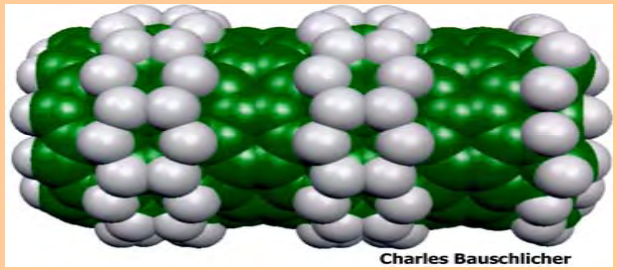

Nanotechnology and Policy

Ken Geiser
Lowell Center for Sustainable Production
University of Massachusetts Lowell
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Nanotechnology

- An extension of current science
- A revolutionary breakthrough that offers a wide range of commercial applications
- A technology that is already in current use
- A system that has the potential for significant social and economic impacts
- A host of materials with uncertain and concerning health and environmental impacts

Nanotechnology is an Enabling Technology

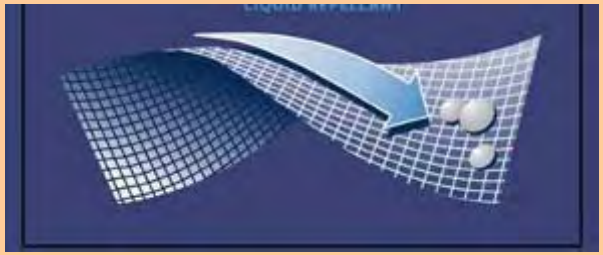
- Computing and Communication
- Materials and Manufacturing
- Health Care and Drugs
- Energy and Environmental Protection
- Cosmetics and Domestic Products
- Vehicles and Transportation
- National Security

Nanotechnologies in Commerce Today

- Sunscreens and Cosmetics
  - Nanosized TiO_2 and ZnO in some **sunscreens**
  - Nanosized Fe_2O_3 in some **lipsticks**
- Composites
  - Carbon nanotubes and fibers in **auto bumpers** and **tennis rackets**
  - Nanoclays in **plastics**

Nanotechnologies in Commerce Today

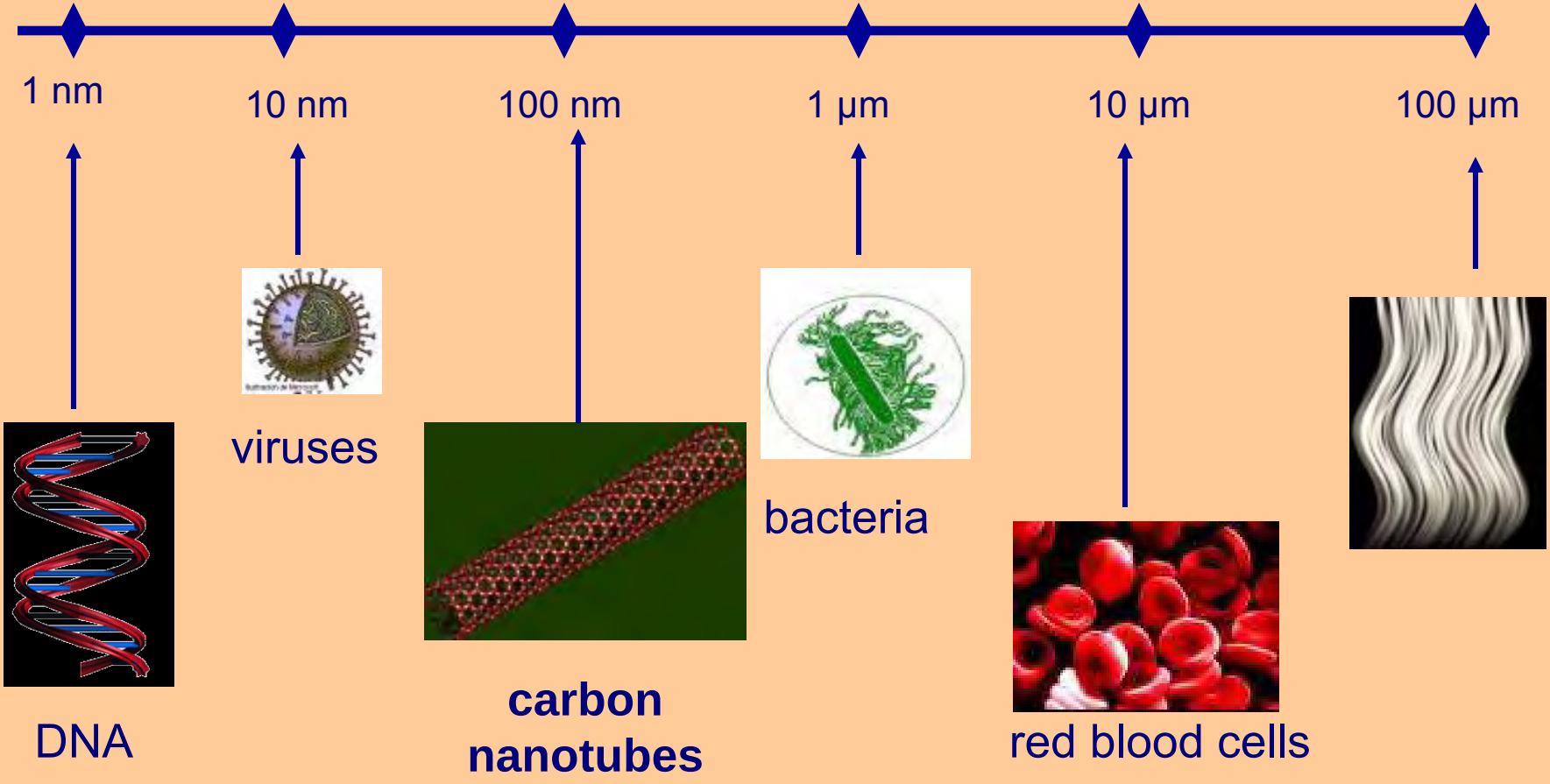
- Coatings and Surfaces
  - Water repellency (textiles)
  - Anti-bacterial properties
  - Wear and scratch resistance
  - Stain resistance
- Harder/tougher cutting tools



1. Definition

- The term “nanotechnology” was coined during the 1970s to define processes smaller than “microtechnologies”
- Nanotechnology involves precision placement, measurement, manipulation, processing and modeling at the nanoscale
- Nanostructures are material with at least one dimension 100 nanometers or less

Nanometer (nm) Scale



U.S. Federal (NNI) Definition

- researching and developing technologies that work at the atomic, molecular or macromolecular level of the scale of 1 to 100 nanometers
- involving structures, devices and systems that have novel properties and functions because of their scale
- controlling or manipulating materials at the atomic level

Nanomaterials are Not New

- Most biological processes occur at the nanoscale
- Combustion processes and many chemical processes generate unintended nanoscale particles (e.g. soot particles, flour dust, welding fumes)
- Portions of many conventional industrial chemicals (carbon black, paint pigments, silica, etc.) are nanoscale
- Indeed, nanomaterials are manufactured from known chemicals such as carbon, iron, silicon, titanium

Nanomaterials are Very New

- However, nanomaterials have different properties from bulk chemicals because of
  - **Scale**
  - **Surface area per unit of mass**
  - **Quantum effects**
- And, nanotechnology and our ability to measure, manipulate and process at the nanoscale are very new

2. Nanoscience and Nanomanufacturing

Nanoparticles

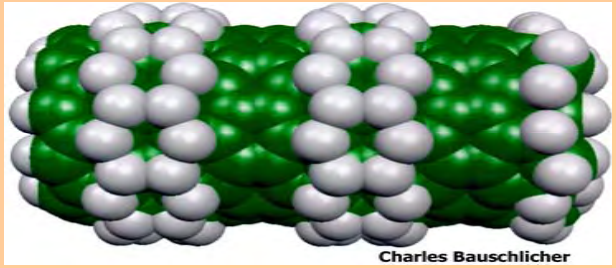
- Nanolayers (e.g. quantum wells)
  - structures with 1 nano dimension
- Nanowires (e.g. nanotubes)
  - structures with 2 nano dimensions
- Nanostructures (e.g. fullerines, quantum dots)
  - 3 nano dimensional structures

Production Techniques

- Compaction and consolidation
- Thin film epitaxy
- Nanoscale lithography
- E-Beam lthography
- Self-assembly
- Nanoscale crystal growth
- Polymerization

Nanotubes

- Carbon nanotubes were first developed in 1991 by Sumio Lijima
- They consist of hexagonal lattices of carbon atoms arranged spirally to form concentric cylinders
- Single walled nanotubes (SWNTs) may have a diameter of 1.4 nm



Nanotubes

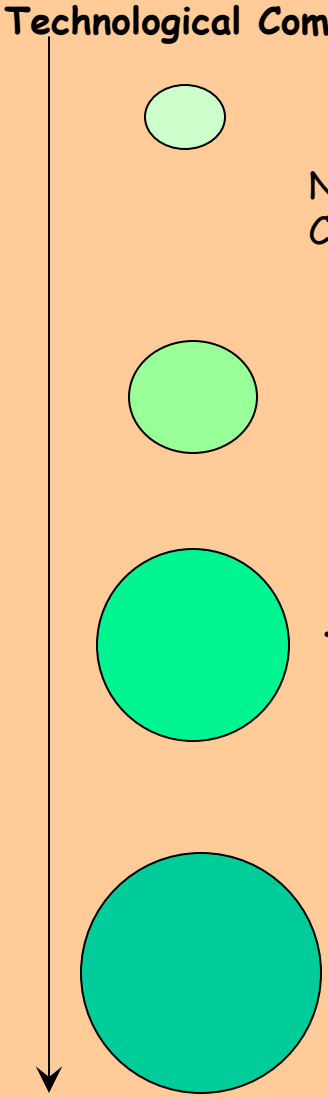
- Nanotubes are stronger than steel, but flexible and light weight, can behave like semiconductors, and transfer heat better than any other known material
- Current nanotubes are made from carbon, silicon and iron
- Carbon nanotubes can be bought today over the Internet

Nanomachines and Nanodevices

- Nanotechnology already produces smart materials that respond to changes in their environment
- Molecular nanotechnolgy promises to produce nanoscale devices that can react, compute and replicate
- It remains debatable whether these nanomachines are capable of self replication and autonomous direction

3. Nanotechnology Development

Stages of Nanotechnology Development



First Generation ~2001: Passive nanostructures

Nano-structured coatings, nanoparticles, nanostructured metals, polymers, ceramics, Catalysts, composites, displays

Second generation ~Now: Active nanostructures

Transistors, amplifiers, targeted drugs and chemicals, actuators, adaptive structures, sensors, diagnostic assays, fuel cells, solar cells, High performance nanocomposites, ceramics, metals

Third Generation ~ 2010: 3-D nanosystems and systems of nanosystems

Various assembly techniques, networking at the nanoscale and new architectures, Biomimetic materials, novel therapeutics/targeted drug delivery

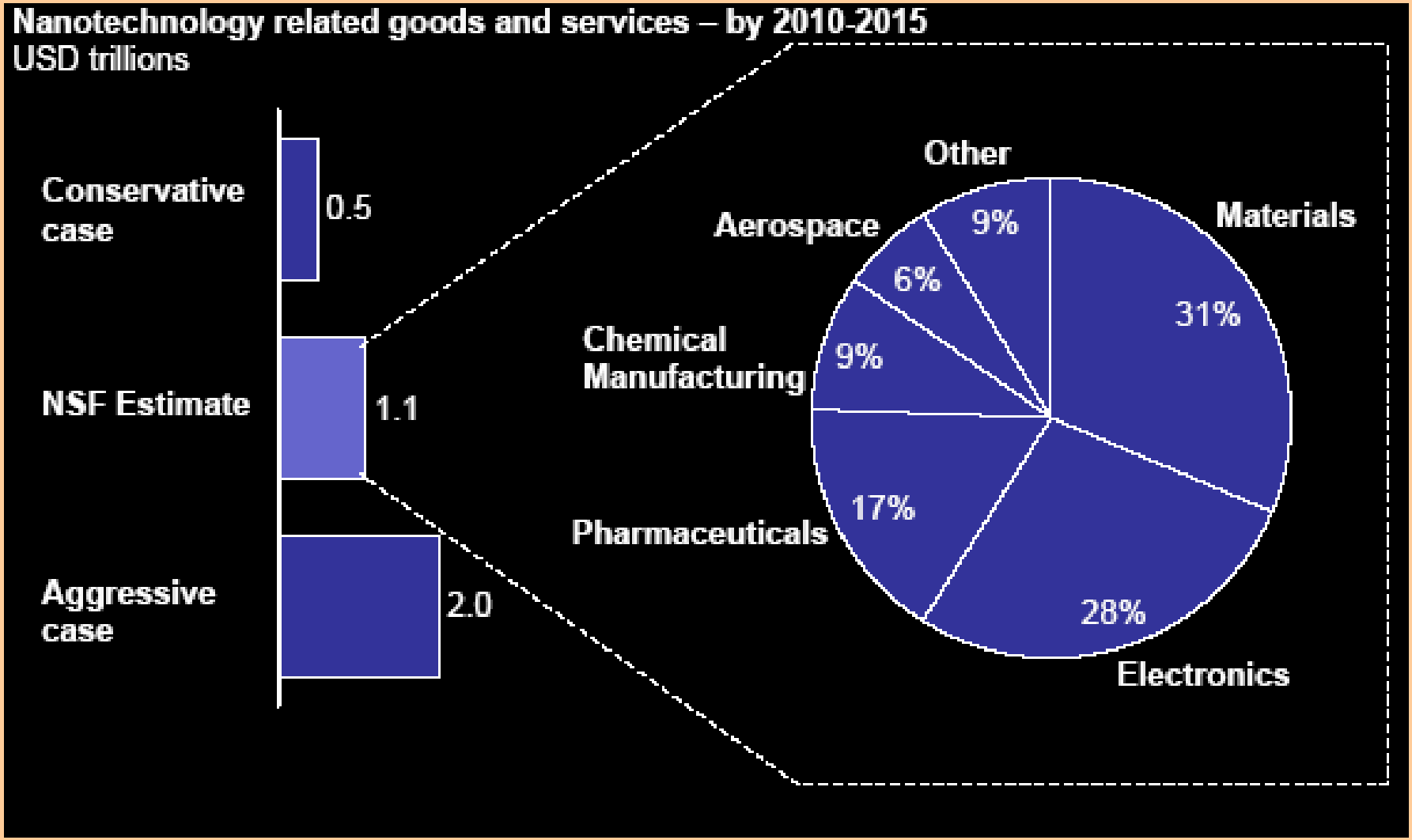
Fourth Generation ~2015 Molecular Nanosystems

Molecular devices "by design", atomic design, emerging functions

Current Investments

- Worldwide national government investment in 20 countries today reaches $4 billion annually
- Combined worldwide government and corporate funding exceeded $7.6 billion in 2004
- U.S. government nanotechnology R&D funding reached $1.6 billion in 2004 making nanotechnology the nation’s largest government funded science initiative

Projected Growth of Nanotechnology



U.S. National Nanotechnology Initiative (www.nano.gov)

- Launched in 1997 by President Clinton to
  - advance research
  - facilitate technology transfer
  - train a workforce
  - study social and environmental effects
- Funds programs in 11 agencies with the largest share going to the Department of Defense
- Funding has grown from $116 million in 1997 to just over $1 billion in FY 2006
- Provided over 2,500 research grants over the past 7 years

Nanotechnology Industry

- Industry is developing around the world
- 26 countries have nanotechnology development programs (China has a very large national program)
- Large firms include GE, HP, Dupont, Intel
- Over 500 small firms already exist in the United States

Future Applications

Technological Convergence

- Nanotechnology is inherently multidisciplinary based in physics, chemistry, biology and engineering
- Collaborations already involve nanotechnology, biotechnology and information technology
- The prospects are truly awesome offering significant social and ethical dimensions

4. Nanotechnology and Environmental and Health Policy

Potential Hazards of Nanotechnology

- Scientific studies of effects are limited
- We do know:
  - greater surface areas means increased bioactivity
  - inhaled particles reach all areas of the respiratory tract
  - blood and lymph transport exposes bone marrow, lymph nodes, spleen, heart and central nervous system
  - there is evidence of inflammatory and anti-oxidative responses as well as mitochondrial distribution and oxidative stress

Potential Hazards of Nanotechnologies

- Studies show nanoparticles pass through cell membranes
- Studies in bass show nanoparticles pass through the blood/brain barrier
- Studies show nanoparticles agglomerate and transport larger molecules
- 2006--Germany withdraws first product know to be “leaking” nanoparticles

Potential Exposures to Nanotechnologies

- In research labs
- In industrial production facilities
- In environmental releases
- In products in commerce
- In wastes

Federal Statutory Authority

- **Media Specific Pollutants**
  - Clean Air Act of 1970
  - Clean Water Act of 1972
  - Resource Conservation and Recovery Act of 1976
- **Occupational Health**
  - Occupational Safety and Health Act of 1970
- **Products**
  - Federal Hazardous Substances Act of 1960
  - Consumer Product Safety Act of 1972
- **Chemicals**
  - Toxic Substances Control Act of 1976

Regulatory Challenges

- What agencies have what authority?
- When is a substance nanoscale (characteristics and nomenclature)?
- Are nanoscale substances New or Existing substances?
- What scientific evidence is there for regulation?
- Is there a basis for precaution?

Nanotechnology and Health Policy

- To date no public health agency has moved to regulate nanotechnologies
- A case:
  - Titanium dioxide nanoparticles in sunscreen.

    FDA considered, but did not regulate, because there is no active ingredient in sun screen

Nanotechnology and Occupational Health Policy

- Some 2 million workers may be exposed to ultra fine particles, nanotechnology may involve another 1 million workers
- An interagency Working Group has been established
- NIOSH has begun funding studies of occupational exposures
- ANSI has begun to develop voluntary guidelines
- OSHA has no specific standards, but argues that current standards are applicable
  - Hazard Communication Standard, Respiratory Protection Standards and PELs on cadmium, titanium dioxide and graphite

Toxic Substances Control Act

- Regulatory power to require testing
- Responsibility on industry to provide data on risks
- Regulatory power to restrict (ban) chemicals in commerce
- Divides chemicals into New and Existing
- Requirement for Pre-Manufacture Notice (PMN) on all new chemicals
- Quaternary National Inventory Update

Nanotechnology and Environmental Policy

- May, 2005 EPA under its TSCA authority proposed a Voluntary Pilot Program for collecting information from firms in the nanotechnology industry
- Public hearing held in June
- Referred to National Pollution Prevention and Toxics Advisory Committee (NPPTAC)
- Recommendations presented in November, 2005

NPPTAC Recommendation

- Voluntary industry reporting program
- Two levels
  - Basic: physical characteristics, quantity and existing effects data
  - In-Depth: Basic plus new test data
- Begin Section 8 reporting regulatory process
- Program to be evaluated in two years
- EPA still considering recommendations

Environmental Movement Responses

- 2002 -- ETC Group proposes ban on all further production until effects research catches up
- 2004 -- Environmental Defense proposes 10% of NNI funds go to effects research
- 2005 -- NRDC proposes restricting environmental releases, requiring PMNs, developing an inventory, and requiring export notififcation

Policy Options

- Increased research on social and environmental effects
- Restrictions on environmental release
- Product labeling on nano ingredients
- National inventory of uses and distribution
- Precautionary occupational protections

What to Do?

- Do nothing
- Wait for more science
- Wait for other nations to act
- Begin regulations now