Center for Integrated Nanotechnologies (CINT)

Bob Hwang
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Department of Energy Nanoscience Centers

Center for Nanoscale Materials
Molecular Foundry

Center for Functional Nanomaterials
Center for Integrated Nanotechnologies

Center for Nanophase Materials Sciences

Los Alamos National Laboratory
Sandia National Laboratories
Access to extensive facilities at LANL and Sandia

- Microelectronics Development Lab & MESA
- Compound Semiconductor Research Lab
- National High Magnetic Field Lab
- Lujan Neutron Scattering Center
- Synthesis, Characterization, & Theory
- Biosciences
CINT Milestones in last year

CINT at full operations (Core and Gateway)

1st BES review of operations (April, 2007)

Permanent CINT management team (Oct. 2007)
CINT’s focus is on Nanoscience Integration

The science of nanomaterials integration

Combining diverse nanomaterials together into composite structures across length scales and into nanosystems to discover, understand, and design materials with novel properties and performance.

Bi-functional materials

Directed assembly

Active nanosystems

Nanocomposite materials

Metal

Semiconductor

Co

CdSe

Combining ferromagnetic & semiconducting behavior

Nanoscale inhomogeneities

Engineered nanocomposites

Switchable metamaterials

Nanowire arrays

Nanomechanical arrays

Length scale

Nano

Micro
Science Thrusts

Nanophotonics & Optical Nanomaterials
Synthesis, excitation and energy transformations of optically active nanomaterials and collective or emergent electromagnetic phenomena (plasmonics, metamaterials, photonic lattices)

Nanoscale Electronics, Mechanics & Systems
Control of electronic transport and wavefunctions, and mechanical coupling and properties using nanomaterials and integrated nanosystems

Soft, Biological, & Composite Nanomaterials
Solution-based materials synthesis and assembly of soft, composite and artificial bio-mimetic nanosystems

Theory & Simulation of Nanoscale Phenomena
Assembly, interfacial interactions, and emergent properties of nanoscale systems, including their electronic, magnetic, and optical properties
CINT Nanoscience Integration Challenges

**Energy Transfer**
What are the fundamental limits and enabling principles that will enable us to integrate nanoscale heterostructures into systems that detect, transfer, and transduce energy with extreme sensitivity and efficiency?

**Emergent Properties**
What are the collective properties of composite nanoscale systems that cannot be predicted in terms of the individual constituents? How can we design integrated nanoscale systems with desired behaviors?
Addressing CINT Challenge in Energy Transfer: *Electrically Driven Energy-Transfer LED*

- **n-type contact**
  - Ti/Al/Ni/Au
  - 3 nm n-type GaN
  - 3 nm InGaN QW
  - 10 nm undoped GaN
  - thick p-type GaN

- **p-type contact**
  - Pd/Au

- >10% color-conversion efficiency ($\eta_{cc}$)

$$\eta_{cc} = \frac{I_{NC}}{I_{QW}} = 12\%$$

- **Future work:**
  - IR Energy-transfer LED (III-V QWs & lead-salt NCs)
  - PV structures utilizing ET from NCs to QW

with Nanosystems Thrust

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Semiconductor nanomaterials will enable previously unattainable control of electronic properties for integrated nanosystems

Growth of electronic Si, Ge and Si/Ge nanowires

Integration by directed assembly

Nanowire sensing

Potential impact

- Energy applications: high efficiency thermoelectrics
- National security: ultra sensitive chem/bio sensors
- Industrial competitiveness: future nanoscale electronic and photonic devices
CINT Thrust Leaders

Nanoscale Electronics, Mechanics & Systems
- Mike Lilly
- Victor Klimov
- Mike Nastasi
- Igal Brener

Nanophotonics & Optical Nanomaterials
- Bruce Bunker

Soft, Biological & Composite Nanomaterials
- Andy Shreve

Theory & Simulation of Nanoscale Phenomena
- Sasha Balatsky
- Mark Stevens
Discovery Platforms™

Standardized modular, micro-laboratories—designed and batch fabricated for:
- Integrating nano and micro length scales
- Studying properties of nanoscale materials and devices
- Directly accessing wide range of CINT characterization tools

**Electrical Transport & Optical Spectroscopy Platform™**

**Cantilever Array Platform™**

**Hybrid Discovery modules**

Discovery Platforms™ are fabricated in MESA
Discovery Platform coupling of techniques - unprecedented understanding

Energy Transfer in nanomaterial systems

- Synthesize nanowire
- Manipulate nanowire to platform
- Structural & chemical characterization
- Electrical & Optical characterization
Vibrant User Community

NSRCs are Science-based User Facilities

Outstanding User program developed from Outstanding Science Program
CINT’s User Calls

2006 Call for User Proposals
176 proposals (129 accepted, 73%)
32 States
10 Foreign Countries

2007 Call for User Proposals
101 proposals
79 accepted, 78% success rate

Jump Start Program
Total requests: 257
Approved: 36 (2003)
32 (2004)
21 (2005)