www.nano4me.org

Today's Presenter

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NACK National Network
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www.nano4me.org

Today's Desired Outcomes

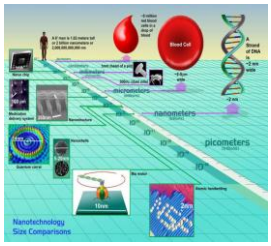
Participant Understanding of:

1. What it is --- some nanotechnology basics.
   - Size and properties
2. Why you should care --- some of the impact of nanotechnology.
   - Applications, Jobs Today, and Future Predictions
3. Where you can find it --- some nanotechnology education resources.
   - The NACK National Network

1. WHAT: Some nanotechnology basics.

Nanotechnology!

- What is it? What do you know about it?
- Broad term, referring to the manipulation of matter at the atomic level.
- Encompasses many scientific disciplines.
- Impacts daily life and our future greatly.

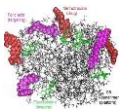


http://www.tzhealth.com

National Nanotechnology Initiative

NNI Vision

A future in which the ability to understand and control matter at the nanoscale leads to *a **revolution** in technology and industry that benefits society.*


Nanotechnology is:

the creation of functional materials, devices, and systems through control of matter at the scale of *1 to 100 nanometers*, and the exploitation of novel properties and phenomena at the same scale.





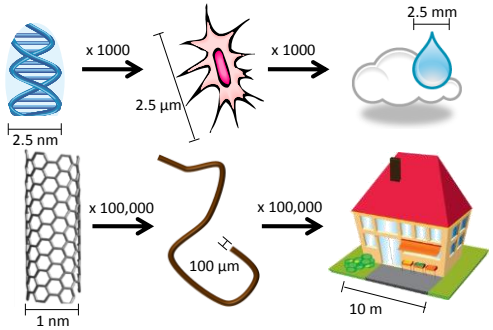
How Small is a Nanometer?

A nanometer is one billionth of a meter.

If a nanometer were the size of a marble, a meter would be the size of:

A. The Sun
B. The Earth
C. The moon
D. The Grand Canyon's depth

How Big Small is a Nanometer?



Adapted from: www.nano.gov

A Nanometer is Very Small – so teaching scale is **important**

- Here is a you tube video that we use in our outreach to *drive* this point home

Museum of Science, Boston

Why is making things so small so good?

More functionality per square unit area

1993 ➡ 2004

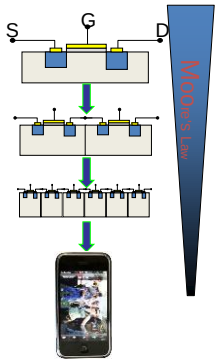
First IBM-compatible Laptop (Circa 1986)
Toshiba T1100
CPU 80C86 @ 7.16 MHz
640K RAM, 2 Floppies
9 lbs

16 GB (23,000 Floppies)
Phone, Camera, GPS
Accelerometer (MEMS)
Proximity Sensor
Light Sensor
5-10 hr Battery
4.7 oz

Smaller circuits = smaller faster devices >>>>>>
More value per dollar $$$$$

Why smaller is better: the transistor

- Devices get smaller and more powerful because transistors get smaller
  - The transistor is the basic component of electronics (see right)
  - Transistors are made of silicon, metal, and other selected elements
- Currently, ~ 2 Billion transistors per chip
- To fit billons on a chip, transistors needed to shrink to the nanoscale
- Chip makers and researchers noticed interesting phenomenon at this size and this has led to nanotechnology discoveries and applications across multiple disciiplines



Nano: Enabling Technologies

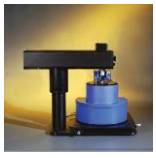
- **Using** nano-scale materials and **understanding** them are two different things!

Scanning Electron Microscope (SEM)

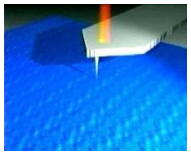
Modern tools:

- Help us to **see** and **manipulate** matter at the nano-scale
- Allow us to understand how (and why) the small structures work

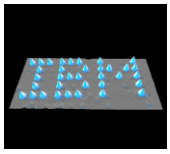
Nano: Enabling Technologies



Atomic Force Microscope (AFM)
Veeco Model CP-II



Depiction of AFM probe tip



I B M spelled out with Xenon Atoms on a Nickel Surface by an STM-based tool

Nanotechnology is:

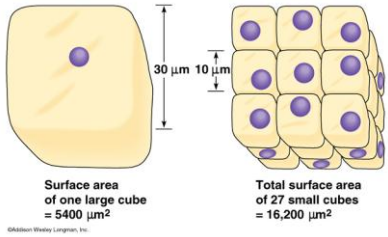
the creation of functional materials, devices, and systems through control of matter at the scale of 1 to 100 nanometers, and the exploitation of *novel properties* and phenomena at the same scale.





Why is nanotechnology different?

- Because of their size, nano-products have **unique properties** not found at the everyday, macro scale
  - Ex:
    - Large surface to volume ratios = high chemical reactivity

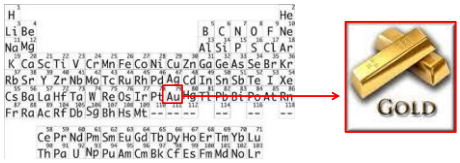


Why is Nanotechnology Different?

- Because of their size, nano-products have unique properties not found at the everyday, macro scale
  - Ex:
    - Large surface to volume ratios = high chemical reactivity
    - Same scale as light's wavelength = manipulate light
    - Same scale as cells = interaction with biological systems
- Unique properties can be tailored by adjusting the size and shape of nanoscopic components

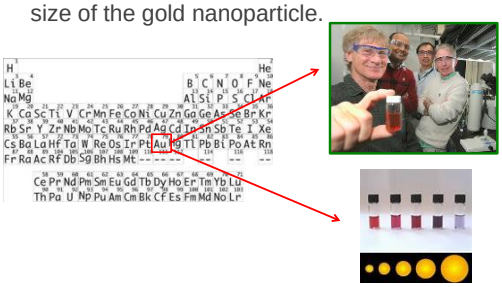
The Gold We Know:

- Material properties don't change with size.



The Gold We Are Discovering:

- Material properties (e.g. optical) change with the size of the gold nanoparticle.



Controlling Materials at the Nanoscale Controls Their Properties

From left to right: 80 nm silver nanospheres, 20 nm silver nanospheres, 40 nm gold nanospheres, 12 nm gold nanospheres, 200 nm silver nanoplates, 120 nm silver nanoplates, and 60 nm silver nanoplates.

Source: http://nanocomposix.com/kb/general/color-engineering

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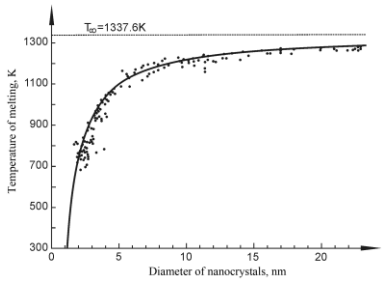
Size Affects Properties:
Gold Melting Point Depression



http://www.intechopen.com/books/thermodynamics-physical-chemistry-of-aqueous-systems/heterogeneous-melting-in-low-dimensional-systems-and-accompanying-surface-effects

So …Nano Gold Behaves Differently

Size

Chemistry

Shape

From left to right: 80 nm silver nanospheres, 20 nm silver nanospheres, 40 nm gold nanospheres, 12 nm gold nanospheres, 200 nm silver nanoplates, 120 nm silver nanoplates, and 60 nm silver nanoplates.

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Nano Gold Behaves Differently……
and not only that

- Each element on the Periodic Table can give us new capabilities at the nanoscale
- The periodic table is now multidimensional!

2. WHY: Some nanotechnology impacts - forecasts.

NACK NETWORK Building College-University Partnerships for Nanotechnology Workforce Development

Why should I care?

- Please give me some data on why I should consider teaching more about nanotechnology.
  - Is nanotechnology a real trend or just a fad?
  - Will their be jobs in industry for people who get training in nanotechnology

The impact of nano on products….

"It has been estimated that the worldwide market value of **products incorporating nanotechnology** will:

- increase by 100X over the two decades

The impact of nano on products….

"It has been estimated that the worldwide market value of **products incorporating nanotechnology** will:

- increase by 100X over two decades
- from about $30 billion in 2000 to about $3 Trillion in 2020
- .....from 0.8% of GDP to 5% of GDP…"

Mihail Roco, May 2011
Chemical Engineering Progress

The im…or

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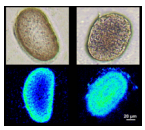
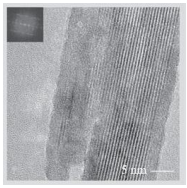
Mihail R… 2011
Chemica…ering Progress

Some examples of nanotechnology in history





Example of Roman Nanotechnology:
4th Century Lycurgus Cup

- In reflected light, cup appears *green*; in transmitted light, it appears *red*
- Cause: 40 ppm Au nanoparticles & 300 ppm Ag nanoparticles embedded in silica glass

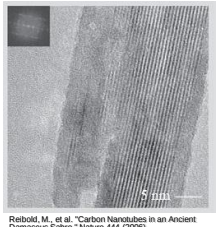
Did they know they were using nanotechnology?

References: (1) Paul Mulvaney, Not all That's Gold Does Glitter, MRS Bulletin, December 2001, pg.'s 1009-1013

(2) Barber, D J and Freestone, I C, An investigation of the origin of the colour of the Lycurgus Cup by analytical transmission electron microscopy, *Archaeometry*, **32** (1), 33-45, 1990.

Nanotechnology in the Middle Ages

Arab craftsmen made steel swords of legendary strength. Today we know these swords had carbon nanotubes and nanowires in the material. This is the oldest known use of carbon nanotubes and nanowires. These nanostructures may account for the swords' strength.



Reibold, M., et al. "Carbon Nanotubes in an Ancient Damascus Sabre." Nature 444 (2006).

Carbon nanotubes and carbon nanowires in Damascus steel sword.

How about right here?

Diverse Applications

Movie

Cancer:
Detection/
Treatment

Textiles

Copying Nature
(Biomimetics)

Household

Energy

Clean Water

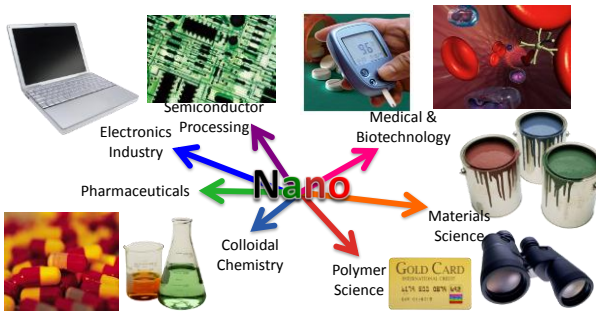
A Lot more Products !!!

- The Project on Emerging Nanotechnologies keeps track of the impact nanotechnology has in the economy and public and environmental health
- Inventory of over 1,000 consumer products
- Funded by Woodrow Wilson International Center for Scholars and The Pew Heritage Trust

http://www.nanotechproject.org/inventories/consumer/

So..where is nanotechnology used today?

Because nanotechnology's unique phenomena are **based on size** it is studied and implemented in a **broad range of scientific fields and industries**.



National Nanotechnology Initiative

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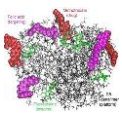
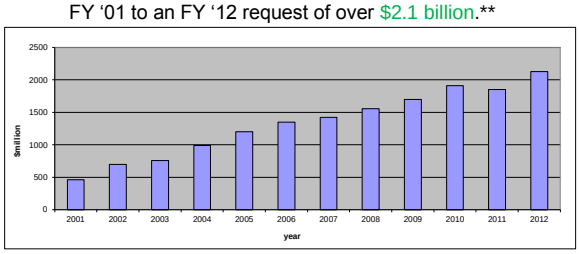



National Nanotechnology Initiative

NNI Budget Information

NNI expenditures* have grown from $464 million in FY '01 to an FY '12 request of over $2.1 billion.**



* All numbers shown above are actual spending, except 2011, which is estimated spending under the continuing resolution, and 2012 , which is requested amount for next year (FY '09 figure shown here does **not** include ~$500 million in additional ARRA funding).
** 2012 figure shown here does **not** include DOD earmarks included in previous yrs. ($75 M '10)

What is the Demand for Nanotechnology Skilled Workers?

National Nanotechnology Initiative

A New Industrial Sector

An NSF study said 6 million nanotechnology workers will be needed worldwide by 2020, with **2 million of those in the US**.

• There are more than **70 nano-specific degree programs** in higher education institutions across the U.S.

• Many of these jobs can be filled by workers with **2-year degrees**

• There are currently at least 2 dozen Associate's Degree programs in the US, with **new programs launching every semester**

National Nanotechnology Initiative

NNI Strategic Plan: Organizing the Innovation Pipeline

Goals

- Advance world-class nanotechnology research and development
- Foster the transfer of new technologies into products for commercial and public benefit
- Develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology
- Support responsible development of nanotechnology

Industries that Drive Demand

- Electronic/Semiconductor
- Biotechnology and Medical
- Pharmaceutical
- Optics/Optoelectronics
- MEMS
- Materials Design and Testing
- Food Industry/Water Purification
- Forensics
- Sales/Marketing
- University Research & Teaching
- Many More!

3. WHERE: Where you can find it -- some nanotechnology education resources.

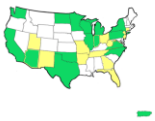
- The NACK National Network

NACK NETWORK Building College-University Partnerships for Nanotechnology Workforce Development

What is NACK?

NACK NETWORK Building College-University Partnerships for Nanotechnology Workforce Development

The Mission of NACK is to enable Nanotechnology Education at:



- 2-year Community & Technical Colleges
- 4-year Universities and Colleges in Partnership with Community & Technical Colleges

NACK's Approach

- Build Partnerships

- Educate for a Wide Spectrum of Industries

- Broad Foundational Nano Education

- Enable CC/TC Delivery in Entire US

PCAST Report (April, 2012, page 12)

PENNSTATE

REPORT TO THE PRESIDENT AND CONGRESS ON THE FOURTH ASSESSMENT OF THE NATIONAL NANOTECHNOLOGY INITIATIVE

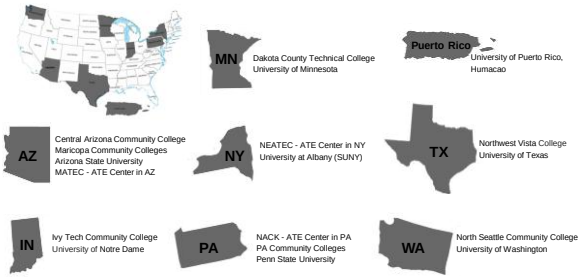
Workforce Development

With the support of the NSF's Advanced Technology Education (ATE) program, Penn State has developed a nation-wide partnership of research universities and community colleges that is bringing meaningful core-skills nanotechnology workforce education to technical and community colleges across the United States. This partnership, the NSF National Nanotechnology Applications and Career Knowledge (NACK) Network, fosters (1) resource sharing among community colleges and research universities for nanotechnology workforce development, (2) the availability of course materials, for web or in-class use, covering a core set of industry-recommended nanotechnology skills and (3) broad student preparation for careers in the wide spectrum of industries utilizing micro- or nanotechnology. NACK has created and offers continually updated, free-of-charge core-skills course lecture and lab materials, web-accessible equipment capability, and faculty development workshop curricula. Since the inception of the nationwide effort in 2008, NACK's research university-community college partnership hubs have been set-up and are functioning in Puerto Rico, New York, Indiana, Minnesota, Texas, and Washington State. Others are underway and these are in addition to the hub comprised of 30 Pennsylvania schools and funded by the State of Pennsylvania since 1998. To-date, there have been over 800 graduates from the nanotechnology core-skill classes offered by the NACK hubs, 20,881 web downloads of NACK educational materials, and 957 educators who have completed professional development workshops. The Penn State nanotechnology workforce development programs began as a Pennsylvania-focused activity with the founding of Pennsylvania Nanofabrication Manufacturing Technology (NMT) Partnership funded by the State in 1998. In 2003 the additional component of an NSF ATE regional center for nanotechnology workforce education was added. In 2008 this NSF ATE activity evolved into the NACK Network nationwide workforce development partnership. By creating education pathways from high school to skilled manufacturing careers across the country, the NACK Network is working to train the U.S. nanotechnology manufacturing workforce.

"With the support of the NSF ATE program, Penn State has developed a nation-wide partnership of research universities and community colleges that is bring meaningful core-skills nanotechnology workforce education to technical and community colleges across the United States....."

NACK Network
Nanotechnology Education Hub Areas

A working, productive nanotechnology workforce development network involving research universities and community and technical colleges across the U.S.



www.nano4me.org

NACK Courses — "Physical" offering at University Park

- This suite of six courses is taught twice/year – as a **service** by Penn State – for PA 2-year and 4-year degree-granting institutions
- Credits come from "home" school
- Taken to-date at University Park by 774 students from community colleges, colleges, and universities.
- Central Facility Model—i.e., facility for a region

NACK Network — Building College-University Partnerships for Nanotechnology Workforce Development

What is the PA NMT Partnership

Capstone Semester = 18 credit hands-on immersion experience offered at Penn State for all PA partner schools

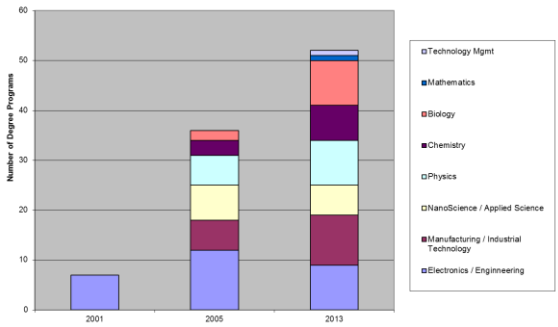
National Advisory Council

NACK Network — Building College-University Partnerships for Nanotechnology Workforce Development

- Alcatel-Lucent
- Bio-Link Center
- Boeing
- Corning
- Cyoptics
- Dupont
- General Electric
- Imerys
- Information & Communications Technology Center
- Johnson & Johnson
- Lockheed Martin
- 3M
- National Council for Advanced Manufacturing
- National Coalition for Advanced Technology Centers
- Northrop Grumman
- PPG
- Plextronics
- Semiconductor Research Corporation
- Strategic Polymers
- Stryker
- Tyco
- University of Minnesota

As of May 2013

Diversity & Growth of Disciplines of PA Degree Programs in Nanotechnology



What approach is taken?

A General Approach to Nanotechnology/Nanofabrication with the Objectives of:

1) Providing a solid, broad information base that an individual can build upon; and
2) Creating a versatile nanotechnology workforce that can move from industry to industry with the ebb and flow of international market forces

Summary of Skill Sets Taught in the 6 Nanotechnology Courses

Basic Nanotechnology EHS Awareness
- Basics of Chemical and Material Properties—Role of Scale
- Chemical and Materials Handling, Storage, and Disposal
- Nanotechnology Health, Safety, and Environmental issues

Nanotechnology Equipment and Processing Foundation Skills
- Chemical Hoods and Glove Boxes: Use and Maintenance
- Cleanrooms: Use and Maintenance
- Pumps, Flow Control Systems, Scrubbers, Sensors: Use and Maintenance
- Vacuum Systems: Use and Maintenance
- Plasma Generating Systems: Use and Maintenance
- Furnaces, Ovens, and Rapid Thermal Annealing Equipment: Use and Maintenance
- Chemical Facilities and Maintenance
- Contamination Control
- Process Integration
- Introduction to Statistical Process Control

Nanotechnology Patterning
- Optical, e-beam, and Ion Beam Lithography
- Stamping and Imprinting Lithography
- Chemical techniques; e.g., Block co-polymer and SAMs

Nanotechnology Fabrication
- Top-down Fabrication
  - Reactive Ion, Sputter, and Wet Etching
  - Chemical Vapor and Physical Vapor Deposition Systems
  - Ion Beam, Plasma, and Chemical Materials Modification
  - Nanoparticles: Etching and Grinding Approaches
- Bottom-up Fabrication
  - Chemical, Physical, and Biological Self-Assembly
  - Nanoparticles: Colloidal Chemistry
  - Nanoparticles: Plasma Approaches
  - Nanoparticles: Chemical Vapor Deposition Approaches

Nanotechnology Characterization
- Optical Microscopy
- Scanning Probe Microscopy
  - Atomic Force Microscopy
- Electron Microscopy
  - Scanning Electron Microscopy (SEM and FE-SEM)
  - Transmission Electron Microscopy (TEM and FE-TEM)
- Chemical Characterization
  - X-ray (EDS)
  - Secondary Ion Mass Spectroscopy
  - Auger Electron Spectroscopy
  - Fourier Transform Infrared Spectroscopy
- Electrical Characterization
  - Current-Voltage Measurements
  - Capacitance Measurements
  - Opto-electronic Device Measurements
- Physical Characterization
  - Spectrophotometer
  - Profilometer
  - X-ray Diffraction

Nanotechnology Professional Skills
- Team Building
- Problem Solving
- Project Organization and Planning
- Research Skills
- Assessing Cost of Ownership
- Presentation Skills
- Technical Reporting and Documentation
- Handling and Generating Intellectual Property

Institutions That Have Hired Capstone Semester Graduates for Micro- and Nanotechnology Jobs

II-VI Corporation
Accellent
Adhesives Research, Inc
Advanced Acoustic Concepts
Advanced Cooling Technologies
Advanced Gas Technologies
Advanced Powder Products
Advantech
AGAM
Agere
Alcoa
Allied Electronics
Alsbin Products
AMAX Minerals
Amedeo
Amgen Inc.
Apogee Photonics
Arrow International
Avail Technologies
Avnet
BioElectroSpec
B. Braun
Boston Applied Technologies
BD (Becton, Dickinson)
BP Solar
Bridge Semiconductor
Busch Vacuum
Cabot
Cabot Microelectronics
Carbon NanoProbes
Celgene-LifebankUSA
Chemcut
Correge Sensors
Cosmos Technologies
Crystalplex
Cygnics
Dendreon
DRS Laurel Technologies
Dana Corporation
Doucette
Don's Salads
Dow Chemical
Drexel University
Eastman Chemical Company
East Penn Manufacturing
Ex One
Fairchild Semiconductor
Fincor Automation
First Energy
F.S. Elliott
General Dynamics Robotic System
General Electric
Glass automatic
GlaxoSmithKline
Globalfoundries
GTS
Haraeus Noblelight
Hale Products
Hershey Medical Center
Illuminex
Infinera
Inovative Micro Technology
Intel Corporation
iNDEX
IQE
Johnson & Johnson
Johnson Matthey
Judson Technologies
Keystone Communications
Keystone Engineering
Keystone Research & Pharmaceuticals
Kongsberg Defense
Kurt J. Lesker
Kyowa America
LCM Technologies
Lehighton Electronics
Lockheed Martin
Lucent Technologies
Lutron Electronics
Maxima Technologies
Max Levy Autograph
Meadow Burke Products
Membrane Assays
Merck
Mintera Corporation
NanoHorizons
Natural Nano, Inc
North American Hoganas
North Carolina State University
Northrup Grumman, Inc
Optellios
Optinel Systems
PQI
Penn State CNEU
Penn State Dubois
Penn State Applied Research Lab
Penn State Electro-Optics Center
Pfister Energy
Philips Medical Systems
Philips Respironics
Plextronics
Probes Unlimited
Proconex
PPG
PPL
QorTek
Restek
Rhetech
Rohm and Haas
Ross Technologies
RJ Lee
Schroeder Industries
Scientific Systems
Seagate Technologies
Siemens Co.
SI International
Slack Pek
Solar Innovations
Solarity
Spectrum Technologies
Strainrite
Strategic Polymers
Structure Probes Inc.
Synthes
Telecardia
Textron Lycoming
Thermo Electric PA
Transene
Tyco Electronics
US Air Force
Uniroyal Optoelectronics
University of Florida
University of North Carolina - Charlotte
University of Pittsburgh
Vectron International
Velox Semiconductor
Western Digital
Westfalia Technologies
Westmoreland Mech. Testing & Research
Xactix

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Job Titles for Nanotechnology Graduates

Nano in the Title … Maybe Not??

Biological Laboratory Tech.	Laboratory Tech.	Production Scientist
Biofuels Tech.	Lithography Tech.	Quality Control Tech.
Chemical Laboratory Tech.	Materials Science Lab Tech.	Research Assistant
Cleanroom Tech.	Medical Devices Tech.	SEM Operator
Deposition Tech.	Microfabrication Tech.	SPM Operator
Device Tech.	Nanobiotech Researcher	Scientist Specialist
Equipment Maintenance Tech.	Nanoelectronics Expert	Solid State Tech.
Engineering Tech.	Nanofabrication Tech.	Test Tech.
Etch Tech.	Nanotechnologist	Thin Films Tech.
Failure Analysis Tech.	Process Tech.	Vacuum Tech.

Source - NACK Alumni Committee

Survey of PA NMT Capstone Graduates

(Completed March, 2011)

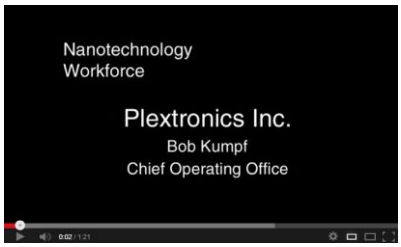
Some Survey Findings:

- When they completed the nanotechnology 6 course suite, 59% were enrolled in a 2-year associate's degree program and 41% in a baccalaureate program.
- 95% said it was a valuable education experience and 90% said it influenced their educational pathway
- At the time of the survey, **69% are employed in a nano field** & 65% said the capstone influenced their career pathway
- **95%** are currently either working or in a degree program full-time

What does industry say about NMT Grads?

- Cyoptics, Inc. (Breiningsville, PA):
  - … relies heavily on PA NMT graduates to staff manufacturing operations.
  - "combination of nano-scale theoretical as well as hands-on training have in their educational toolbox enable them to "hit the ground running", significantly reduce in house training time and enable them to be valuable long term contributors to bottom line company profitability."

What does industry say? Plextronics Testimonial



Robert J. Kumpf, Ph.D.

The Portal to NACK Resources

Nano4Me.org

For
- Students
- Alumni
- Educators
- Industry

NACK Network — Building College-University Partnerships for Nanotechnology Workforce Development

Today's Desired Outcomes

Participant Understanding of:

1. What it is --- some nanotechnology basics.
   - Size and properties
2. Why you should care --- some of the impact of nanotechnology.
   - Applications, Jobs Today, and Future Predictions
3. Where you can find it --- some nanotechnology education resources.
   - The NACK National Network

NACK Network — Building College-University Partnerships for Nanotechnology Workforce Development

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Bringing Nanotechnology to Education & Industry!

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