【S-1】

Nanotechnology and Occupational Health Addressing Potential Health Risks

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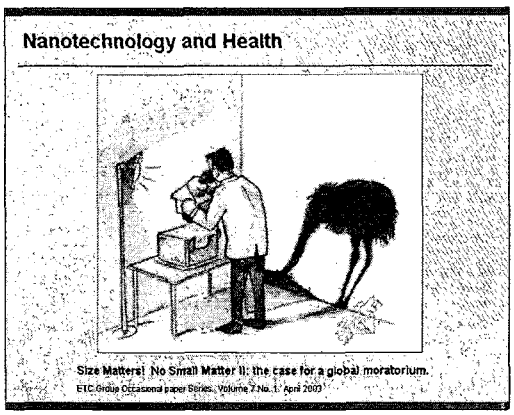
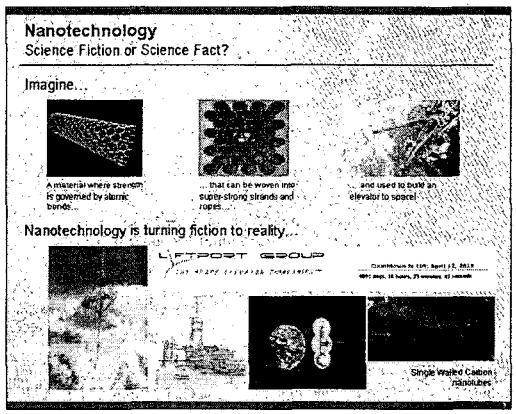
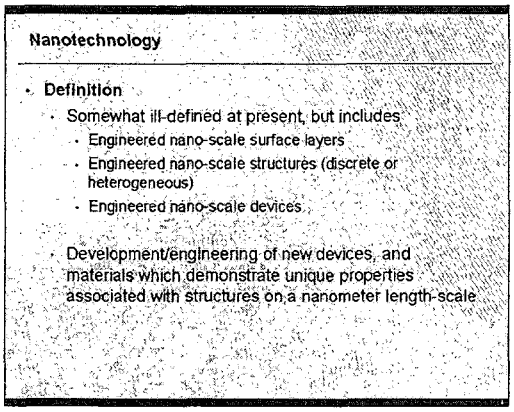
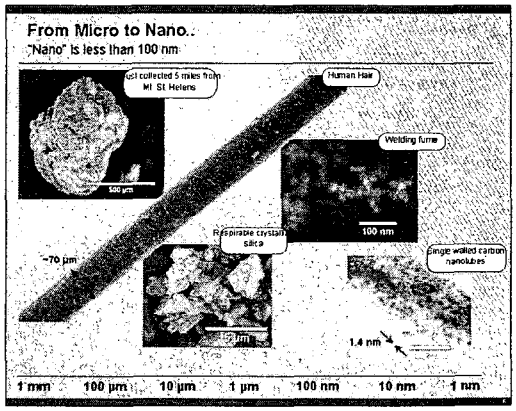
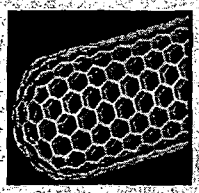








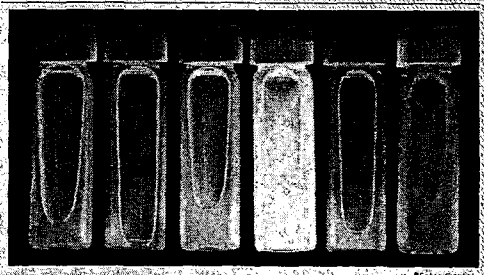
Unique Structures and Morphologies
Single Walled Carbon Nanotubes



- 1.4 nm in diameter
- Micrometers in length
- Unique physical, chemical and electronic properties

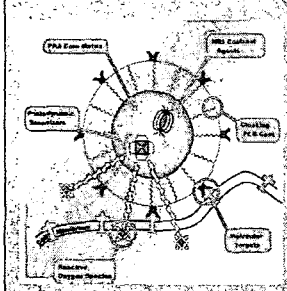
Transmission Electron Microscopy

Unique Quantum Properties
Quantum Dots - size-determined fluorescence

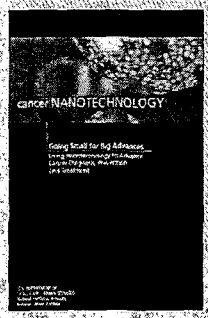


Smaller → Larger

Unique Devices
'Smart' multifunctional nanoparticles

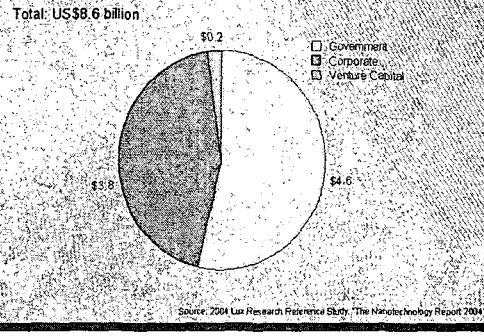


From NCI & R. Kopelman



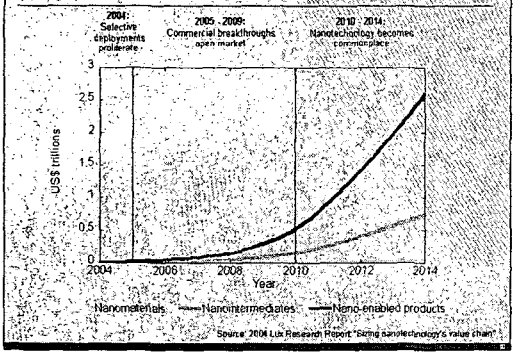
Nanotechnology
Global nanotechnology R&D investment in 2004 (US$ billions)

Total: US$8.6 billion



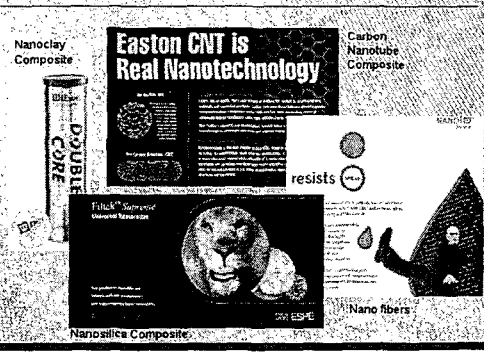
Source: 2004 Lux Research Reference Study "The Nanotechnology Report 2004"

Nanotechnology
Global forecast of products sold incorporating nanotechnology



Source: 2004 Lux Research Report "Sizing nanotechnology's value chain"

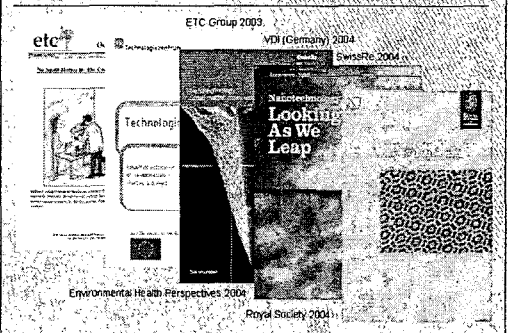
Nanotechnology is 'Now'
Selected consumer products



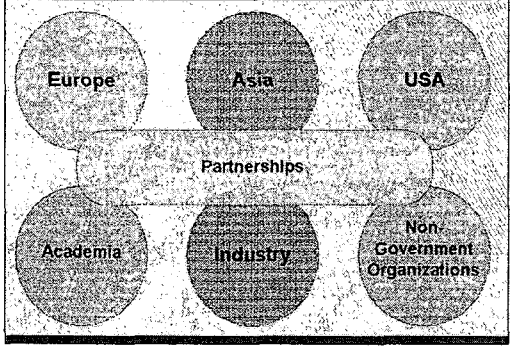
Defining the Issue
Nanotechnology and Occupational Health

- **Nanotechnology - The Motivation**
  - Purposely engineered nanostructured materials and devices demonstrate new, unique and non-scalable properties and behavior
- **Responsible Nanotechnology - The Challenge**
  - Does the nature of engineered nanostructured materials and devices present new safety and health risks?
  - How can the benefits of nanotechnology be realized while proactively minimizing the potential risk?

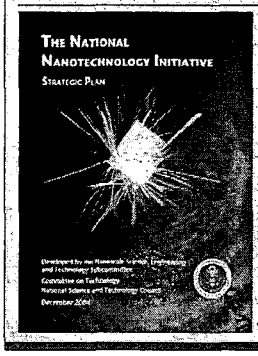
Concern over the Potential Impact of Nanotechnology



Impact of Engineered Nanomaterials
Global initiatives



US National Nanotechnology Initiative
Strategic Plan



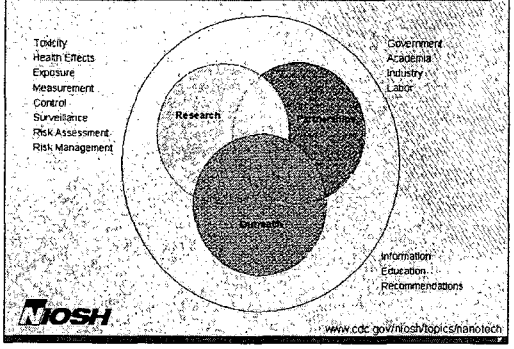
- **Goal 4: Support responsible development of nanotechnology**
  - Environmental, health and safety implications
  - Ethical, legal and all other societal issues

Program Component Area 7: Societal Dimensions

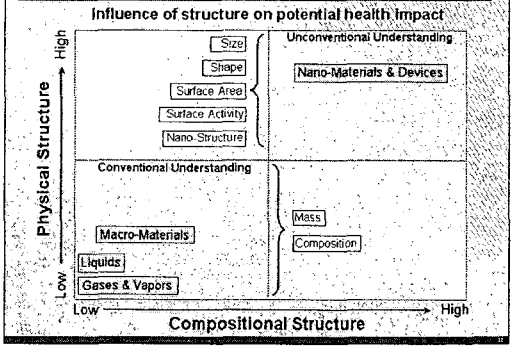
- Environmental, health and safety research
- Education
- Broad societal implications

www.nano.gov

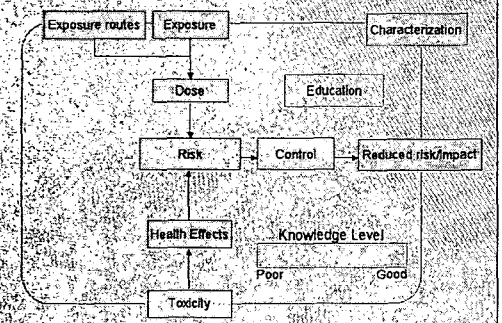
The NIOSH Nanotechnology Initiative
Addressing the implications and applications of nanotechnology in the workplace



Potential Health Impact
What makes 'nano' different?



Addressing Occupational Impact



Setting Boundaries

Engineered nanomaterials which potentially present new challenges

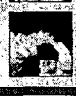
- Criteria:
  - Nanomaterials capable of entering or interacting with the body
  - Nanomaterials which potentially exhibit nanostructure-dependent biological activity

Nanoparticles
Simple, complex, "smart" Aerosols, powders, suspensions, slurries

Comminution
Aerosols from grinding, cutting, machining nanomaterials

Agglomerates
or aggregates of nanoparticles

Degredation/Failure
Aerosols and suspensions resulting from degradation and failure of nanomaterials



Aerosolized suspensions
Including slurries and solutions of nanomaterials

?

Unintentional use
Potential exposure from unanticipated unintentional use

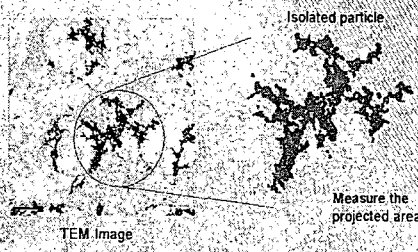
Monitoring Nanoscale Aerosol Exposures

Options

- **Adapt current mass-based approaches**
  - Continuity with the past
  - Sensitivity and relevance issues
- **Measure size distribution**
  - Provides a lot of information
  - Impractical in many instances
- **Monitor number concentration**
  - Relatively simple
  - Difficult to differentiate between process-related and background aerosols
  - Relevance?
- **Monitor aerosol surface area concentration**
  - Relevant for some materials
  - Is this achievable?

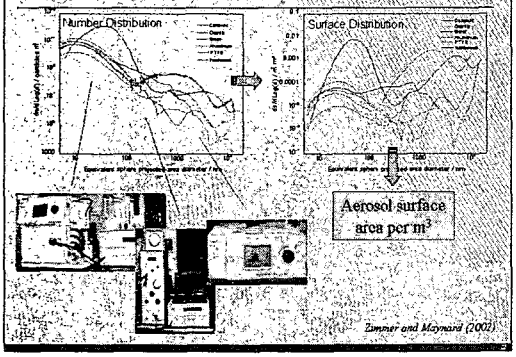
Aerosol Surface-Area Measurement

Transmission Electron Microscope Analysis



Aerosol Surface-Area Measurement

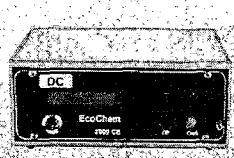
Derived from size distribution measurements



Aerosol Surface-Area Measurement

Using attachment rate

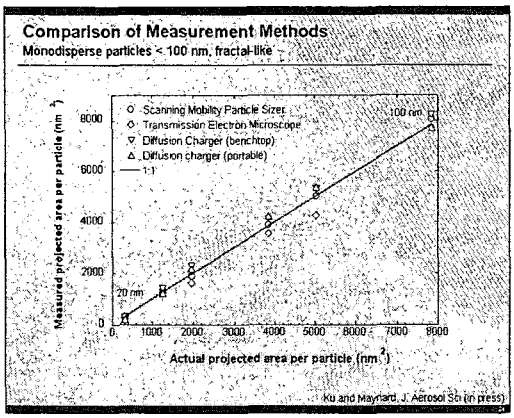
Charge on Aerosol ∝ Surface Area

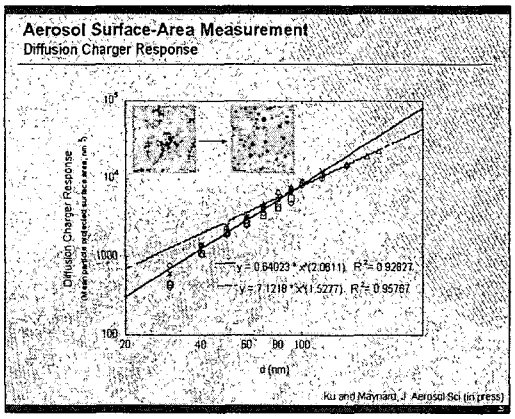


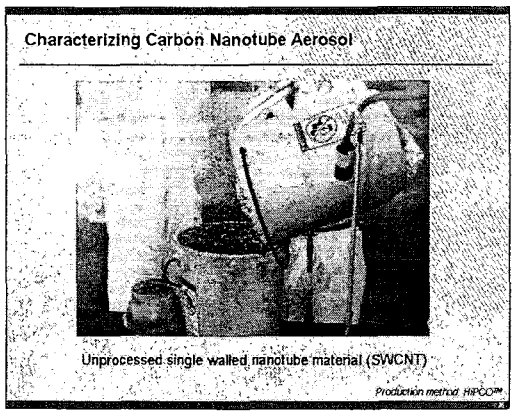
Ions

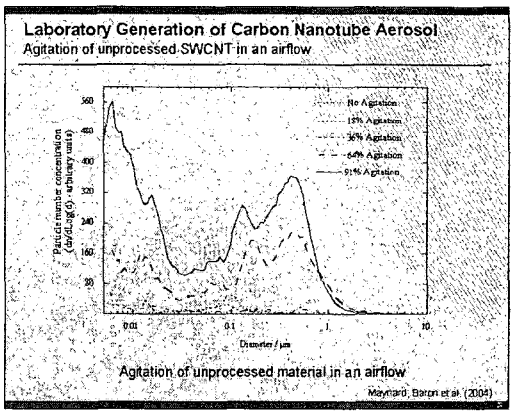
Electrometer

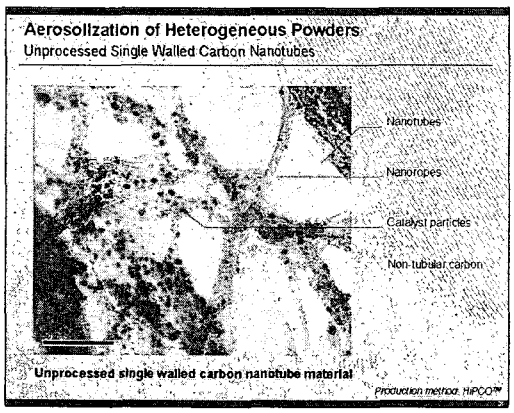
DC2000 CE Diffusion Charger
EcoChem

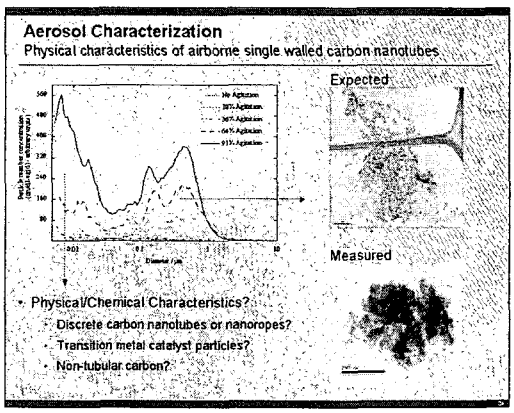

Comparison of Measurement Methods
Monodisperse particles < 100 nm, fractal-like
Scanning Mobility Particle Sizer
Transmission Electron Microscope
Diffusion Charger (benchtop)
Diffusion charger (portable)
1:1
100 nm
20 nm
Measured projected area per particle (nm²)
Actual projected area per particle (nm²)
Ku and Maynard, J. Aerosol Sci (in press)


Aerosol Surface-Area Measurement
Diffusion Charger Response
Diffusion Charger Response
y = 0.64023 * x^(2.0611), R² = 0.92827
y = 7.1218 * x^(1.5277), R² = 0.95787
d (nm)
Ku and Maynard, J. Aerosol Sci (in press)


Characterizing Carbon Nanotube Aerosol
Unprocessed single walled nanotube material (SWCNT)
Production method: HiPCO™

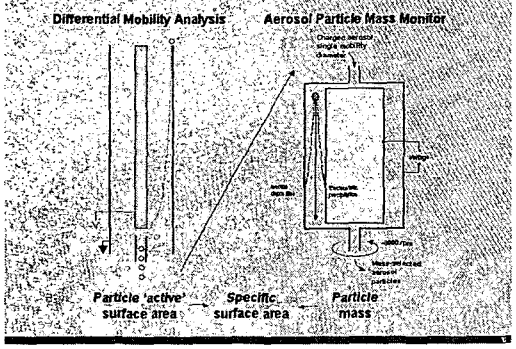

Laboratory Generation of Carbon Nanotube Aerosol
Agitation of unprocessed SWCNT in an airflow
No Agitation
15% Agitation
36% Agitation
64% Agitation
91% Agitation
Particle number concentration (dw/dlog(d), arbitrary units)
Diameter / µm
Agitation of unprocessed material in an airflow
Maynard, Baron et al. (2004)


Aerosolization of Heterogeneous Powders
Unprocessed Single Walled Carbon Nanotubes
Nanotubes
Nanoropes
Catalyst particles
Non-tubular carbon
Unprocessed single walled carbon nanotube material
Production method: HiPCO™


Aerosol Characterization
Physical characteristics of airborne single walled carbon nanotubes
Expected
Measured
Physical/Chemical Characteristics?
Discrete carbon nanotubes or nanoropes?
Transition metal catalyst particles?
Non-tubular carbon?

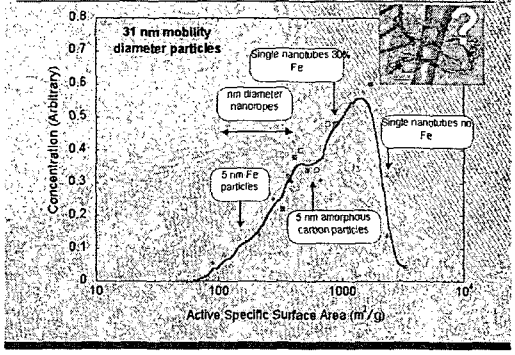
Aerosol Characterization

On-line 'Specific Surface Area' measurements



Aerosol Characterization

'Active' specific surface area

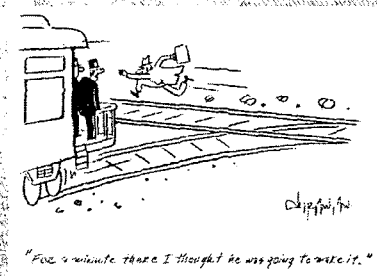


Summary

- Occupational safety and health is a key component of responsible nanotechnology
- Nanotechnology challenges conventional approaches to addressing occupational safety and health risk
- Nanomaterials and devices of concern include those capable of entering the body and causing harm as a result of their nanostructure
- Proactive risk assessment and management requires extensive strategic research
- Current knowledge provides a staring point for addressing risk

The Challenge:

Environment, Safety and Health Research



Development of responsible, sustainable nanotechnologies through proactively addressing risk