

Welcome to NACK's Webinar

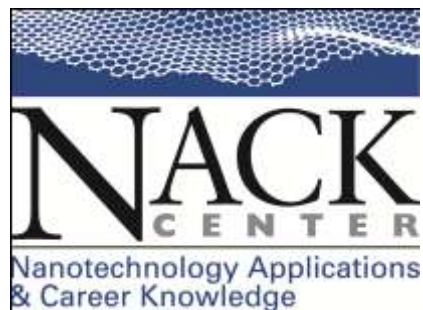
Building a NanoLab: Equipment and Program Overview

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faculty in Nanotechnology Education

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NACK is the NSF ATE National Center for
Nanotechnology Applications and Career
Knowledge

The NACK National Center is located at
Penn State University



National
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Center for Nanotechnology Education and Utilization (CNEU) Regional Center

Nanotechnology Applications and Career Knowledge (NACK) National Center

The Pennsylvania State University



Outline

- Overall Goals of Nanotechnology Educational Facilities
- Starting Facility
 - Minimum Equipment List and Approximate Costs
- Teaching Cleanroom Facility
 - Clean Room Enclosure
 - Infrastructure
 - Additional Equipment List and Approximate Costs



Overall Goals of Nanotechnology Educational Facilities

- Hands-on experiences
 - Students
 - Workshop attendees
 - Incumbent workers
- The equipment provide an education experience
- Cost effective manner



Overall Goals of Nanotechnology Educational Facilities

- To meet the needs of industry:
 - safety protocol, environmental issues, processing system design, process algorithms, material characteristics, contamination issues, and characterization
- By integrating and mastering these skills
- Our feedback from both industry and students
- The lab activities also inspires



Overall Goals of Nanotechnology Educational Facilities



One Extreme

- Begin with a few courses



Entry Model

- Begin with a few courses
- Setup a Starting Facility



Entry Model

- Begin with a few courses
- Setup a Starting Facility
- Can then evolve into a Teaching Cleanroom



Starting Facility

- Can begin by offering the first two courses of the Capstone Course Set
- These two introductory courses cover Safety and an Overview of Processing and Characterization
- These two courses require a limited equipment suite
- Can add to this equipment suite as add courses from the Capstone Course Set



Starting Facility

Recommended Equipment Suite:

1. Chemical Hood (Wet Benches) with Spinner
2. Thermal Evaporator
3. Vacuum Trainer
4. Vacuum Simulator (Software)
5. Optical Microscopes



Starting Facility

Can do all the Labs of the First Two Courses of
Capstone Course Set



Starting Facility Equipment – Wet Benches (Chemical Hoods)

- Integral spinner
- Need safer design and layout
- Cost: \$45,000 New (2008)
- Price range:
 - Used: \$8,000 – New:\$55,000
- Recommended for minimum suite



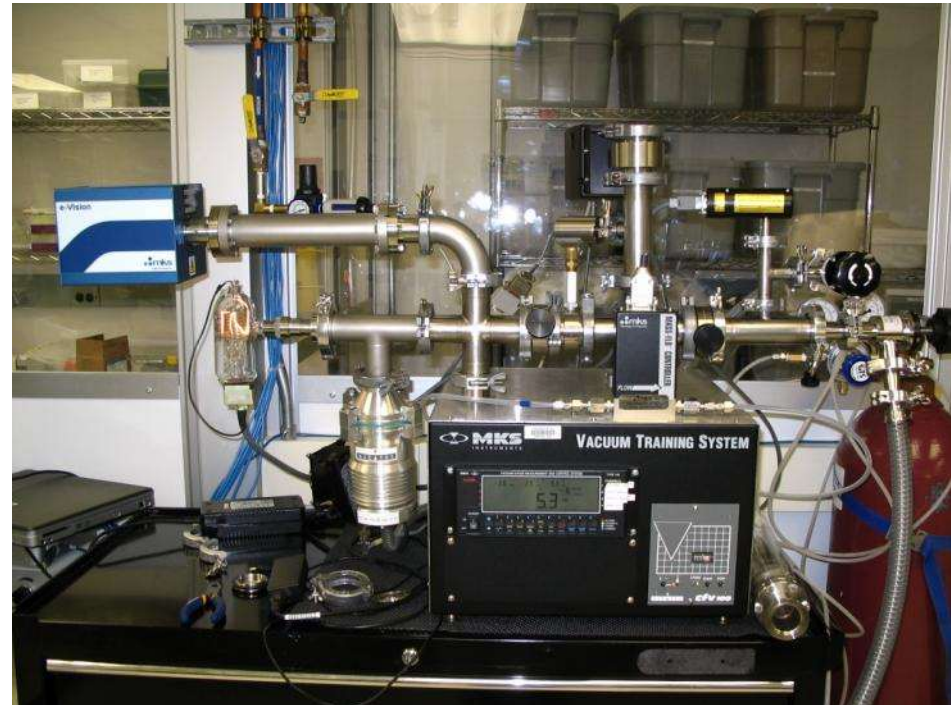
Starting Facility Equipment - Evaporator

- Thermal evaporator
- Thermally deposit elemental metals
- Al, Au, Ag
- Cost: \$20,000 used (2005)
- Price Range:
 - Used \$15,000 – \$50,000 new
- Recommended for minimum suite



Starting Facility Equipment – Vacuum Trainer

- Vacuum components and subsystems
- Most of the common vacuum hardware
- Used in conjunction
- Cost: \$23,000 New (1998)
- Recommended for minimum suite



Starting Facility Equipment--Optical Microscopes

- Microscopes with data storage.
- Dark Field
- Bright Field
- Wide price range, \$7,000 used with approximately \$7,000 for data capture
- Recommended for minimum suite



Tools and Systems

- Equipment should be chosen based on the following criteria:
 - Table top or small floor standing models
 - Low operational costs
 - Low installation costs



Tools and Systems

- Equipment should be chosen based on the following criteria:
 - Table top or small floor standing models
 - Low operational costs
 - Low installation costs
- Many of the items can be purchased used (but they should be in excellent condition).
 - Prices on used equipment will vary considerably, based on availability and market conditions
 - Evaluating used equipment in person is very important



Questions?



An Alternate Model

- Begin by Teaching the full Capstone Course Set



The Other Extreme

- Begin by Teaching the full Capstone Course Set
- Set-up a full Teaching Cleanroom Facility



Teaching Cleanroom Facility

- Enables the full Capstone Course Set
- Uses a Clean Room Enclosure
- Infrastructure Requirements
- Equipment List and Approximate Costs



Teaching Cleanroom Facility

- The goal is to provide cost effective resources for a complete hands-on experience



Teaching Cleanroom Facility

- Cost is an aggregate of a number of factors:
 - Laboratory & clean room structure
 - Permitting and Design Costs
 - Material Cost
 - Installation Costs



Teaching Cleanroom Facility

- Cost is an aggregate of a number of factors:
 - Processing equipment
 - Procurement
 - Maintenance
 - Consumables
 - Safety



Teaching Cleanroom Facility

- Cost is an aggregate of a number of factors:
 - Labor
 - Facility Maintenance
 - Facility Development



Clean Room Enclosure

- Not absolutely necessary, but...
 - Improve device yield
 - Inspire conscientiousness and prepares



Clean Room Enclosure

- Not absolutely necessary, but...
 - Improve device yield
 - Inspire conscientiousness and prepares
- Unfiltered lab space has millions of micron size particles per cubic foot.
 - Depending upon the nature of lab experiments
 - Class 100,000 is cost effective



Clean Room Enclosure

- At Penn State we selected class 100,000 as a cost effective solution
 - “Modular Hard Wall”
 - 1000 square feet. Approximately 200,000 dollars (2006)
 - Flooring
(chemical and static resistant)
 - Approvals
 - Existing facilities removal
 - Structure
 - Install
 - New facilities



Cleanroom Enclosure

- Upon evaluation, the class 100,000 clean room did not
 - Did not require additional electrical service
 - Minimal state permits
 - No reoccurring charges for environmental monitoring
 - Arguably the same impact for education
 - Valid model, most pharmaceutical clean rooms are this design
 - Less cost for gowns



Clean Room Enclosure

- We considered a class 1000 industrial clean room.
 - The same size class 1000 “hard wall” clean room in the same building was estimated to be 800,000 dollars (2005).
 - The large increase in cost was mainly due to HVAC environmental control
 - The class 1000 clean room also cost more to maintain.
 - Gowns, filters, online monitoring, maintenance



Questions?



Infrastructure

- At Penn State, overhead costs cover many operational expenses. Other institutions should consider these costs.
 - Rental
 - Electricity
 - Facility cleaning
 - Air pre-filters
 - Police/safety monitoring.
 - Network
 - Chemical waste disposal



Infrastructure

- We pay a nominal fee for LN_2 and N_2 gas (“House Nitrogen”). High purity nitrogen is purchased by the bottle.
- CNEU maintains a separate DI water system



Additional infrastructure costs

- Fixed cost
 - Eye wash / shower
 - Chemical storage cabinets \$1,500
 - SCBA air packs \$1,000
 - Compressed dry air
 - Card access system, \$3,500
 - Police / fire monitoring
 - Fire extinguishers
 - Hand tools
 - Computers
- Reoccurring costs
 - Gowns, gloves, mats, etc
 - Process gas
 - Chemical spill kits
 - Consumables such as probe tips, beakers, chemicals, deposition metals, substrates, vacuum pump oil, etc.....



Tools and Systems

- Equipment was chosen based on the following criteria:
 - Table top or small floor standing models
 - Allows for re-arrangement of tools in room, when necessary
 - Maximizes floor space usage
 - Operational flexibility
 - Some systems can act as back-ups if primary system is not available. Important for NMT Lab scheduling

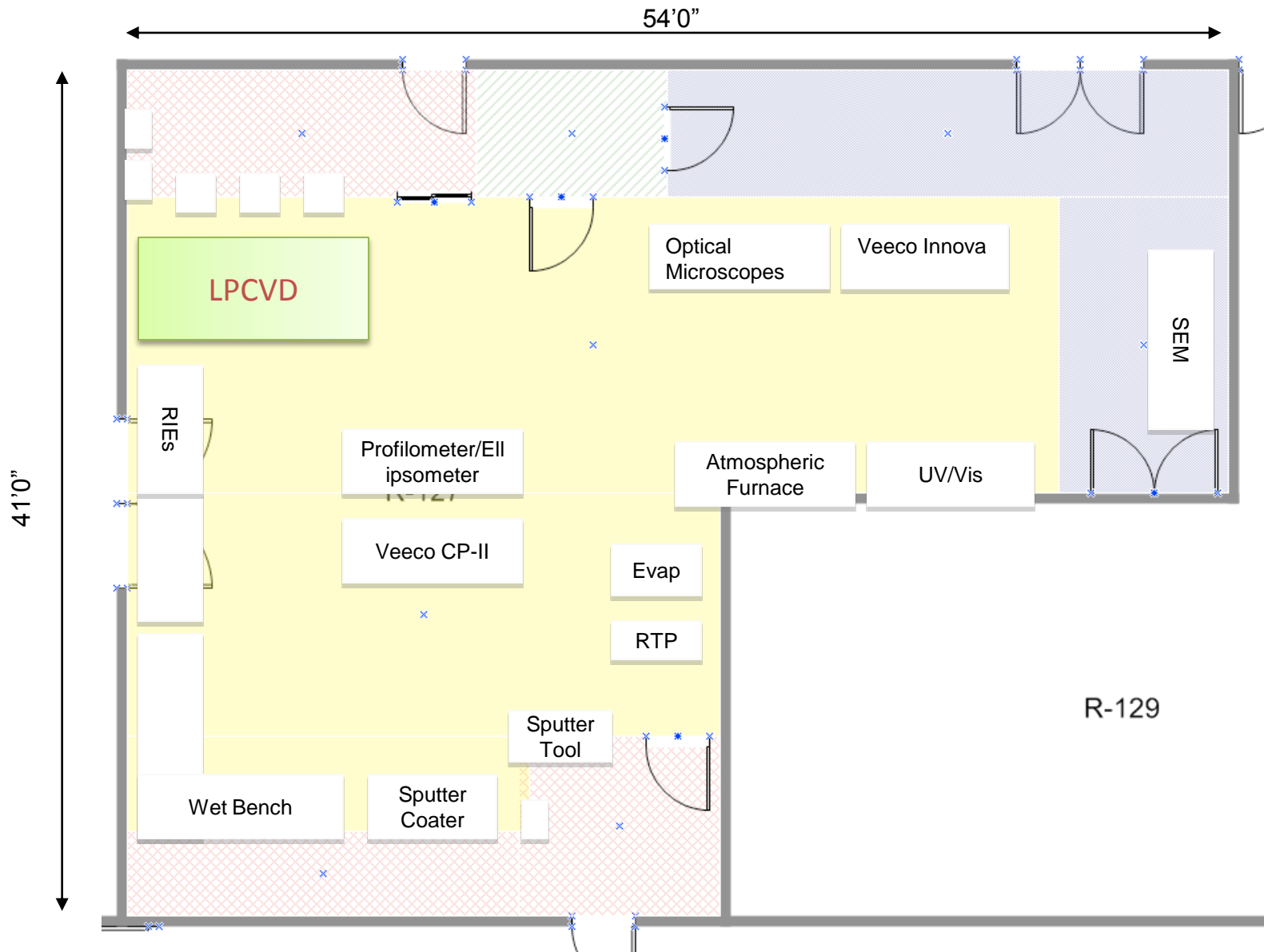


Tools and Systems

- Many of the items were purchased used, but in excellent condition.
 - Prices on used equipment will vary considerably, based on availability and market conditions
 - Evaluating used equipment in person is very important



Teaching Clean Room Layout



Initial Equipment List

- Recommended Equipment Suite for Starting Facility
 1. Chemical Hood (Wet Benches) with Spinner
 2. Thermal Evaporator
 3. Vacuum Trainer
 4. Vacuum Simulator
 5. Optical Microscopes



Equipment List

- Plus Additional Equipment Needed for a Complete Facility
 1. Low Pressure Chemical Vapor Deposition
 2. Atmospheric Pressure Furnace
 3. Sputtering Tool
 4. Reactive Ion Etcher
 5. Scanning Probe Microscope (available via web access)
 6. Scanning Electron Microscope (available via web access)
 7. Spectrophotometer (available vis web access)
 8. Profilometer
 9. Ellipsometer



Questions?



Fabrication Equipment - LPCVD

- Low Pressure Chemical Deposition (LPCVD)
- The LPCVD system is used to deposit nanowires and thin films
- Current chemistry is designed for zinc oxide nanowires.
- Cost \$35,000 New



Fabrication Equipment – Atmospheric Furnace

- 3 inch tube furnace
- 3 zone temperature control with a maximum temperature of 1100°C
- Gas – Ar, N₂, O₂
- Used for anneals, crystallization, oxidation growth
- (Can save money by using LPCVD furnace)
- New \$8,000 with quartz ware (2006)



Fabrication Equipment - Sputtering

- This type of coating systems is designed for electron microscopy sample preparation
- A turbo pump is used on this systems to obtain fine grain, contamination free coatings
- Materials available are Au, Pt, Al, Cr, SiO₂, Ni, and C
- Cost: \$23,000 (2006)
 - Used: \$7,000 – New: \$23,000



Fabrication Equipment - Sputtering

- This type of coating systems is for depositing multi-layer thin films
- A turbo pump is used to obtain contamination free coatings
- Materials available are Au, Pt, Al, Cr, SiO₂, Ni, and C
- Cost: \$70,000 New (2008)
- Used: \$30,000 – New: \$70,000



Fabrication Equipment - RIE

- Reactive ion processing
- The reactive ion processing system can be used to modify surface morphology, modify surface chemistry, dry phase cleaning, and etching
- Our system has CF_4 , O_2 ,
- Cost: \$12,000 used (2005)
 - Plus \$10,000 repair (2007)
- Price range:
 - Used: \$12,000 – New: \$70,000+



Fabrication Equipment - RIE

- Reactive ion etching (RIE)
- RIE system can be used to modify surface morphology, modify surface chemistry, dry phase cleaning, and etching
- System has CF_4 , O_2 ,
- Cost: \$22,000 used + \$1,500 for used chiller (2008)
- Price range:
 - Used: \$12,000 – New: \$70,000+



Questions?



FESEM

- Zeiss FESEM
- Available as remote access from NACK
- Resolution 1nm
- Valued at \$500,000



Characterization Equipment – Scanning Probe Microscope

- Available as remote access from NACK
- Capable of measuring many surface characteristics with sub-nanometer resolution.
- Capable of remote access over the internet
- Cost: \$70,000 New (2004)



Characterization Equipment – Scanning Probe Microscope

- Available as remote access from NACK
- Capable of measuring many surface characteristics with sub-nanometer resolution.
- Many enhancements over the CP-II
- Capable of remote access over the internet
- Cost: \$90,000 New (2008)



Characterization Equipment – SEM

- Scanning Electron Microscope (SEM)
- Available as remote access from NACK
- Capable of imaging samples with resolutions in the 1-20 μ m range
- Capable of remote access over the internet
- Base unit \$60,000 to \$150,000
- Our system is on loan from R.J. Lee company, and is valued at \$250,000
- Have new web-accessible FESEM coming from industry donations (\$500,000)
- New FESEM resolution 1nm



Characterization Equipment – UV/VIS Spectrophotometer

Spectrophotometer
\$40,000 new



Characterization Equipment - Profilometer

- Capable of nanometer scale resolution
- Cost: \$40,000 New



Characterization Equipment - Ellipsometer

- Used to measure the thickness of films transparent to He-Ne laser light.
- Cost: \$25,000 used (2005)



Questions?



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Nov. 16-18

Hands on Intro to Nano Workshop



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Nov 19: Environmental Applications of Nano

**February 25, 2011: Introduction to Nanofabrication:
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