The U.S. National Nanotechnology Initiative and Small Business Research Enterprises

T. James Rudd, Ph. D.
National Science Foundation

International Congress of Nanotechnology

San Francisco, CA

November 3rd, 2005

National Nanotechnology Initiative (NNI)

- Multi-agency U.S. Government program to accelerate the discovery, development,and deployment of nanoscale science, engineering and technology.
- Goals are to maintain a world-class R&D program; to facilitate technology transfer; to develop educational resources, a skilled workforce,and supporting research infrastructure and tools ;and to support responsible development of nanotechnology.

Agencies in the National Nanotechnology Initiative

- National Science Foundation
- Department of Defense
- Department of Energy
- National Institutes of Health
- National Institute of Standards
- National Space Administration
- Environmental Protection Agency

Program Component Areas

- Fundamental Nanoscale Phenomenon
- Nanomaterials
- Nanoscale devices
- Instrumentation Research ,Metrology
- Nanomanufacturing
- Acquisition of Major Research Facilities
- Societal Dimensions

Industry Liaison in Support of Technology Transfer and Commercialization

- Chemical Industry
- Semiconductor/Electronics Industry
- Industrial Research Institute
- SBIR/STTR programs

Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) Program at the National Science Foundation

Participating Agencies

DOD	Defense
HHS	Health
NASA	Space
DOE	Energy
NSF	**~$104Million**
DHS	HomeLand Security
USDA	Agriculture
DOC	Commerce
EPA	Environment
DOT	Transportation
DoED	Education

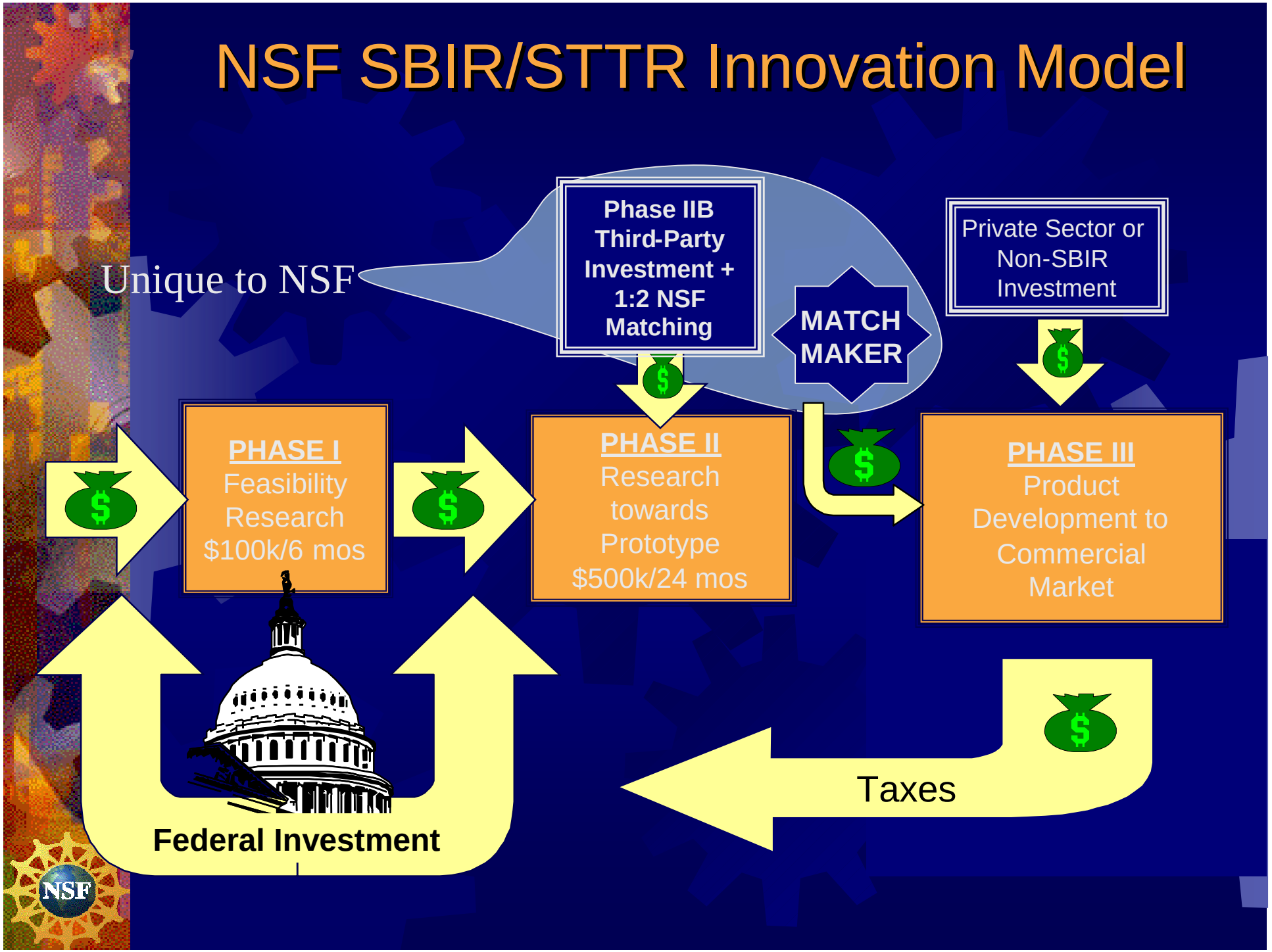
TOTAL ~ $2.0B

Est. FY 2004

Topics Supported at NSF

- Electronics
- Advanced Materials
- Biotechnology
- Information Technology
- Special Topics
  - Manufacturing Innovation
  - Security Technologies

NSF SBIR/STTR Innovation Model



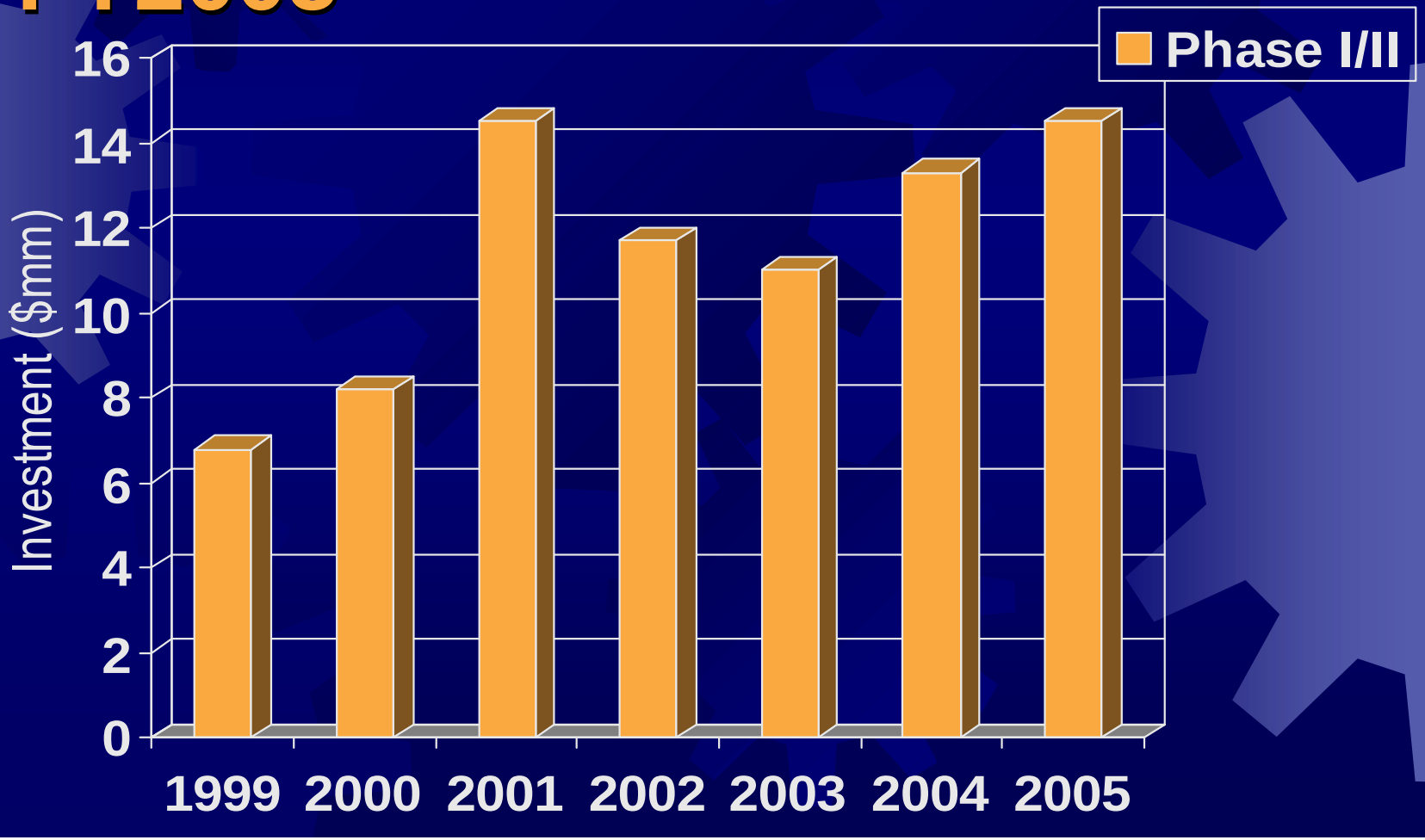
NSF SBIR/STTR Phased Project Structure

- Phase I Feasibility Research – ~10-15% success rate at NSF
  - SBIR – 6 months – up to $100,000
  - STTR – 12 months – up to $100,000
- Phase II – Concept Development – ~30-40% success rate at NSF
  - SBIR/STTR – 24 months up to $500,000
- Phase IIB unique to NSF – Matches Third Party Investment
  - NSF - $50,000 to $500,000
  - Investor - $100,000 to $1,000,000
- Phase III – Commercial Application Private Funding

Nanotechnology Thrusts in SBIR/STTR at NSF

- **Synthesis and Processing** - techniques for synthesis, fabrication, and processing of nanostructures
- **Materials, Devices, Systems, and Architectures** - techniques for processing and converting molecules and nanoprecursors into functional nanostructures; nanostructured materials, nanocomponents and nanodevices
- **Nanomanufacturing** - techniques for synthesis and scale-up of structures, devices and systems employing nanostructured materials and processes with nanoscale control

NSF SBIR/STTR Grants in NANOTECHNOLOGY in Millions of Dollars from FY1999 to FY2005



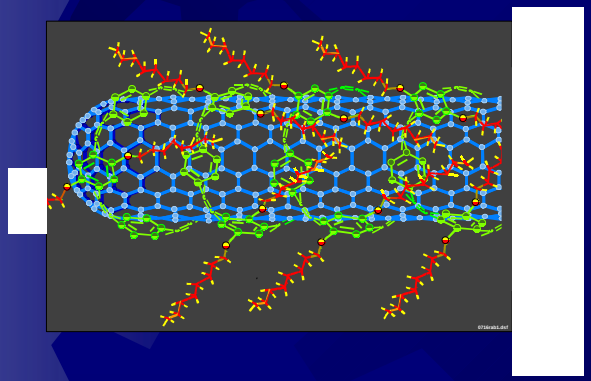
Major Product Areas Funded

- Nanoparticle composites
- Nanofilter membranes
- Nanocrystalline coatings
- Nanobiomaterials
- Nanoelectronics
- Nanophotonics
- Nanomagnetics
- Nanomanufacturing

Nanoparticle composites

Eltron Research Inc
Richard A. Bley

Incorporation of Carbon Nanotubes Into Nylon Filaments



Goals

- To Incorporate SWNTs Into Nylon Filaments
- To Make Very Strong, Light Weight Structural Materials Using This Polymer Composite
- To Make Electrically and Thermally Conductive Composites For Use In EMI Shielding And As Adhesives

Technical Objective

- Formulate Synthesis For Making Functionalized Polymer That Wraps SWNT
- Develop Viable Functional Groups
- Develop Methods For Making Composites
- Determine Mechanical, Electrical and Thermal Properties

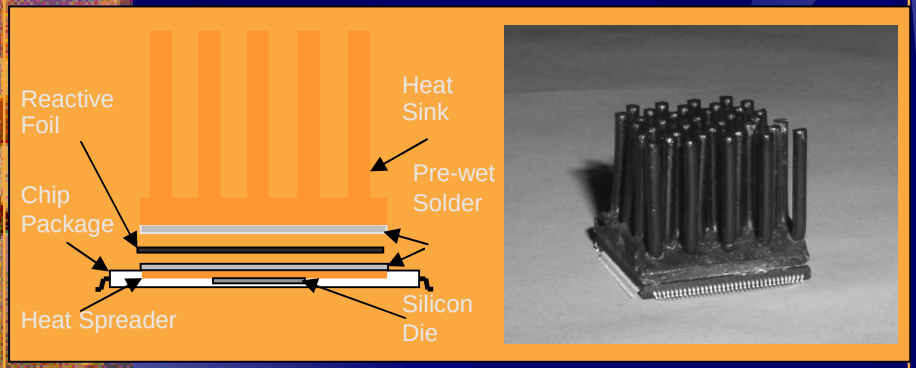
Commercialization Strategy

- Patent Application
  U.S. Provisional Application Serial No. 60/497,896.
  U.S Patent Application Serial No. 10/927,628.
- Have Interested Corporation (Henkel) But Still Need to Demonstrate Method Produces Desired Properties in Composites

Reactive Nanotechnologies

Tim Weihs & Jai Subramanian

Reactive Mounting of Heat Sinks



Technical Objectives

1. Select configuration for mounting heat sinks to dies/spreaders.
2. Optimize configuration for best thermal performance and ease of commercial insertion.
3. Characterize configuration to demonstrate reliability and repeatability.

Goals

Heat sink to die/spreader optimization and characterization.

- Determine optimal configuration for heat sink mounting. (April 2004)
- Optimize thermal performance of above configuration. (October 2004)
- Optimize and characterize performance of heat sink to silicon joints. (April 2005)
- Gather long term reliability data and complete characterization efforts. (October 2005)

Commercialization Strategy

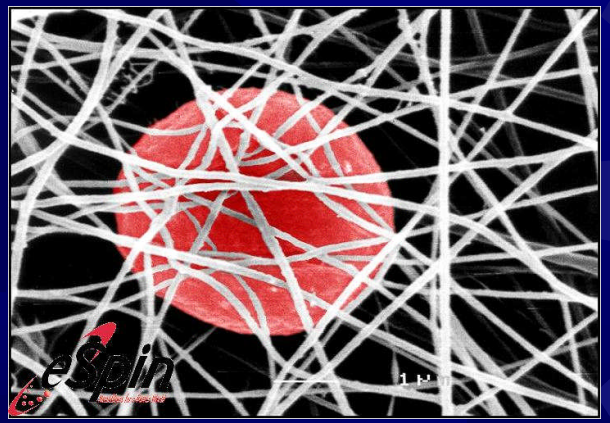
- Market strategy: engage end-users and partner with established companies in the adjacent markets: solders, adhesives, etc.
- Reach broader market by:
  - Leveraging performance and reliability data results from the grant work.
  - Leveraging capabilities in shaping foils, ignition methods and foil-solder pre-forms
  - Aligning closely with market enablers like sub-con. assemblers and thermal management solution providers.

Nanofilter membranes

eSpin

High Efficiency Nanofilter Media

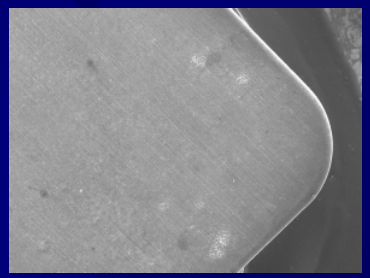
- Technology:
  - Nanofiber from Solution
  - Spinning technology
  - Web manufacture
- SBIR Follow-On Funding:
  - FleetGuard Diesel Filter
  - State of Tennessee



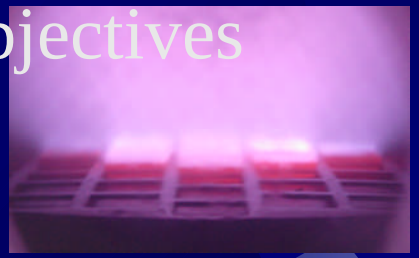
Nanocrystalline coatings

Vista Engineering Inc.
Raymond G. Thompson
DMI-0349769

Nanocrystalline Diamond Coated Cutting Tools



Technical Objectives

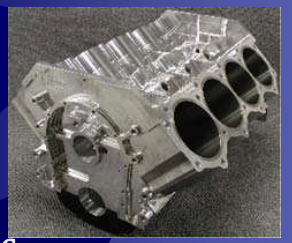


Batch Process
Intrinsic Film Adhesion
Robust Process Parameters

Goals

Product to Market 2005
Venture Capital 2004 – 2005
Win in Growing Market -
$300M in 2010

Commercialization Strategy

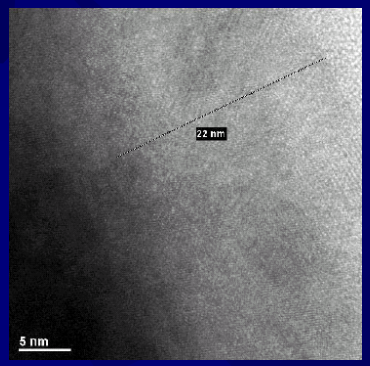


High-end
High Productivity
Partner with Tool Manufacturer
Automotive Applications

ALD NanoSolutions, Inc.
Dr. Karen J. Buechler
DMI-0422220

STTR Phase II: Novel Nanocoated Ferromagnetic Materials

γ-Al_2O_3 growing epitaxially to iron particle surface



Goals:

- Use Particle-ALD™ to Deposit Nanothick Films on Fine Particles
- Develop Pilot Scale Production Capabilities for Particle-ALD™
- Develop Link to Consumer Products for Nanocoated Fine particles through use of Strategic Partners

Technical Objectives:

- Develop Atomic Layer Deposition (ALD) chemistry for placing conformal, pinhole-free, and nanothick alumina films on individual primary particles
- Produce Kilograms of nanocoated fine iron powders using a scaleable fluidized bed process
- Characterize the product: film thickness, composition, crystallinity, particle size distribution, surface area, oxidation resistance, magnetic moment

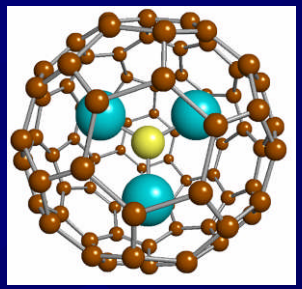
Commercialization Strategy:

- Work with Strategic Partners to Design materials for the Aerospace, Elecronic, and Automotive Industries
- Using Facilities proven during Phase II, provide materials for Consumer Product Development
- License or Manufacture coated particles designed through Phase II to Strategic Partners as needs dictate

Nanobiomaterials

Luna Innovations
Charlie Pennington

"Nuclear-Magnetic Resonance (NMR) Properties of Carbon Nanomaterials for Medical Applications"



Goals

- Increase production efficiency by 10X
- Enhance water solubility while maintaining low apparent molecular weight
- Develop high field strength MRI contrast agents

Technical Objectives

- Enhance Production Efficiency for $Gd_3N@C80$ and other Trimetaspheres
- Optimize and Finalize functionalization of Gd3N@C80
- Optimize and functionalize $Er_3N@C80$, $Ho_3N@C80$, and $Tb_3N@C80$

Commercialization Strategy

- Competitive advantage-25X more sensitive than current MRI agents
- Establish wide customer base sales through emerging and established pharmaceutical companies
- Ability to produce "site-directed" contrast agents

Real-Time Analyzers

Providing Chemical Information When & Where You Need It

Dr. Stuart Farquharson

Nanomaterial for Microchip Sensors

Goal

Build a microchip chemical analyzer that simultaneously separates chemical species and provides surface-enhanced Raman activity to allow < 5-min analysis of < mL samples at ppm concentrations.

Technical Objectives

- Develop Separation Chemistry
- Design & Build SERS Microchip
- Build Analyzer (fluid delivery)
- Test Analyzer (figures of merit)
- Product Design with Customers

Commercialization Strategy

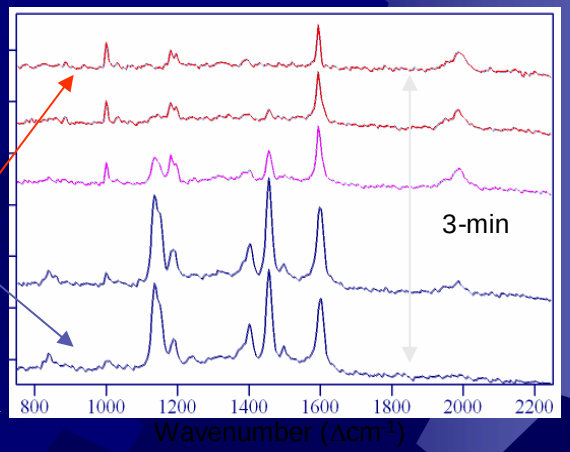
- Protect with patents
  (two submitted 10/02, third in 01/03)
- Develop applications with strategic partners (pharmaceutical, medical, clinical, biotech)
- Leverage exclusive use against investment

Results To Date

phenyl acetylene

p-aminobenzoic acid

2 chemicals separated and identified in 3-min



Applied Spectroscopy, 57, 479 (2003)

Nomadics, Inc

Lawrence F. Hancock and Joongho Moon

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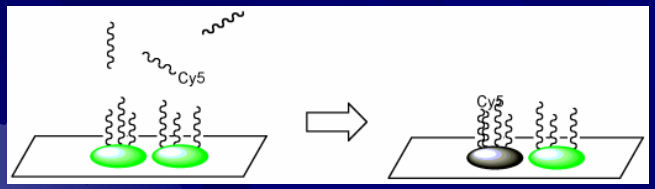
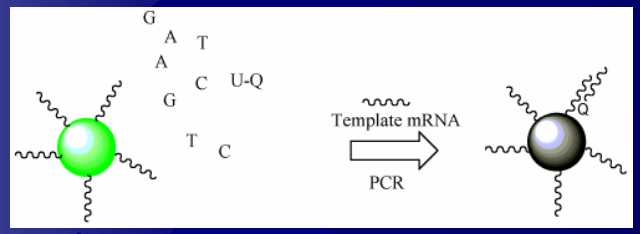
617-441-8871,lhancock@nomadics.com

Fluorescent Polymer Nanoparticles

Gene Expression Reagents



q-RT PCR Reagents



Goals

- Develop and Launch
  - **Gene Expression Reagents**
  - **q-RT PCR Reagents**

"Improved Photostability"
"Enhanced Sensitivity"
"Wide Dynamic Range"

Technical Objectives

- **Optimize PPE Nanoparticles**
- **Demonstrate PPE Fluorescence Quenching Enhancement**
- **Gene Expression & q-PCR Reagents**
  - Define Specifications and Performance
  - Compare Specs. And Performance with Competitors
  - SOP's and QA/QC Procedures
  - Protocols
  - Beta Test
  - Draft Instructions/Application Notes

Commercialization Strategy

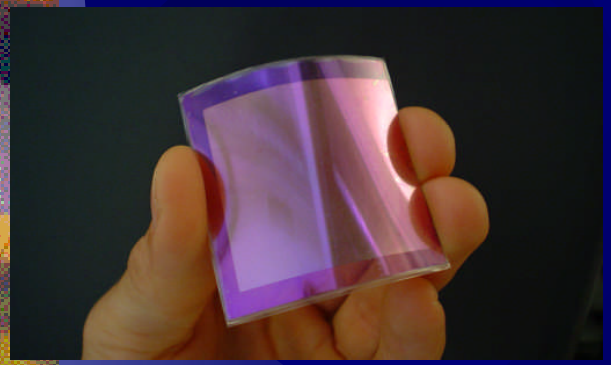
- Direct integration of PPE nanoparticles into widely practiced experiments on existing bioanalytical instrument platforms.
- Introduction of PPE-based labels and nucleotide conjugates in application-specific reagent kits.
- License and/or partner with established reagent suppliers and equipment

Nanoelectronics

Nanosys Inc.

SBIR 0422147

Nanocomposite Solar Cells



Goal:

• Develop high performance, low cost lightweight flexible solar cells

Approach:

• Innovative solar cell design that combines precisely engineered inorganic semiconductor nanocrystals with a light-weight, flexible host-matrix

Technical Objectives:

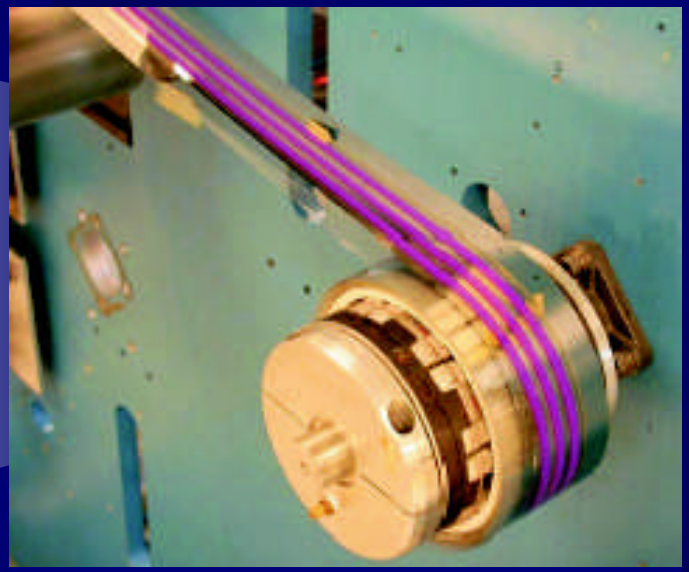
• Develop optically and electronicly enhanced nanocrystals
• Develop new Device Components
• Develop Advanced Device Architectures

Commercialization Strategy:

• Nanosys focuses on nanotechnology element in the end product
• Partner with industry leaders to jointly develop and manufacture nano-enabled component into end product.
• Our partner provides marketing resources and access to end customers

Photovoltaics : Nanoparticle co-sensitizers for increased efficiency

From Light to Power



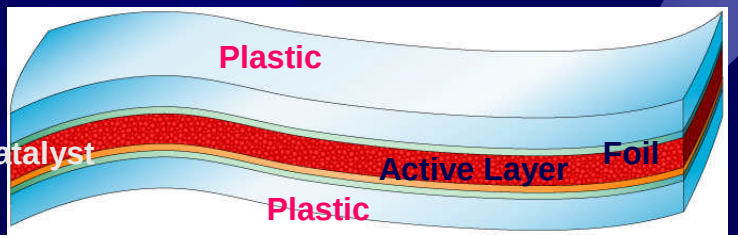
Polymer photovoltaic products in a variety of form factors for commercial, industrial, military and consumer applications

- Uses photoactive dyes & conducting polymers
- High-speed manufacturing processes
- Low temperature environment
- Uses low cost materials
- Highly scaleable

- Mass customization from a single source
- World solar PV market: CAGR > 35%
- 20+ patents pending

Schematic of Dye Sensitized Titania Cell

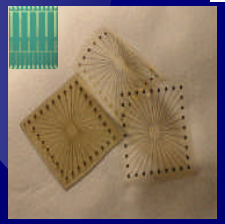
Total thickness 0.01 inch



Thin Film Transistors: Silicon Nanowires

High Performance, large area nano-structured macro-electronics substrate technology

TFT Backplane Drivers – Integrated Edge Electronics



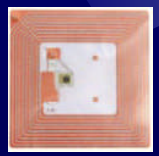
Beam-Steering Antennas

- **Eliminates high-temperature steps required for semiconductor deposition**
- **Dramatically reduces manufacturing cost, time and complexity**
- **Deposition on virtually any substrate material possible**

A variety of application areas:

- **Portable & large-area flat panel displays**
- **Low-cost RFID and smart cards**
- **Electronically steerable phased-array RF antennas**

RFID Tags



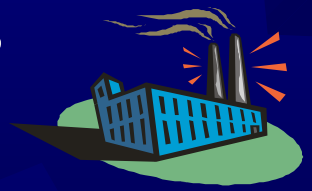
nanophotonics

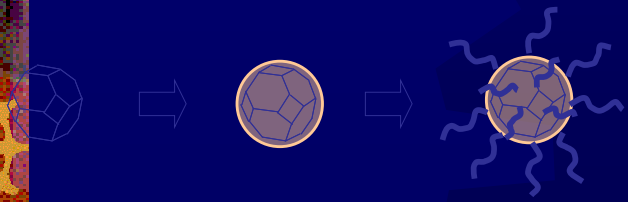
InnovaLight
Frederic Mikulec

Continuous Flow Reactor & Size-Selection Scheme for Use in High Throughput Manufacture of Si Nanoparticles

Goals:

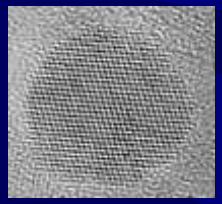
- Si nanomanufacturing system
- Process parameters
- 5 grams/hour





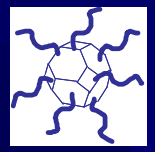
Technical Objectives:

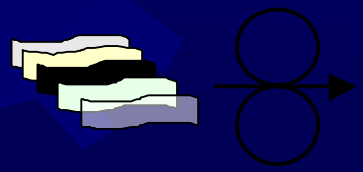
- High quantum yields
- Tunable emission
- Defect-free particles



Commercialization Strategy:

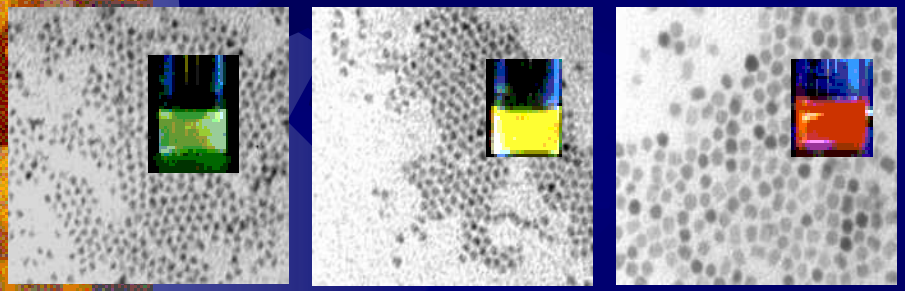
- IP portfolio
- Cell phones, exit lighting (short term)
- Solid-State Lighting





Semiconductor Nanocrystal (Quantum Dot) Manufacturing

A New Scale-Up Technology for Industrial Production of High-Quality Semiconductor Nanocrystals



2.5 nm CdSe **3.5 nm CdSe** **5.5 nm CdSe**

Goals:

NN-Labs will offer customers colloidal semiconductor nanocrystals with the:

- Highest Quality: stable, surface flexibility, narrow size distribution
- Lowest Price: affordable
- Broadest Range: II-IV, III-V, and IV-VI semiconductor nanocrystals

Technical Objectives

- Develop large-scale synthetic protocols for type II-IV, III-V, IV-VI semiconductor nanocrystals
- Stabilize these nanocrystals with dendron ligands
- Establish industrial standards
- Assemble Auto CB Synthesizer™

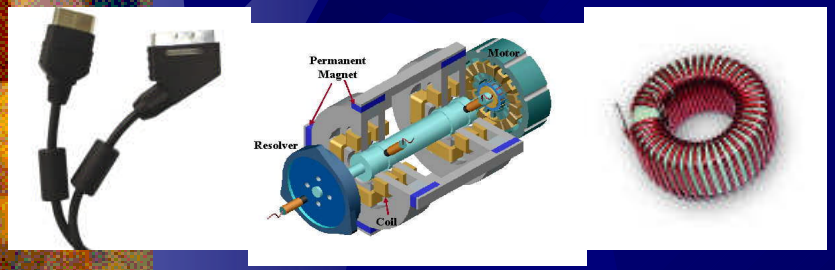
Commercialization strategy

- Focus on electronic and biological applications
- Patent and license the synthesis protocol
- Advertise: Commercial ads and conference exhibits
- Secure financial support from VC and strategic partners

Nanomagnetics

Nano-magnetic materials

Nanocrystalline FeCo for EMI Suppression



Goals

- Scale up the production and the consolidation process
- Tailor materials for EMI suppression up to 1 GHz
- Optimize material properties for enhanced bearing performance in flywheel energy storage and artificial implants
- Low loss magnetic cores and inductors

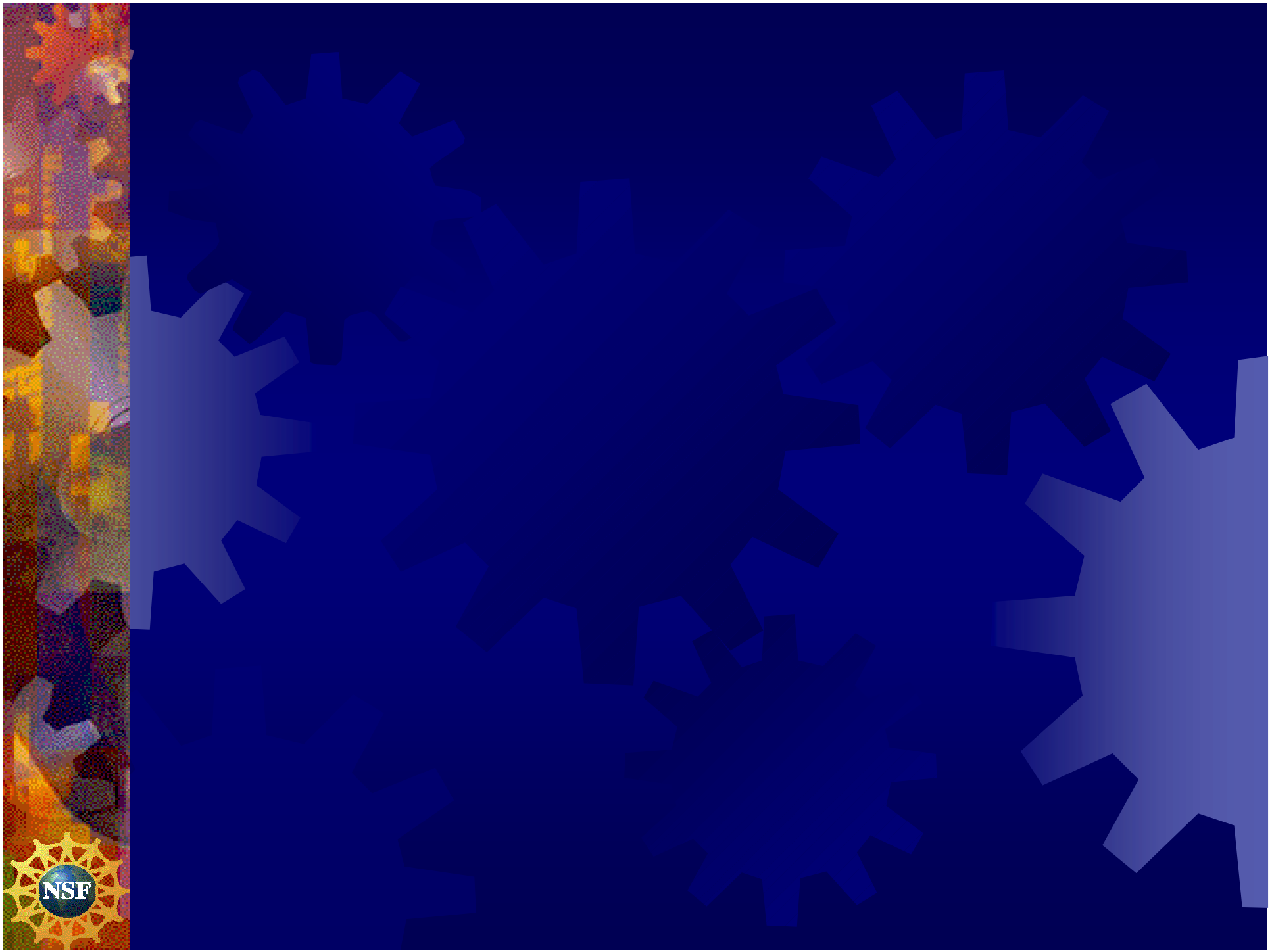
Technical Objectives

- Production of nano-sized FeCo and their consolidation to near net shapes
- Magnetic Characterization and EMI testing
- Fabrication of magnetic bearings and their testing
- Fabrication of materials for inductors and their testing

Commercialization Strategy

- Strategic Alliances
- Worldwide licensing for a fixed fee
- Spin off a separate business unit

Nanomanufacturing


NSF

Thank you!

- tjrudd@nsf.gov
- www.nsf.gov/eng/sbir
- www.nano.gov