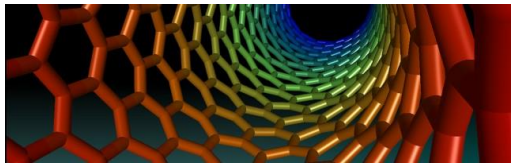
INVEST IN YOUR FUTURE: NANOTECHNOLOGY WORKFORCE EDUCATION OPPORTUNITIES

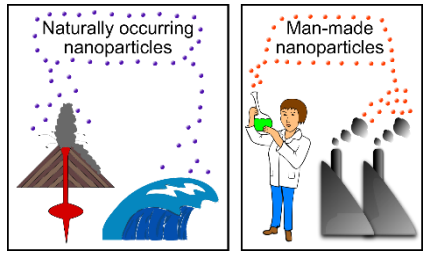
Fall 2021

NACK NETWORK
Building College-University Partnerships for Nanotechnology Workforce Development

PennState College of Engineering

Adding Nanotechnology Knowledge and Skills to your academic toolbox is an extremely good investment.





Who am I?

Bob Ehrmann

Managing Director
PA Nanofabrication Manufacturing Technology (NMT) Partnership
rke2@psu.edu

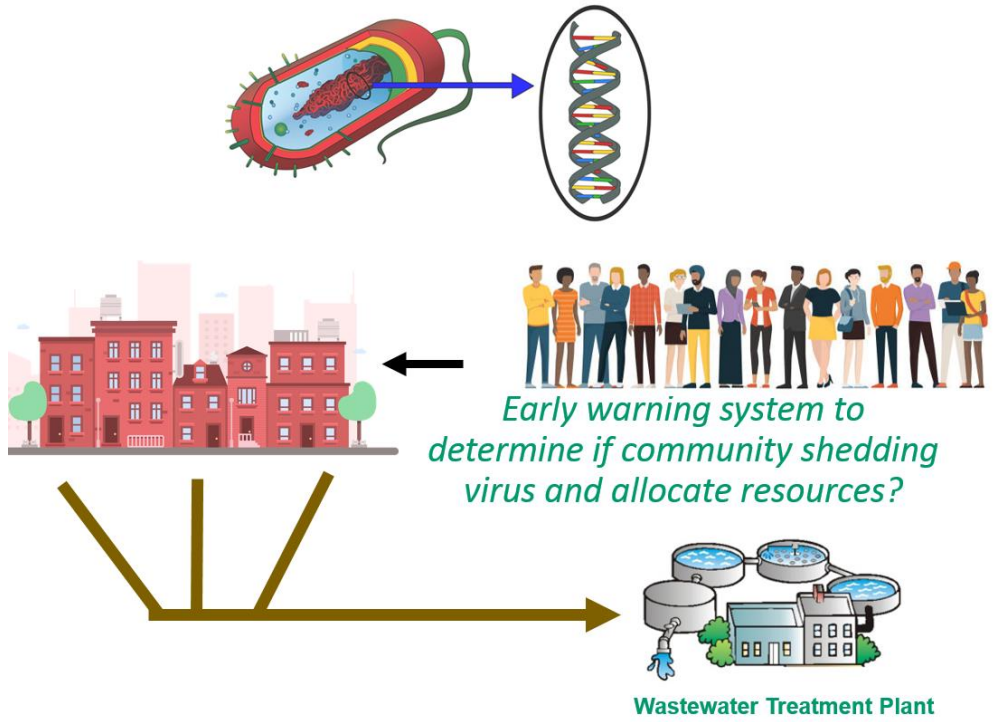
Nanotechnology in the Covid 19 Era

An example of why nanotechnology is important?

Why understanding nanotechnology is relevant?

Nano's contribution to fighting COVID-19:

- Point of Care and Laboratory Testing
- At-home Tests
- PPE
- Oxygen generators
- Sensors
- Antimicrobial Coatings
- Antibody testing
- Vaccine development
- Vaccine delivery systems
- Medical research (virus understanding)
- EVERYWHERE you can think of



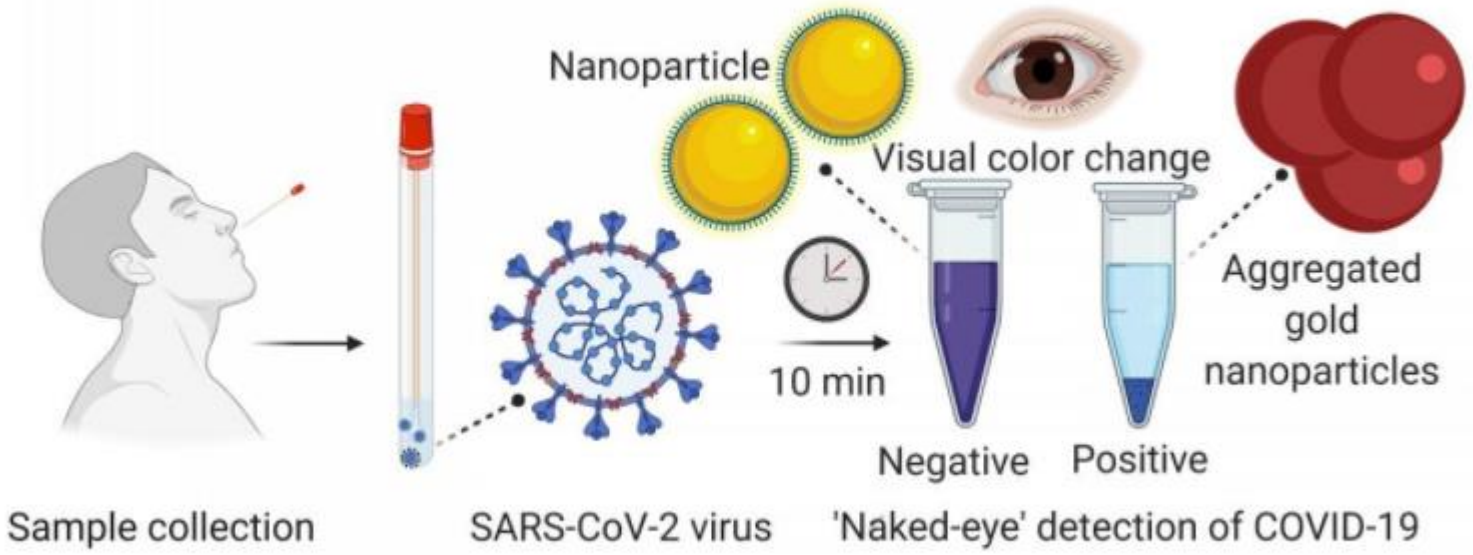
VA Tech: Monitoring for Coronavirus in Sewage led by NanoEarth Researchers

Point of Care Testing

UMSOM

5-29-20

Rapid COVID-19 Test



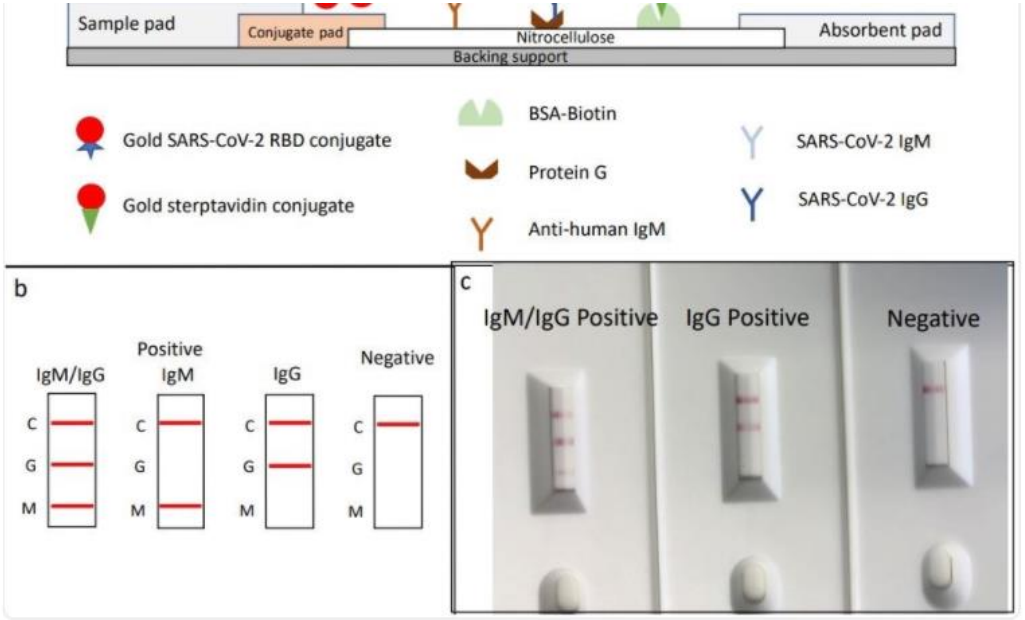
Point of Care Testing

Rapid SARS-CoV-2 IgM-IgG combined antibody test

10-15-20

Gold nanoparticle enabled Covid Test

CEO & co-founder of GaDia SA



Schematic illustration of rapid SARS-CoV-2 IgM-IgG combined antibody test and example of typical results. a, Schematic diagram of the detection device; b, illustration of different testing results; c, example of typical results obtained with the RDT.

Vaccines: WHAT IS MESSENGER RNA (mRNA) AND WHY IS IT SO IMPORTANT

mRNA can be thought of as a set of instructions that tell your body's cells how to make proteins. While COVID-19 may seem new to many of us, **researchers have been studying coronaviruses for over 50 years**. During this time, they've also been learning how mRNA technology can help develop effective vaccines.

Here's how mRNA technology used in COVID-19 vaccines works:

The mRNA vaccine tells your body to make a small, non-infective portion of the outer part of the COVID-19 virus particle called a "spike protein".

This trains your immune system into recognizing the virus and your body responds by building antibodies.

Later, if you are exposed to the real virus, these antibodies are then able to attack it and prevent you from getting sick. The antibodies' ability to prevent sickness is what is meant when people say a vaccine provides immunity.

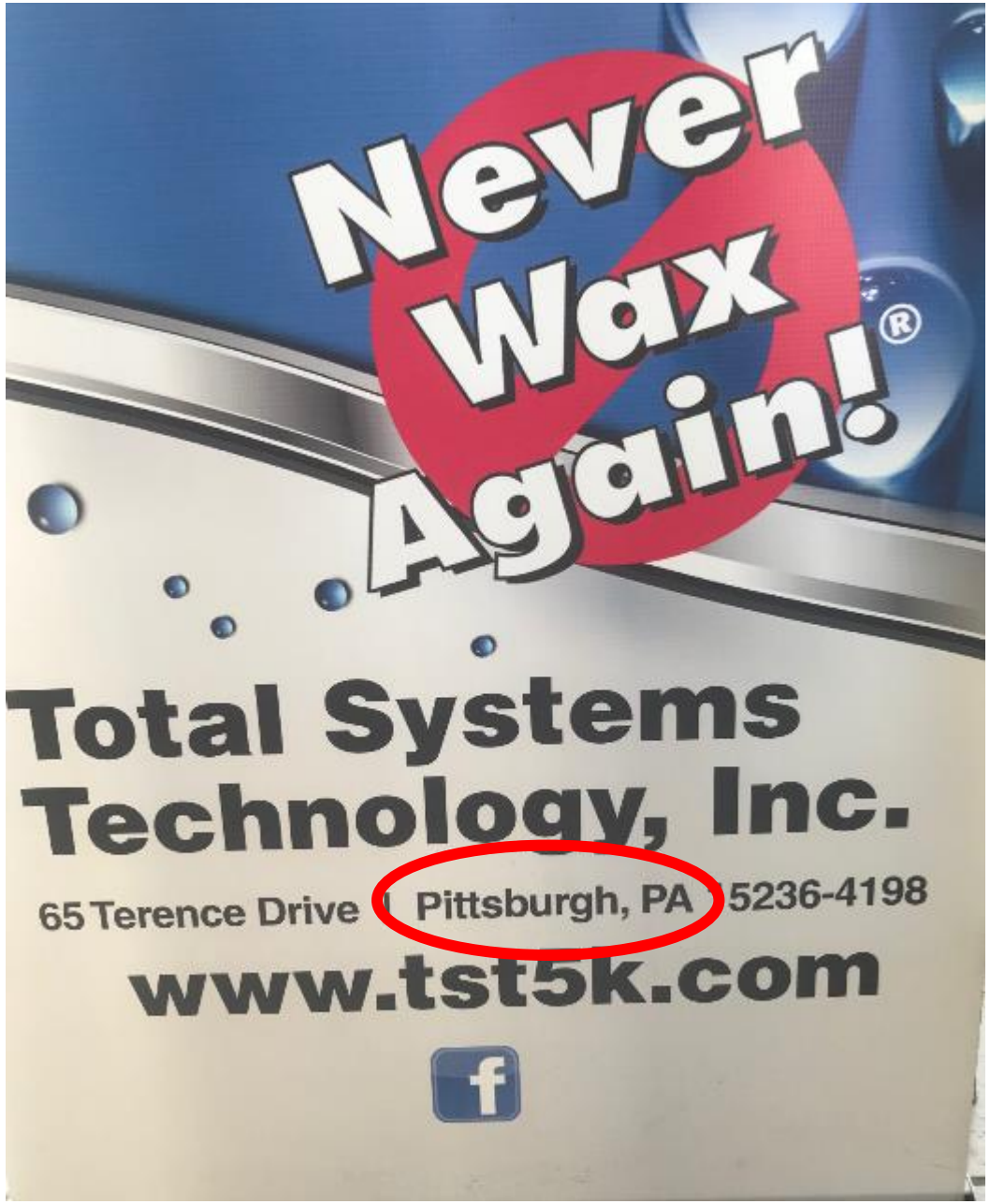
A key benefit of mRNA vaccines is that the process to develop them can be standardized and scaled up more efficiently than other methods, which has been especially important in our response to COVID-19.

Nanotechnology!

- Broad term, referring to the manipulation of matter at the near atomic level.
- Encompasses many scientific disciplines.
- Impacts daily life and our future greatly.

Bob's Car Shopping Story – August 2019


TST 5000™ with PTFE
Nanoparticle Technology
5000 Particles of PTFE PER SQUARE INCH
Wax
100 Times Larger Than
Polymer Silicone
100 Time Larger Than
TST 5000™
with PTFE
TST 5000™
with PTFE
NO DRIFT
STAYS ON TOP
5 YEARS
POLYMER-
SILICONE
DRIFTS IN
1/2-1% PER DAY
WAX
DRIFTS OFF
1-2% PER DAY
PAINT
PRIMER
METAL OR FIBERGLASS


Never
Wax
Again!®
Total Systems
Technology, Inc.
65 Terence Drive Pittsburgh, PA 15236-4198
www.tst5k.com

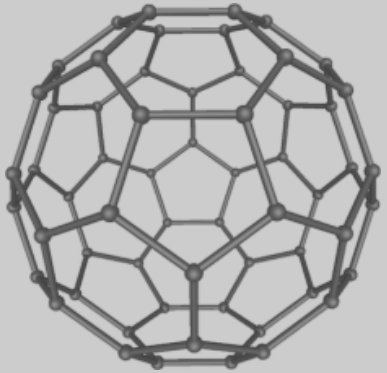

Nanotechnology
is
Ubiquitous

Okay -------
Let’s back up a bit:

What is Nanotechnology?

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.



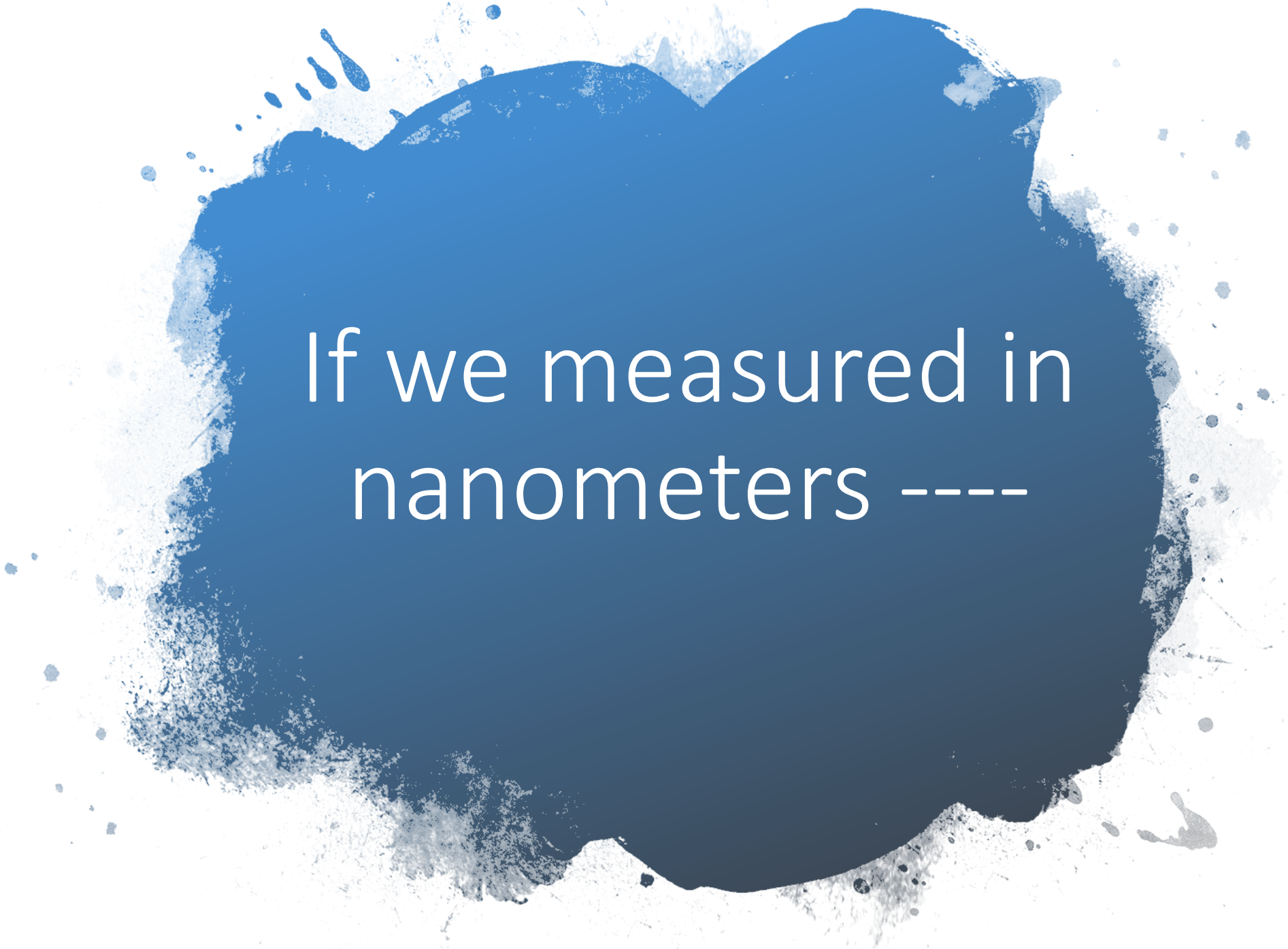
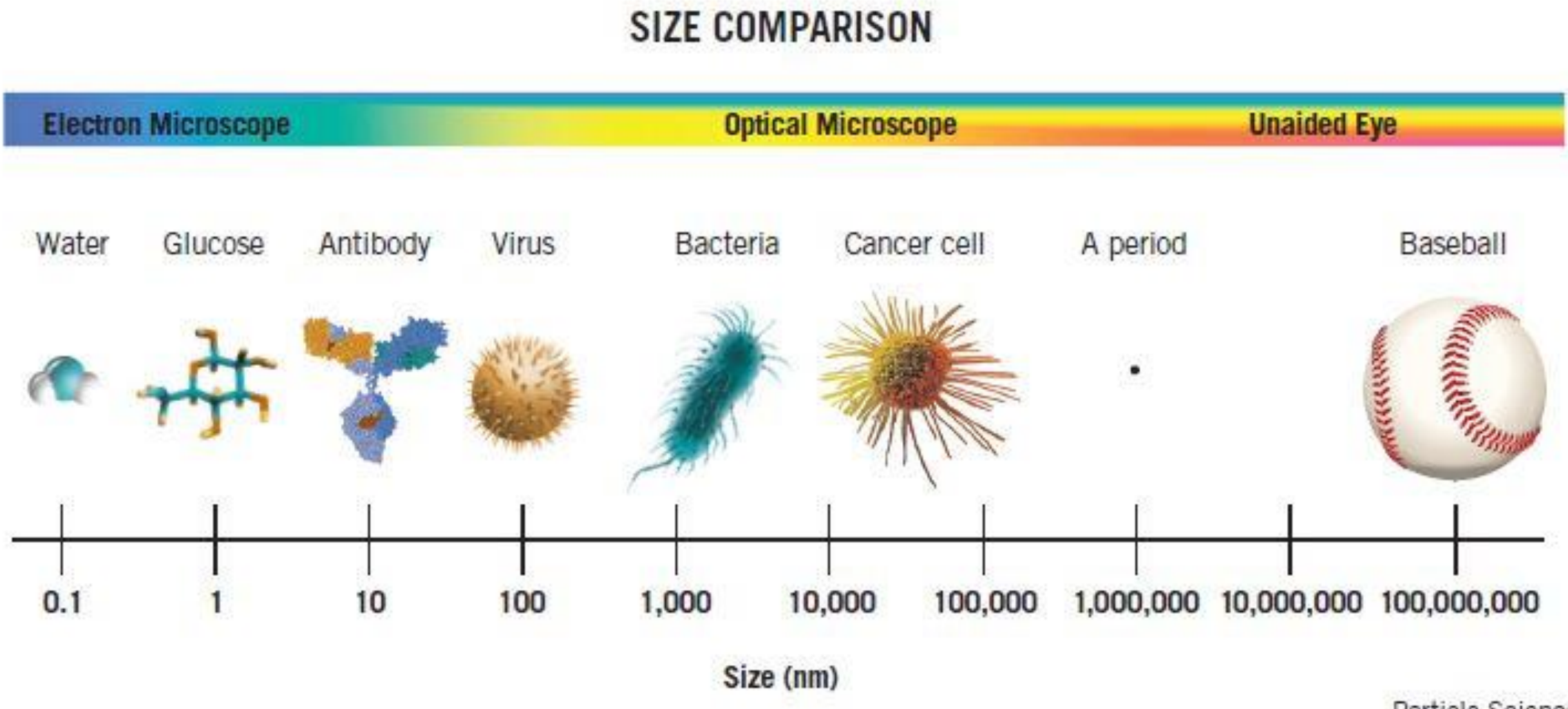

If we measured in nanometers ----

Figure 1


SIZE COMPARISON
Electron Microscope
Optical Microscope
Unaided Eye
Water
Glucose
Antibody
Virus
Bacteria
Cancer cell
A period
Baseball
0.1
1
10
100
1,000
10,000
100,000
1,000,000
10,000,000
100,000,000
Size (nm)
Particle Sciences

How small is a nanometer?

And if the Earth were **one meter** in diameter, a nanometer would be…

Material Properties at the Nanoscale

Macroscale Gold:

Material properties don't change with size.

- reactivity
- melting point
- optical absorption
- etc.

Nanoscale Gold:

Material properties change with the size of the gold nanoparticle.

- reactivity
- melting point
- optical absorption
- etc.

What makes the nano-scale special?

1. Very large surface-to-volume ratios
2. Geometry effects color
3. Physical & chemical properties change
4. Very small structures

Nanotechnology

How did we get here?

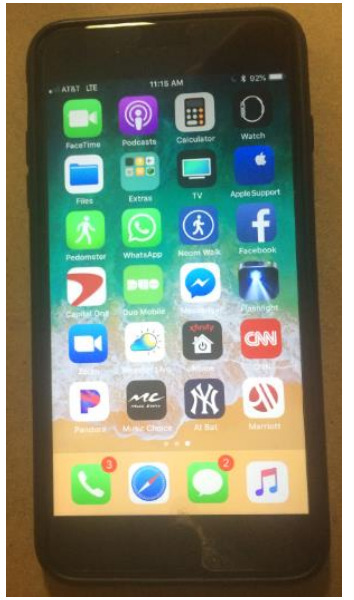
Modern Electronics (in 1991)

http://consumerist.com/2014/01/17/the-smartphone-has-effectively-replaced-all-the-technology-offered-in-this-1991-radio-shack-ad/

One Example of the Impact of Nanotechnology: Cell Phones

1993

2004



2016

What fits in a cell phone?

Nanotechnology and Computers

1986

First IBM-compatible Laptop

Toshiba T1100
CPU 80C86 -- 7.16 MHz
640K RAM
2 - 5 ¼ " Floppies
9 lbs

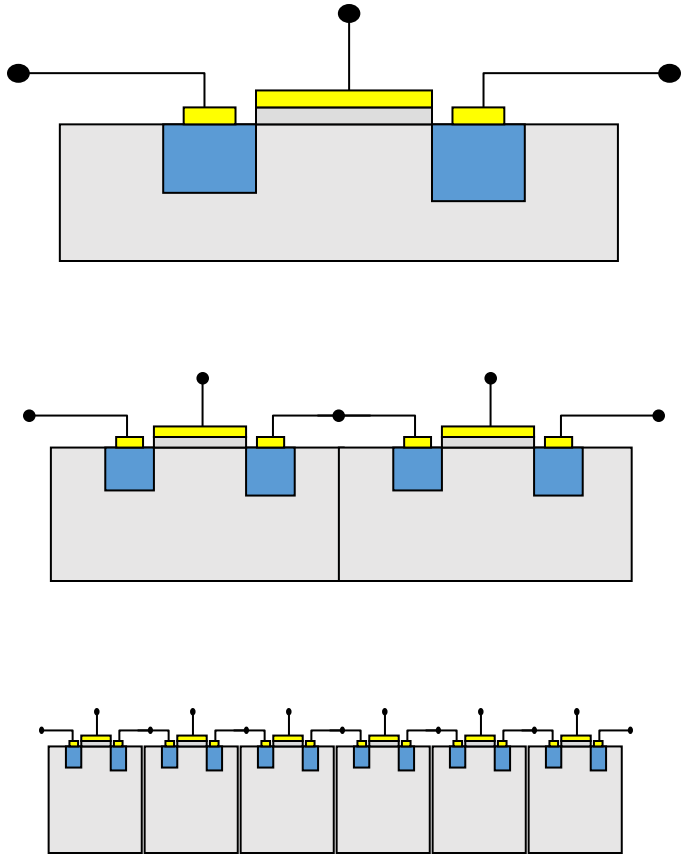
2019

Lenovo ThinkPad X1 Laptop - 14"
Intel Core i5 8250U --- 1.60 GHz
8 GB RAM
256 GB SSD
2.5 lbs

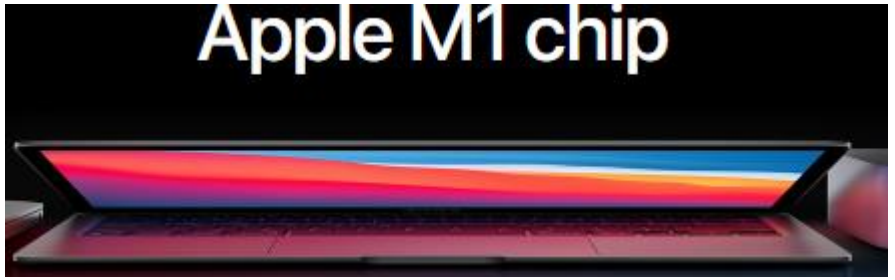
Micro to Nano- electronics

On the SAME size real estate !!!

- 100's of transistors on a chip in the 1960's
  - **10-30 micron** gate length
- 1988
  - **1 micron** gate length
- To millions in the 1990's
- To > 10 billion in 2019
  - ***7 nanometer*** gate length
- To > 16 billion in 2020
  - **5 nanometer** gate length



Breaking News:



Packed with an astonishing 16 billion transistors, the new M1 chip integrates the CPU, GPU, Neural Engine, I/O, and so much more onto a single tiny chip. Combined with the new macOS Big Sur, M1 delivers category-smashing speed, mind-bending graphics, and power efficiency and battery life that defy belief.

5 nm gate length - >> **16 billion** transistors per chip

Apple Event
November 10, 2020

Nano: Enabling Technologies

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

Zeiss Ultra 60

Scanning Electron Microscope (SEM)

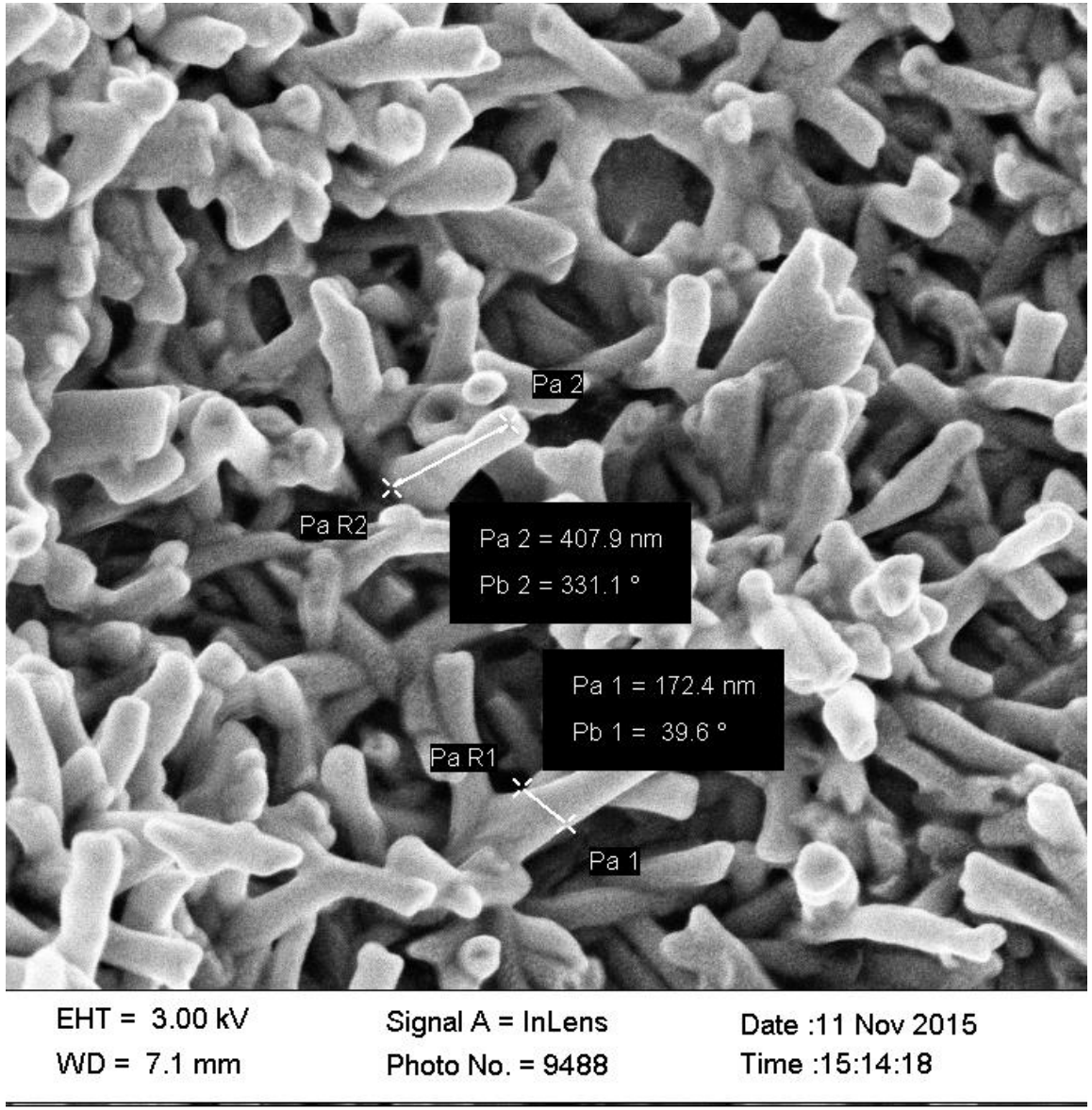
Modern tools:

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

Lotus Effect

Video link: https://youtu.be/MFHcSrNRU5E

Lotus Leaf via FESEM

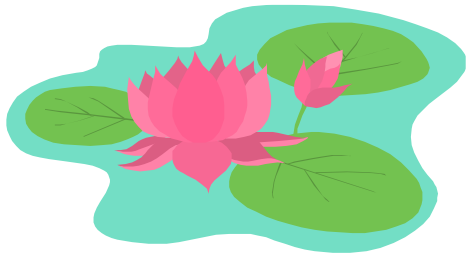


Diverse Applications

Movie

Cancer: Detection/ Treatment

Textiles



Copying Nature (Biomimetics)

Energy

Household

Clean Water

Sports

Video links from previous slide

- Cancer Detection and Treatment
  - https://youtu.be/OG7dMUE0rII
- Copying Nature (Biomimetics)
  - https://youtu.be/7is6r6zXFDc
- Household
  - https://youtu.be/50UlSSy7PFE
  - https://youtu.be/1nYNOB3K_wg
  - https://youtu.be/uRfmDoOc60c
- Clean Water
  - https://binged.it/2FWmtKP
- Textiles
  - https://youtu.be/apFyWc-fxO0
  - https://youtu.be/BvTkefJHfC0
- Energy
  - https://youtu.be/1GFst2IQBEM
  - https://youtu.be/Ds3sA1vqx1w
  - https://youtu.be/5AnMsyIT26A
  - https://youtu.be/t7EYQLOlwDM
- Sports
  - https://youtu.be/9VDeJ7rLUYU
  - https://youtu.be/lZ_D2nqqmZQ

National Nanotechnology Initiative (2000)

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

Goals:

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

"By 2020, 70% of all new advanced technology products will incorporate nanotechnology"…will you have the training necessary to compete in tomorrow's workforce?

* M. Roco

Nanotechnology Workforce Video

Building College-University Partnerships for Nanotechnology Workforce Development

Nano Workforce Video

www.cneu.psu.edu/nmt-capstone/

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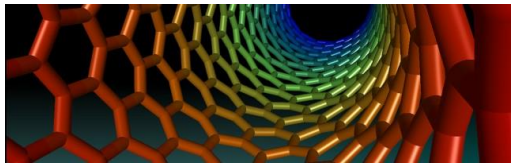
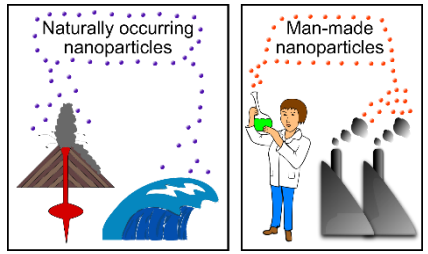




Market and Jobs Information

As the market expands, the number of **jobs** needing different skill levels in nanotechnology will increase.

Thus, it is essential that a sufficient **supply** of qualified **workers** be developed to fill that need.

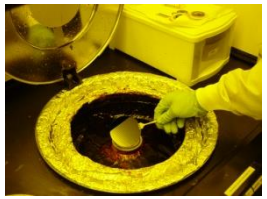
Nanotechnology education programs are available to you in Pennsylvania

Undergraduate – The PA NMT Capstone Semester

Graduate – M.S. in Engineering at the Nanoscale (1 year) – NOTE: I'm not going to cover this one today due to time constraints but contact me if you are interested in learning more.

What is the PA NMT Partnership

PA Associate & Baccalaureate Students



“Hands-On” Capstone Semester @ PSU

Grads to PA Industry / Academia

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

PA NMT Capstone Semester—A "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 960
- students from community colleges, colleges, and universities.
- Central Facility Model—i.e., facility for a region

The NMT Capstone Semester

- **Provides unique graduate level experience working in a cleanroom environment**
- **Consists of 6 three credit courses**
  - **E SC 211 through E SC 216**
- **Lab and lecture component**
- **Group based activity**

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
Alden Products
AMAX Minerals
Amedeo
Amgen Inc.
Apogee Photonics
Aquion Energy
Arrow International
ASML
Avail Technologies
B. Braun
Berry Plastics
BioElectroSpec
Boston Applied Technologies
BD (Becton, Dickinson)
BP Solar
Bridge Semiconductor
Busch Vacuum
Cabot
Cabot Microelectronics
Carbon NanoProbes
Celgene-LifebankUSA
Chemcut
Correge Sensors
Cosmos Technologies
Cree
Crystalplex
Cyoptics
Dendreon
DRS Laurel Technologies
Dana Corporation
Doucette
Don's Salads
Dow Chemical
Drexel University
Dupont
Eastman Chemical Company
East Penn Manufacturing
Emerson Network Power
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
IBM
Illuminex
IM Flash Technologies
Infinera
Inovative Micro Technology
Intel Corporation
iNOEX
IQE
Johnson & Johnson
Johnson Matthey
Judson Technologies
Keystone Communications
Keystone Engineering
Keystone Research & Pharmaceuticals
Kongsberg Defense
Kurt J. Lesker
Kyowa America
Lawrence Livermore National Lab
LCM Technologies
Lehighton Electronics
Lockheed Martin
Lucent Technologies
Lutron Electronics
Macron Dynamics
Maxima Technologies
Max Levy Autograph
Meadow Burke Products
Membrane Assays
Merck
Micron Technology
Mintera Corporation
MXL Industries
NanoHorizons
Nanovus
Nascent Devices
Natural Nano, Inc
NIST
North American Hoganas
North Carolina State University
Northrup Grumman, Inc
Optellios
Optinel Systems
P2I
Penn State CNEU
Penn State Dubois
Penn State –Advanced Coatings - ARL
Penn State Applied Research Lab
Penn State Electro-Optics Center
Pennsylvania Dept of Environmental Protection
Pfister Energy
Philips Medical Systems
Philips Respironics
Plextronics
Probes Unlimited
Proconex
PPG
PPL
QorTek
Qorvo
Restek
Rhetech
Rohm and Haas
Ross Technologies
RJ Lee
Schroeder Industries
Scientific Systems
Seagate Technologies
Siemens Co.
SI International
Slack Pek
Solar Innovations
Solarity
Solvay OLED
Spectrum Technologies
SPI Supplies
Strainrite
Strategic Polymers
Structure Probes.
SuperPower
Synoptics
Synthes
Telecardia
Textron Lycoming
Thermo Electric PA
Transene
Tyco Electronics
US Air Force
US Army Research Laboratory
Uniroyal Optoelectronics
Universal Display Corporation
University of Florida
University of North Carolina - Charlotte
University of Pittsburgh
Vectron International
Velox Semiconductor
Western Digital
Westfalia Technologies
Westmoreland Mech. Testing & Research
Xactix

What approach is taken?

- **A General Approach to Nanotechnology/Nanofabrication with the Objectives of:**
-
  - Providing a solid, broad information base that an individual can build upon; and
  - Creating a versatile nanotechnology workforce that can move from industry to industry with the ebb and flow of international market forces

The NMT Capstone Semester

- Additional benefits of the NMT capstone semester
  - Exposure to **tens of million dollars** worth of equipment
  - **Unique job skills** that set you apart from other candidates entering the job market
  - **Resume** building
  - **Networking**
- Work towards a **certificate, minor, or major** at institutions across the state-including yours.

Some current **focus areas**

Building College-University Partnerships for Nanotechnology Workforce Development

- Nanotechnology Educational Standards and **Personnel Certificates**

ASTM INTERNATIONAL

Created 3 certificates which cover the 6 ASTM Nanotechnology Workforce Education Standards

To be attained by individuals completing course-work / programs and passing corresponding tests

ASTM Workforce Certificate in Nanotechnology
Health and Safety

ASTM Workforce Certificate in Nanotechnology
Characterization

ASTM Workforce Certificate in Nanotechnology
Fabrication & Processing

Summer 2022 NMT Capstone Semester

- Class starts Monday 5-16-22
- 18 credits in 12 weeks
- Classes Monday - Friday
  - Lab 8-11 AM or 3:30-6:30 PM
  - Lecture 12-3 PM

Spring 2022 Virtual - NMT Capstone Semester

- Class starts Monday 2-14-22
- 18 credits in 12 weeks
- Classes Monday - Friday
  - 9 AM to 4 PM
  - Lectures and Labs

How much is Housing?

Expense	Amount
On Campus Apartment	$2,817
On Campus Townhome	$3,279
Off Campus (usually sublets)	$1200 - 2500

*Food is on your own.

So what's next…?

1) Talk to your school's nanotechnology program advisor

2) Reserve your seat by emailing Sue Barger: sbarger@engr.psu.edu

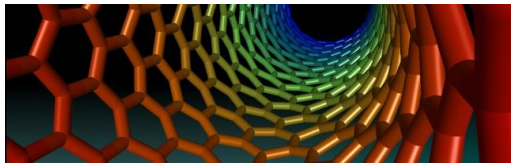
Application Deadlines for 2022 Nanotechnology Capstone Semesters at Penn State University

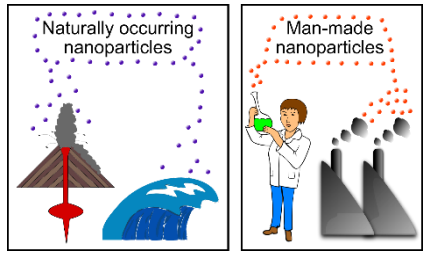
Semester	Reserve your seat by…	Submit your application by…
Spring 2022	ASAP	12-1-21
Summer 2022	1-31-22	2-15-22

Interested …… but want to gather more information: Connect with your local NMT focal contact or contact Sue or me.

Thank you for your Time and Attention !

Adding Nanotechnology Knowledge and Skills to your academic toolbox is an extremely good investment.





PA NMT CONTACTS

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NACK NETWORK Building College-University Partnerships for Nanotechnology Workforce Development

Bringing Nanotechnology to Education & Industry!

www.nano4me.org


Questions ??

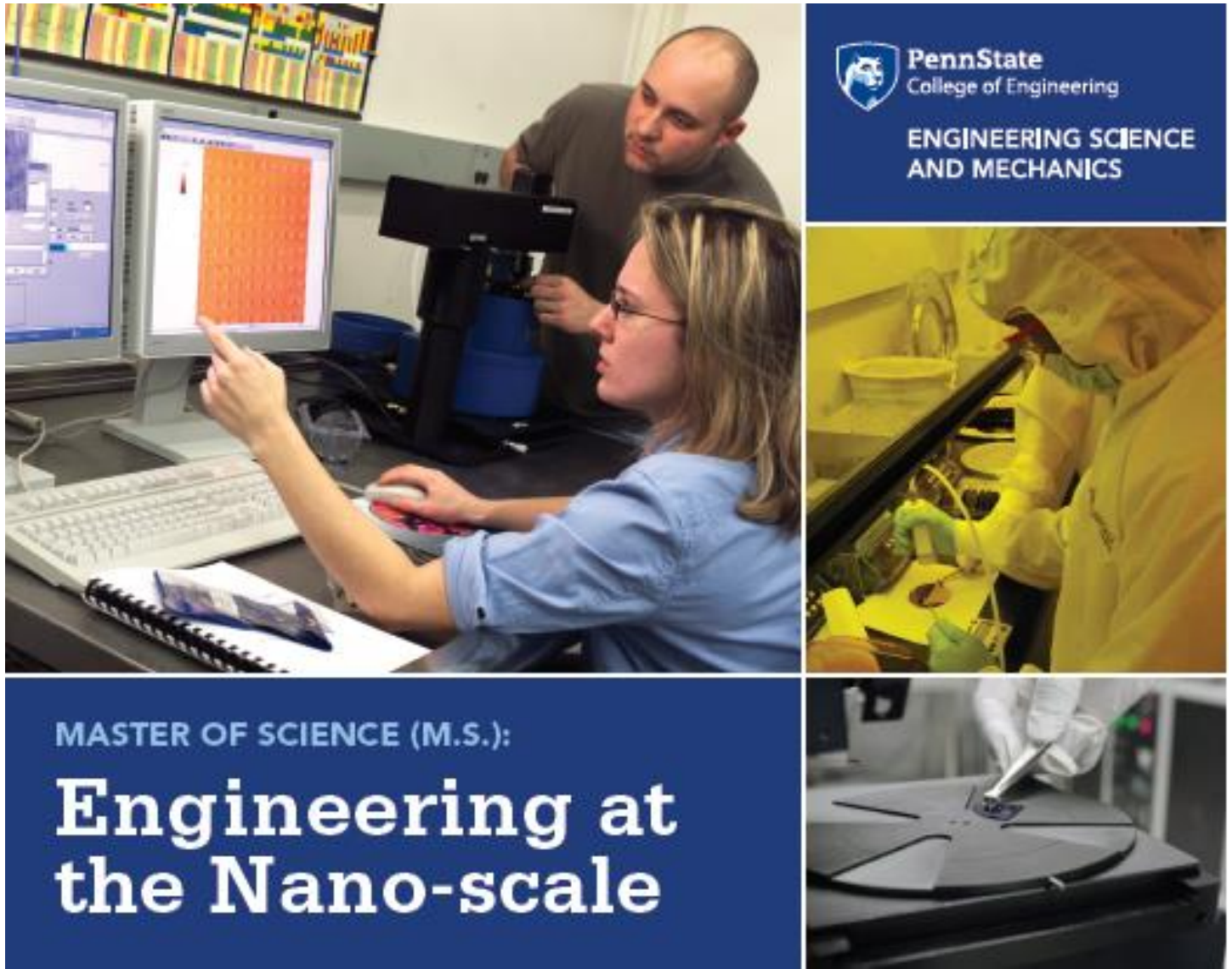
MS in Engineering at the Nanoscale

Supplemental Information

Taking it to the Next Level

M.S. in Engineering at the Nanoscale

M.S. in Engineering at the Nanoscale



- One year M.S.
- 30 credits
- Non-thesis
- Scholarly paper
- Hands on Intensive

M.S. in Engineering at the Nanoscale

- This M.S. program is recommended for individuals with B.S. degrees in science, engineering, mathematics, or related fields
- This M.S. program is recommended for those looking to pursue a career in biomedicine, aerospace, electronics, or advanced materials
- To apply contact Tammy Coval
  - (814) 863-4586
  - tlc21@psu.edu
- Your next steps…
  - Complete the GRE and send scores to Penn State
  - Submit 3 letters of recommendation and your transcripts
  - Include a CV or resume as a statement of intent
  - Take and submit scores for TOEFL or IELTS (international only)

M.S. in Engineering at the Nanoscale: Degree Structure

Fall Semester:

- Nanotechnology: Materials, Infrastructure, and Safety
- Engineering at the Nanoscale
- Pattern Transfer at the Nanoscale
- Two Electives
- Individual Study

Spring Semester:

- Fabrication and Characterization for Top-down Nanomanufacturing
- Fabrication and Characterization for Bottom-up Nanomanufacturing
- Two Electives
- Individual Study

Summer Semester (3 credits):

- Individual study and complete your M.S.!

- **Electives can be customized to complete emphases in energy, electronics and photonics, and nanomaterials; or to explore cutting-edge topics such as bionanotechnology, nanomechanics, and smart nanostructures.**

M.S. in Engineering at the Nanoscale: Degree Requirements

	One-year residence-based MS degree
Total number of course credits	27
Minimum number of course credits from the ESM department	15 (5 core courses)
Minimum number of 500 level course credits	21 out of 30
Colloquium credits	None
Research credits	3 (E SC 596)
Total number of credits	30

Visit: http://www.esm.psu.edu/students/prospective/graduate/