nanoPROFESSOR
Hands-On Nanotechnology Education

PREPARING STUDENTS FOR THE GROWING FIELD OF NANOTECHNOLOGY

NANOINK CORPORATE OVERVIEW

NanoFabrication Systems
- Nanolithography tools for researchers

Nano BioDiscovery
- Nanoscale Protein Arrays

NanoProfessor
- Hands-on Nanotechnology Education

NanoGuardian
- On-Dose NanoEncryption ™ Technology for securing the global drug supply chain

Headquarters: Illinois Science + Technology Park, north of Chicago

MEMS Facility: Campbell, CA

NanoInk currently has over 250 patents and applications filed worldwide and licensing agreements with Northwestern University, Stanford University, University of Strathclyde, University of Liverpool, California Institute of Technology and the University of Illinois at Urbana-Champaign

THE NANOSCIENCE GAP

- The NSF (National Science Foundation) estimates that by 2015 there will be a need for **2 MILLION** nanotechnology workers and approximately **6 MILLION** supporting jobs worldwide.

- The NSF estimates that by 2015 companies employing these nano-savvy workers will produce **$1 TRILLION** of nano-based products.

- The NNI (National Nanotechnology Initiative) estimates that today there are only **100,000** researchers working on nanotechnology worldwide.

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THE NANOSCIENCE GAP

Conservatively, the nanotech workforce needs to grow by 20 FOLD in the next 6 years!

THE NEED

"There is a not a labor shortage, but there is a skills shortage. Our industry needs more innovative young scientists, technologists, engineers, and mathematicians to replace the baby boomers as they retire."

Rick Stephens, SVP of HR and Administration
Boeing Company
February 4, 2009
Aerospace Industries Association

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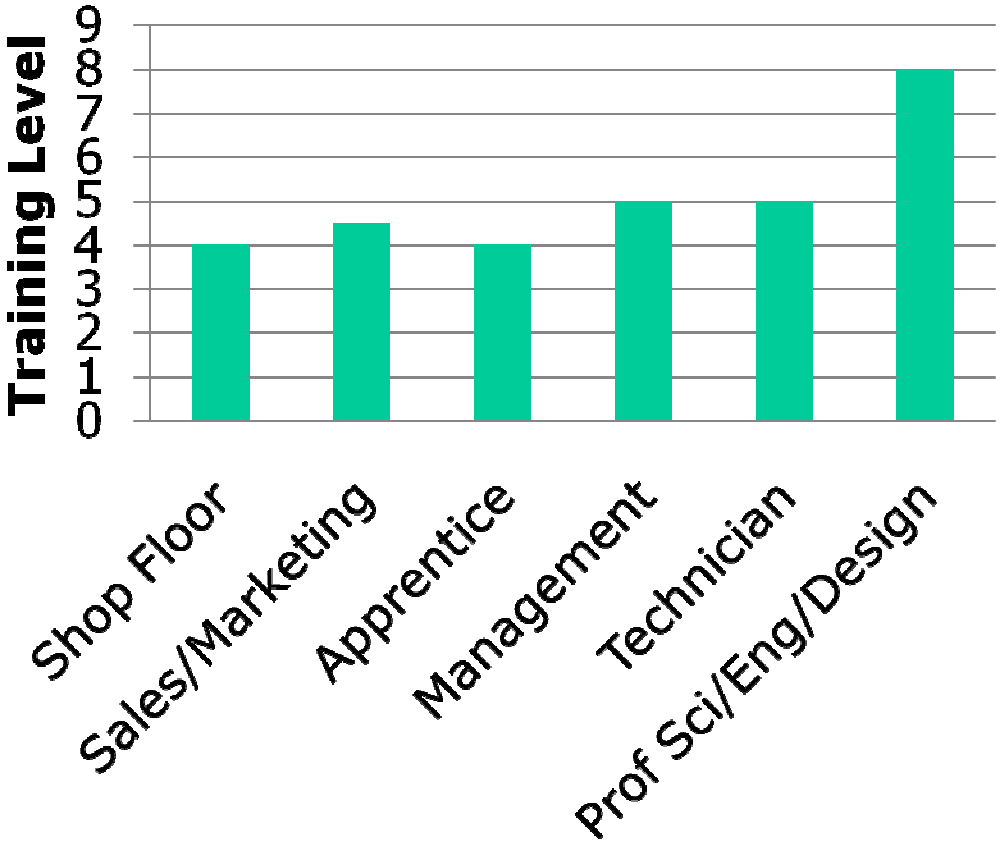
Presented by UK Government Knowledge Transfer Network (survey across EU)

May 2011



"Highest need" 90%

Topic	Level
Analysis and Microscopy	6
Metrology and Measurement	6
Regulatory and Health	6
Environment and Safety	6
Nano/micro Fabrication	6

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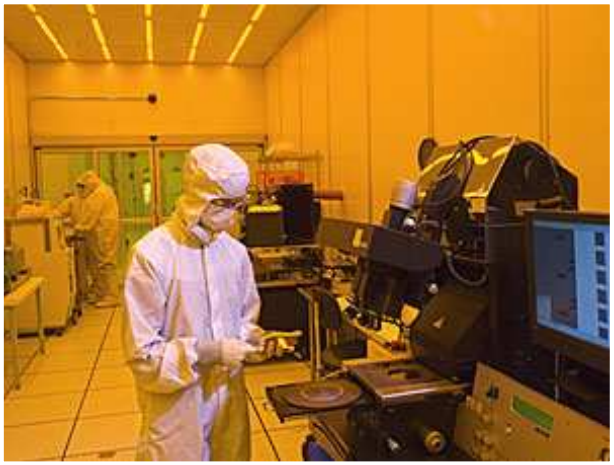
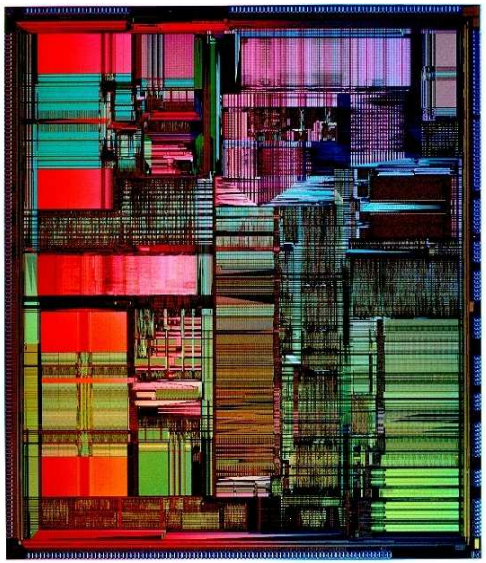
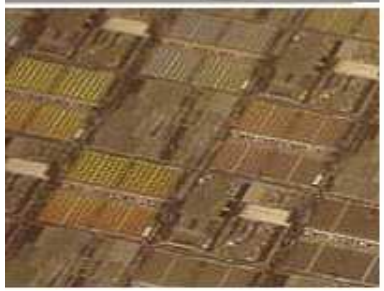
HISTORY OF NANOTECHNOLOGY



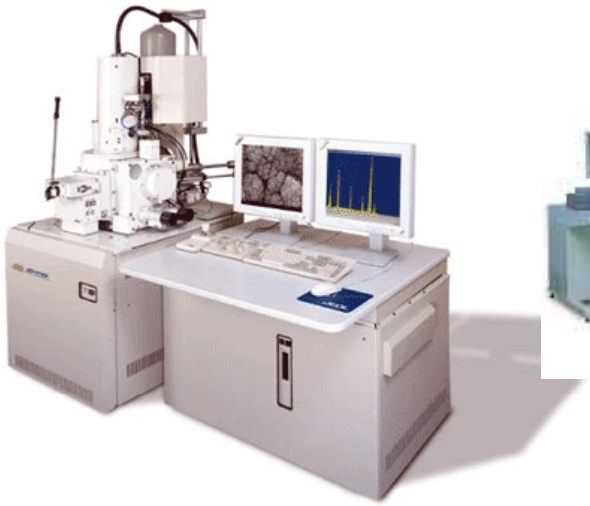


Nanotechnology has been primarily driven by the semiconductor industry and the need for smaller, faster, and more efficient chips.

Packing more and more transistors onto a single chip made many aspects of modern life possible.



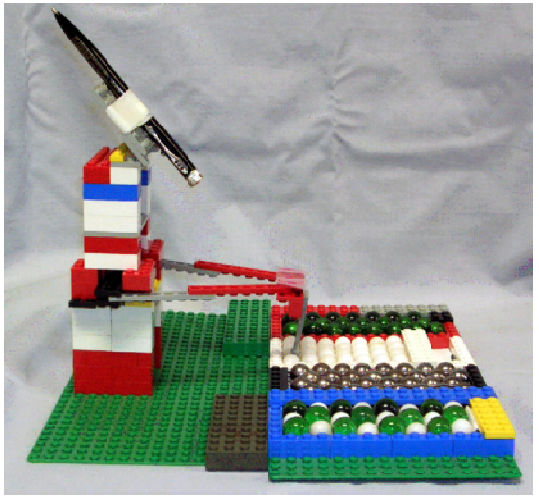
TRADITIONAL NANOTECH TOOLS



E-Beam Lithography
$10 Million Purchase
Significant Annual Maintenance Fees

UNDERGRADUATE NANOSCIENCE EDUCATION TODAY

- Low cost macroscopic models and simulations
- PowerPoint presentations, videos, or video lectures
- Museum exhibits / town hall meetings
- Collaborative agreements with Tier 1 research institutions for “hands-on” lab access



Lego AFM

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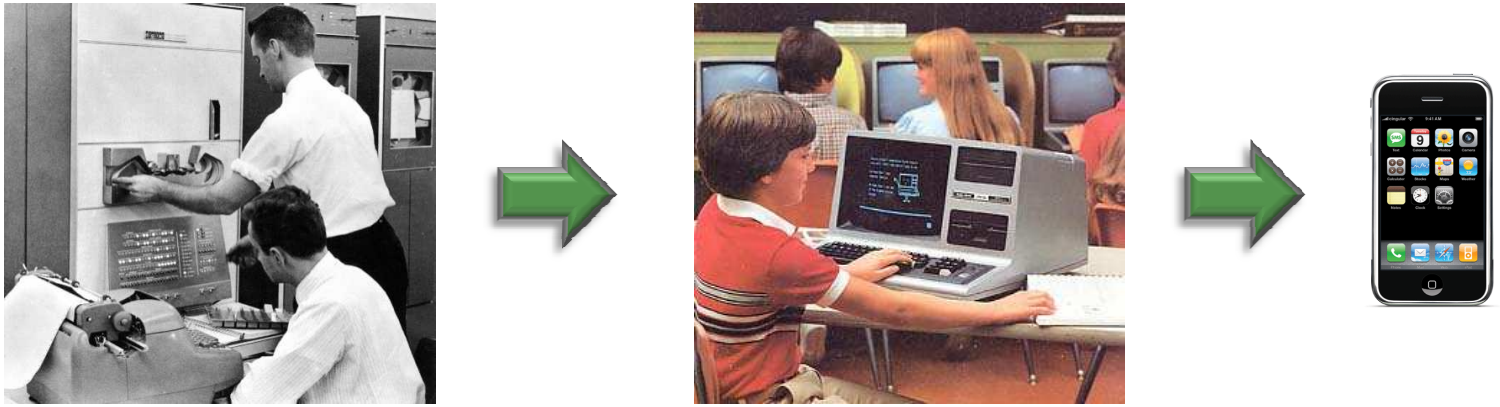
COMPUTER LABS SHOW THE WAY



- 1970s and 1980s: IT expertise limited to a few IT “specialists”
- School-based computer labs transformed IT skills from “specialists” to millions of IT-savvy workers
- The “IT Explosion” occurred

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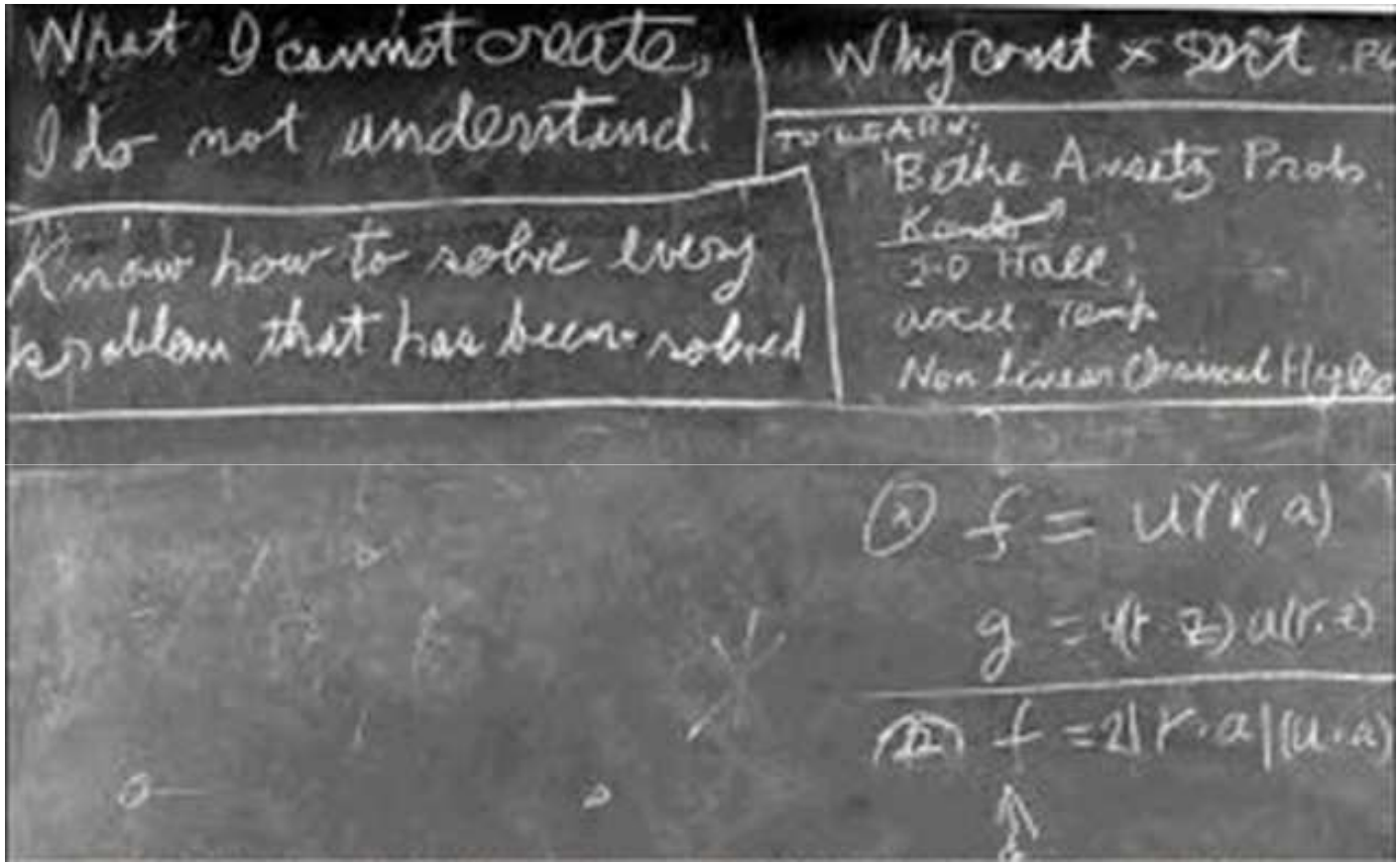
NANOPROFESSOR'S GUIDING PRINCIPLE



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NANOPROFESSOR'S GUIDING PRINCIPLE

"What I cannot create,

I do not understand."

Richard Feynman, PhD
Nanotechnology Visionary
Nobel Laureate

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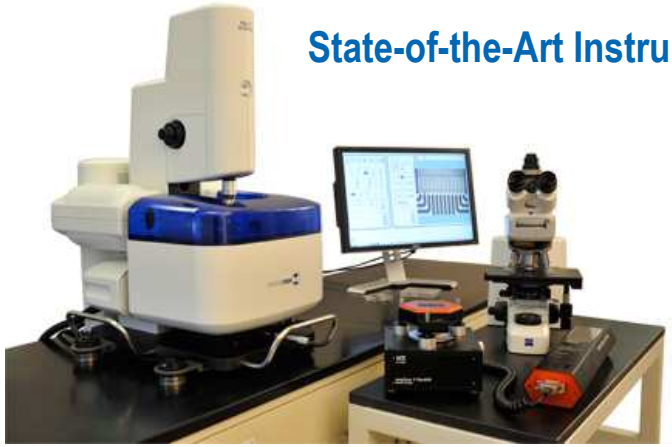
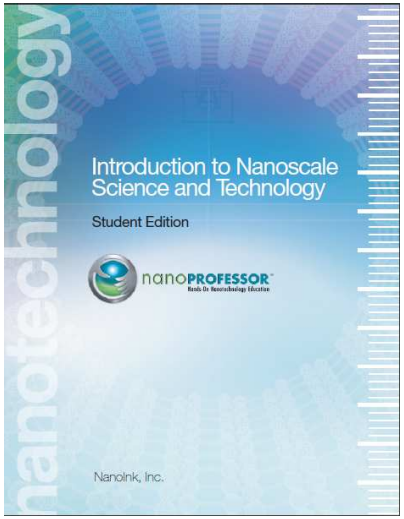
NANOPROFESSOR

State-of-the-Art Instrumentation



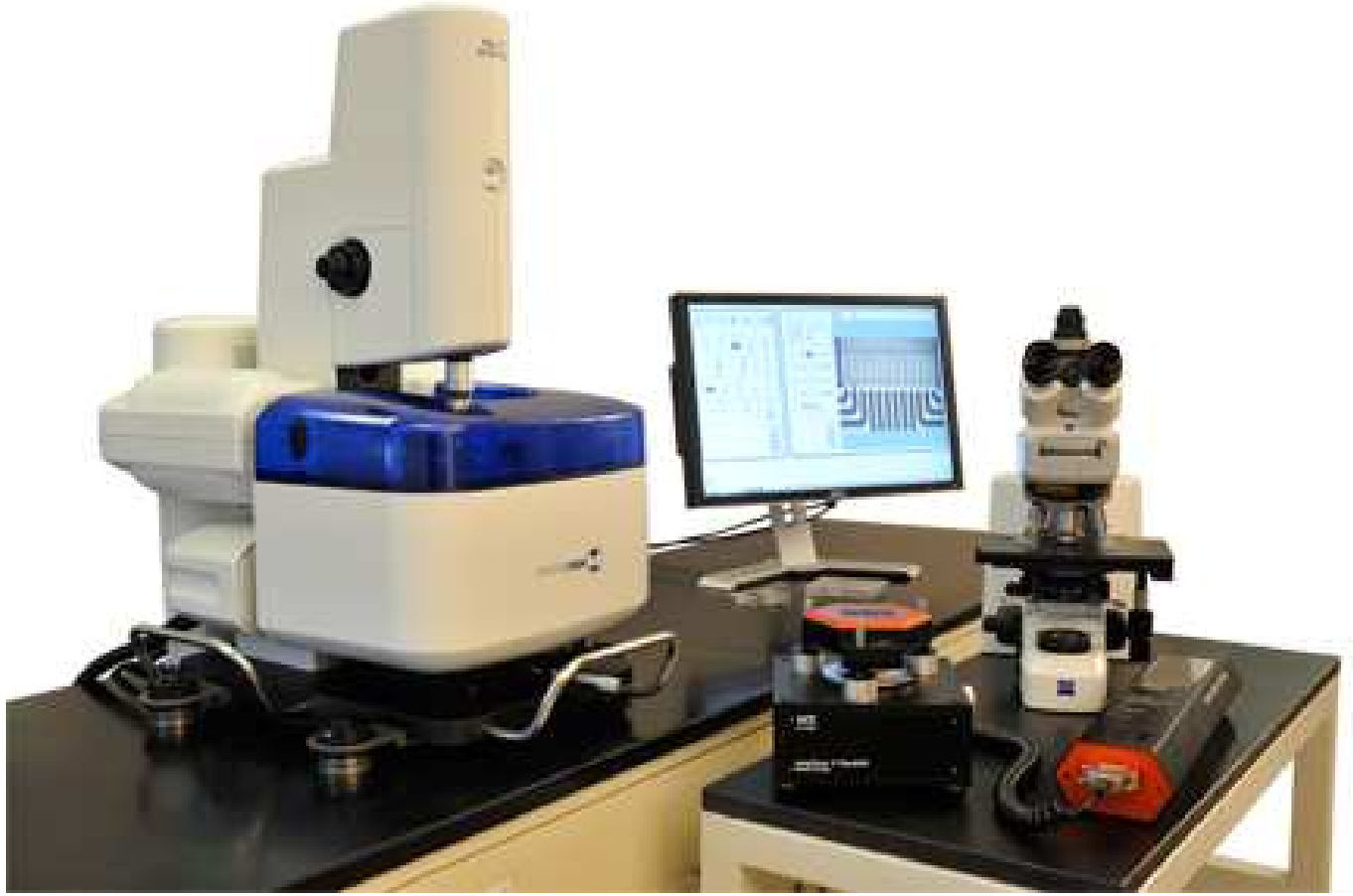
Expert-Designed Nanoscience Curriculum



Extensive Instructor & Institution Support

Hands-On Lab Experiments

NANOPROFESSOR INSTRUMENTATION



HEART OF THE NANOPROFESSOR

NLP 2000
Desktop Nanofabrication System

- Allows students to pattern quickly and easily at the nanoscale
- Provides students with valuable nanotech experience working with multiple materials from metallic nanoparticles to biological agents
- A true desktop system
  - > No cleanroom required
  - > No vacuum required

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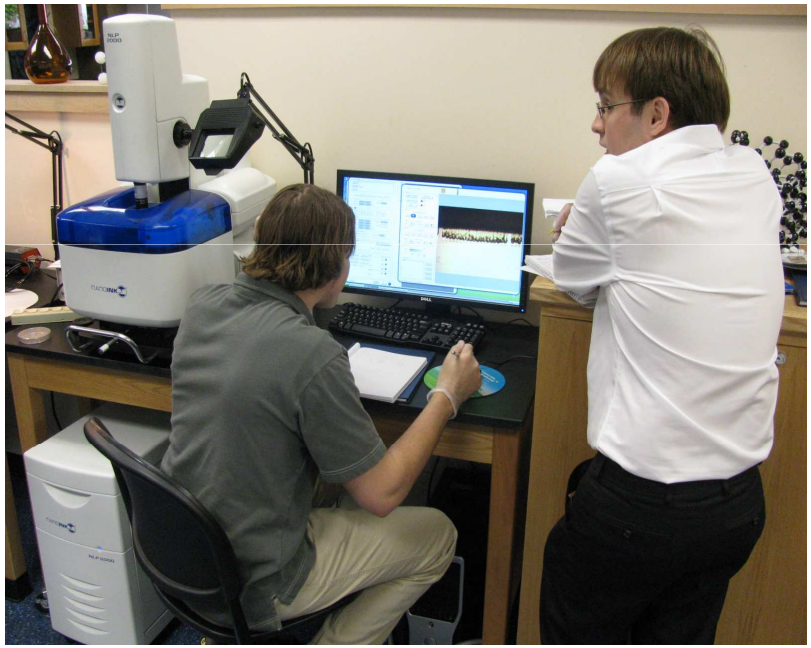
NLP 2000 DESKTOP NANOFABRICATION SYSTEM

NLP 2000 Features

- Environmental chamber provides control of temperature and humidity
- Large patterning area enables more dynamic experiments
- High quality visual and video capabilities allow students to easily view and record experiments



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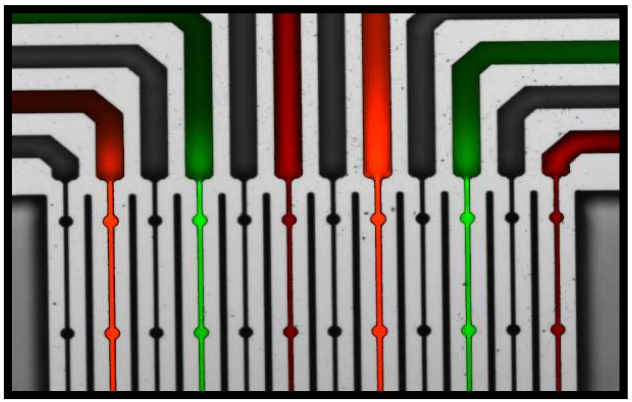
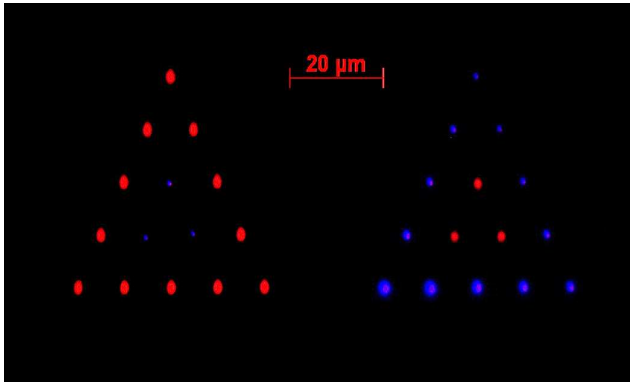
NLP 2000 BENEFITS

- Direct patterning with nanoscale precision
- Broad range of materials with which to experiment *and* learn
  - > Metallic Nanoparticles
  - > Organic/Inorganic chemistry.
  - > Biologic Materials
  - > Polymer s
- Flexibility to evaluate nanoscale properties of different molecules at the same time





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ATOMIC FORCE MICROSCOPE (AFM)

Nanosurf EasyScan 2 Flex AFM

- Modes: contact, dynamic, and LFM
- 100-micron scan range
- XY drive resolution: 1.5 nm
- Z drive resolution: 0.15 nm
- Upgradable

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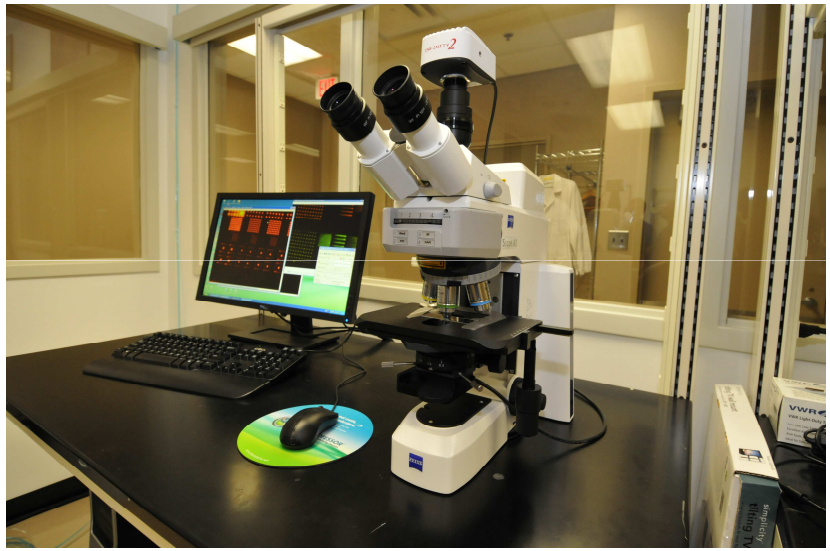
FLUORESCENCE MICROSCOPE

Zeiss LED Fluorescence Microscope

- 10x, 20x, and 50x objectives
- Reflected light fluorescence
- Resolution at least 1 micron
- Filters: rhodamine/red 530, alexia 488/FITC, and DAPI/ blue



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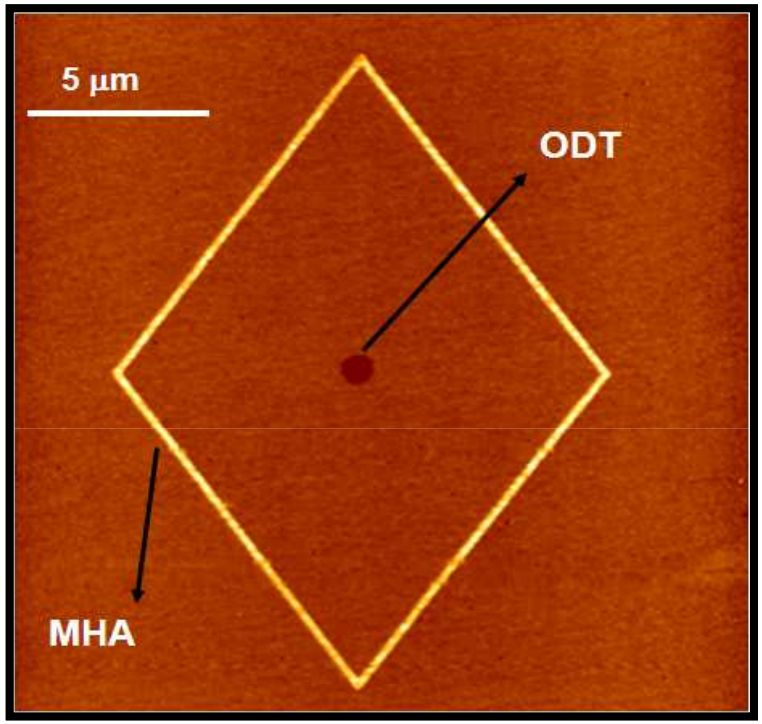
UNPARALLELED PRECISION OF DPN



Lines and features down to 10's of nm…

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VALUE OF DPN

"Nanomanufacturing processes previously considered fundamental science are now key enablers to solve critical issues in the evolution of many products, fueling the innovation cycle to realize completely new products. These processes include bottom-up directed assembly, top-down high-resolution patterning and manipulation, molecular and biological systems engineering, and hierarchical integration across multiple length scales."

Jeff Morse, Managing Director,
National Nanomanufacturing Network
National Nanomanufacturing Network Newsletter
March 2011 Issue

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APPLICATIONS OF DPN

- Metallic Nanostructures (Top-Down Nanolithography)
- Direct Patterning of Proteins
- Direct Patterning of Polymers
- Photonics and Optical Engineering
- Clinical Engineering, drug delivery, personalized medicine.
- Electronic Engineering, Directed Placement
- Biology, Toxicology, Diagnostics, Single Cell Studies

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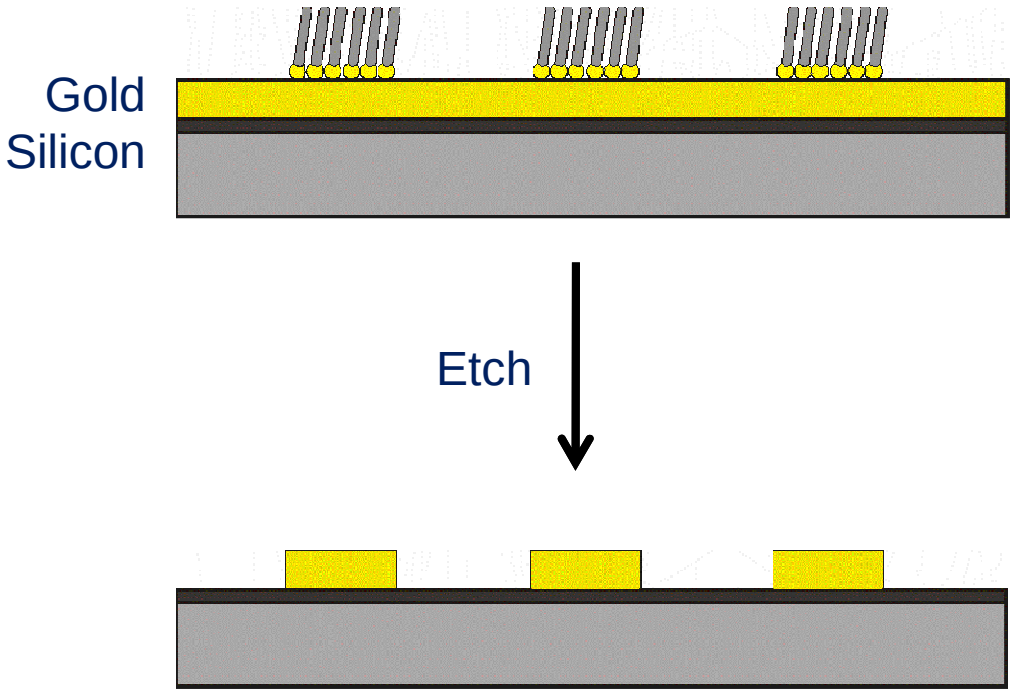
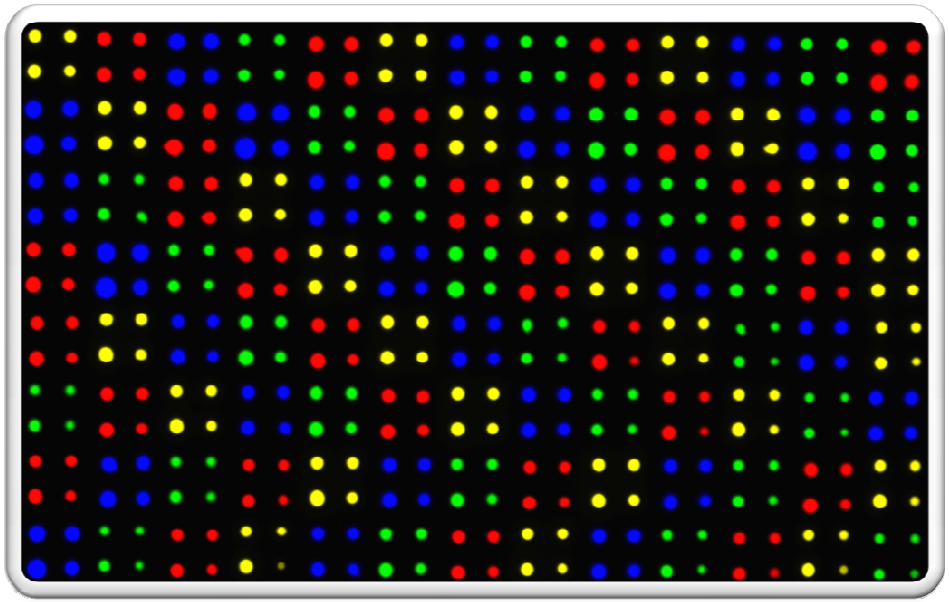
METALLIC NANOSTRUCTURES

Top Down Nanolithography





DIRECTED PATTERNING OF PROTEINS

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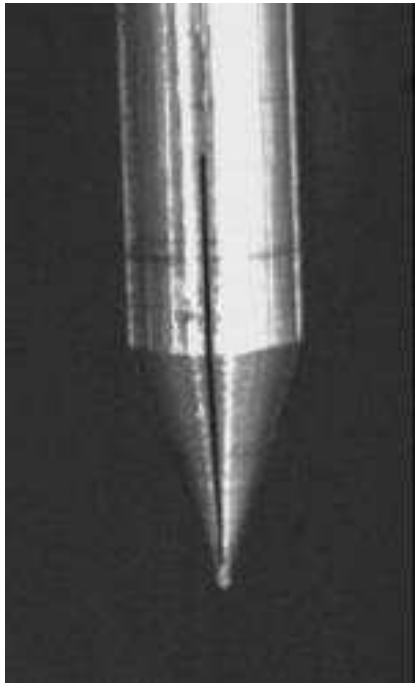
TRADITIONAL BIOLOGICAL PATTERNING

Pin from Conventional Robotic Microarray Contact Printers



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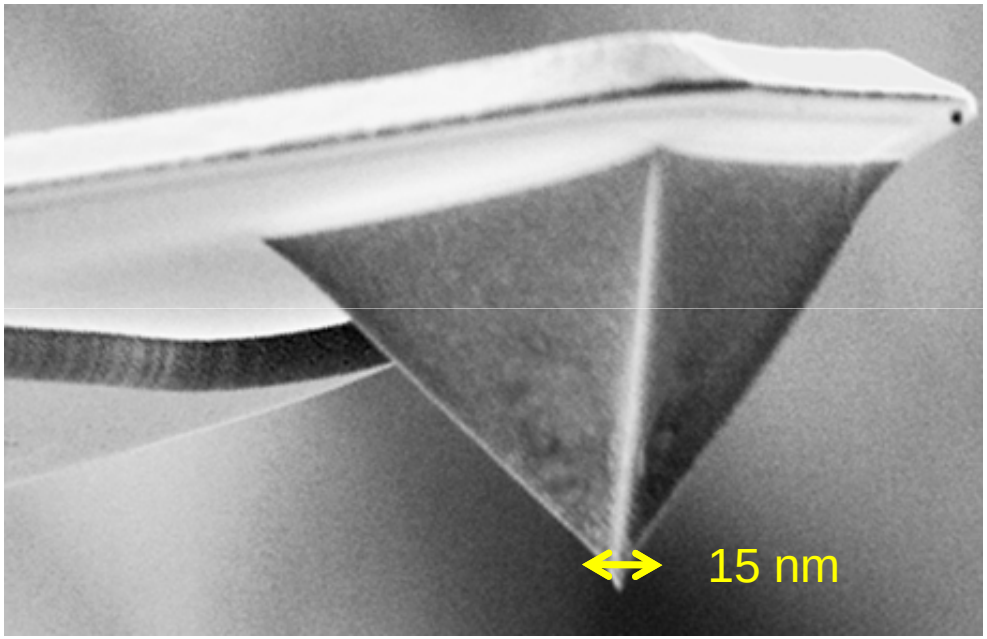
DPN AND BIOLOGICAL DEPOSITION

NanoInk's DPN uses nano-sized tips to more gently transfer biologic materials to substrates making it more sample friendly and effective.



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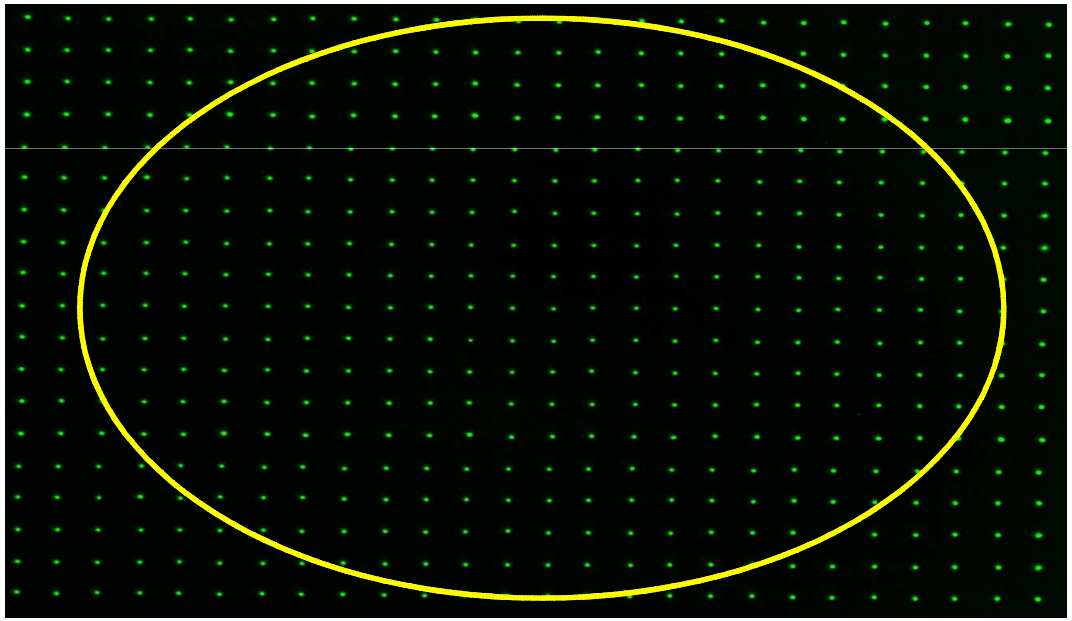
DPN AND BIOLOGICAL DEPOSITION

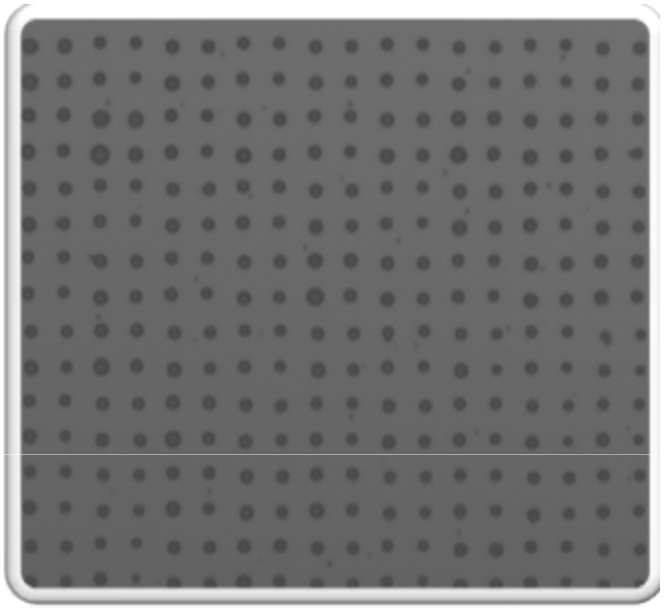
NanoInk's NLP 2000 and DPN Expands the Usefulness of Samples While Reducing Research Costs



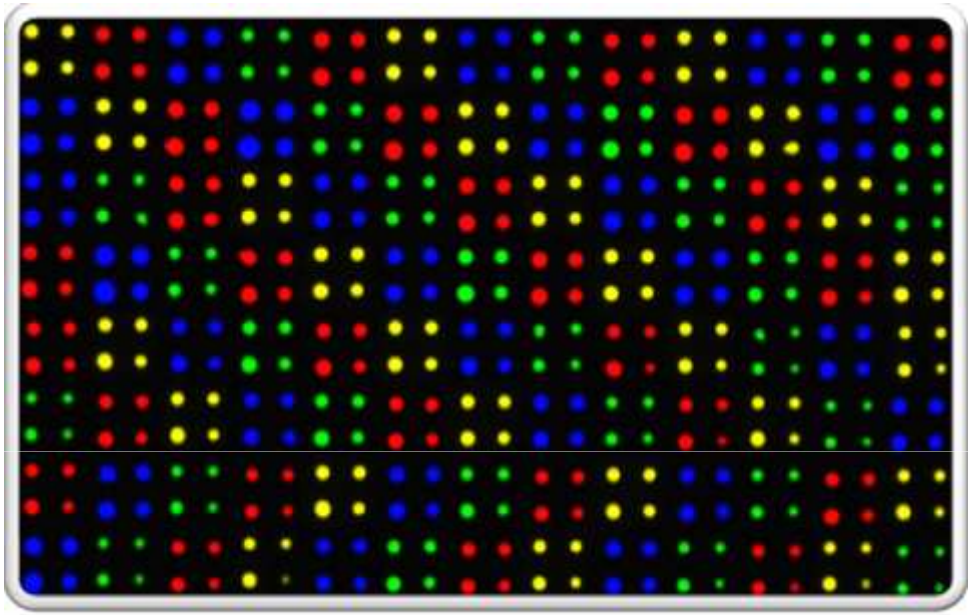
Approximately 250 nano-scale features (6.6µm apart) fit within a conventional 100µm spot

NLP 2000 MULTIPLEXED PRINTING

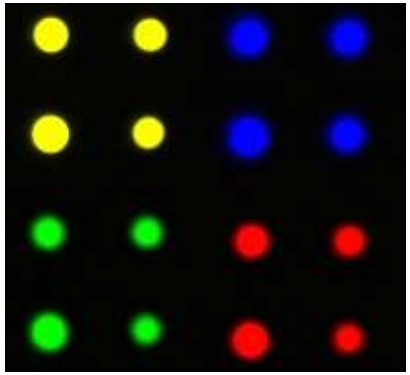
Bright Field Microscopy (100 x)



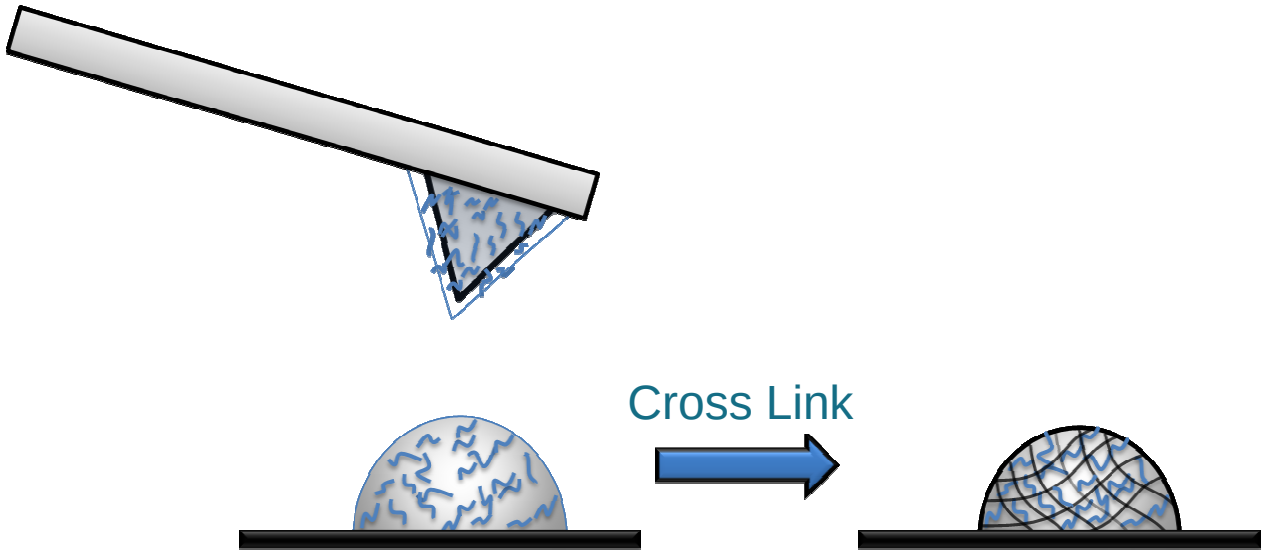
4 Channel Fluorescent Excitation



Anti-Sheep	IgG alexafluor 350
Anti-Goat	IgG alexafluor 488
Anti-Mouse	IgG alexafluor 546
Anti-Rabbit	IgG alexafluor 647



4 µm Diameter Spots
with 16 µm Spacing



DIRECTED PATTERNING OF POLYMERS

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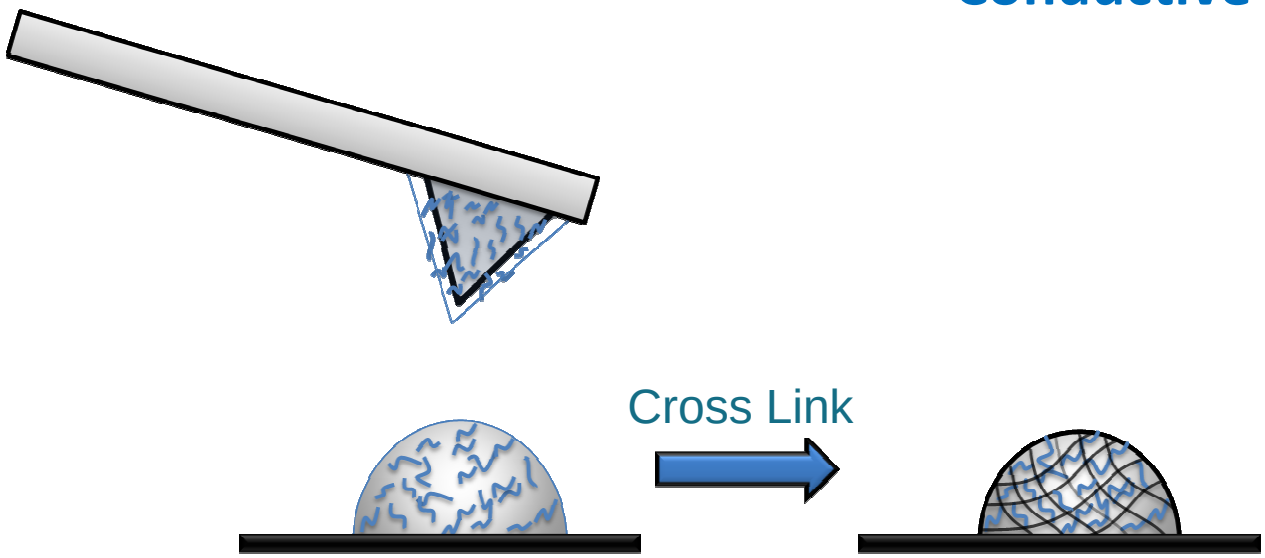
Polymer Inks

- Hydrogels, biologicals
- Acrylic polymers
- Conductive polymers



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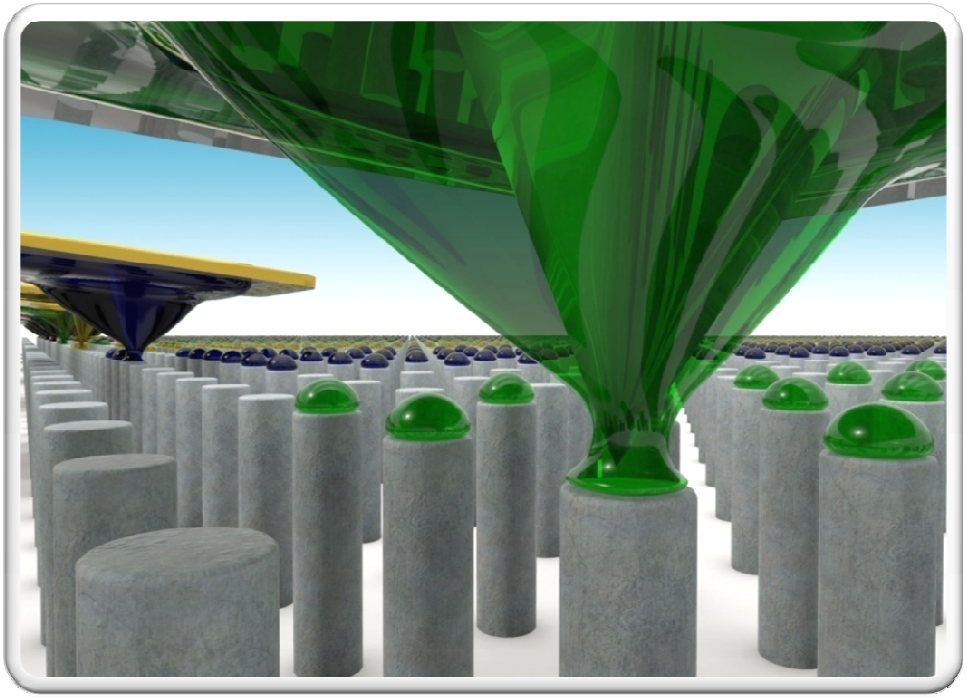

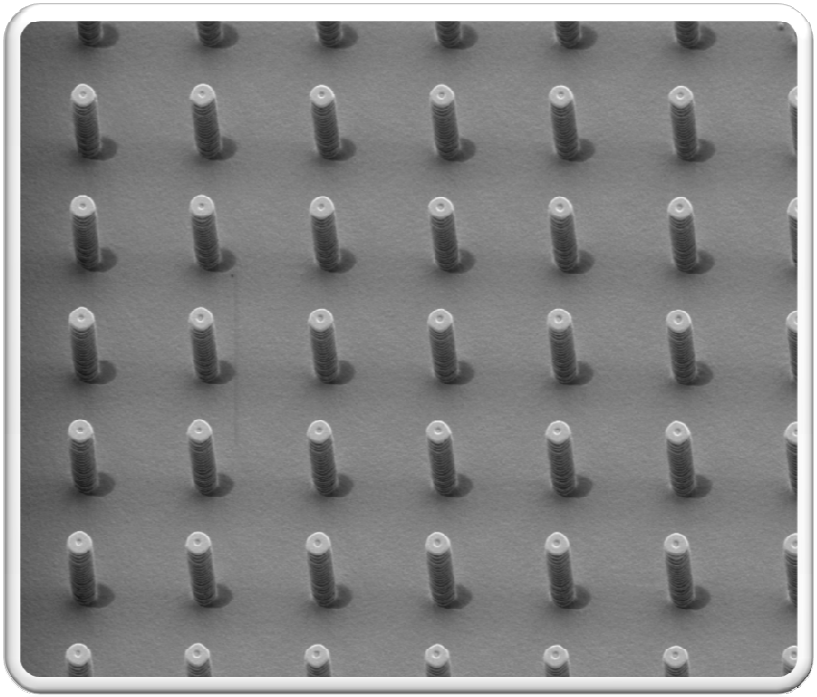

Microstructure Functionalization

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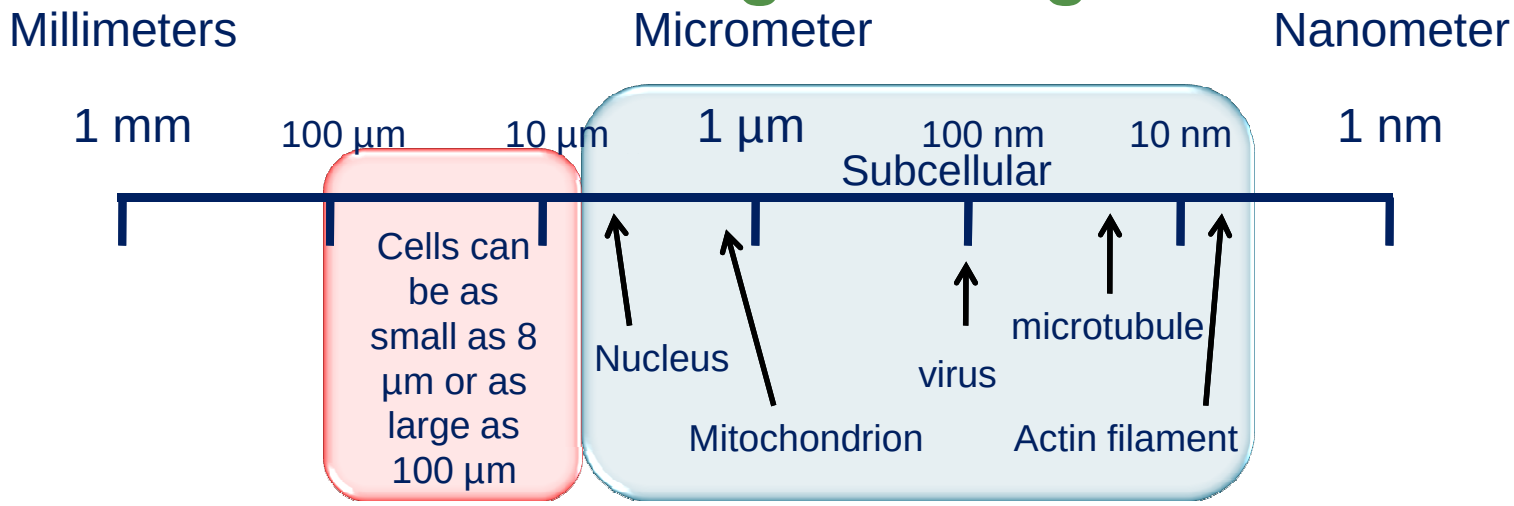
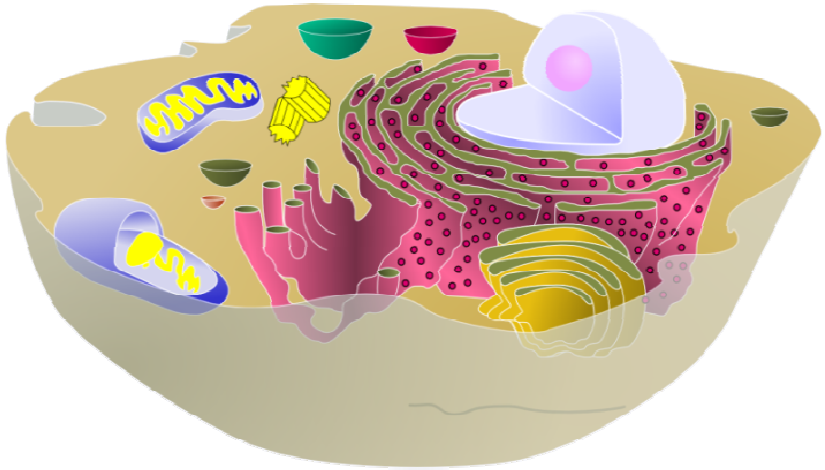
Cell Engineering



The manipulation of a single cell requires the deposition of biomaterials with feature sizes that are much smaller than the cell itself



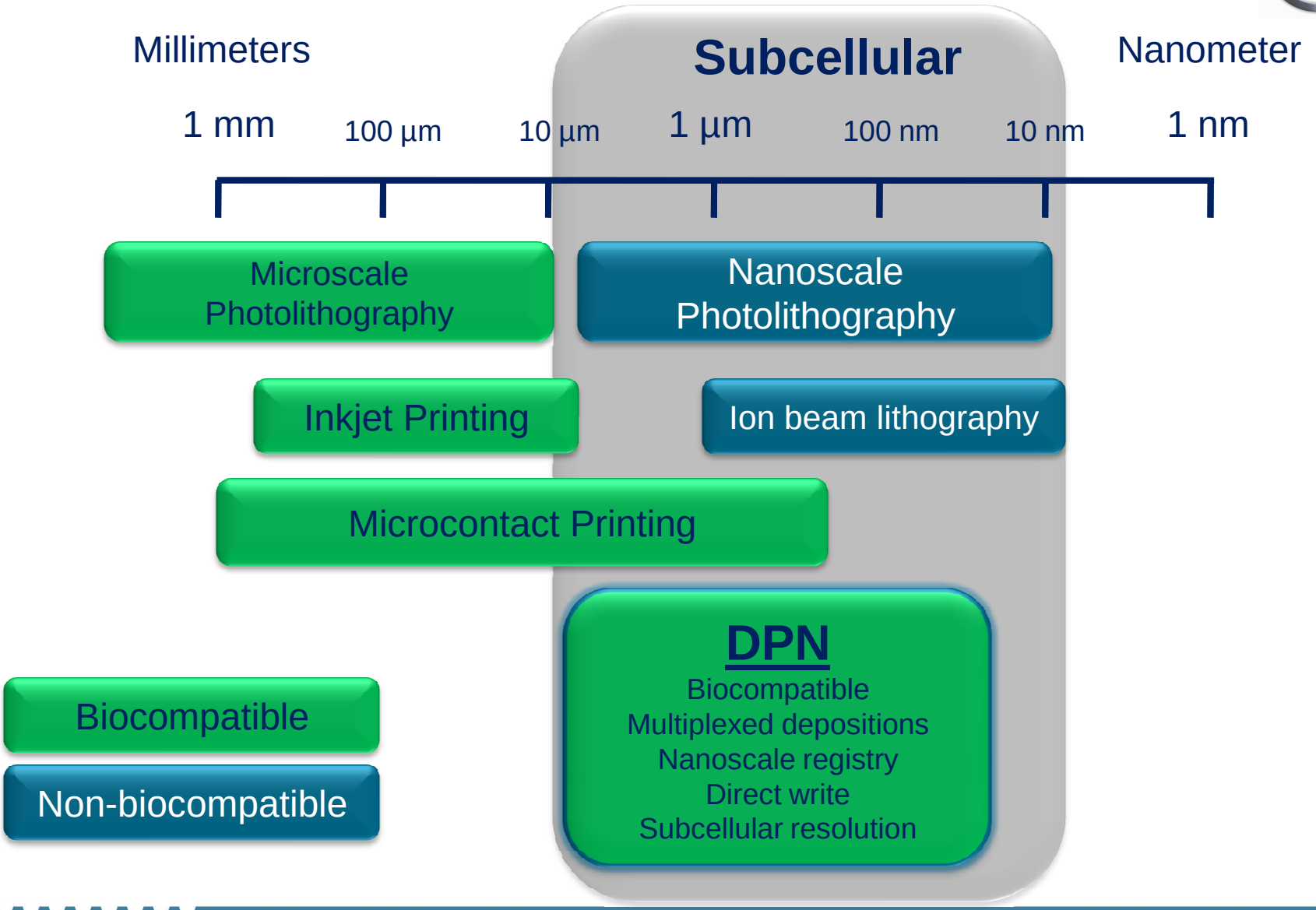
Requirements:

- < 10 micron feature sizes
- Must be biocompatible

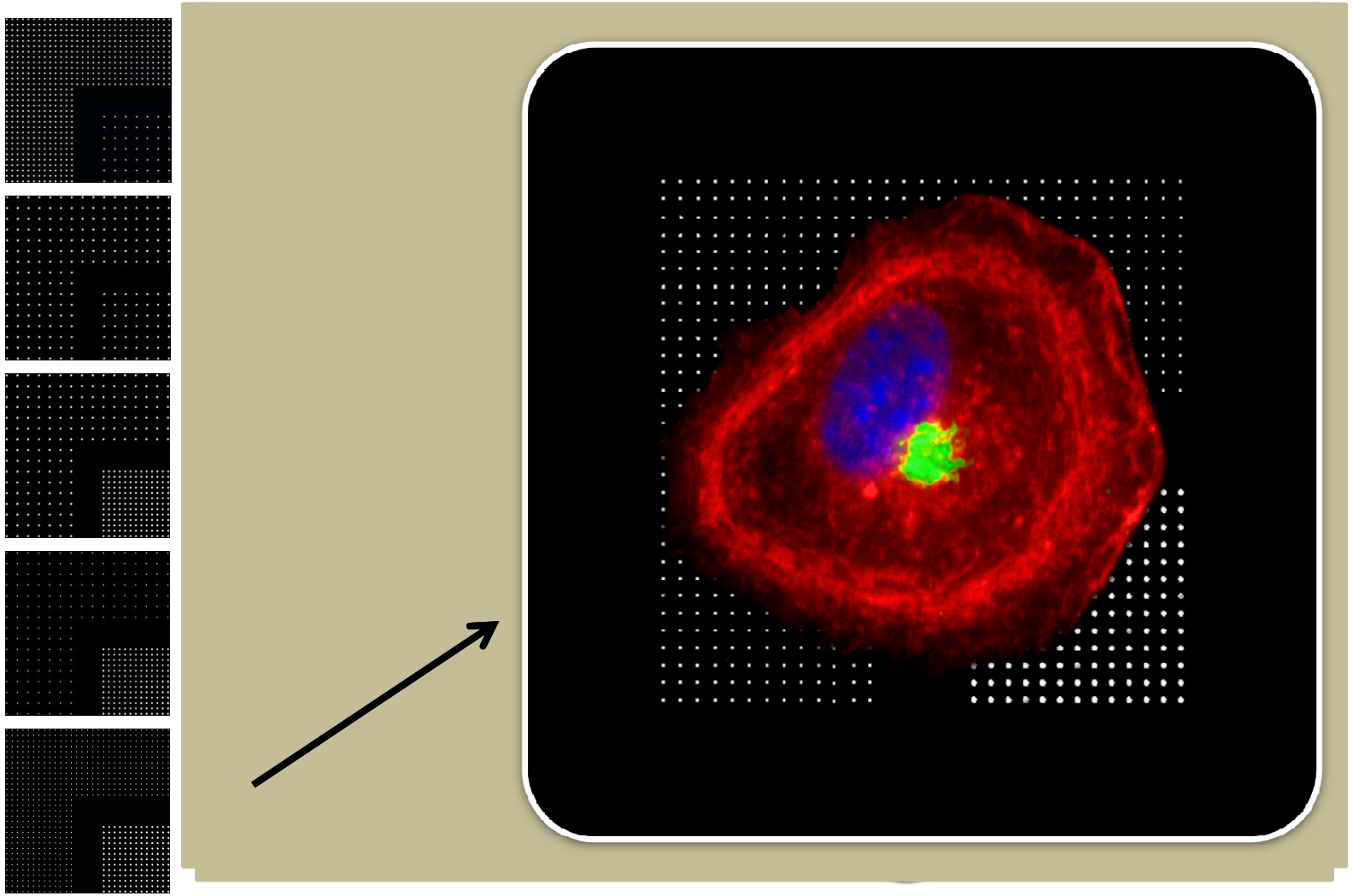
Bonus:

- Complex multicomponent patterns

Subcellular Resolution



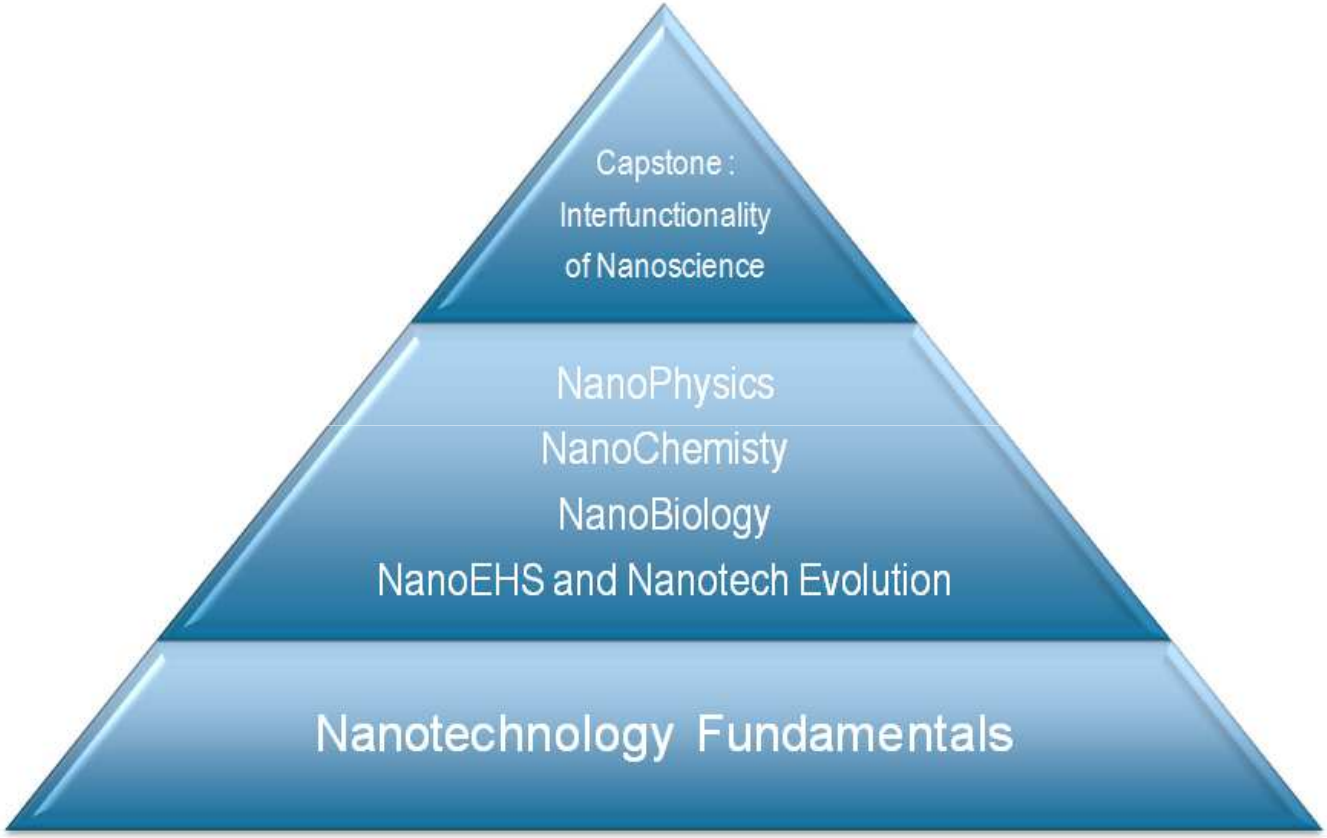
Nanopatterns & cell behavior



NANOPROFESSOR INSTRUMENTATION

TECHNICAL COLLEGE NANOPROFESSOR LAB

EXPERT-DESIGNED CURRICULUM



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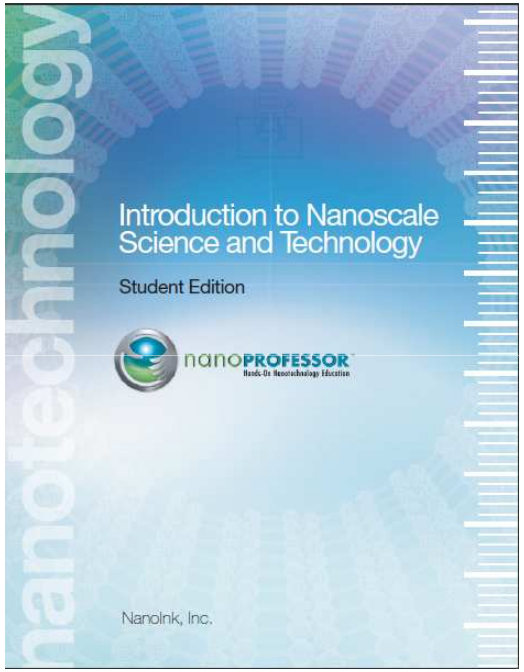
EXPERT-DESIGNED CURRICULUM

Nanotechnology Fundamentals

- Exploring the Nanoscale
- Nanotechnology Applications
- The Mathematical Language of Scale
- Working at the Nanoscale
- Imaging Technologies
- Nanofabrication Tools



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EXPERT-DESIGNED CURRICULUM

NanoPhysics

- Forces and Interactions
- A Closer Look at Fluidics
- The Wave Nature of Light
- Practical Applications

SUBJECT MATTER EXPERT

Deb Newberry
Director
Nanoscience Technology Program
Dakota County Technical College
Director
Nano-Link
(NSF-funded regional center for nanotechnology education)

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EXPERT-DESIGNED CURRICULUM

NanoChemistry

- Periodicity of the Elements
- Chemical Bonding
- Intermolecular Forces
- Nanoscale Structures
- Practical Applications

SUBJECT MATTER EXPERT

Richard Holz, PhD
Professor and Chair
Department of Chemistry
Loyola University of Chicago

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EXPERT-DESIGNED CURRICULUM

NanoBiology

- Biological Molecules: Components of the Molecular Machinery of Life
- Structural Hierarchy in Biology Viewed from the Bottom-Up
- Biological Function at the Nanoscale
- Practical Applications

SUBJECT MATTER EXPERT

Steve Lenhert, PhD
Assistant Professor
Department of Biological Science
& Integrative Nanoscience Institute
Florida State University

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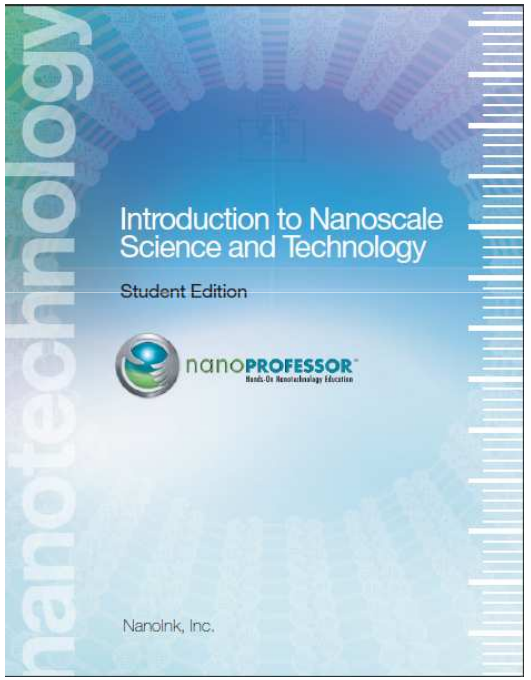
EXPERT-DESIGNED CURRICULUM

NanoEHS & Technological Evolution

- The Technology Maturity Model
- Global Impact of Nanotechnology
- Societal Issues & Opportunities
- Nanobusiness Regulation



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EHS PERSPECTIVES

Subject Matter Experts

- Robert Tanguay, PhD
  Associate Professor, Department of Environmental and Molecular Toxicology
  Director, NIEHS Toxicology Training Grant
  Oregon State University

- Kristen Kulinowski, PhD
  Faculty Fellow, Department of Chemistry
  Director, External Affairs for the Center for Biological and Environmental Nanotechnology (CBEN)
  Director, International Council on Nanotechnology (ICON)
  Rice University

EHS PERSPECTIVES

Subject Matter Experts

- Walt Trybula, PhD
  Director, Nanomaterials Application Center (NAC)
  Texas State University
- Elijah Petersen, PhD
  Postdoctoral Researcher,
  National Institute of Standards and Technology
- Jennifer Kuzma, PhD
  Associate Professor & Resident Fellow
  Humphrey Institute of Public Affairs, Institute on the Environment
  University of Minnesota

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NanoProfessor 101

Excerpts from the

Student Lab Guide

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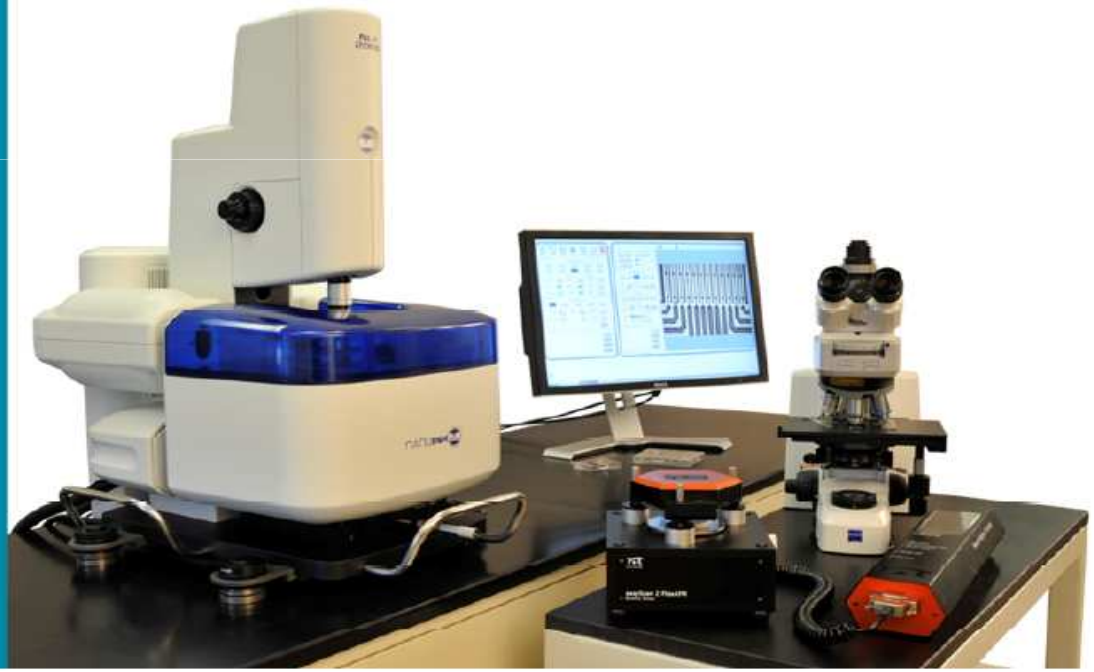

CUTTING–EDGE HANDS-ON NANOTECH LABS

- LAB 1: Exploring the Nano-Scale
- LAB 2: The Dynamics of Working with Nanostructures
- LAB 3: Understanding Nanoscale Fluidics
- LAB 4: Nanoscale optical structures
- LAB 5: Working with Self-Assembling Monolayers
- LAB 6: Building a Functional DNA Array
- LAB 7: Creating Patterns with Phospholipids and Proteins
- LAB 8: Directing Cell Movement with Nanoscale Patterns
- LAB 9: Creating a Lipid-Based Biosensor

NEW CUTTING–EDGE HANDS-ON LABS

- **LAB # 10: ETCHING TO THE FUTURE**
  - > Students work by combining Top-Down and Bottom-Up techniques to pattern at the nanoscale.
  - > Students mask a gold surface with nanoscale patterns using an alkanethiol self-assembling ink (Bottom-Up).
  - > An industry standard gold citrate reduction is then employed to etch away the unprotected portions of surface leaving behind gold nanoscale patterns (Top-Down).
  - > Such patterning can also be performed on other substrates such as Silicon. The patterns are designed by the students using the NLP 2000 bit-map software, and may range from simple circuit elements, eye catching patterns such as diffraction gratings, or more novel patterns at the nanoscale.

NEW CUTTING–EDGE HANDS-ON LABS

- **LAB # 11: ENTERING THE WORLD OF POLYMERS**
  - > Students gain an understanding about the characteristics of polymers
  - > One remarkable property of some polymers is superabsorbence, the ability of the three-dimensional hydrophobic network of a hydrogel to take within it great amounts of water.
  - > Students create nanoscale patterns made from poly (NIPAM), using the NLP 2000
  - > Hydrogels applications range from the controlled release of pharmaceuticals to metal extraction and waste-water treatment and many, many, more.

NEW CUTTING–EDGE HANDS-ON LABS

- **FUTURE LAB: FLEXIBLE CIRCUITS**
  - With the addition of a source-meter, the electrical characteristics of nanoelectronics created using the NanoProfessor suite of equipment can be explored.
  - Resistors, capacitors, inductors, diodes and transistors can be constructed at the nanoscale by Dip-Pen Nanolithography (DPN).
  - At the nanoscale these fundamental electronic elements take on new form and use new materials such as conductive polymers. The patterns of these elements can even be printed on a flexible substrate, making a flexible circuit.

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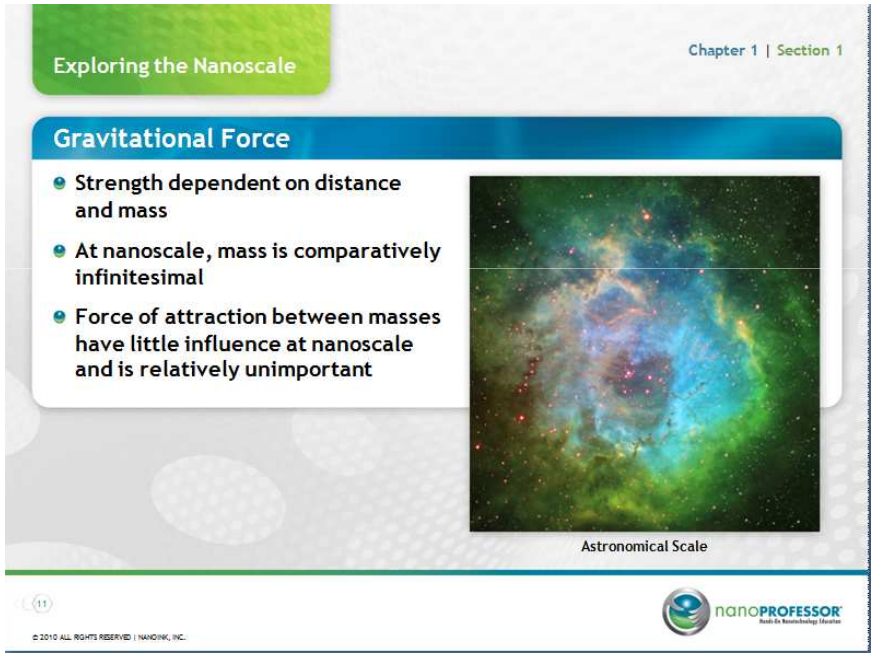
NEW CUTTING–EDGE HANDS-ON LABS

- **FUTURE LAB: BLINDED BY LIGHT**
  - > Display technology is delving into the nanoscale, with the latest very thin OLED television screens as an example. With the techniques developed for the nanoelectronics laboratories, OLED elements can be printed using the NLP 2000.
  - > Such patterns can be printed on flexible substrates and when the proper voltage is applied these printed patterns of pixel diodes will literally light up.
  - > The display industry is a multi-billion dollar industry and advanced flexible displays are being actively pursued by companies and well as researchers around the world.

NANOPROFESSOR SUPPORT

- Instructor Support
  - > E-based Instrumentation Training
  - > Detailed Instructor Notes for Labs
  - > Course Lecture PowerPoints
  - > Assessments and Rubrics
- Integration Support of Nanoscience Into Existing Curriculum
- Curriculum and Lab Supplies
- Equipment and Curriculum Training
- Instrument Maintenance



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Example: Integration into an existing program

FIRST YEAR

First Semester Coursework		*Credit Hours*
CHM 121	General Chemistry I	5
ENG 101	Composition	3
MTH 140	Pre-calculus	5
NAN 121	Fundamentals of Nanoscience I	4
First Semester Total Credit Hours		*17*

Second Semester Coursework		*Credit Hours*
BIO 110	Principles of Biology	4
MTH 165	Elementary Statistics	4
PHY 121	Introductory Physics I	5
NAN 122	Fundamentals of Nanoscience II	4
Second Semester Total Credit Hours		*17*

Summer Semester Coursework		*Credit Hours*
PHY 122	Introductory Physics II	5

Example: Integration into an existing program

SECOND YEAR

First Semester Coursework		*Credit Hours*
Humanities or Social Science Elective*		3
NAN 211	Nanoelectronics	3
NAN 221	Nanobiotechnology	3
NAN 231	Nanomaterials	3
NAN 295	Independent Research or Approved Elective	3
First Semester Total Credit Hours		*15*

Second Semester Coursework		*Credit Hours*
SPE 101	Fundamentals of Speech Communication	3
NAN 241	Nanoscience Manufacturing	3
NAN 299	Nanoscience Internship	6
Second Semester Total Credit Hours		12

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Example implementation routes

- Integration to existing program.
  - Very flexible. Build new courses around modules:
    Chemistry, Biology, Physics, Engineering all fit.

- Stand-alone “NanoProfessor” course (~2 x 4 credit hours in present form- expanding).

- NLP tool can be used for research electives (as per UK Bachelor degree programmes-
  e.g. Imperial College London, University of Strathclyde.

- UK DTC’s NLP used as introduction in Nanotechnology to research degree (MPhil, PhD).
  e.g. University of Liverpool (proposed), Glasgow (implemented), Cambridge (proposed).

- Nb. The NLP is a cutting edge research tool!

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NANOPROFESSOR IMPLEMENTATION

- NanoProfessor implementation can occur within 90 days of purchase.
- NanoInk and distributor will install equipment and train faculty on instruments, curriculum and labs.
- Continuing on-line support available.

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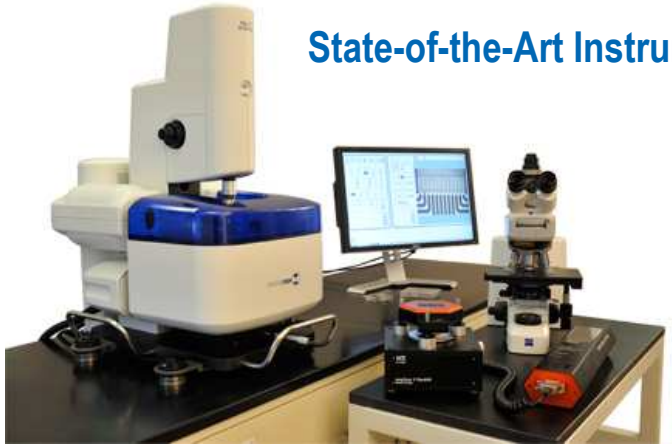
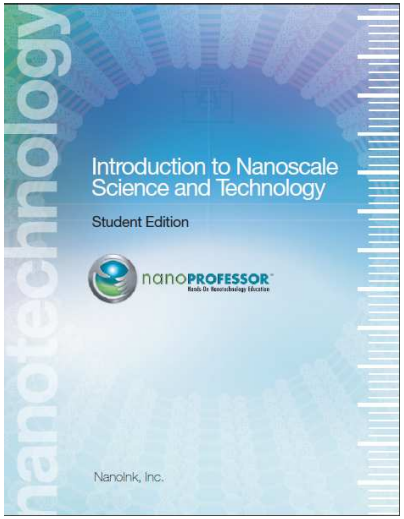
NANOPROFESSOR

State-of-the-Art Instrumentation



Expert-Designed Nanoscience Curriculum



Extensive Instructor & Institution Support

Hands-On Lab Experiments