Nanotechnology Manufacturing & Commercialization

Robert J. Celotta

CNST Center for Nanoscale Science & Technology

Nanotechnology Innovation Summit, Washington, December 8, 2010

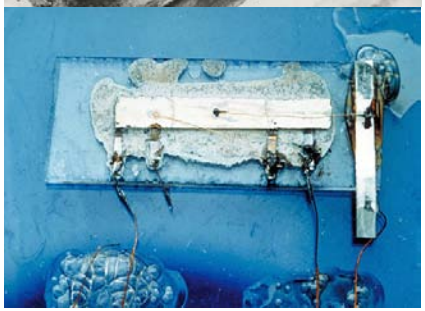
NIST National Institute of Standards and Technology • U.S. Department of Commerce

Taking Discoveries to Production

Transistor
(1947)

LSI and The Computer Museum

Integrated
Circuit
(1958)

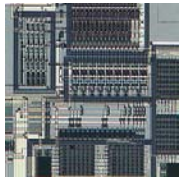


Texas Instruments

iPod Nano
2008

Hundreds of billions of perfect and reliable transistors required at low cost!

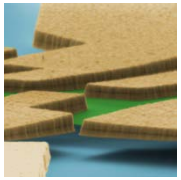
Nanomanufacturing
- many things to many people



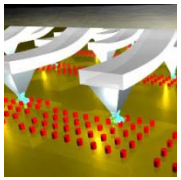
- Make small features on large objects;

- Make nano sized objects;

- Make nanoscale objects to obtain special properties;
  - generally the salient feature of nanotechnology



- Incorporate nanoscale objects in larger objects; or,



- Use nanotechnology to manufacture other things

Nanomanufacturing Offers Several Benefits

- Agile manufacturing
  - Ability to use modular nano-parts to easily reconfigure assembly line
- An intrinsic bias toward “green”
  - Use less material; smaller tools
  - Potentially reversible assembly for recycling
- Substantial energy savings in some cases
  - Less energy used in nanomanufacturing
  - Energy savings from manufactured products

Areas Where Energy Savings are Expected

- Catalysis
  - Lower temperature reactions and reduction of byproducts
- Coatings
  - Lower friction, superhydrophobic surfaces
- Light-weighting
  - Reduced rotating, sliding, and conveying weights
- New Materials
  - Ultra-hard, wear resistant
- Separations
  - Alternative to distillation or evaporation processes
- Thermal Management
  - Better heat transfer fluids, low conductivity barriers
- Engineered Nanomaterials
  - Thermoelectrics, photovoltaics, batteries

Source: Nanomanufacturing for Energy Efficiency, DoE Workshop Report, 2007

What Are the Needs of Nanomanufacturing?

- We need methods that are:
  - Scalable
    - Ability to increase production when increased resources are available
      - Scalability through nanomaterial, component, and device design
  - Fast and reliable at low cost
  - Sustainable
    - cradle-to-cradle
  - Safe

But how do we get there?

The rise and fall of corporate R&D

Out of the dusty labs

Mar 1st 2007 | BARCELONA, PALO ALTO AND ZURICH

From *The Economist* print edition

Technology firms have left the big corporate R&D laboratory behind, shifting the emphasis from research to development. Does it matter?

Corbis

How can government help?

Harvard Business Review OnPoint ARTICLE

Connect and Develop

Inside Procter & Gamble's New Model for Innovation

by Larry Huston and Nabil Sakkab

The Idea in Brief

A better approach to innovation? The **connect and develop** method. Through this radical alternative, you **connect** with *external* sources of new ideas: university and government labs, Web-based talent markets, suppliers, even competitors. Then you **develop** those ideas into profitable new or refined products—swiftly and cheaply—using your firm's R&D, manufacturing, and marketing prowess.

Current Federal Government Support via the National Nanomanufacturing Network (NNN)

- NSF
  - Center for Hierarchical Manufacturing (CHM)
  - Center for High-Rate Nanomanufacturing (CHN)
  - Center for Scalable and Integrated NanoManufacturing (SINAM)
  - Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS)
- DoE
  - Center for Integrated Nanotechnologies (CINT)

Current Federal Government Support via the National Nanomanufacturing Network (NNN)

- NIST
  - Center for Nanoscale Science and Technology (CNST)
- Information:
  - InterNano: A communications resource for nanomanufacturing: http://www.internano.org
- Potential funding sources:
  - DoE Industrial Technology Program
  - NIST Technology Innovation Program
  - NSF Nanomanufacturing Program

And, support for increased federal funding has been strong…

- President's Council of Advisors on Science and Technology (PCAST) report (2010) recommends:
  - "a greater emphasis on manufacturing and commercialization " and "…doubling the investment in nanomanufacturing …over the next five years"
  - "…support at least five Signature Initiatives over the next two to three years, with each Signature Initiative funded at levels adequate to achieve its stated goals, presumably between $20 million and $40 million annually."
- NNI proposes three signature initiatives:
  - Nanoelectronics for 2020 and Beyond
  - Nanotechnology for Solar Energy Collection and Conversion
  - Sustainable Nanomanufacturing – Creating the Industries of the Future

NNI - Sustainable Nanomanufacturing Signature Initiative

- Key requirements: scalable, controllable, sustainable & safe
- Thrust 1: Design of scalable & sustainable nanomaterials, components, devices & processes
  - Carbon-based nanomaterials, metamaterials, cellulosic materials
  - Demonstration of materials and processes
  - Technology transfer
- Thrust 2: Nanomanufacturing measurement technologies
  - Consortium on metrology for roll-to-roll, R2R
  - Fast, robust process control measurement systems
  - Technology benchmarking and transfer with industry

NNI Signature Initiative: Targeted Inter-Agency Collaboration with FY11 budget request – lead by NIST/CNST & NSF

Significant Measurement and Standards Issues Exist

- Making fast nanoscale measurements to allow process control
  - Photons vs. electrons
    - Photonics and nanophotonics
- Making reliable, but cost appropriate measurements
  - 1M$/ sq m vs. 40$/sq m
- Specifying measurement protocols and standards
  - Process control
  - Electrical, mechanical, chemical properties of supplies and products
- Promulgating measurement protocols and standards into documentary standards
  - Supply chain integrity
- Nano environmental, health, and safety measurements
  - Safety during production, use, and at end life

In short, we have our work cut out for us….

- NIST/CNST Workshop:
  - The New Steel? Enabling the Carbon Nanomaterials Revolution: Markets, Metrology, Safety, and Scale-up
    - Center for Nanoscale Science and Technology, Gaithersburg, MD, February 28 – March 1, 2011
  - Topics:
    - Carbon nanomaterial manufacture
    - Quality control/certification of carbon nanomaterials (raw material and finished products)
    - Integration of carbon nanostructures into products
    - Manufacturing scale-up
    - Life cycle
    - EH&S
  - Further information: Alex Liddle (Alex.Liddle@NIST.gov)

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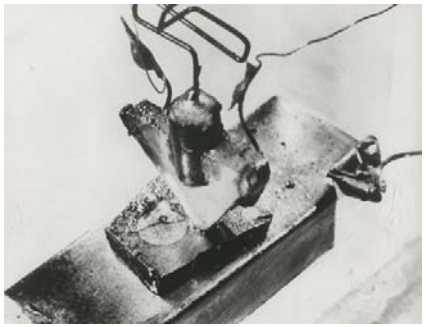
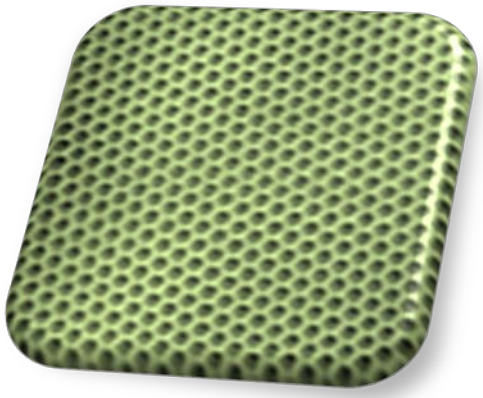


LSI and The Computer Museum

iPod Nano 2008

Graphene



"It's tough to make predictions, especially about the future."

- Yogi Berra

Questions?

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