Nanotechnology: Opportunities and Impacts of a Scientific Revolution

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Nanotechnology: Opportunities and impacts of a scientific revolution

• What is nanotechnology?
• The tools of nanotechnology
• Nanotech in the 21st Century
Feynman’s vision: “There’s plenty of room at the bottom”

• Why can’t we manipulate materials atom by atom?
• Why can’t we control the synthesis of individual molecules?
• Why can’t we write all of human knowledge on the head of a pin?
• Why can’t we build machines to accomplish these things?
Nature’s benchmarks

- DNA (50 atoms per bit of information)
- Molecular motors
- The human brain
  - 100 trillion \((10^{14})\) connections
  - a million billion \((10^{15})\) bits of memory
  - a million billion \((10^{15})\) calculations per second
- Self-assembled composites (shells)
What is nanoscience

• A revolution in the way we look at the physical world

• Allows the study of materials at length scales where properties are determined

• Addresses materials behavior at dimensions of 1-100 nm
  – Properties depend on size (\textit{small is different})
  – New and unexpected phenomena
  – Requires atom-by-atom assembly

Interactions of protein molecules

Natural methane storage in clathrate molecules
Oak Ridge National Laboratory is investing $2B in world-class nanotech tools

Why now?

- New tools for atomic-scale characterization
- New capabilities for single atom/molecule manipulation
- Computational access to large systems of atoms and long time scales
World-class capabilities for nanotechnology at ORNL

The Spallation Neutron Source

- Nation’s largest civilian science project
- $1.4B in buildings and equipment
- World’s most powerful pulsed neutron source
- Nanoscale structure and dynamics of materials and biological systems
- 1500-2000 scientific users annually

First neutrons produced April 28, 2006
World-class capabilities for nanotechnology at ORNL
The Center for Nanophase Materials Sciences

- DOE’s first nanoscience center
- $65M in buildings and equipment
- State-of-the-art synthesis and characterization of nanoscale materials and structures
- Available to universities and industry based on competitive peer review

The CNMS is located next to the Spallation Neutron Source

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY
World-class capabilities for nanotechnology at ORNL

Leadership-class computing

- Large-scale simulation needed to predict materials properties and trends
- We are building the world’s most powerful computer for scientific research
- Predicting new materials rather than explaining existing ones

Building to 1 petaflop by 2008

Understanding microbial molecular and cellular systems

Designing innovative nanomaterials
The promise of nanotechnology

- More powerful computers
- New materials 100 times as strong as current materials
- New approaches for medical diagnosis and treatment
- New catalysts for cleaner, more efficient chemical and energy industries
- New technologies for energy production and conversion
- Fast chemical analyses
• Recruit nano companies and grow our own

• Build a pipeline of new talent
  – Scientists and entrepreneurs

• Establish a Southern Alliance for Nanotechnology

• Create a nano commercialization facility to leverage existing research facilities

• Leverage $2 billion of new nano facilities
• Connect with world-class researchers
• Access patented technology
• Plant the seed of a new business
Nanotechnology in the 21st Century

- Dramatic advances at the frontiers of physics, chemistry, materials sciences, and biology
- New products and services for medicine, materials, information technology, energy, environment, biotechnology, and national security
- Broad engagement of the public to address societal implications

Nanoscience will change the nature of almost every human-made object in the next century.

National Science and Technology Council, 2000