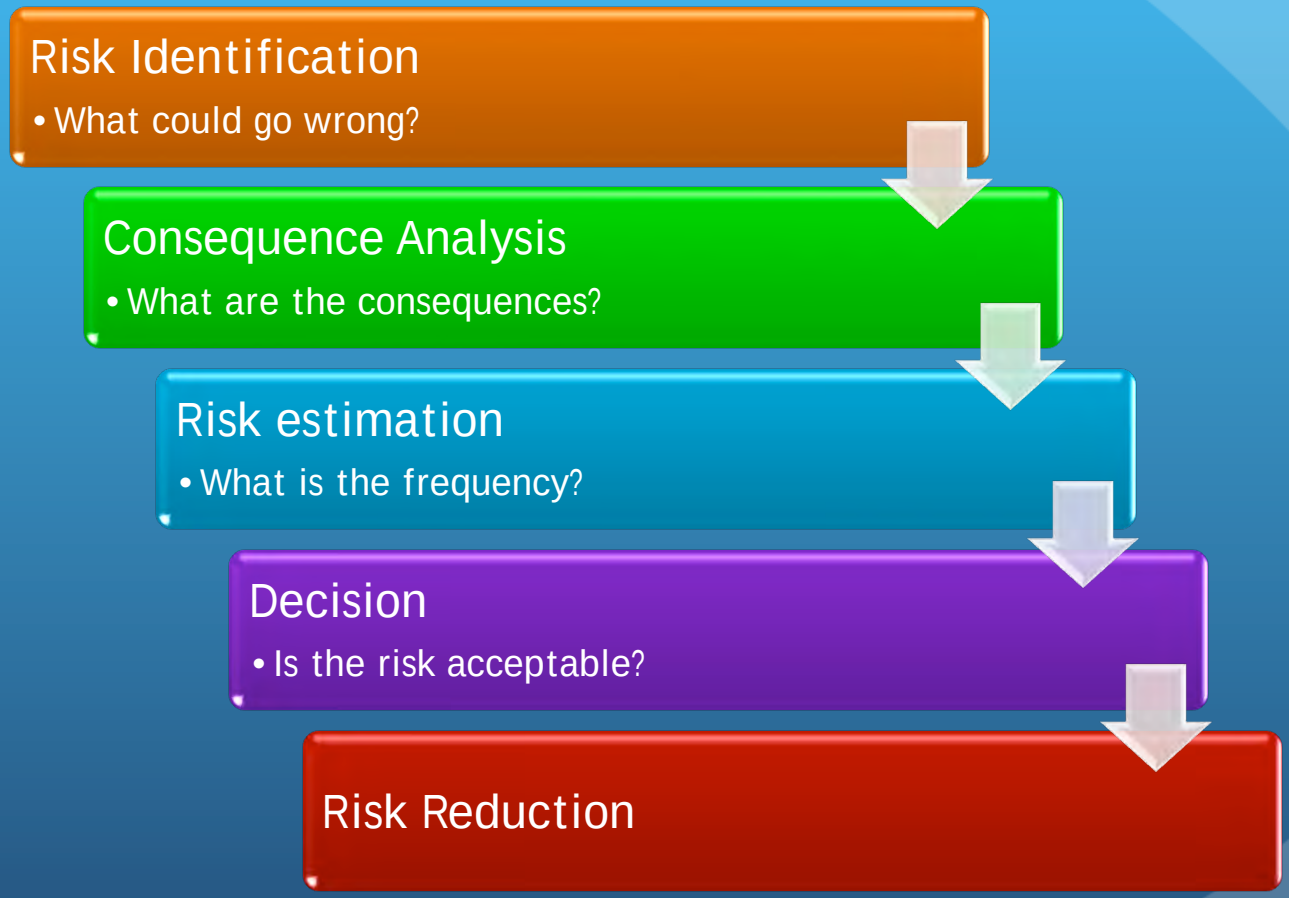
Francisco Balas

Instituto de Nanociencia de Aragón (INA) – Zaragoza

Summary

- Some words on risk perception and analysis
- Some basic concepts of nanotechnology
- Identification of risks in nanotechnology
- What (and how) to measure in nanosafety
- Hygiene measures for nanotechnology (Filtration and protection)
- Conclusions and perspectives

Stages of Risk Analysis



Risk perception

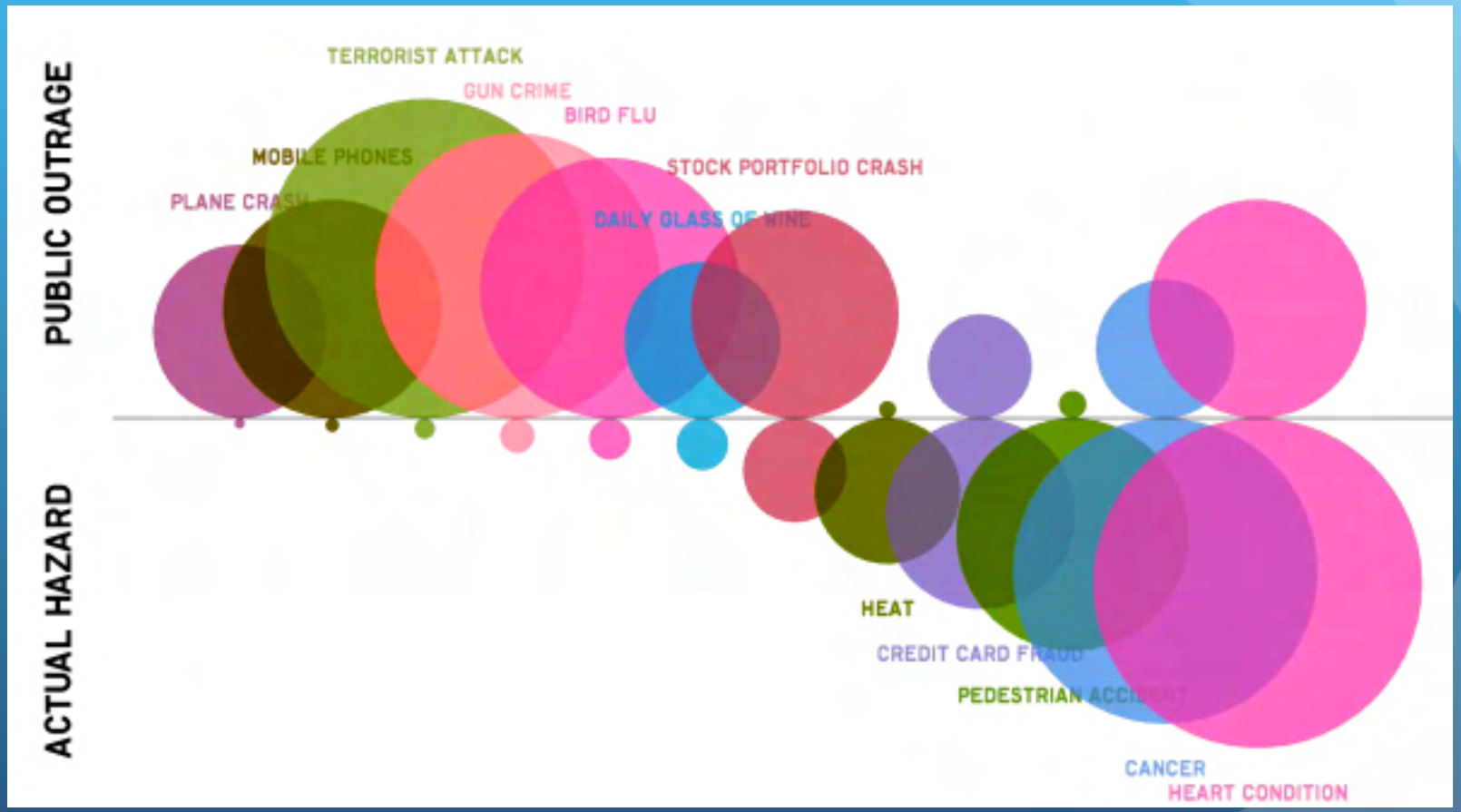
- Risk perception is one opinion of the likelihood of risk (the probability of facing harm) associated with performing a certain activity or choosing a certain lifestyle

- Risk is a normal part of everyone daily life

Risk perception

- Our perception of risk is often influenced by whether we feel in control of a perceived risk
  - Smoking vs. Nuclear power
- Risks are (sometimes) unavoidable
  - Safety guidelines
  - Common sense

Risk perception and actual hazards



via Susanna Hertrich's REALITY CHECKING DEVICE (susannahertrich.com)

What about nanotechnology?

Nanotechnology has been plagued by a lot of hype, but cynicism and criticism have not been far behind.

Sci-fi writers exploit fears of nanorobots turning into killers and the media can run amok when news about potential health problems with nanoproducts surface

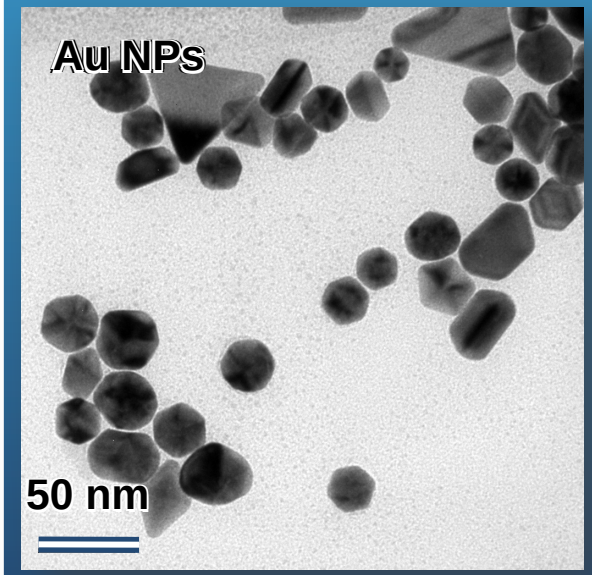
Some see doomsday scenarios of molecular self-assembly turning the world into “grey goo”

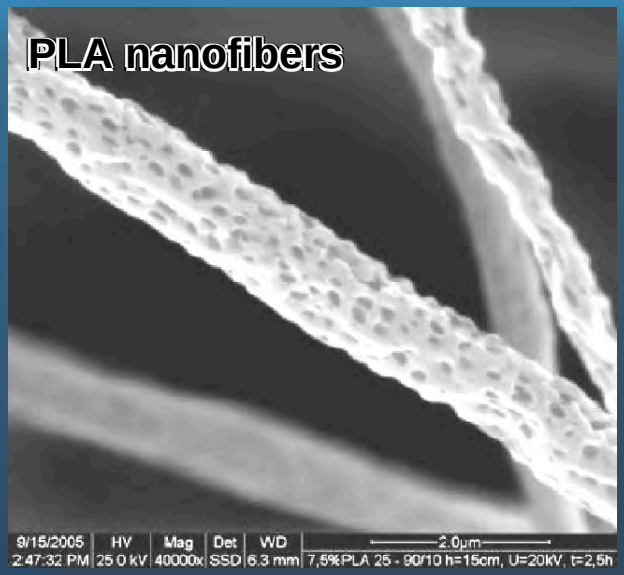
http://www.nanowerk.com/spotlight/spotid=1781.php

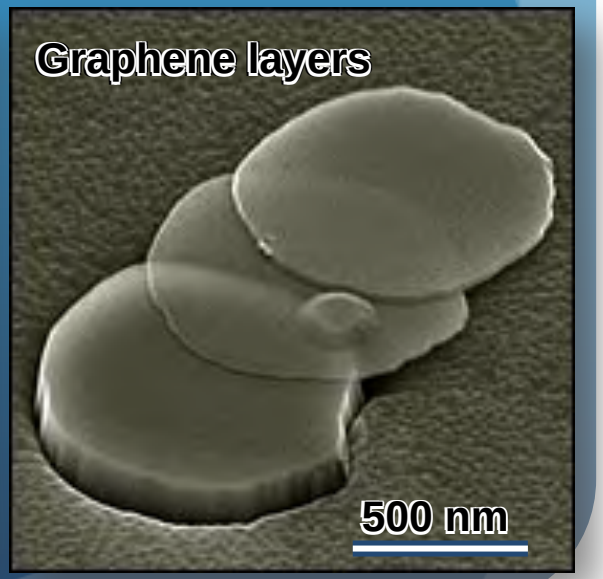
What means nanotechnology?

Nano-objects: Solids with at least a dimension smaller than 100 nm

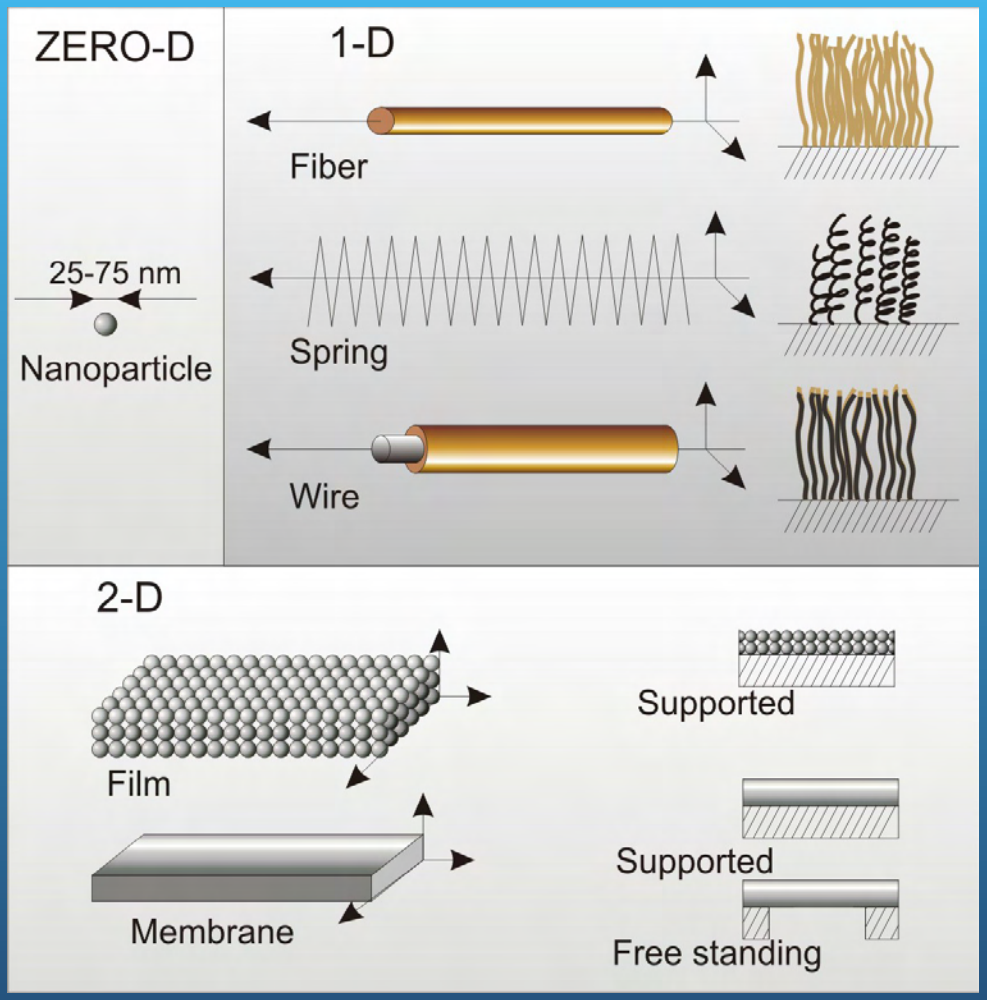
- Nanoparticles: All the dimensions are smaller than 100 nm
- Nanofibers (nanowires): Two dimensions are smaller than 100 nm
- Thin films: Only one dimension is smaller than 100 nm







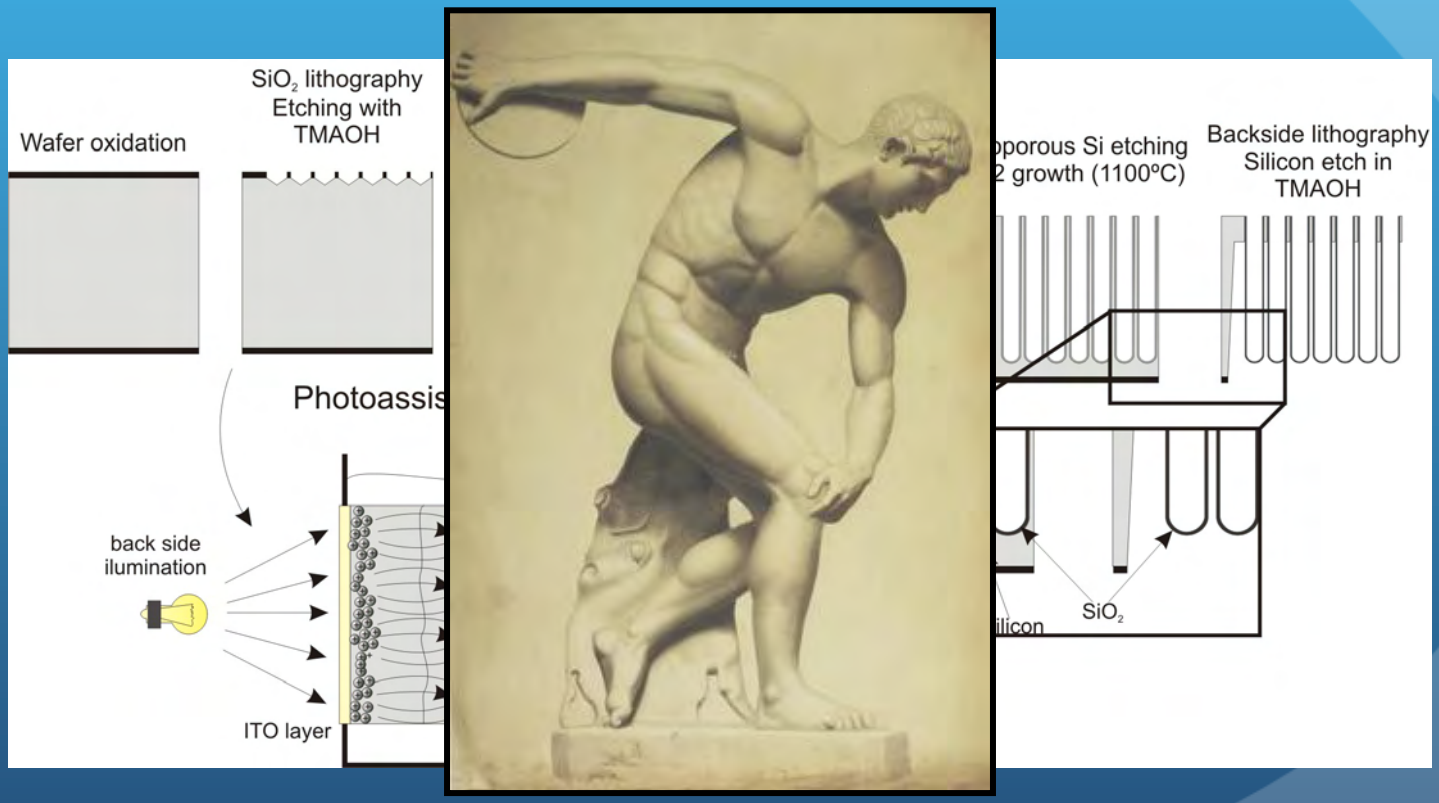
What means nanotechnology?



Nanoscale materials: at least one dimension below 100 nm

Manufacturing methods in nanotech

Top-down procedures



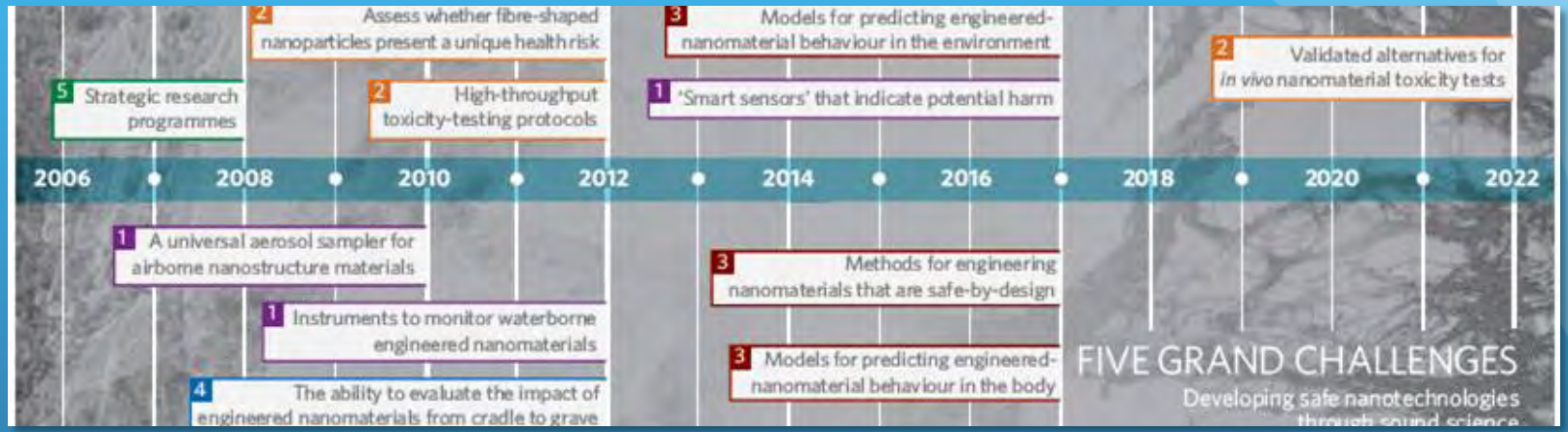
Manufacturing methods in nanotech

Bottom-up procedures

A. Monzon, U. Zaragoza, (2008)

Nature inspired…

Great challenges in nanotechnology



"*The spectre of possible harm — whether real or imagined — is threatening to slow the development of nanotechnology unless sound, independent and authoritative information is developed on what the risks are, and how to avoid them*"

Maynard, Nature 2006, 444, 267

Nanoparticles are in the air…

Aerosol: Suspension of solid (or liquid) particles in a gas phase, with particles between 2 nm and 200 µm

- Natural aerosols (earth volcanoes, desert storms, wildfires
- Artificial aerosols
  - Anthropogenic aerosols (industrial activities, motor soots, paintings)
  - Engineered-nanoparticle aerosols (Specific synthesis of nanomaterials)

Shanghai at dawn (2008)

… and among us

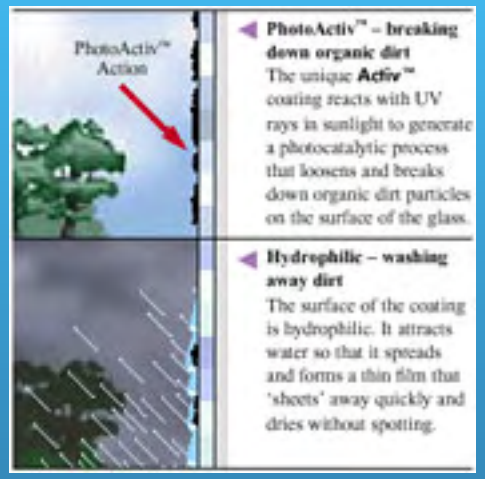
Nanotechnology is rapidly advancing, with more than 300 nanoproducts already on the market.

Over 500 nano-products available in 2007 (Woodrow Wilson Center)

Over 3000 products today

Some of the Top 10 Nanotech products in 2005 (Forbes)

Zelen: Fullerene face cream



Pilkington: self-cleaning glass

O´lala: chocolate chewing gum with nanoparticles

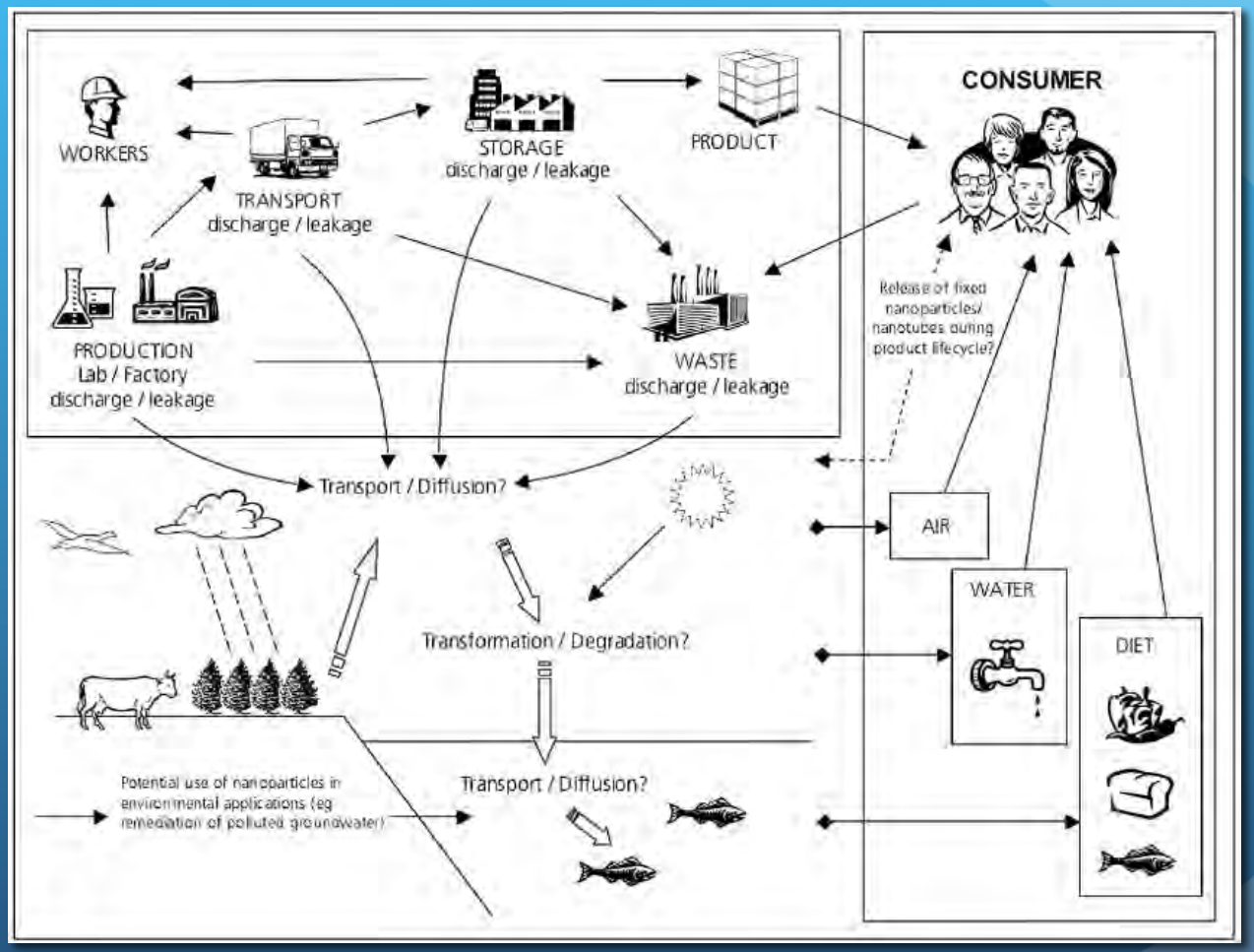
ARC outdoors: non-stinking socks

Nutralease: oil with 30 nm capsules

… and some of the health related applications

- Cancer
- Inmunosupressants
- Hormone theraphy
- Cholesterol
- Appetite control
- Bone replacement
- Contrast agents (MRI)

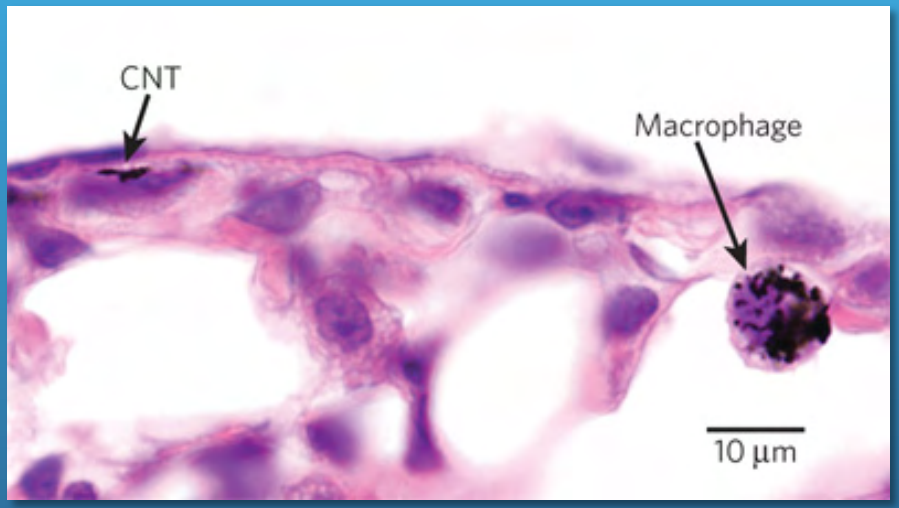
Exposure routes to Engineered Nanoparticles



National Institute for Resources and Environment, Japan (www.nire.go.jp/eco_tec_e/hyouka_e.htm)

Health effects of nanomaterials

Exposure risks: Respiratory diseases



When inhaled by mice, multiwalled carbon nanotubes (CNTs) can embed themselves in the lining of the lung

Ryman-Rasmussen. Nat. Nanotech. 2009, 4, 747

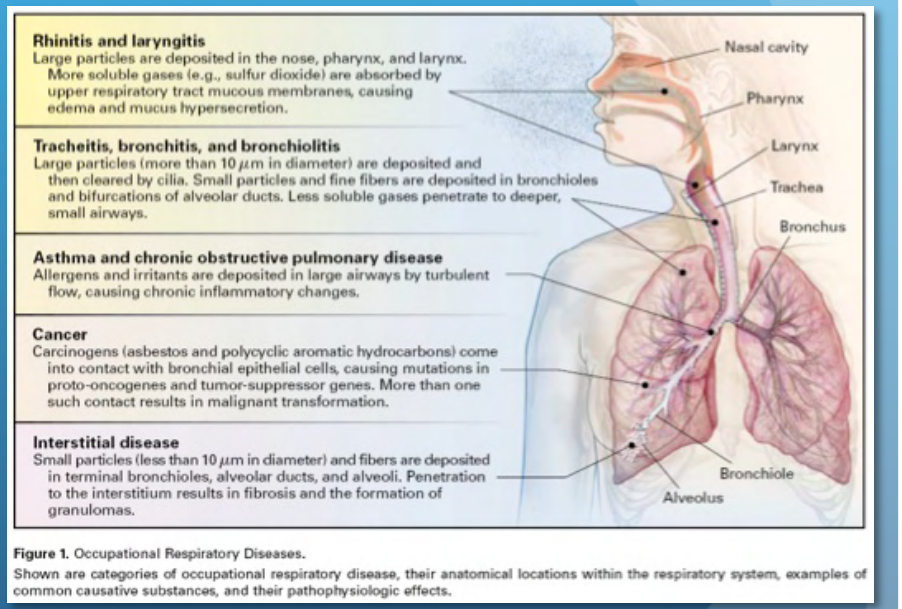
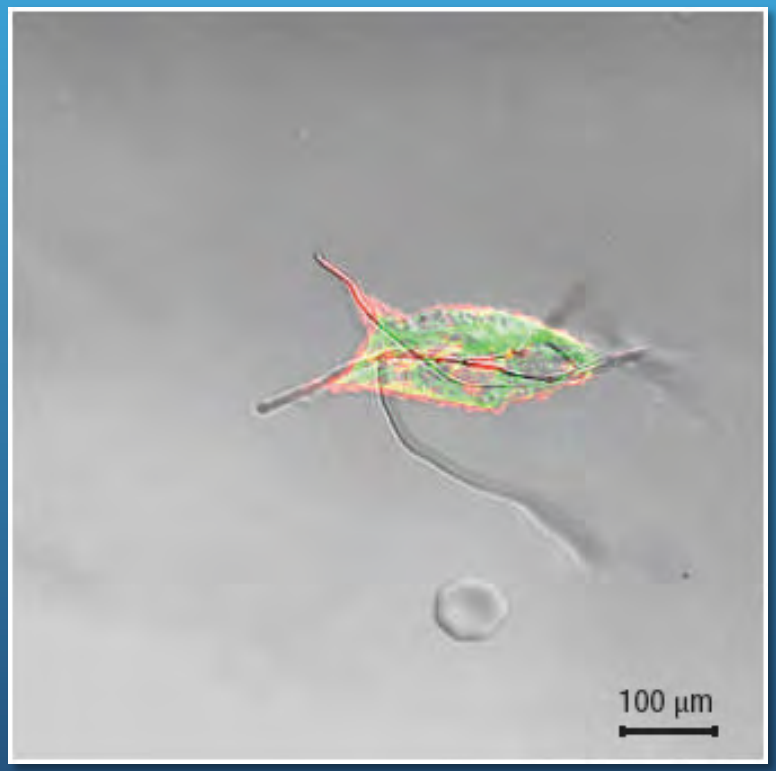


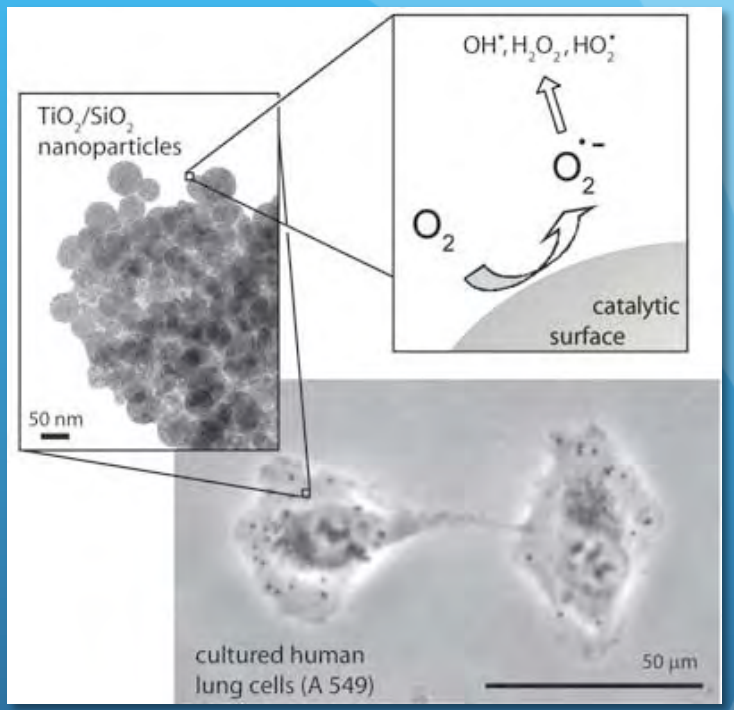
Figure 1. Occupational Respiratory Diseases.
Shown are categories of occupational respiratory disease, their anatomical locations within the respiratory system, examples of common causative substances, and their pathophysiologic effects.

Beckett. New Engl. J. Med. 2000, 342, 406

Is there any risk with Engineered Nanoparticles?

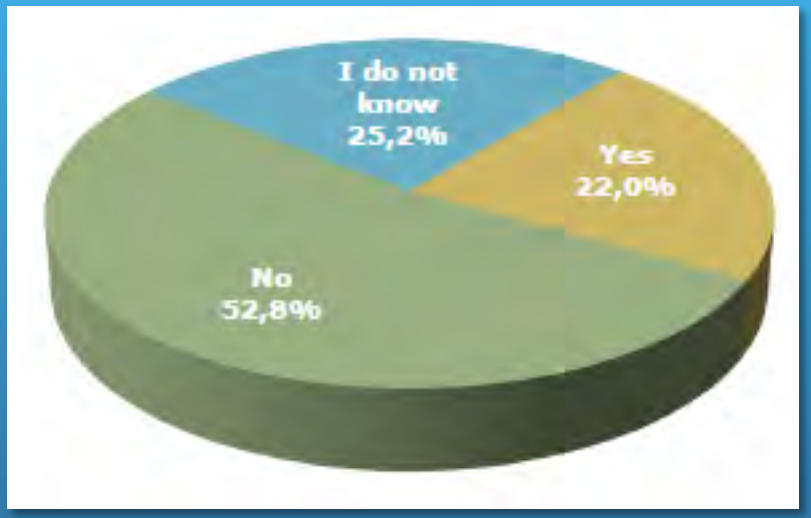
Rat lung cells and CNT (Stone, Nat. Nanotech. 2006, 1, 23)





Epithelial cells and TiO_2 ENPs (Limbach, Env. Sci. Technol. 2007, 41, 4158)

Are we aware of those risks?



Can your nanoparticles become airborne during processing?

- An internet survey realized from April to June 2009 revealed that about a quarter of the respondents reported not knowing whether the nanomaterials they made would become airborne during synthesis, 22% reported knowing that the nanomaterials would become airborne
- Interestingly, more than a half of the respondents knew that their materials will not be in the air after synthesis, even when using their synthetic processes will not be sure of the final state of nanomaterials

Balas, Nat. Nanotech. 2010, 5, 9

Laboratory protection methods

Table 1 | Relationship between laboratory protection measures and knowledge of nanomaterials becoming airborne during synthesis.

		General laboratory safety during synthesis and handling (%)					
		No special protection	Local extraction on lab bench	Standard fume hood	Fume hood with nanosize filters (for example, HEPA)	Special nanosafe fume hood	Other
May nanomaterials become airborne at any stage of synthesis? (%)	Yes	20.8±5.0	16.7±4.7	50.0±5.9	6.3±3.4	4.2±3.0	2.1±2.0
	No	22.1±3.1	16.8±2.8	49.6±3.6	7.1±2.1	2.7±1.5	1.8±1.2
	Don't know	34.6±5.4	11.5±4.0	44.2±4.0	7.7±3.5	1.9±1.3	
	Overall	24.0±1.6	15.2±1.4	47.5±1.8	7.8±1.1	2.8±0.8	2.8±0.8

The researchers recognized that their nanomaterials could become airborne, but many used little to no laboratory protection. Confidence intervals are given as ±standard error, with $100(1-\alpha) = 68.3\%$. The row labelled overall summarizes the answers from all respondents.

- Nearly 40% of researchers working with nanomaterials reported using none or only weak means of general laboratory protection, 47.5% used standard laboratory hoods and 10.6% used nano-enabled hoods
- Even when the researchers recognized that their materials could become airborne, respondents using little to no general laboratory protection (20.8% for no protection and 16.7% for local extraction) were many
- Statistical analysis showed that there was no statistically significant difference regarding the method of general protection chosen between researchers responding yes or no to the potential presence of airborne particles

Balas, Nat. Nanotech. 2010, 5, 9

Personal protection methods

Table 2 | Relationship between the use of personal respiratory protection devices and knowledge of nanomaterials becoming airborne during synthesis.

		Personal protection equipment when handling nanomaterials (%)					
		None	Mouth mask without filters	Respiratory mask with standard filters	Full face-shield with standard filters	Mask or shield with specially designed filters	Full-body protective equipment
May nanomaterials become airborne at any stage of synthesis? (%)	Yes	29.8±5.6	36.2±5.8	27.7±5.5		4.3±3.1	2.1±1.9
	No	57.7±3.6	17.1±2.9	16.2±2.9	4.5±1.8	2.7±1.5	1.8±1.3
	Don't know	50.9±5.6	28.3±2.3	15.1±5.1	1.9±1.5		3.8±2.5
	Overall	48.8±1.8	24.4±1.6	18.4±1.5	2.8±0.8	2.8±0.8	2.8±0.8

Many respondents had poor personal protection despite having declared that the nanomaterials they synthesized could become airborne. Confidence intervals are given as ±standard error, with $100(1-\alpha) = 68.3\%$. The row labelled overall summarizes the answers from all respondents.

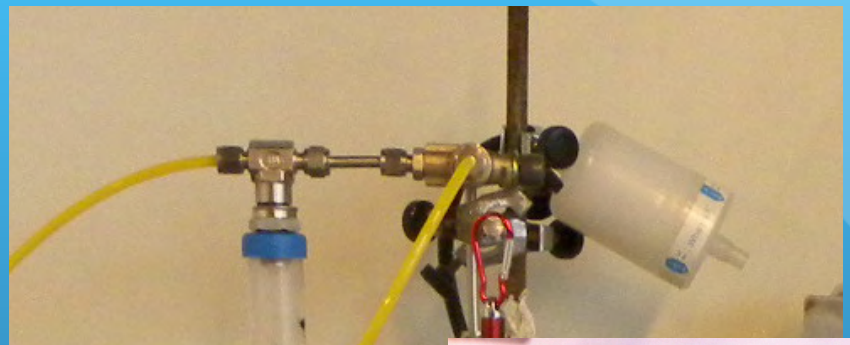
- 48.8% reported not using any type of respiratory protection and 24.4% used a mouth mask without filters (ineffective form of protection), less than 6% reported using nano-enabled mask filters or higher protection levels
- Respondents with poor personal protection (29.8% using no protection and 36.2% using a mask without filters) were high, despite having declared that the nanomaterials they synthesized could become airborne
- Researchers who considered that nanomaterials might become airborne were significantly more likely to use some method of personal protection than those who did not

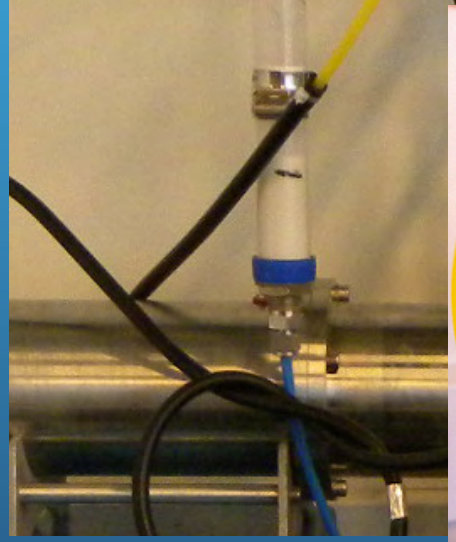
Balas, Nat. Nanotech. 2010, 5, 9

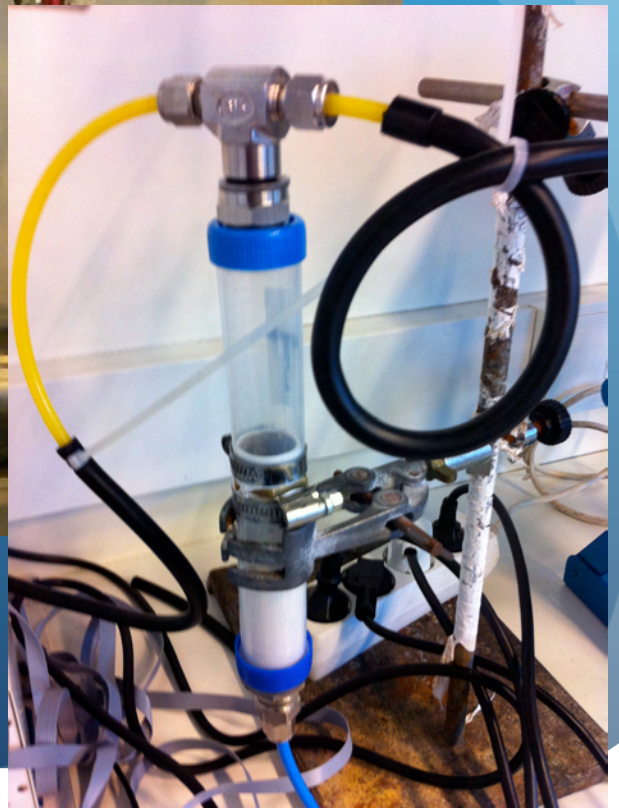
What to measure?

- Aerosol formation
- Aerosol deposition
- Filter efficiency
- Protective equipment (clothes) efficiency

Engineered nanoparticle aerosols







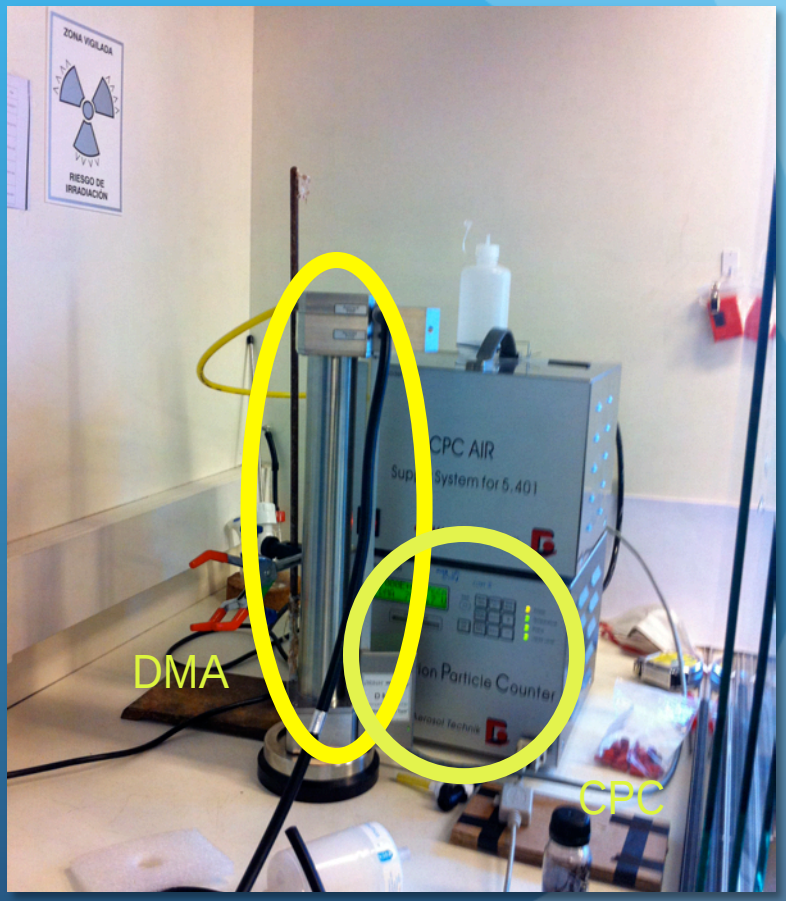
ENP aerosol production

- Nanoparticle control
- Aerosol dynamics in the environment

Engineered nanoparticle aerosols

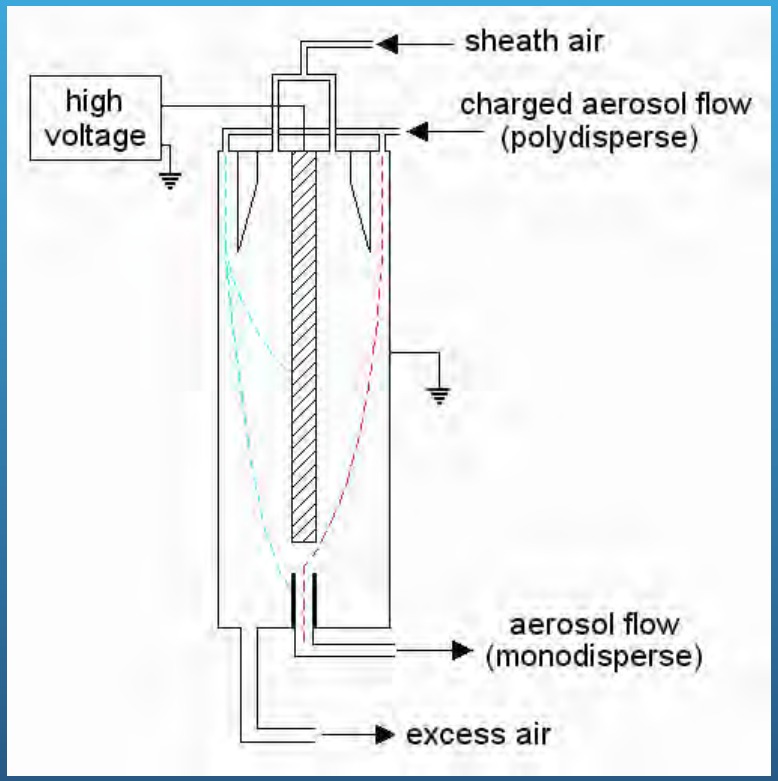
Scanning Mobility Particle Sizing (SMPS)

- Electrostatic classification (Differential mobility analyzer, DMA)
- Optical detection (Condensation particle counter, CPC)
- 5 nm < D_P < 1100 nm

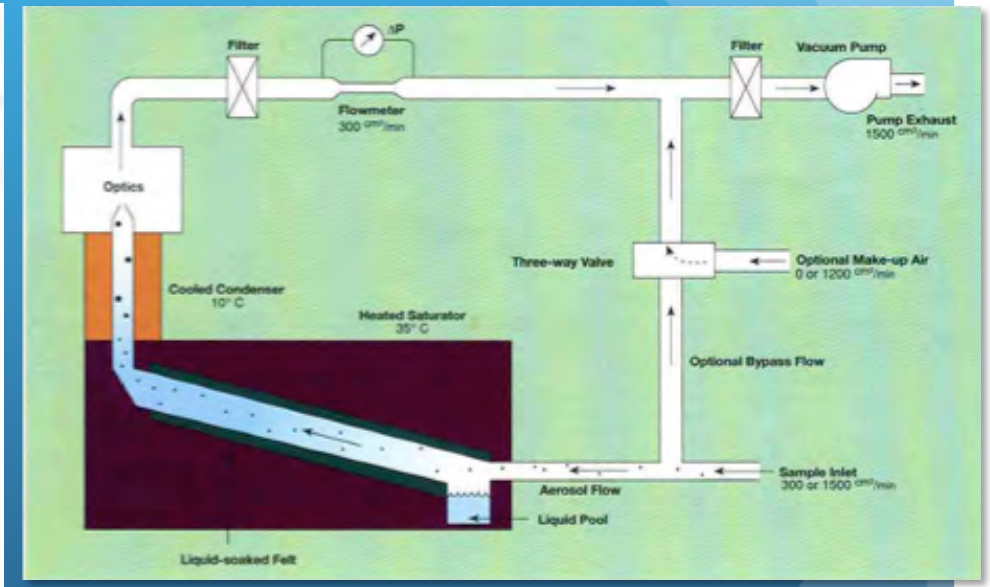


Engineered nanoparticle aerosols

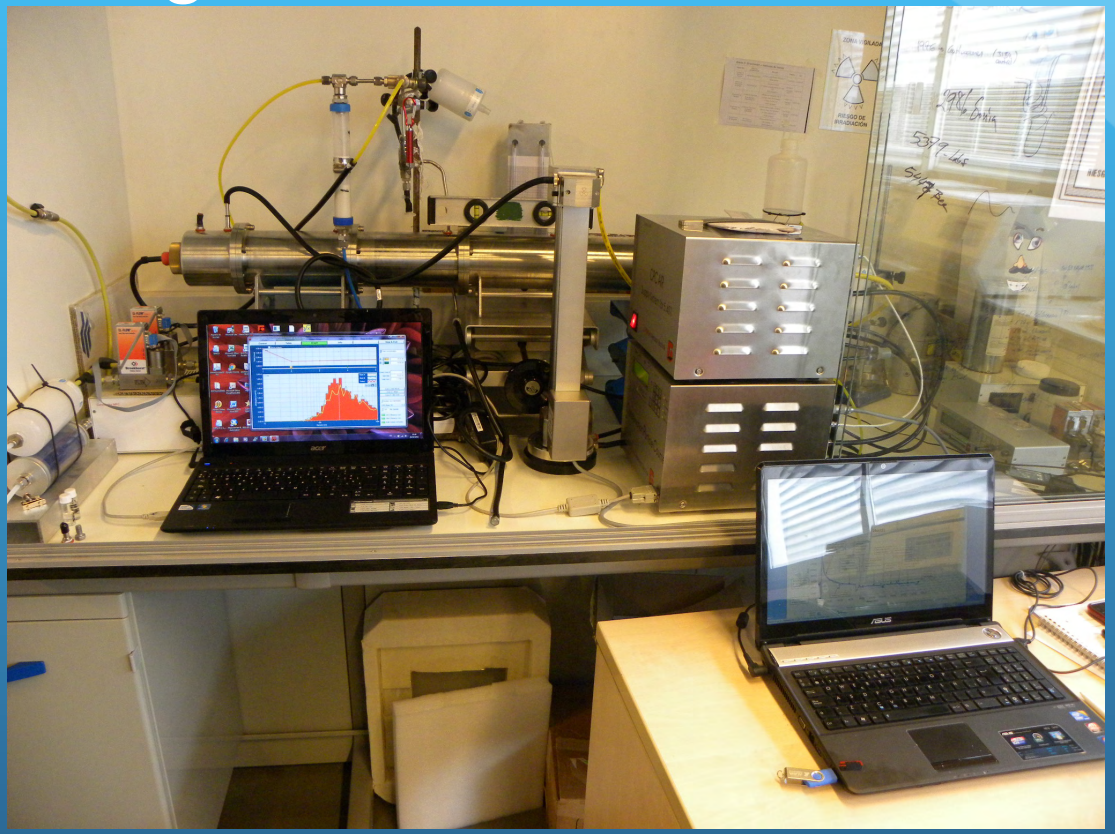
Electrostatic classification



Optical quantification



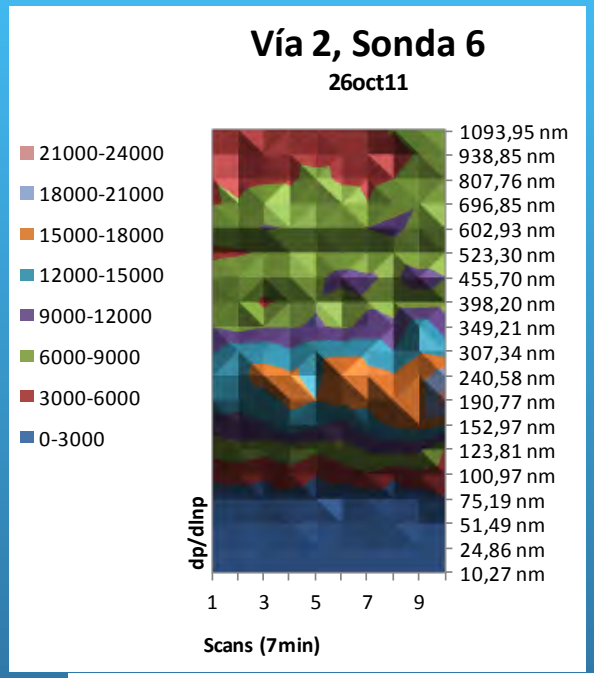
Aerosol generation and control

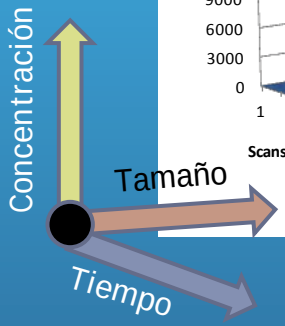


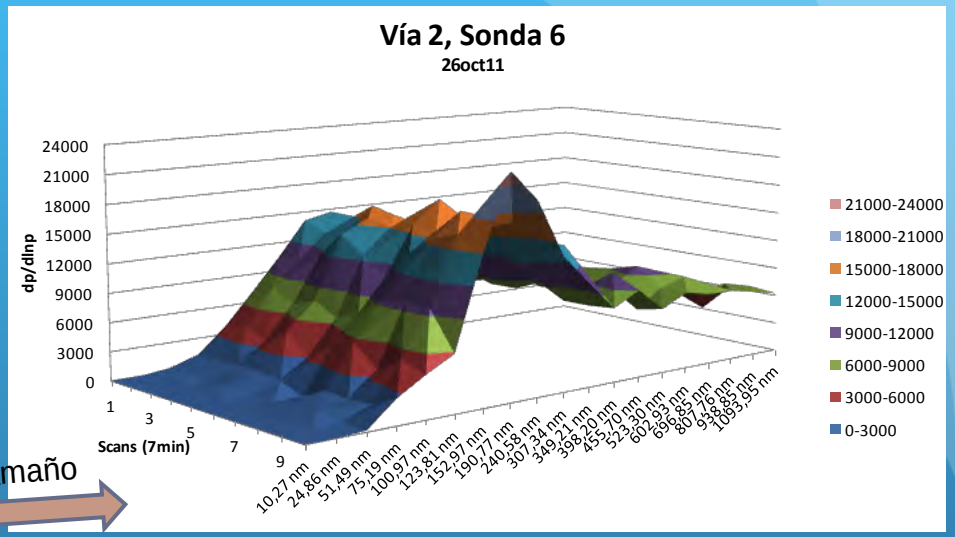
Dispersion tube for nanoparticle aerosol testing

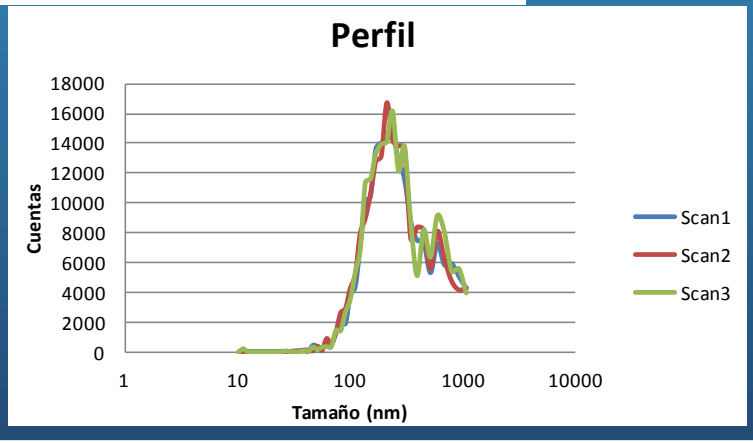
- Agglomeration/aggregation in air
- Nanoparticle surface charge
- Deposition in different surfaces and mechanical elements

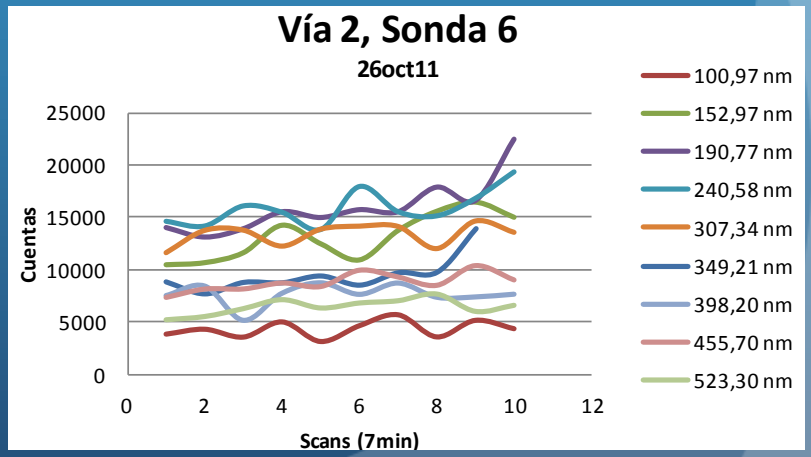
Engineered nanoparticles in aerosols







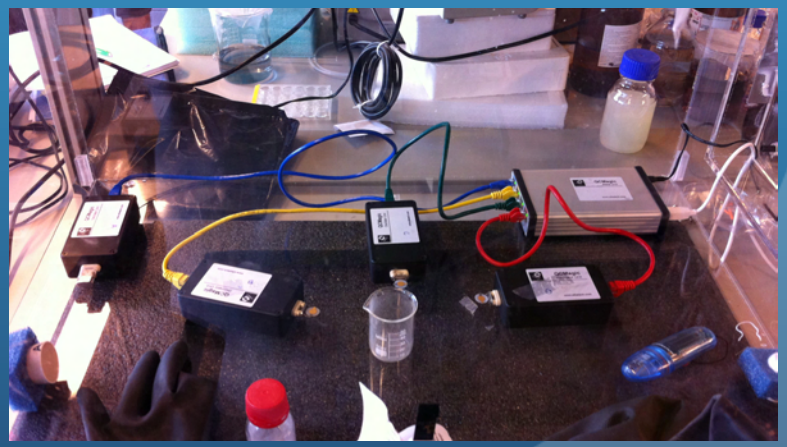




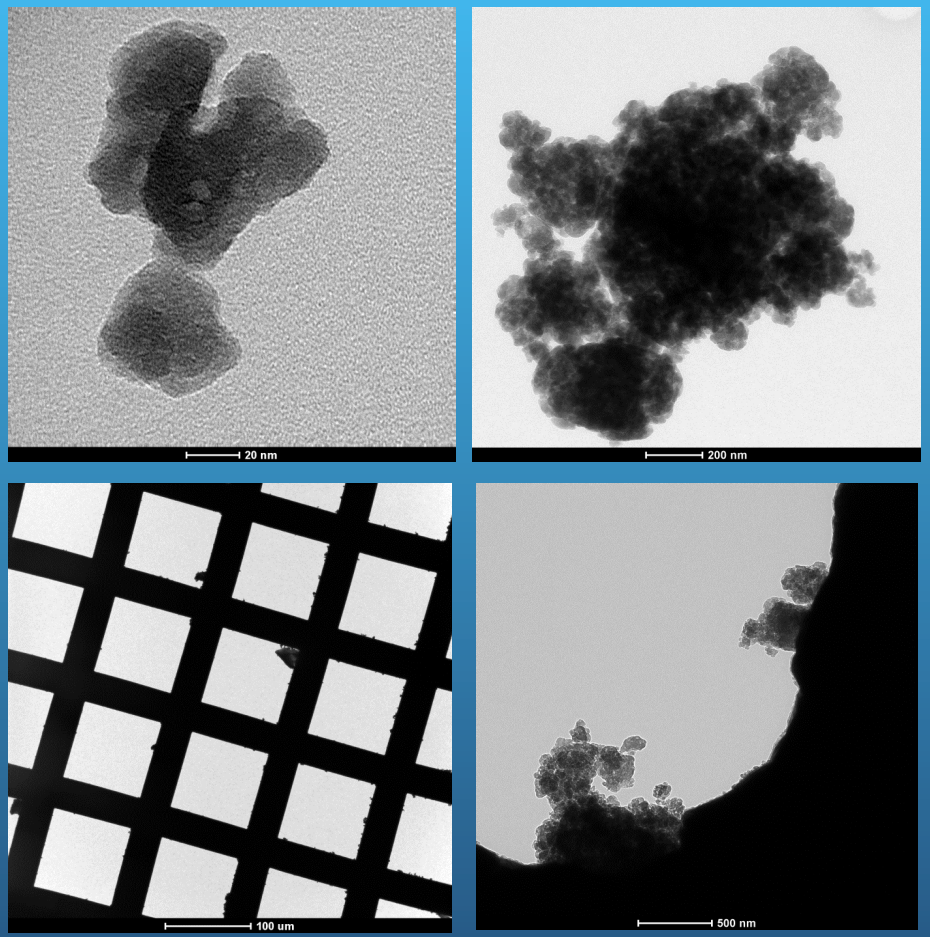
Aerosol dispersion monitoring in controlled environments

Test chamber for nanoparticle aerosols

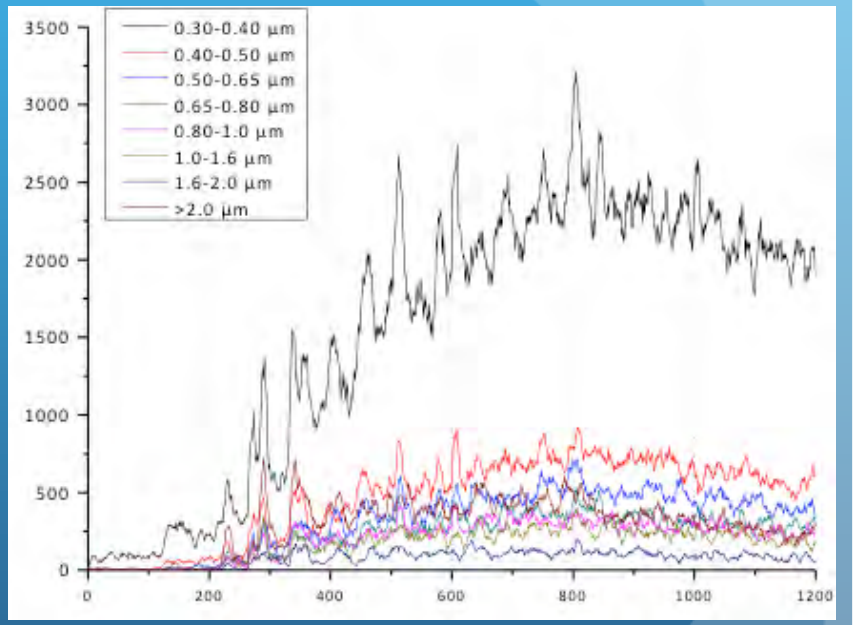
- Agglomeration/aggregation in air
- Mass analysis and deposition
- Risk assessment of laboratory operations with nanoparticles



Aerosol dispersion monitoring in controlled environments



SiO_2 ENPs collected from aerosol dispersion experiments under controlled conditions



Evolution of the ENP concentration in the Environment after weighing

Nanoparticle dispersion in the environment

Self-cleaning installation for dispersing engineered nanoparticles

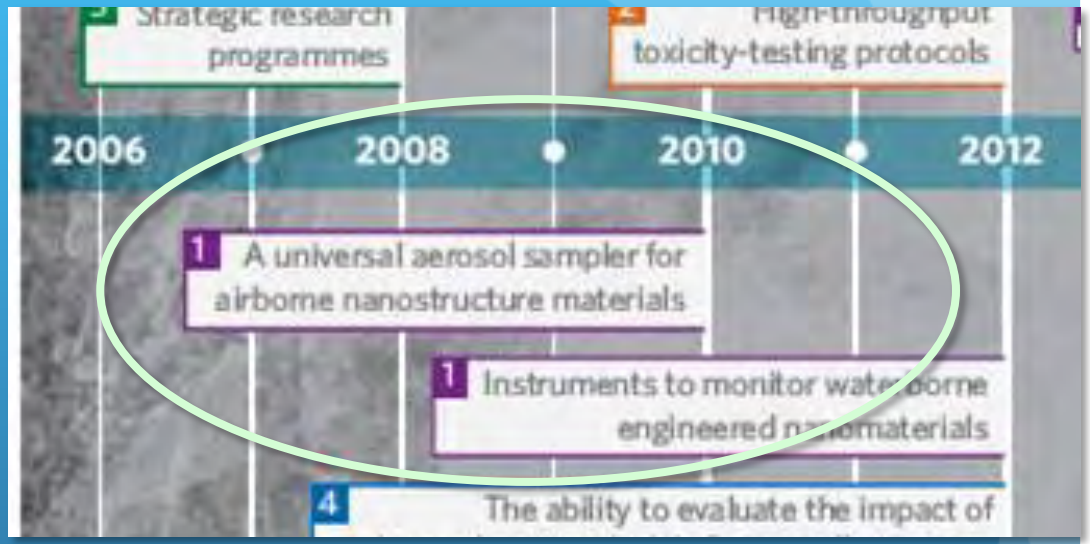
Controlled environments (II)

Installation for engineered nanoparticle aerosols

- Effect of nanoparticle properties in risk assessment (aggregation, dispersion, deposition…)
- Effect of atmosphere conditions in nanoparticle aerosols (humidity, temperature, pressure…)
- Assessment of laboratory operations in nanotechnology
- Environmental impact of nanoparticles
- Health impact of nanoparticles (Animal tests)

And now, in what are we working?

- One of the five challenges(Maynard):
  - developing instruments for assessing the exposure



- Difficult task because nanomaterials produced in the laboratory are not always readily distinguishable from those already in the environment

- Other possible factors:
  - Costs of nanosafety measures
  - Familiarity (or lack thereof) of the researchers with nanomaterials

Other things we need…

- Need for additional research of (possible) adverse health effects of nanomaterials
  - Continuous exposure conditions in research laboratories
  - Short-term exposures as a consequence of certain laboratory operations
- General guidelines (provided by reliable organizations)
- Accepted exposure levels and monitoring procedures
  - TLVs for ENPs
- Self-regulation in nanoscience and nanotech

Thank you for your attention