Nano-Materials Roadmap
Impact on Space Transportation, Space Science and Earth Science

Biomimetics and Bio-inspired Systems
Impact on Space Transportation, Space Science and Earth Science

CNT = Carbon Nanotube

Nano-Materials Roadmap Program Content

- Nanotechnology Program Elements
  - Nanoelectronics and Computing
  - Sensors
  - Structural Materials

Acknowledgement

Experimental Work:

- Meyya Meyyappan (Program Director)
- Viktor Stolc (Genomics/Nanopore)
- Jonathan Trent (Protein Nanotubes)
- Jie Han (Bio-Sensors)
- Jun Li (Bio-Sensors)

Carbon Nanotube

CNT is a tubular form of carbon with diameter as small as 1 nm. Length: few nm to microns.

CNT is configurationally equivalent to a two-dimensional graphene sheet rolled into a tube.

CNT exhibits extraordinary mechanical properties: Young’s modulus over 1 Tera Pascal, as stiff as diamond, and tensile strength ~ 200 GPa.

CNT can be metallic or semiconducting, depending on chirality.

Diagnostics, Sensing and Imaging
- Nanotubes, Fullerene, Nanoparticles, Nanowires, Quantum Dots
- Nanodevices for Fast Genomics and Proteomic

Drug Delivery
- Encapsulating Materials, Nanoporous Systems
- Nano-Surgery/Manipulation
- Molecular Machine, Nano-controlled Energy Deposition

Novel Materials/Concepts
- Cylindrical Nanotubes (CNT) for sensing and processing
- Nanomaterials for bio-nanometric functionality
- Technology and Materials for Drug Design
- Nano-Bio interface for drug design
Solid-state nanopores for DNA sequencing:
the fastest method for sequencing nucleic acids

1 subunit/microsecond = 1 human genome in 2hrs

HGP: 13 years /single genome/ $3 billion
Impact/Applications:

Rapid extraction of genetic information to enable:

1. *In-situ* detection of DNA, RNA, or protein on other planets.
2. Identification of the genetic basis of phenotypic variation among all organisms on Earth.
3. Personalized molecular medicine
   \[1 \text{ subunit/microsecond} = 1 \text{ human genome in 2hr.}\]
High value of Young's Modulus (1.2-1.3 T Pa for SWNTs)
- Elastic limit up to 10-15% strain

Computer Simulations: Characterization of New Materials!

Nanostructured skin effect!

Computer Simulations Generating new IP!


Cerebral Sensory System (inter-neuron) of a cricket

A 4-level denticulate neural tree: 14 branched carbon nanotube junctions

Biological Dendritic Neural Tree
- One-dimensional cable theory
- Hodgkin-Huxley model for action-potential based information flow
- Information processing is coded in (a) branching at the junctions, and (b) time sequence sequencing of the signal spikes
- Input - output - control is based on (a) structural details of the branches and junctions, and (b) via chemical neurotransmitters
- Short and long term memory is part of the structure: evolutionary in nature

Carbon Nanotube: Dendritic Tree
- Electronic, acoustic, thermal, and chemical signal transmission and information processing
- Information processing can be based on (a) branching - switching at the junctions, and (b) time sequence sequencing of signal spikes
- Input - output - control: can be based on (a) structural details, (b) chemical environment, and (c) physical contacts at the ends
- Short and long term memory can be part of structure by defect and chemical adsorbed placement: design for specific purpose/functionality

External Collaborators:
- Prof. K. Cho (Stanford University)
- Prof. Don Brenner (NC State University)
- Dr. Madhu Menon (University of Kentucky)
- Dr. Antonis Andriotis (Crete, Greece)
- Dr. Uri Sagman (CSixty, USA)