Manufacturing 2.0

Challenges And Opportunities

Ben Wang
MFG 2.0

What Is Manufacturing 2.0

Why Does Manufacturing Matter

Translational RD&D

New Manufacturing Paradigm

Questions & Answers
Manufacturing 2.0 Characteristics

- Big M Manufacturing
- A diverse set of non-traditional materials
- Gradually decoupling unit cost from quantity
- Fully integration of many disciplines
Mfg. Innovation Eco-system

Stakeholders

Big “M” Manufacturing

Enablers

Supply chain
MFG 2.0

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Questions & Answers
Wealth Creation

U.S. Exports

- Mfg Goods: 70%
- Non-Mfg: 30%
250% Return on Investment

$1 investment
In manufacturing

$2.48 economic activity
2/3 U.S. scientists and engineers are employed in manufacturing.

**STEM Employment**

- Mfg Sector: 66%
- Non-Mfg: 34%
Innovation Driving Force

U.S. Patents

Mfg Industry 90%

Non-Mfg 10%
Why Manufacturing?

- Major wealth creator
- Compelling returns on investment
- Dominant innovation driver
- Foundational to national security
MFG 2.0

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Questions & Answers
What’s Innovation

- “to innovate... is to challenge and change the status quo to enhance the customer's experience and bring new forms of value to them” GE
- Creation and delivery of new customers value in the marketplace
- Turn knowledge into money
- Turn invention into impact
Value of Translational Research

What is the value of your research in to this so called "Theory of Electricity"?

One day sir, -- you can Tax it!

Source: Wiki Commons
Innovation Chain Is Not Producing Results

Scholarly papers: 7,500
Patent disclosures: 113*
Award patents: 24*
Licensing deals: 23*
Royalty income: ??

*Source: U.S. Licensing Activity Survey Highlights: FY2010, Association of University Technology Managers
Discovery to Application

1940: Teflon
1950: Velcro
1960: Titanium production
1970: Polycarbonate
1980: Lithium-ion batteries
1990: Core-shell electro-catalysts for fuel cells
2000: Catalysts for olefin metathesis
2010: Diamond-like thin films, GaAs, Amorphous soft magnets

We need to do better!

Current Innovation Chain

Basic Research  Applied Research  Technology Maturation  Product Development

Too long  Too costly  Too random

Academia  Valley of death  Industry
Advanced Manufacturing Partnership

“Our first priority is making America a magnet for new jobs and manufacturing.”

President Barack Obama February 12, 2013
President Obama announced the Advanced Manufacturing Partnership (AMP) initiative on June 24, 2011.

Formed a steering committee to provide guidance on this important national initiative.

Committee consists of six university presidents and 12 company CEOs:
- Carnegie Mellon,
- Georgia Tech,
- Michigan,
- MIT,
- Stanford,
- UC Berkeley,
- Allegheny Technologies,
- Caterpillar,
- Corning,
- Dow,
- Ford,
- Honeywell,
- Johnson & Johnson,
- Intel,
- Northrop Grumman,
- P&G,
- Stryker,
- UTC
Advanced Manufacturing Partnership

- Rebuild a strong U.S. manufacturing base
- 5 working teams
  1. Implementing demand-driven workforce solutions for a workforce of lifetime learners
  2. Creating a policy environment that supports technology scale-up
  3. Ensuring that the National Network for Manufacturing Innovation (NNMI) is successful
  4. Identifying, prioritizing and starting work on transformative technologies
  5. Improving the image of manufacturing
Manufacturing-Centric National Initiatives

- Advanced Manufacturing Partnership, 1.0 & 2.0
- Material Genome Initiative
- National Robotics Initiative
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2014: MANUFACTURING’S NEW MOMENTUM
2013
Global Manufacturing Competitiveness Index
REPORT TO THE PRESIDENT ON CAPTURING DOMESTIC COMPETITIVE ADVANTAGE IN ADVANCED MANUFACTURING

Executive Office of the President
President’s Council of Advisors on Science and Technology

JULY 2012
Cross-Cutting Technologies

- Advanced forming and joining technologies
- Additive manufacturing
- Advanced materials design, synthesis and processing
- Advanced manufacturing and testing equipment
- Advanced sensing, measurement and process control
- Biomanufacturing and bioinformatics
- Flexible electronics manufacturing
- Industrial robotics
- Nanomanufacturing
- Sustainable manufacturing
- Visualization, informatics, and digital manufacturing technologies
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The Nobel Prize in Chemistry 1996

Sir Professor Harold W. Kroto  Dr. Robert F. Curl, Jr.  Dr. Richard E. Smalley
C60

Buckyball
Buckminster Fuller and Geodesic Dome
Buckyball

Geodesic dome

Buckminster Fuller
Ratio is $10^8 = 100,000,000$
From Buckyball to Nanotube

- **C60**
- **C70**
- **C80**

70,000 times smaller than a human hair – 500 times stronger than steel
1 gram
Carbon nanotubes’ amazing properties

- Strongest fiber ever been made
- Electrical conductivity of copper or silicon
- Thermal conductivity higher than that of diamond

Dr. Richard Smalley, 1996 Nobel Laureate

**Can These Properties Be Realized In Bulk Materials?**
Buckypaper
Accelerating Tech Insertion of Nanotube Products

- Advanced Helmet Technology
- Actuators
- Sensors
- Field emission
- Robust manufacturing process control
- Nanofoams
- EMI shielding
- Thermal management
- Energy conversion and storage
- Fire and smoke retardant composites
- Lightning strike protection
- High-performance composites

From Nanotubes and Buckypaper to Devices and Systems

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Composites Are Pervasive...

- Turbo-charged plastics (Plastics on steroids)
- Lightweight (better fuel economy) and safe
- Potentially longer product life and lower life cycle cost
- Reaching $110B in U.S.
- Fiber glass, carbon fibers, nano?
EMI Shielding
Fuel Cell Electrodes

Fuel H₂ (Hydrogen) → 2H₂

O₂ (Oxygen) from Air

Un-used Fuel Recirculates

Flow Field Plate
Gas Diffusion Electrode (Anode)
Catalyst

Proton Exchange Membrane

H⁺

Heat (85 °C) Water or Air Cooled

Air + Water Vapor

Flow Field Plate
Gas Diffusion Electrode (Cathode)
Catalyst

H₂O
Topics requiring serious research

- Processing-structure-property modeling
- Sensing, monitoring and process control
- Optimization of nanocomposite manufacturing
- Safety and health issues
Emerging Additive Manufacturing
3D printing: from art to part

Computer Aided Design
Files & Metal Powder

Printed Metal Machine & Process

Post-Processing
3D Metal Printing Applications

- **Aerospace**
- **Automotive**
- **Medical**
- **Repair & Maintenance**
Additive Manufacturing

- Plastics
- Metals
- Ceramics
- Printed electronics

Laser, electron beam, ultra-sound, etc.
Less Known Technology: Printed Electronics

- Direct printing of fine features, as thin as 10μm in line width, on most surfaces
- Rapid production to accommodate last-minute design changes of functional electronics - no need for masks or molds
- Wide range of ink materials
- Relatively cost effective for small lot-size production
Temperature sensor printed with carbon nanotubes

RFID tag and antenna array on carbon fiber

RFID tag on polyimide

RFID tag on silicone
Graphene, Buckyball, Nanotube and Graphite
2010 Nobel Prize in Physics

Sir Professor Andre Geim

Sir Professor Konstantin Noveselov
Opportunities

- Mass customization
- Variable lot size down to one
- On demand manufacturing
- Tool-less manufacturing
- Expanded design space
- New supply chain configurations
Topics requiring serious research

- On-demand manufacturing: impact on supply chain management theories and principles
- Design for additive manufacturing
- A whole new industry sector of additive manufacturing machine tools
Regenerative medicine

36 million American adults and nearly half of all adults 75 and older have hearing loss.

Over 322,000 people around the world die from burn-related injuries every year.

Broken bones take months to heal.

1 in 8 American women gets breast cancer.

Prosthetic limbs and implants leave amputees without a sense of touch.

4 of the top 10 causes of death in poor countries are infectious diseases.

Soldiers and astronauts lack the muscle strength to endure lengthy missions.

26 million Americans have to monitor blood glucose for diabetes.

Stem cell engineering
Shinya Yamanaka
University of Kyoto, Japan

John B. Gurdon
Gurdon Institute in Cambridge, UK

iPS cells can now be generated from humans, including patients with disease. Mature cells including nerve, heart and liver cells can be derived from these iPS cells, thereby allowing scientists to study disease mechanisms in new ways.
Current and future stem cells are not the same as those in the 1960’s

- Embryonic stem cells (SCs) are one category of stem cells

- They (induced pluripotent stem cells) can come from your own body (autologous vs allogeneic) to cure your own illness

- Currently, lab cultures of SCs are all done manually – variability, low yield, contamination, etc.

- First-time yield is crucial

- Full-scale automated production of controlled growth of SCs is goal
Stem Cell Biology

- Pluripotent
- Multipotent
- Unipotent

Stem Cell Engineering

- Isolation
- Reprogramming
- Efficient, scalable & robust technologies

Stem Cell Applications

Manufacturing of diagnostic platforms & regenerative therapies from stem cells

- Diagnostics
- Drug Discovery & Pharmaceuticals
- Tissue Repair

Credit: Todd McDevitt

http://stemcelligert.gatech.edu
Bio-manufacturing of cell therapies

- Scalable production techniques >> 10^9 range
- Characterization of cells and cell derivatives
- Cost of cell products
- Readiness of the supplier base
- Workforce needs
- Regulatory pipeline
Topics requiring serious research

- Scaling up cell culture and expansion
- Process design, monitoring and control
- Logistics and supply chain management for special handling and storage: regulatory, perishable, zero-contamination, 1st time yield, ...
- From stem cell biology to stem cell engineering to stem cell benefits
- Remove, replace, repair, regenerate
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