Nanomanufacturing in the Defense Industry

Nanomanufacturing Summit 2009
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Lockheed Martin Business Areas

Space Systems

Aeronautics

Information Systems & Global Services

Electronic Systems
Nanotechnology in Lockheed Martin

- Ultra Lightweight Structures
- Smart Structures
- Distributed Sensor Systems
- Modeling and Simulation
- Integrated Platforms

Space Systems

Information Systems and Global Services

Control Algorithms for Missions

Electronic Systems

Aeronautics
Nano-enabled Technologies for Air Force

- Morphing Wings
- Photovoltaic Power
- NanoEnergetic Munitions
- Flat Optics
- Thin Film Batteries
- Superconducting Motor Windings
- Laser Protection
- Quantum Well Infrared Photodetectors
- Directed Energy Weapons
- Multifunctional Coatings

Chart Compliments of Air Force Research Labs
Our Challenge

Research → Development → Application → Deployment
Need to Increase TRL Levels

Levels, Players and Objectives Are All Important in Bringing Materials and Devices to Operational Status
Nanomanufacturing Challenges

- **Technical**
  - Strong link between nano-structure and macro-properties requires high degree of control and consistency in high-volume production
  - Uneven dispersion and agglomeration, which ruins high-performance properties
  - Contaminants in factory-quantity materials
  - Price premium for incremental improvement in properties and performance

- **Economic**
  - Brutal competition and fast-dropping prices
  - Rising volumes and quality

- **Other**
  - Inconsistent supplies from different manufacturers
  - Poor understanding of EHS aspects and lack of regulations
  - Lack of real-time characterization tools

Chart Compliments of Lux Research
Example: Road to Production for Sensors  
— A Series of Technical Challenges

- Technology Downselect
- Technology Development
- Military Utility, Incl. Rqts Analyses
- Detailed System Design
- Detailed Platform Integration Design
- Risk Mitigation - Data Collection - Critical Experiments
- M&S Concept Assessment
- Technology Survey
- Concept Maturation
- Technical Feasibility Assessment - System Design - Platform Integration
- Military Utility Concept Maturation (Design & Dvpt.)
- Accelerated Acquisition Production
- TacHELF Program

Prototype Development

- New Modeling techniques and Tools
- Design considerations
  - Low noise floors
  - A large dynamic range
  - Realistic excitation requirements
  - Mechanisms to handle fluctuations in power supplies and static electricity
  - determine and create stable calibration curves
  - acceptable output impedance
  - repeatability, accuracy, precision, bandwidth and reliability

Device Characterization and I/F Development

- New metrology tools and processes
  - Identify new parameters and tools to measure them
  - Identify and measure subsurface defects
  - Establish international standards
- Interface to micro, meso, and macro systems

Production

- New metrology tools and processes
- Packaging
- Scale-up considerations
- Manufacturing costs
- Automation, ideally with self calibration and adjustment
- Handling and environmental
- Radiation Effects
- Failure Modes
Nanomanufacturing Process Needs

- Fabrication Techniques
- Embedded Sensors
- Automation
- Remote Manufacturing
- Automation with Self-calibration and Adjustment
- International Standards
- Calibration Tools Nano-characterization
- Identification of New Measurement Parameters
- Modeling and Simulation (M&S) Tools
- Whole System Scale-up
- Rapid Characterization of 3D structures
- Interfaces to Micro and Macro
- Automatic Comparison to M&S Data
- Accurate Modeling at nm scale
- Nanostructures into Devices / systems
- Metrology

**Economics**
- Cost
- EHS
- High Throughput
MEL at a Glance

Mission: MEL promotes **innovation** and the **competitiveness** of U.S. manufacturing through measurement science, measurement services, and critical **technical contributions to standards**

Divisions
- Precision Engineering (PED)
- Manufacturing Metrology (MMD)
- Intelligent Systems (ISD)
- Manufacturing Systems Integration (MSID)
- Fabrication Technology (FTD)

Measurement Service Areas
- Length, Diameter and Roundness
- Complex Dimensional Standards
- Optical Reference Plane Standards
- Angular Measurements, Surface Texture, Laser Frequency/Wavelength and Ranging, Mass Standards, Force Vibration, Acoustics

Funding
- $50.4 M annual budget
  - $37.0 M NIST appropriations
  - $ 8.7 M Other Agency/External R&D
  - $ 4.7 M Calibration Service Fees/Reimbursable

Staffing
- 174 NIST Staff
- 98 Guest Researchers
- 4 NRC Postdoctoral Researchers
Manufacturing Engineering Laboratory (MEL)

- Current Nanotechnology/Nanomanufacturing Programs
  - Precision Engineering Division
    - Nanomanufacturing Metrology Program
    - Next-Generation Nanometrology Program
  - Manufacturing Metrology Division
    - Mechanical Metrology Program
  - Manufacturing Systems Integration Division
    - AFM Probe Modeling
  - Intelligent Systems Division
    - High precision piezo stages
    - MEMS devices
DoE Industrial Technologies Program (ITP): Mission

*Improve our nation’s energy security, climate, environment, and economic competitiveness by transforming the way U.S. industry uses energy*

Reducing U.S. industrial energy intensity is essential to achieving national energy and carbon goals

| Source: DOE Energy Information Administration, 2006 |

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Help transform nanoscience into industrial processes and products

Focus:

- **Enabling Processes for Nanomaterials Production**: Improve reliability and scale up nanomaterials production processes
- **Nanomaterials Utilization in Industrial Processes**: Scale up manufacturing processes for utilization of nanomaterials in energy-related products

**Top Priorities for Energy Efficiency (based on Lux analysis)**

- Batteries and supercapacitors
- Light weight nanocomposites
- Nanocoatings/nanocomposites for thermal management
- Catalysts for chemical, industrial and automotive applications
- Tribological nanocoatings
- Solid state lighting (LED)
- Solar
- Nanomanufacturing research/commercialization center

Chart Compliments of DoE
Critical challenges for nanomanufacturing include the following:

- **Dispersion**: Nanoparticles must be thoroughly and evenly dispersed within a matrix (e.g., film, coating, or resin), as clumping may make them lose their unique properties.

- **Contamination**: Stray molecules of other materials must be prevented from adversely affecting nanomaterial properties, which are highly sensitive to atomic and molecular interactions.

- **Consistency**: The desired properties of nanomaterials must be consistently achieved in mass production.

- **Environmental, Health, and Safety protocols**: The risk profiles of nanotechnology require further study and clarification.

ITP’s Nanomanufacturing Program activities focus on the following objectives:

- Develop low-cost manufacturing processes to expand near-term commercial use of innovative nanomaterials in
  - Industrial processing
  - Energy-saving and energy-producing products

- Develop technologies to enable expanded use of nanomaterials
  - Directly as a material to enhance material performance
  - Indirectly as an intermediate device (e.g., nanosensors for thermal management)
Questions

Tin Whisker Photo courtesy of Peter Bush, SUNY at Buffalo

“Think Big, Start Small, Scale Rapidly”