OREGON NANOSCIENCE AND MICROTECHNOLOGIES INSTITUTE

Nanotechnology Commercialization in Oregon

February 27, 2012
Portland State University
Physics Seminar

Robert D. "Skip" Rung
President and Executive Director

ONAMI

Nanotechnology Commercialization In Oregon

- NNI goals and economic development motivation
- ONAMI goals and update
- ONAMI gap fund
- Focus on “green” nanotechnology and gap fund portfolio company examples

Goals of the National Nanotechnology Initiative

www.nano.gov

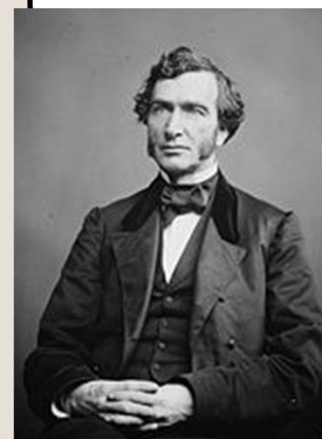
- To advance world-class nanotechnology research and development;
- To foster the transfer of new technologies into products for commercial and public benefit;
- To develop and sustain educational resources, a skilled workforce and the supporting infrastructure and tools to advance nanotechnology;
- To support the responsible development of nanotechnology.

Nano/Micro and Economic Development

the essential argument

- Prosperity and wealth creation are essential for both household well-being and public investment

> ***"National wealth is greatly increased or diminished by the more or less skill, dexterity, and judgment, with which labor is generally applied. As legislators, we can have no subject before us of greater intrinsic importance."***
>
> **Justin Morrill, c. 1854**



s

e same thing as "the leading edge of the applied physical and biomolecular sciences" - for virtually every market sector

- *Therefore, "nano" and micro are key for national and regional prosperity*

Yes, You Can Lose Your Economic Base

“Those Jobs Aren’t Coming Back”

Cities

The 10 Poorest US Cities

- Reading, PA
- Camden, NJ
- Flint, MI
- Brownsville, TX
- Gary, IN
- Detroit, MI
- Cleveland, OH
- Dayton, OH
- Erie, PA
- Rochester, NY

(2010, ranked by average income)

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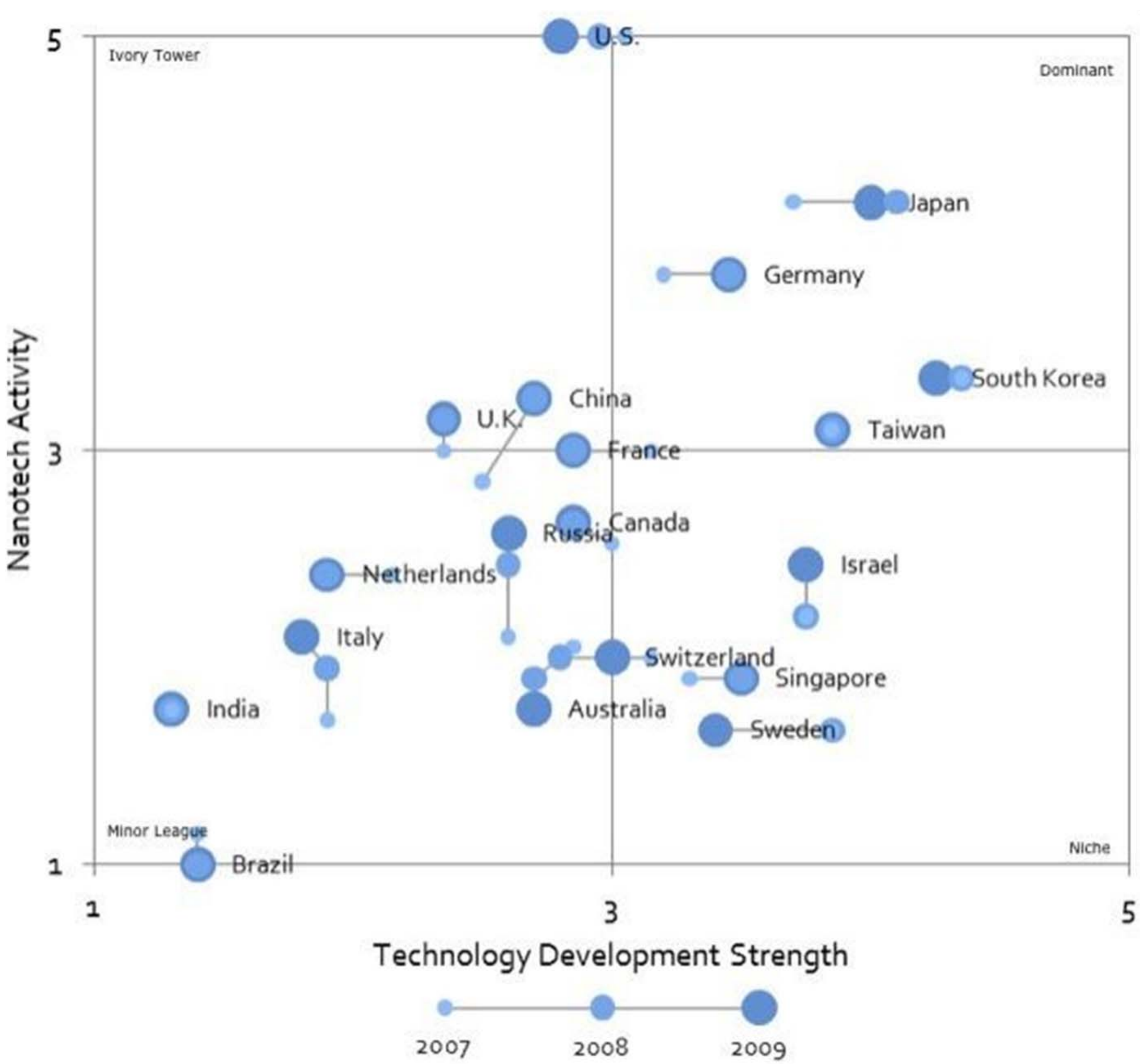
http://www.bizjournals.com/buffalo/blog/the_score/2010/02/getting_the_low_end_of_the_wealth_stick.html

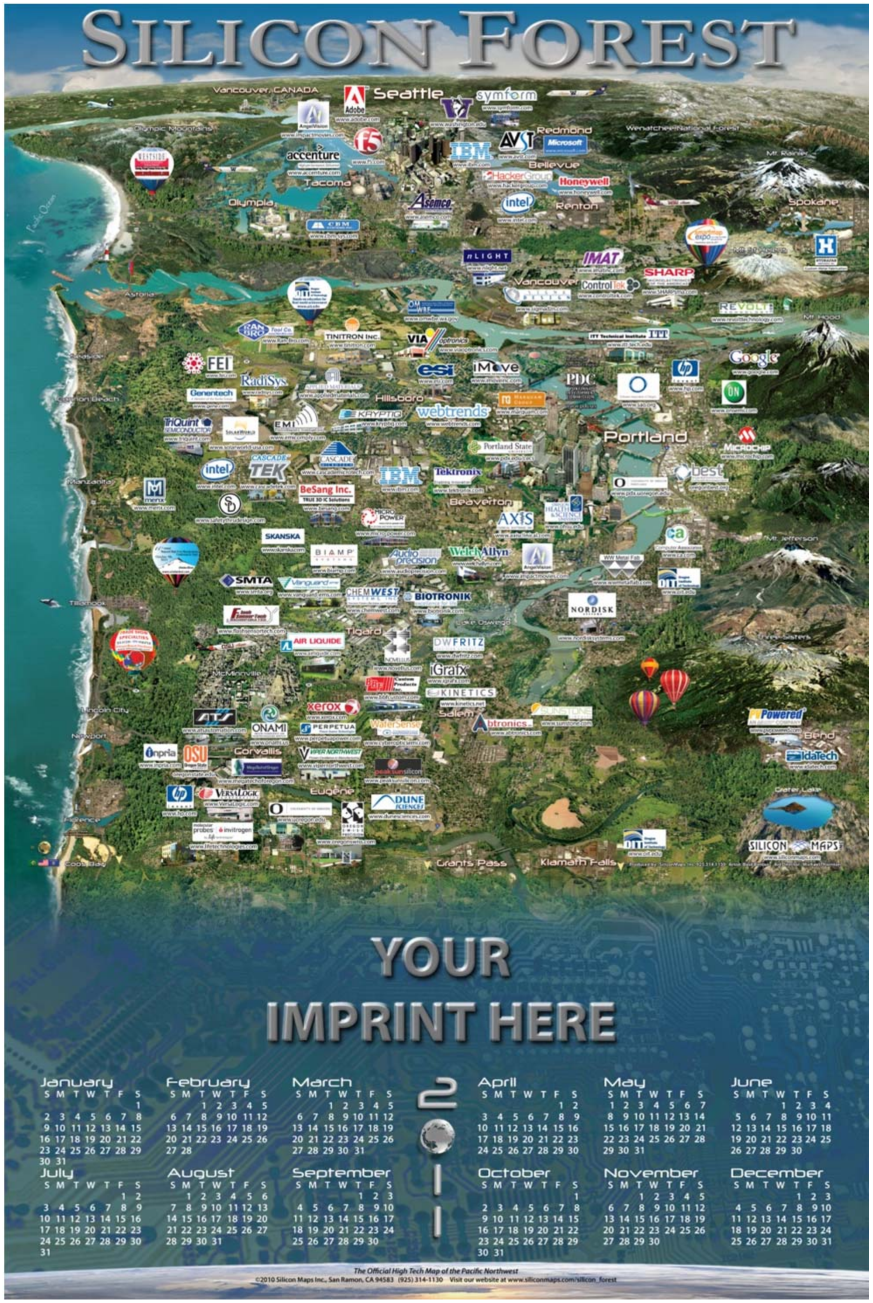
The US' Challenge: Commercialization and Opportunity Retention



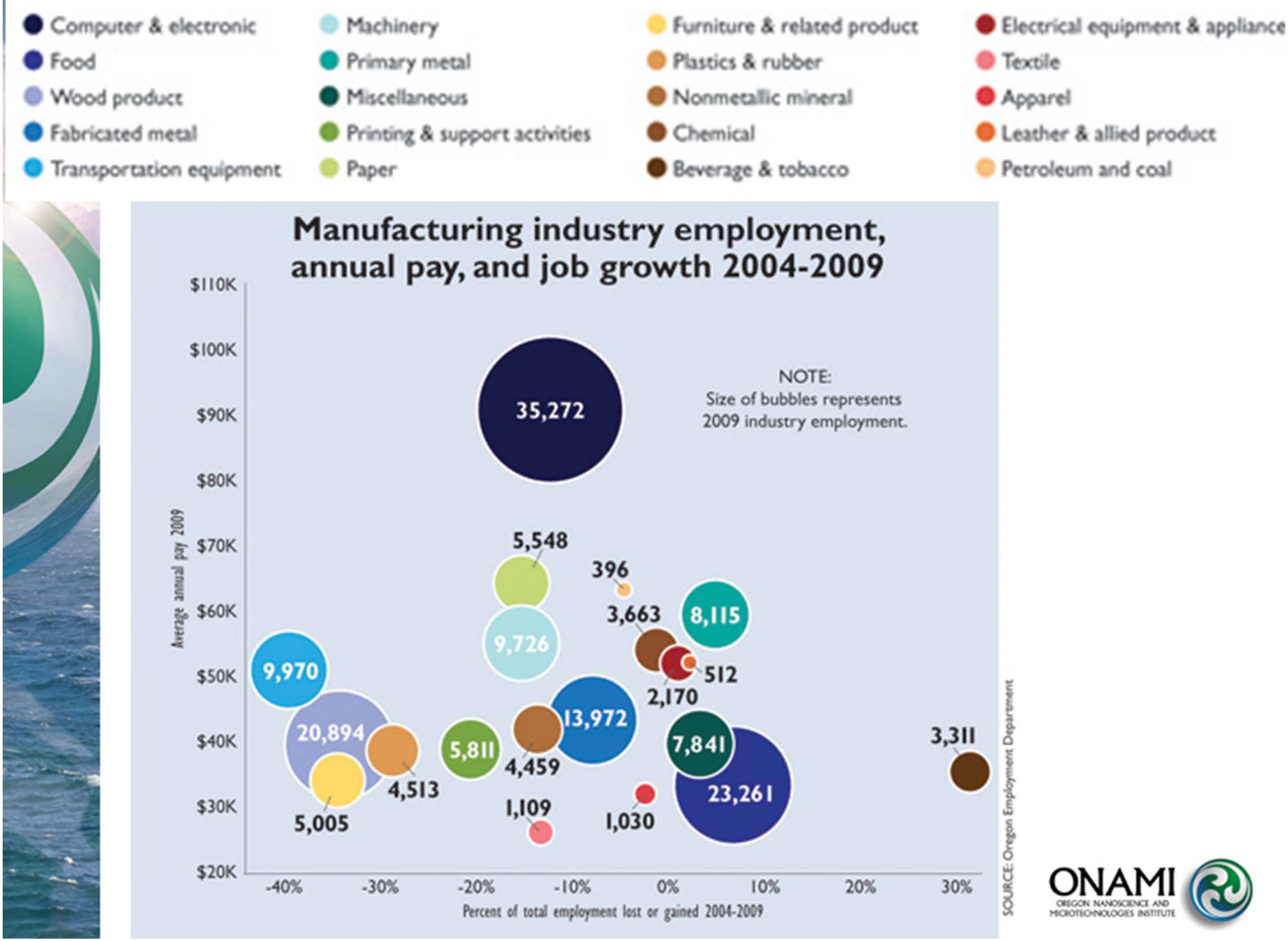
"U.S crosses into 'Ivory Tower' territory"

- Lux Research

Pacific Northwest Micro and Nano Industry Assets



9 posters (3 CA, 2 MA, 2 TX,1 AZ, 1 PNW) available at www.siliconmaps.com



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ONAMI Overview

- Objectives and Performance Metrics
- Gap Fund Process and Portfolio

Current GAP Companies

Mission: Create Jobs and Attract Investment by Accelerating Materials & Device Research and Commercialization in Oregon

- <u>Grow research and talent development</u> at Oregon universities

  Metric: Federal and private awards and contracts

- <u>Support Oregon industry and start-ups</u> with accessible shared high-tech facilities and tools

  Metric: # of external clients, service revenue

- <u>Attract capital to Oregon start-ups</u> via a professionally managed commercialization gap fund

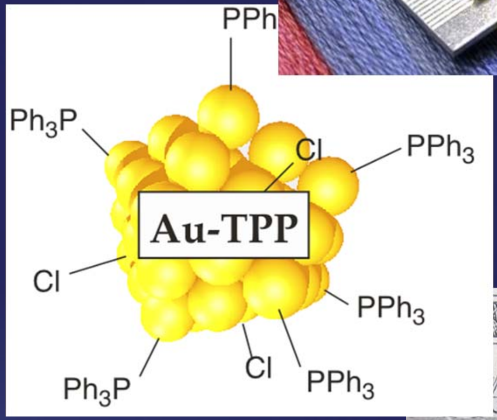
  Metric: #FTE employed, leveraged capital investment and grant $$

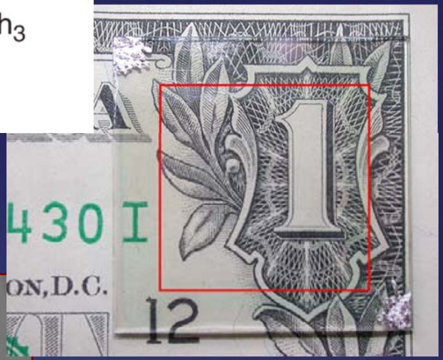
Identified Research Strengths

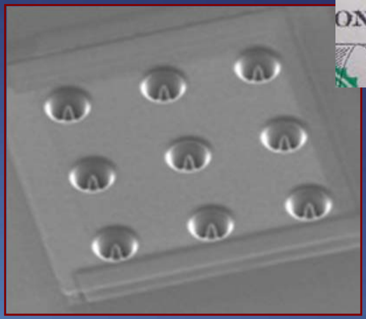
- *Microtechnology-based Energy and Chemical Systems*

- *Green Nanomaterials and Nanomanufacturing*
- *Nanolaminates and Transparent Electronics*

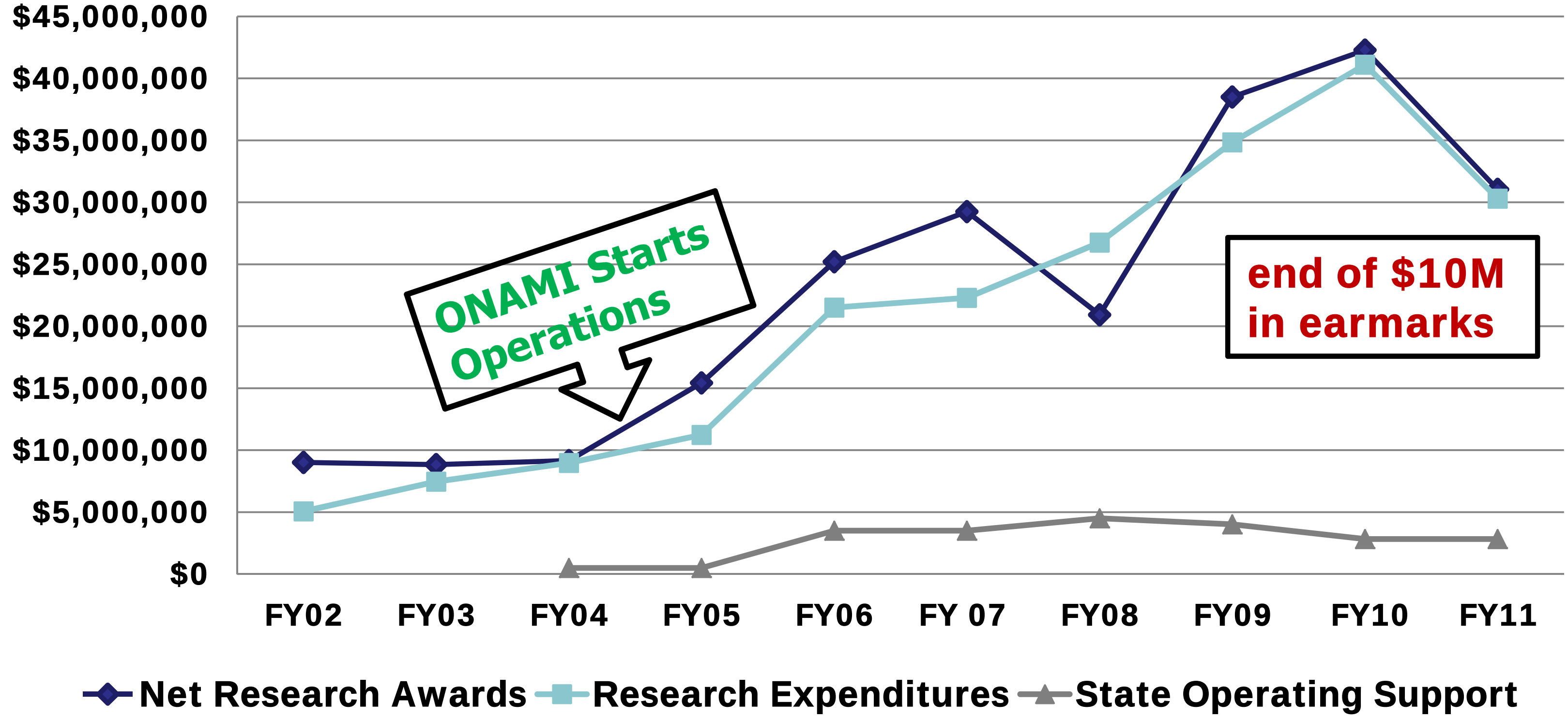
- *Nanoscale Metrology and Nanoelectronics*







ONAMI Research Award History



Latest Highlights:

$21.5M NSF Center for Sustainable Materials Chemistry (Keszler/Johnson)

$2.0M DoE B-N liquid H2 storage material (Liu, UO)

$1.9M NIH Nanomaterial's biological effects (Harper, OSU)

Research enterprise 3-4X larger than when we started

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The "High Tech Extension" Concept

Nanoscience facilities and equipment can best benefit technology development when they are conveniently located and easy to use by businesses. Such access is especially important to the small and medium enterprises (SMEs) that are critical for early stage commercialization. State and regional economic development field staff can serve as "high tech extension" agents.

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ONAMI Shared User Facilities

Center for Materials Characterization (CAMCOR)

CAMCOR is a full-service, comprehensive materials characterization center at the University of Oregon (UO) open to outside clients. Benefit from capabilities, access to analytical experts, priority for time critical data, and remote access from your office. Equipment includes: Transmission electron microscope (TEM), Field emission Scanning electron microscope (SEM), SEM/FIB nanofabrication, Electron Microprobe Analysis (EPMA), X-ray photoelectron spectrometer (XPS), Time-of-Flight Secondary Ion Mass Spectrometer (ToF-SIMS), Single crystal and powder diffractometers, and more.

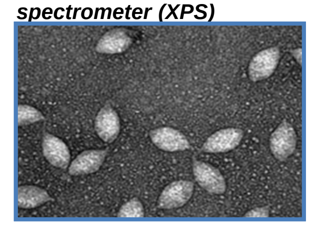
CAMCOR is located in the Lorry Lokey Science Complex, University of Oregon

View inside the CAMCOR Surface analytical laboratory and the X-ray photoelectron spectrometer (XPS)

Center for Electron Microscopy and Nanofabrication (CEMN)

The CEMN at Portland State University (PSU) provides researchers and industry with state-of-the-art facilities for characterization and fabrication of nanoscale materials and devices. Equipment includes: Transmission electron microscope (TEM), Field emission Scanning electron microscope (SEM), SEM/FIB nanofabrication, thin film deposition and sample preparation.

CEMN is located in the heart of Portland



Transmission electron micrograph of virus particles.

Microproducts Breakthrough institute (MBI)

The MBI is a microsystems fabrication facility located on the Hewlett Packard (HP) campus in Corvallis. Through miniaturization, microtechnology has the potential to revolutionize many products. The MBI uses microfabrication methods to support researchers and industry to invent and prototype products for energy, environmental, medical and defense applications. Applications include, blood processing, fuel injection, DNA sample preparation, nanomaterial deposition, and microchannel heat exchangers.

The MBI is managed by Oregon State University and located on the HP Corvallis campus.

ESI laser machining tool at the MBI facility.

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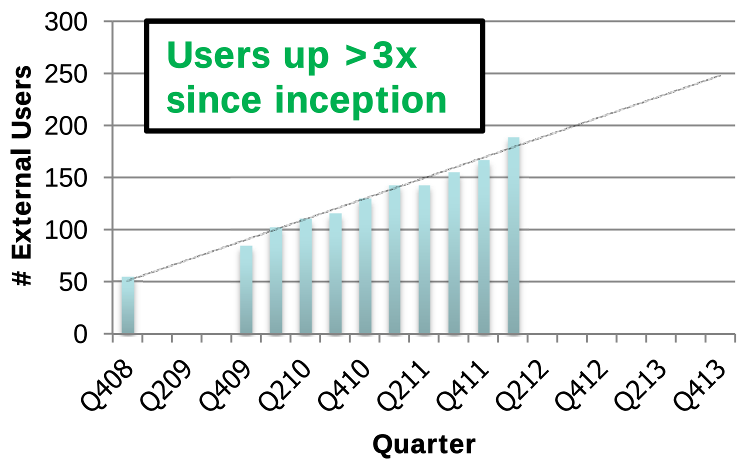
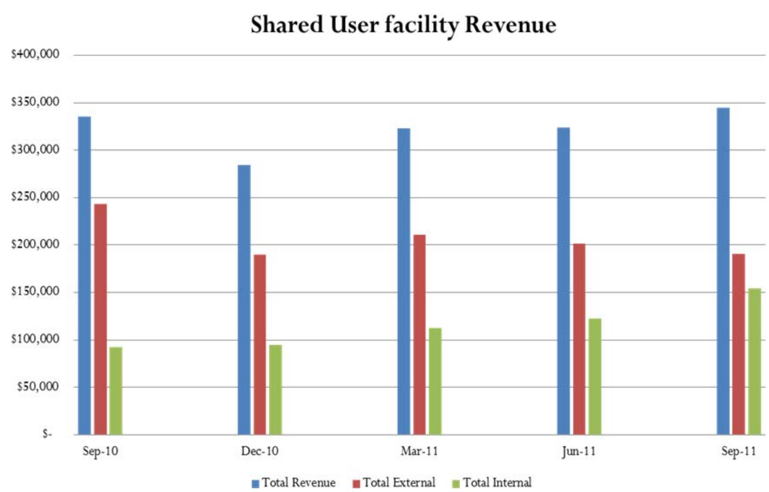
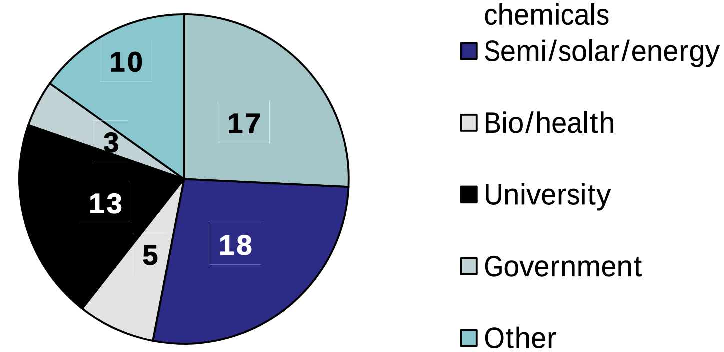
ONAMI High Tech Extension

External Organizations Using SUF (Cumulative)





Clients by Market



1Q2012
189 external clients - cumulative
76 external users - 49 Oregon
9 new clients reported

First-time user grants:
Vitriflex, AISThesis, Oral Biotech, Trimble, Inspired Light, Triquint, Microchip

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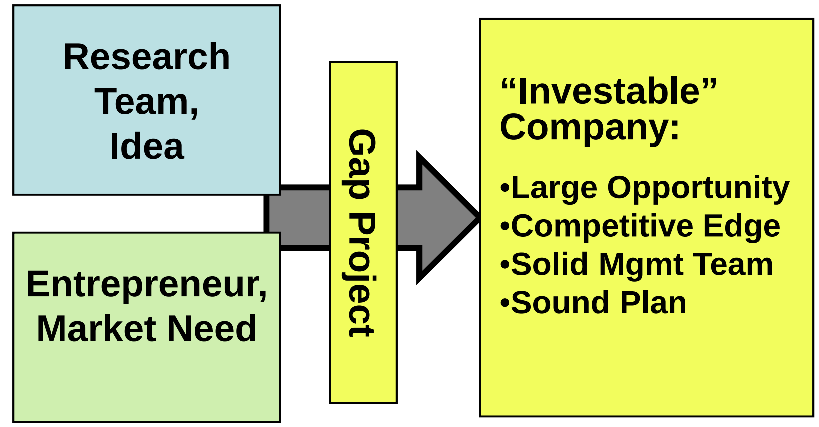
ONAMI Commercialization Gap Fund

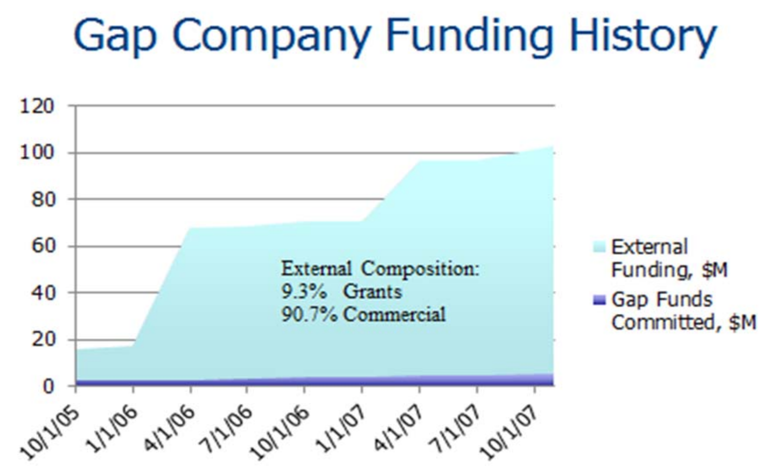
Technology Stage	Company Stage	Funding Source
Research Result	(NA)	NNI Grants
Proven Prototype	***Formation***	***Gap Grants*** ***(state + federal)***
Products, Sales	Development	Early Stage Investors
Product Line Expansion	Growth	Various (private)



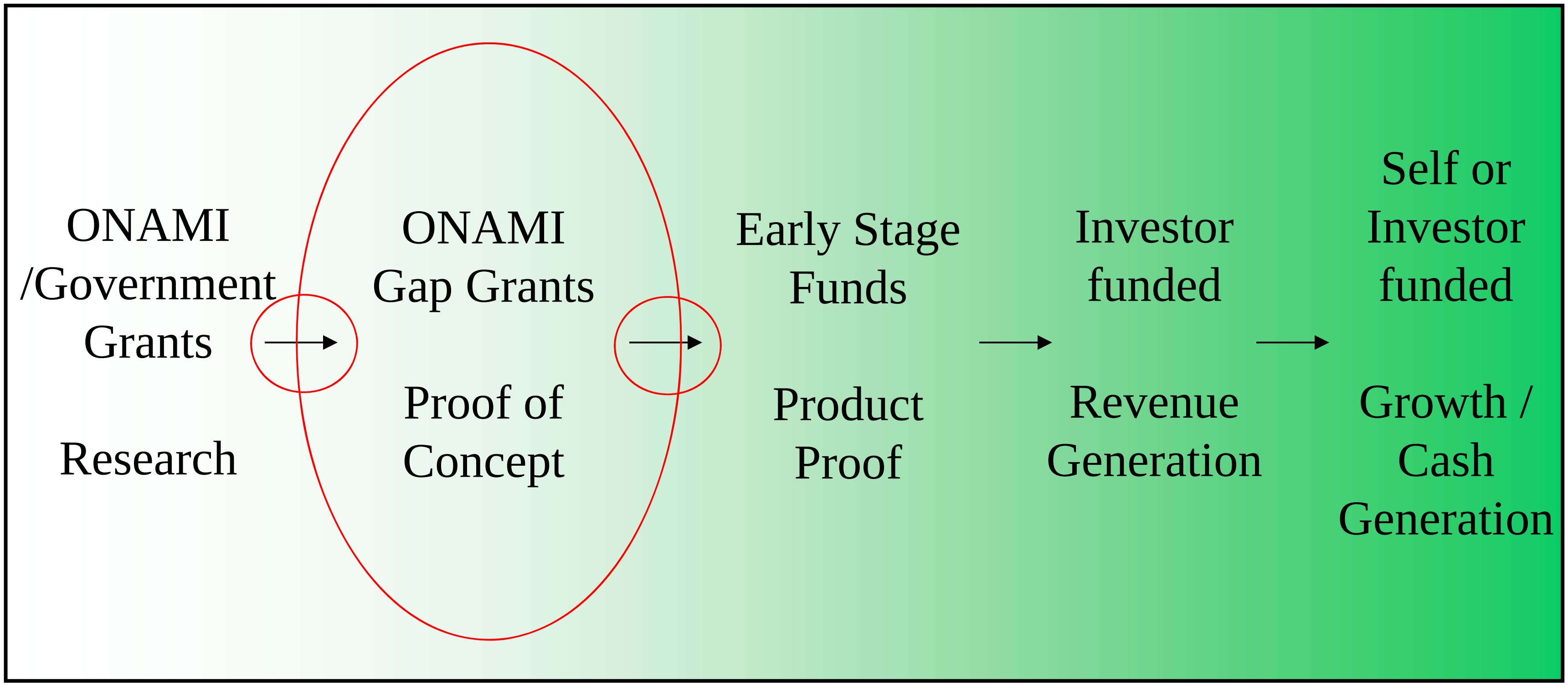
Latest Highlights:

-Additional capital into ZAPS Technologies
-OAF investment offer to PLT
-Perpetua investment/expansion – Coos Bay
-Venture backing: Inpria, ZAPS

$103M External Funding to date
110 FTE currently employed



Review: ONAMI's Role in Technology Commercialization



Focus on interfaces and operations

The ONAMI Gap Fund Portfolio, February 2012

http://www.onami.us/Commercialization/currentProjects.php

Thrust Area and Project Host Campus	**MECS** (microtech-based energy and chemical systems)	**Green Nano** (materials and processes)	**Solid State** (batteries, printed electronics, green electronic materials)	**Nanoscale Metrology**	**Nano Bio-Tech**
OSU	Home Dialysis Plus ABP Mtek Energy Trillium Fiberfuels Apex Drive Labs NWUAV Mtek desal Applied Exergy	Inpria Nanobits CNXL Voxtel Nano CSD Nano Microflow CVO *Amorphyx*	Peregrine/Promat OnTo Technology Energy Storage Solutions Inspired Light	ZAPS Technologies	Northwest Medical Isotopes
PSU/OHSU	*Energy Storage Systems*	Puralytics	Pacific Light Technologies	Flash Sensor	DesignMedix PDX Pharma
UO		Crystal Clear Technologies Dune Sciences	Perpetua Power	NemaMetrics	Floragenex *Quintessence* *Cascade Pro.*

$103M leverage to date, more pending

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ONAMI Entrepreneurs In Residence

Team, Network, Marketand Sales assistance from veteran CEOs

- Augie Sick asick@onami.us
  - *Chemistry, nanomaterials, life science tools*
- Michael Tippie mtippie@onami.us
  - *Biomedical, pharma, nanomedicine*
- John Brewer jbrewer@onami.us
  - *Semiconductors, electronics, optics*

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Nanotechnology and the Environment
there's more opportunity than risk

- "Nano" should be **inherently green** (e.g. dematerialization, optimized material performance)
- It is a **critical enabler** for energy security – efficiency, generation, and storage/transmission
- It is invaluable for direct **environmental applications** (e.g. wastewater remediation)
- Should be developed with systematic **attention paid to EHS** concerns (both real and perceived)
  - However, comprehensive regulation/testing is unlikely to work, and likely to prevent or delay needed benefits
    (and are we *really sure* the pre-nano status quo is safer?)
  - A better way – the **Green Nanoscience approach**

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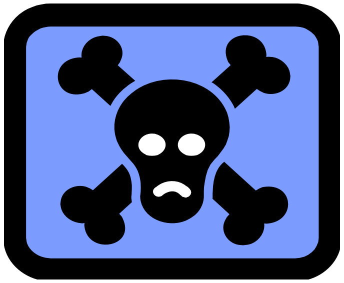
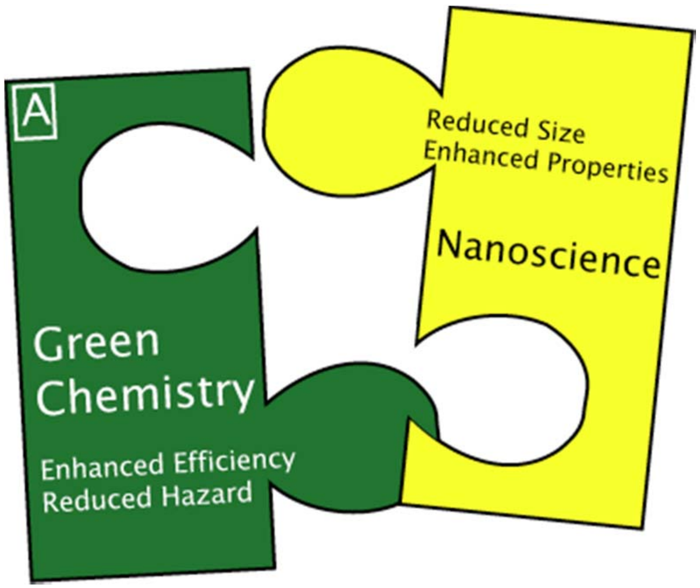
Sure, we're all for innovation and job creation, but what about the downside/risks of "nano"?

Start Worrying -- Details to Follow! Join the discussion! Click here to comment

If you're the type of person who likes to worry, great news! There's an entire culture out there ready to help you. The latest enabler is the front page of the "Home" section in The New York Times



Applying green chemistry to nanomaterials and nanomanufacturing



Higher performance
Cheaper
More convenient
Greener

McKenzie and Hutchison "Green nanoscience," *Chemistry Today*, **2004**, 30.
Dahl, Maddux and Hutchison "Toward Greener Nanosynthesis," *Chem. Rev.* **2007**, *107*, 2228.

Green chemistry: a proactive approach to safer design, production and application of nanomaterials

Green chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products

- Greener solution must meet or exceed <u>functional</u> needs
- Risk = *f* (Hazard, Exposure)

Design for reduced hazard and exposure at the molecular level – inherent safety

More efficient and safer processes

Early feedback and intervention – get the technology right the first time

Principles for greener nanoscience

Green Chemistry Principles

P1. Prevent waste

P2. Atom economy

P3. Less hazardous chemical synthesis

P4. Designing safer chemicals

P5. Safer solvents/reaction media

P6. Design for energy efficiency

P7. Renewable feedstocks

P8. Reduce derivatives

P9. Catalysis

P10. Design for degradation/Design for end of life

P11. Real-time monitoring and process control

P12. Inherently safer chemistry

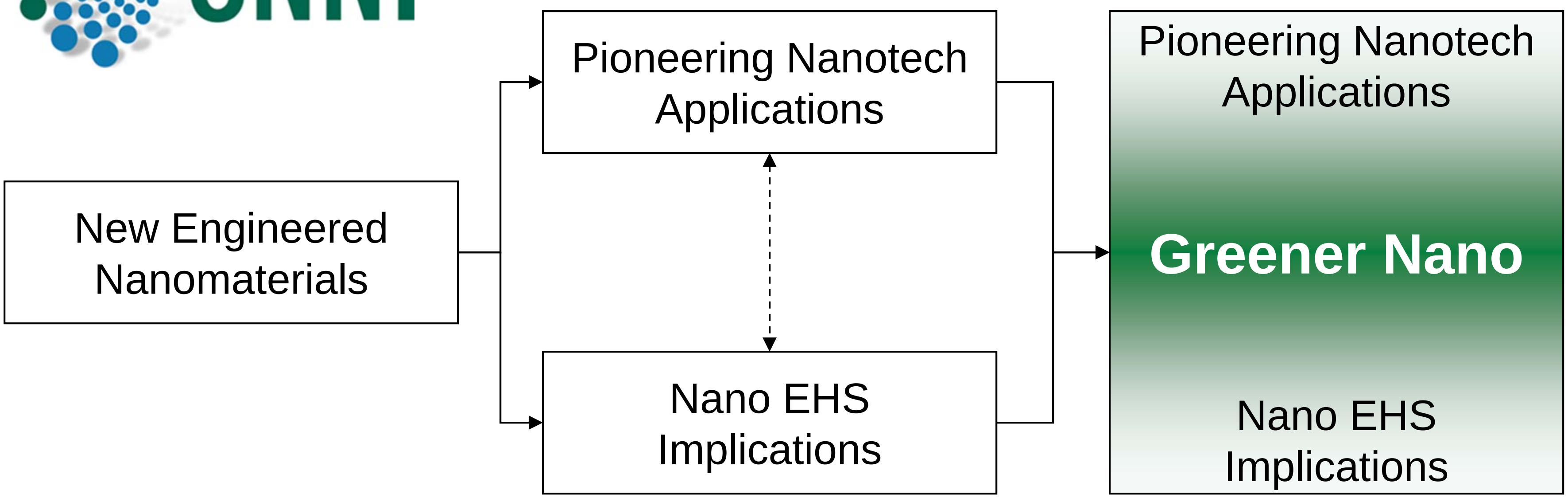
Designing Greener Nanomaterial and Nanomaterial Production Methods

- Design of safer nanomaterials (P4,P12)
- Design for reduced environmental impact (P7,P10)
- Design for waste reduction (P1,P5,P8)
- Design for process safety (P3,P5,P7,P12)
- Design for materials efficiency (P2,P5,P9,P11)
- Design for energy efficiency (P6,P9,P11)

McKenzie and Hutchison "Green nanoscience," *Chemistry Today,* **2004**, 30.
Dahl, J.A.; Maddux, B. L. S.; Hutchison, J. E. *Chem. Rev.* **2007**, *107,* 2228

Coupling Applications and Implications:
An integrative and prioritizing approach

SNNI



SNNI = Nine interdisciplinary teams at four institutions
80 researchers
chemistry, materials, toxicology, engineering

adapted from Hutchison, J.E. *ACS Nano* **2008**, *2*, 395-402

A Green Nano Startup Portfolio

SNNI	Green Nano-Material	Green Nano-Manufacture	Green Nano Application
Safer Design	DUNE SCIENCES		
Reduce e-impact		Crystal Clear Technologies	PERPETUA Power Source Technologies
Waste Reduction		VOXTELNANO	ZAPS TECHNOLOGIES
Process Safety		CSD Nano, Inc	
Materials Efficiency		inpria	ESS Energy Storage Systems LLC; PLT
Energy/H2O Efficiency			Puralytics

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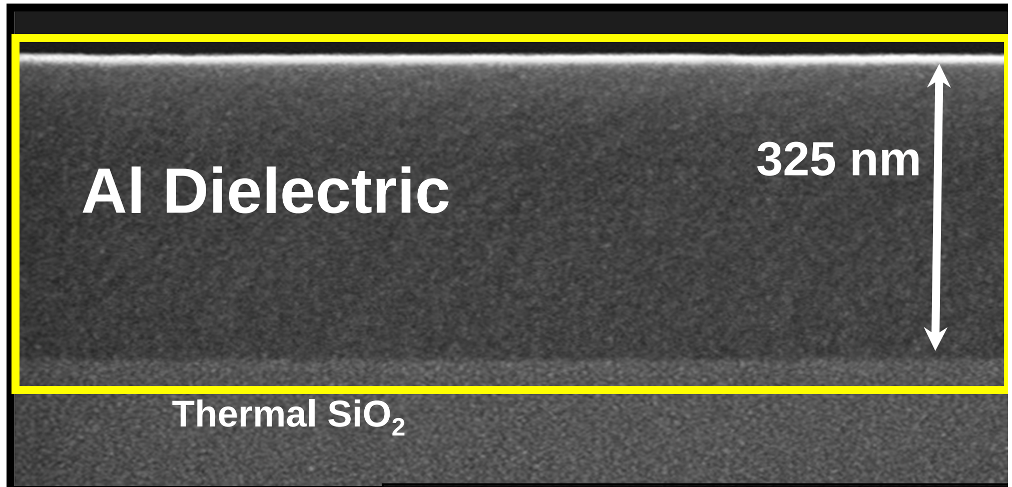
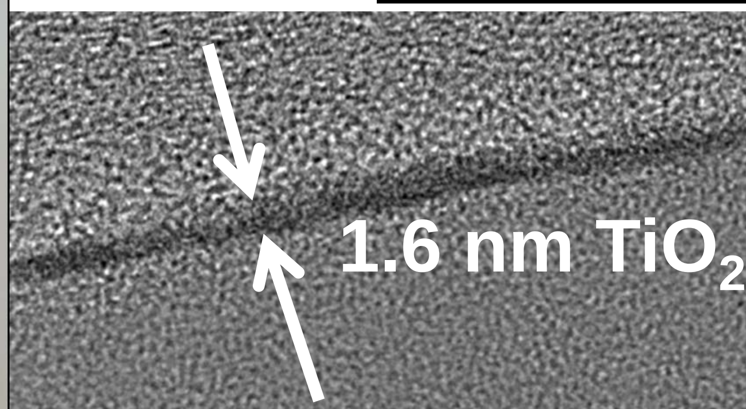
Oregon Nanoscience and Microtechnologies Institute

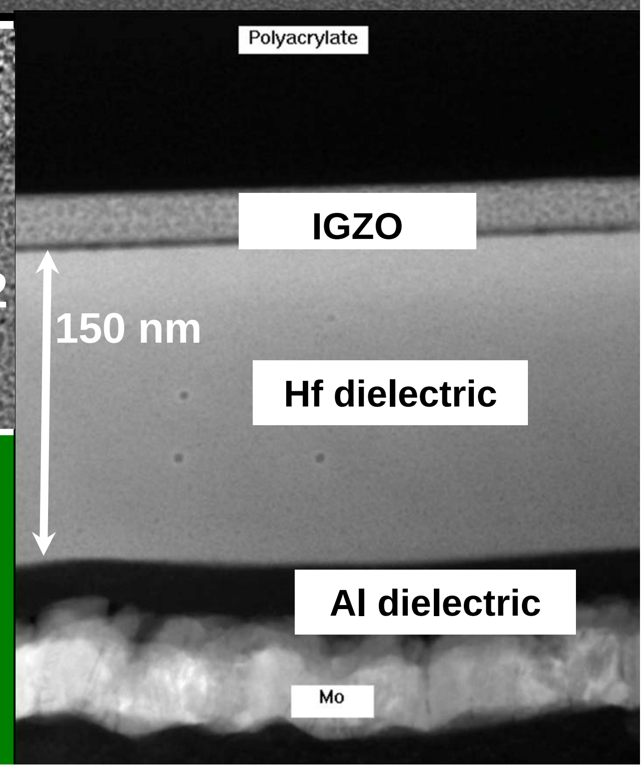
Inpria Corporation (Corvallis, OR)

Inpria develops materials that enable vacuum-quality metal oxide thin films with the speed and low cost of solution processing



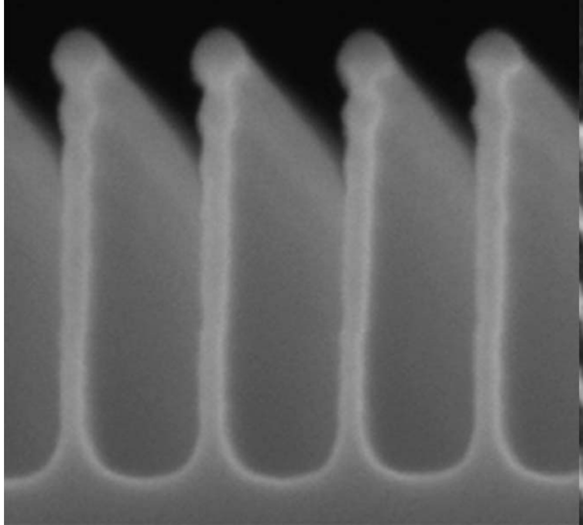


Broad Platform Adaptable to Many Applications

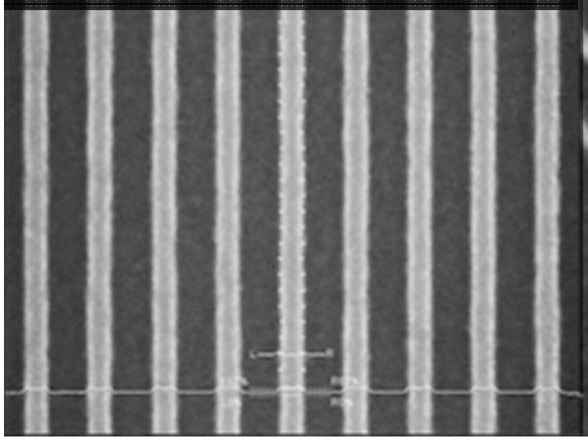


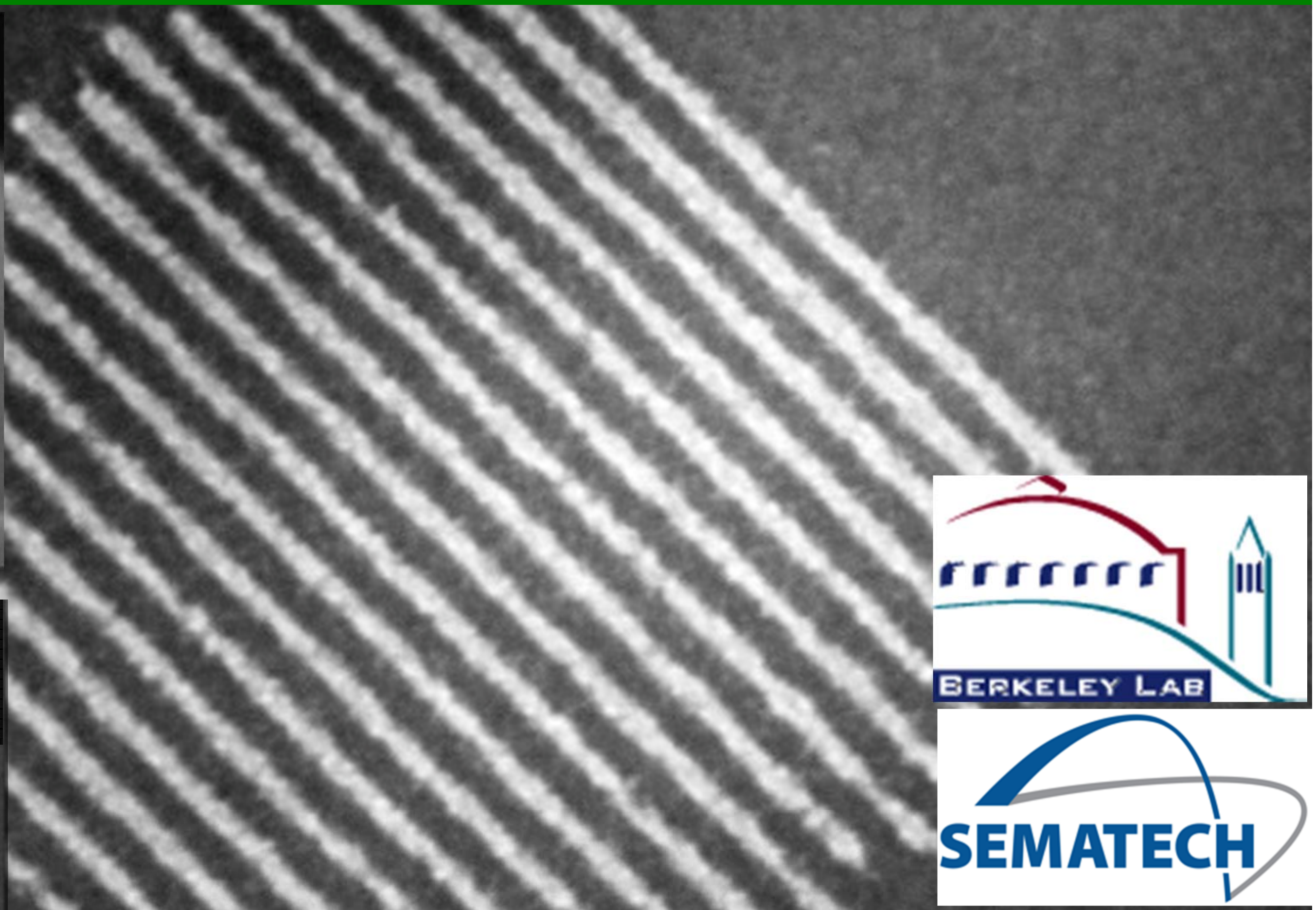
Initial Products: Lithography Resists with Extremely High Etch Resistance

15nm Etched Si Fins



1.6 nm Linewidth Roughness @ 30nm



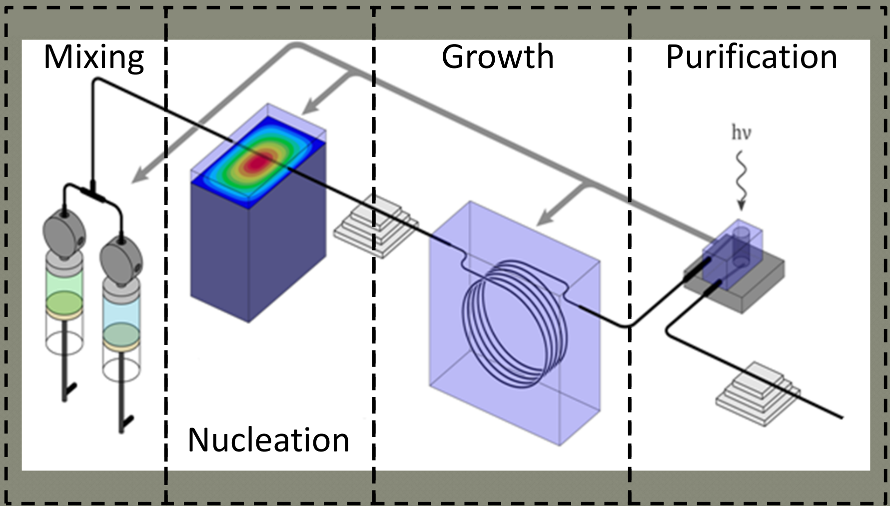


Berkeley Lab

SEMATECH

High resolution resist for EUV Lithography: 15 nm l/s

Voxtel Flow Cell Reactor: Nanoparticle Synthesis



Zoned / Modular Reactor enabling:

- Process Control / Monitoring at each zone
- New chemistries not available to batch processes
- Increased scientific understanding of each step in nanoparticle synthesis (nucleation, growth, ligand exchange)

- Green Aspects
  - o Reduced Waste
  - o Increased Yield
  - o Elimination of Heavy Metals (Pb, Hg, Cd)
- Business Aspects
  - o Reduced Cost
  - o Increased Process Control
    (Particles of known size, shape and chemistry)
- Green Performance and Business Success are compatible.

VOXTELNANO

Nanoparticle Applications within Voxtel

Photovoltaics

Demonstrated 200% efficiency through MEG (multiple exciton process)

Photoreceivers

- Night vision goggles
  - Improved ergonomics
  - Reduced spatial footprint (eyeglass form factor)
- Cameras – Printed Electronics

Security / Anti-Counterfeiting

- Increased difficulty for reverse engineering
- Increased degree of encryption (>10^6/pixel)
- Incorporates time resolved emission as another encryption method.

- ## Covert Taggants
  - Allows tracking and identification of unwilling targets at long stand-off distances
  - Allows tagging and identification of munitions / suppliers

Detectors

- Sensors for large area x-rays and g-rays
- Built in spectrometer through wavelength selective absorption
- Cost effective detection of near infrared / short wavelength infrared

Biosensing

- Allows selective detection and identification of chemical and biohazards.
- Anthrax, E. coli, Salmonella, Ricin

Displays

- Incorporated in NQD-LEDs for highly emissive, high color purity displays

Carbon Nanotubes

- Flow Cell Reactor principles also being applied to synthesis of highly purified, monochiral CNTs.
- (4-hour process versus 2-3 week process)

VOXTELNANO

The World Needs Solid State Lighting

Worldwide Electricity Consumption

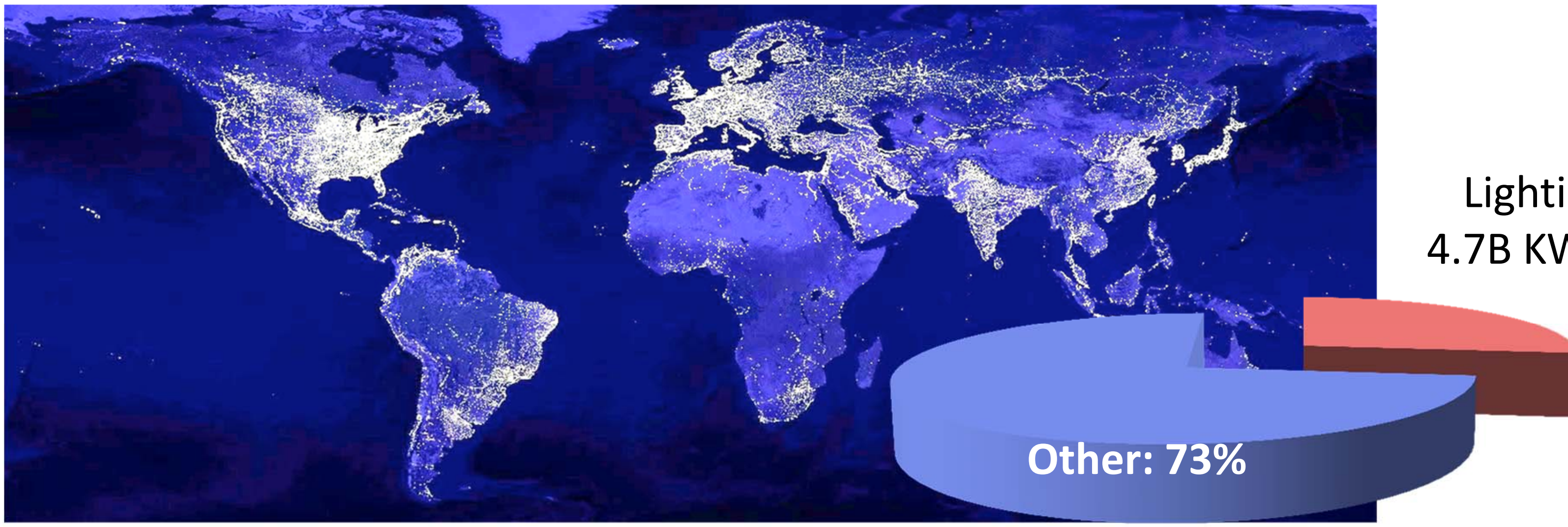


Photo Source: NASA





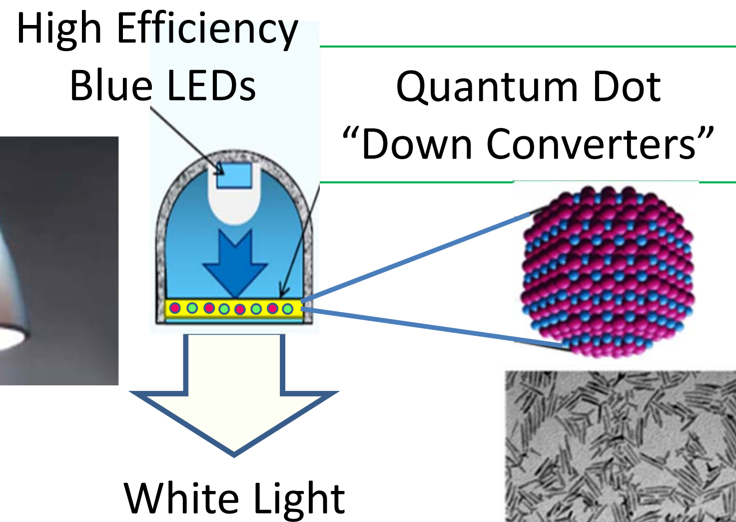

Solid State Lighting Will:

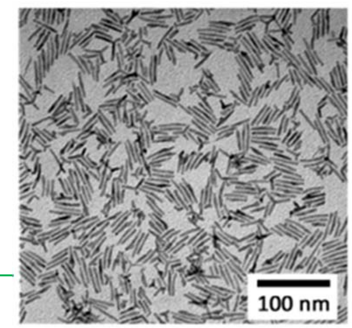
- Save a cumulative 5T kWh of electricity WW in the next decade,
- Remove the need for 500 power plants from the grid
- Reduce cumulative tons of CO_2 emissions by 8B tons (equal to the emissions from all of the passenger cars in the world)

Source: Canaccord Genuity

Pacific Light Technology

efficient lighting through engineered nanomaterials





SSL Bulbs Today Reduce Electricity Usage by:

- 80% vs. Filament Bulbs (But initial price is 2-3x too high)
- 10-20% vs. Florescent (Not sufficient)

PLT’s High Efficiency QD Down Converters Will:

- Reduce Cost by Reducing Number of LEDs (20-50%)
- Reduce SSL “Florescent” Electricity Usage by another 20-50%
- Improve Stability of Color (no objectionable CFL color “shifts”)

Puralytics

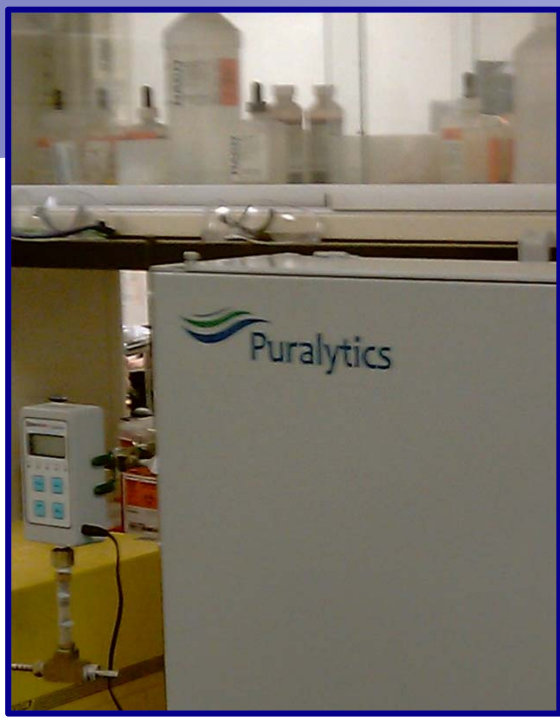
LED NANOTECHNOLOGY WATER PURIFICATION

Green, Lean, and Mean

Mark Owen, CEO
Beaverton, OR

www.puralytics.com

Puralytics Solution

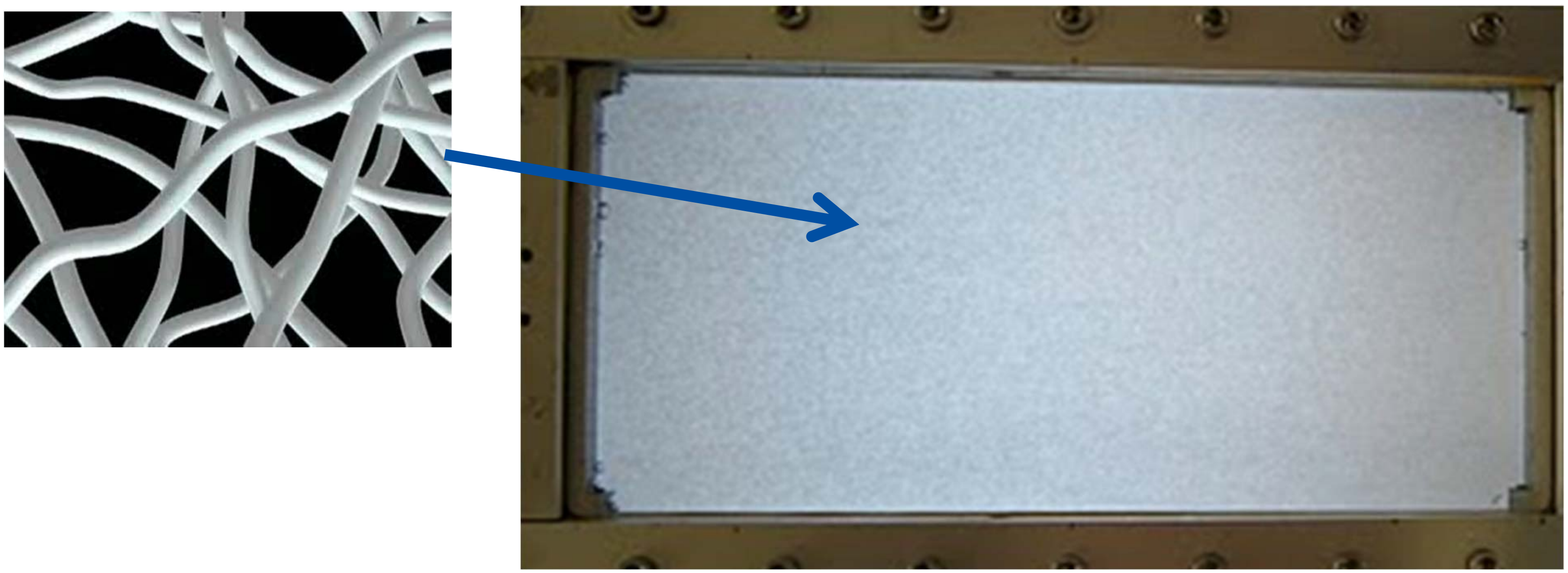


Shield 500 – world's first solid state water purification system

- Novel LED-activated nanotechnology coated mesh for water purification
  - **Green:**
    - Water and electricity reduced
    - Contaminants destroyed
  - **Lean:**
    - Operating Expenses reduced 80%
    - 18 Month Payback
  - **Mean:**
    - Eliminates contaminants competitive systems can't

Destroying Contaminants with Light

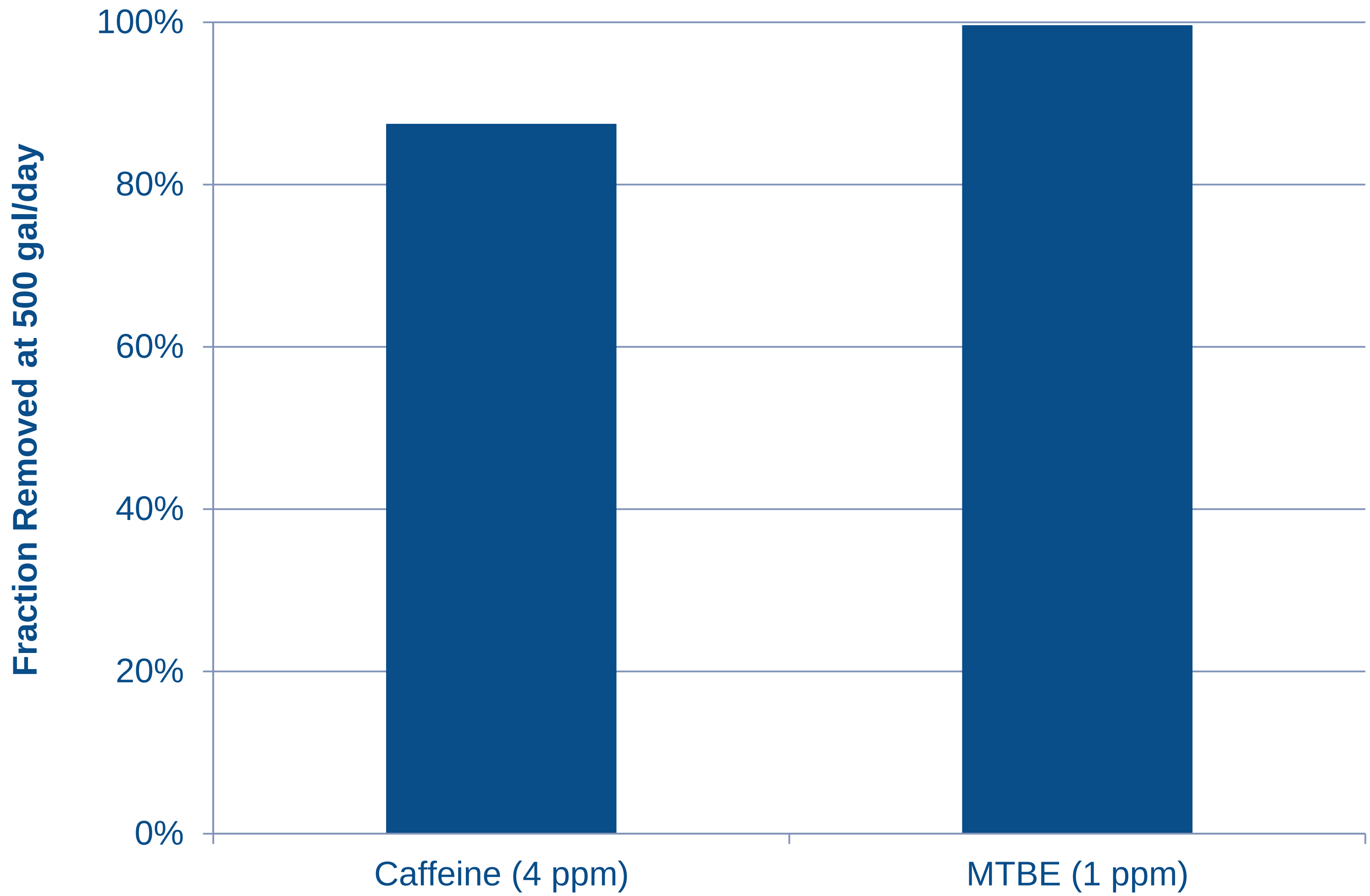
LEDs excite a nanotechnology coated mesh which destroys germs and chemicals



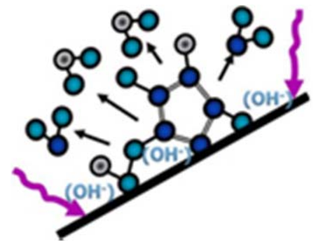
4 Patent Apps Filed, 3 Grants, Field tests successful

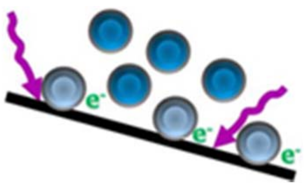
Destroying Contaminants with Light

Shield #113 Performance



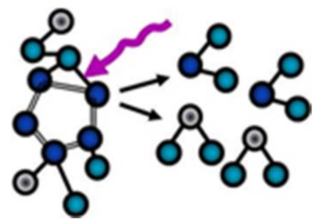
Photocatalytic Oxidation

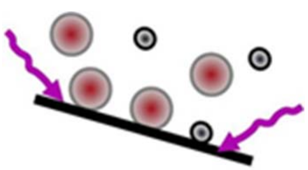




Photocatalytic Reduction

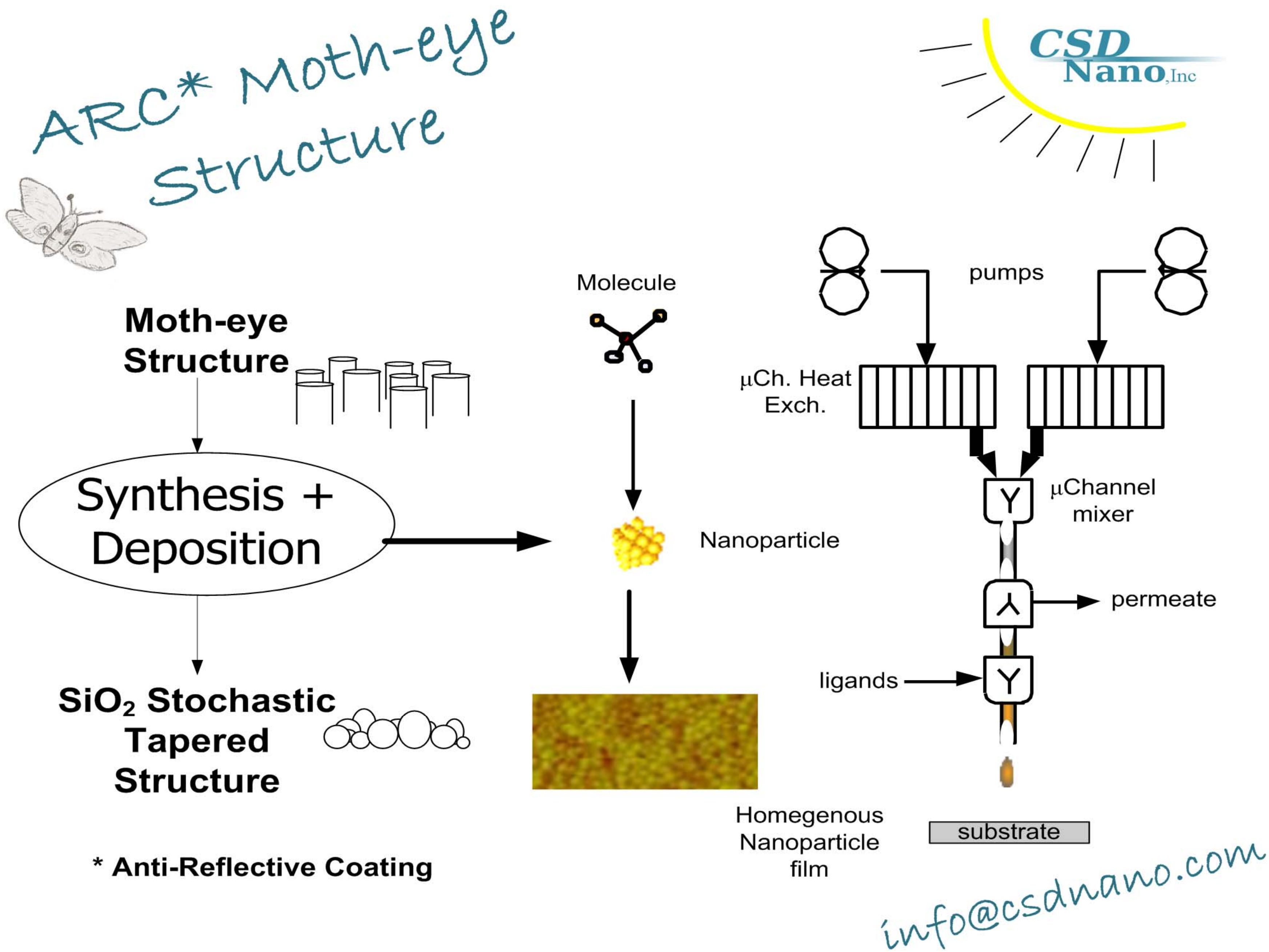
Photolysis





Photoadsorption

Photo Disinfection


ARC* Moth-eye Structure
CSD Nano, Inc
Moth-eye Structure
Synthesis + Deposition
SiO2 Stochastic Tapered Structure
* Anti-Reflective Coating
Molecule
Nanoparticle
Homegenous Nanoparticle film
pumps
μCh. Heat Exch.
μChannel mixer
permeate
ligands
substrate
info@csdnano.com

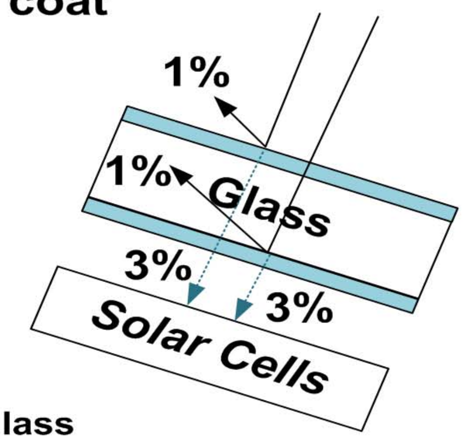
ARC* Moth-eye Structure

CSD Nano, Inc

* Moth-eye structure (<100nm) with polymer hard coat

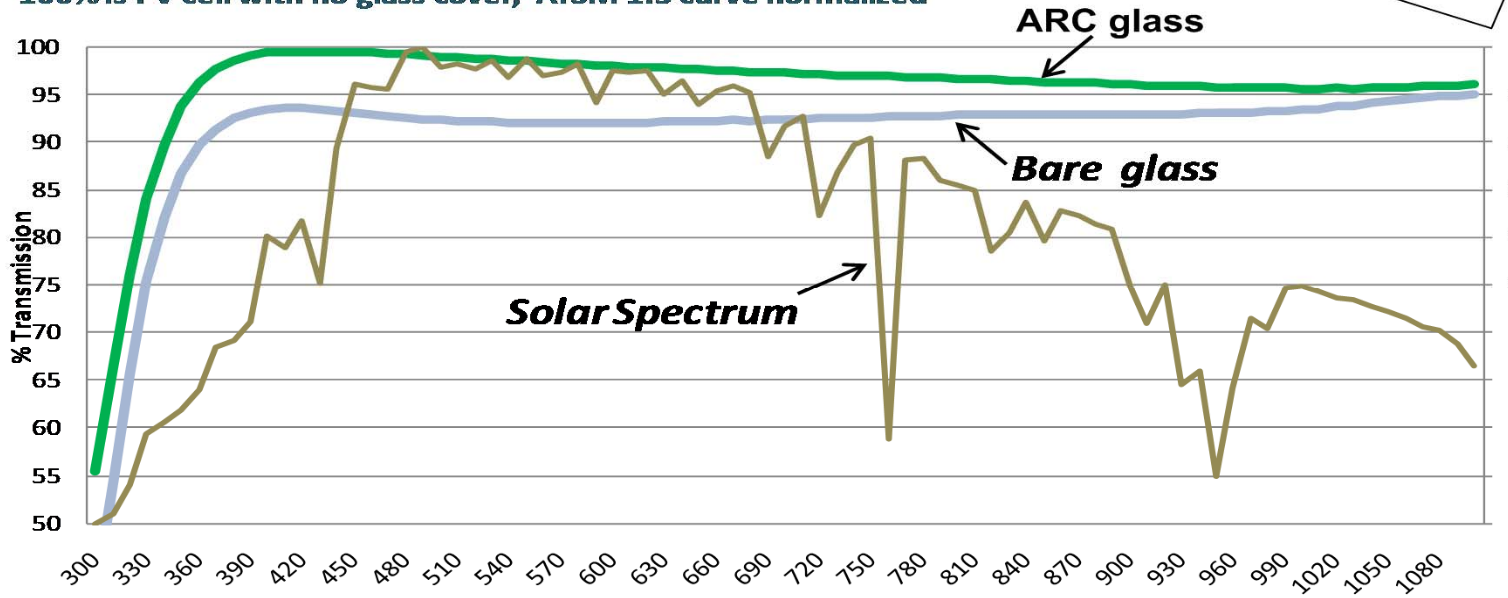
* Average 5.85% increase across 400nm-750nm
(3rd party measured, 12 Eagle 2000 solar cover glass)

* Excellent broadband and angle of incidence performance without extra film layers



Percent Transmission (%T)

100% is PV cell with no glass cover, ATSM 1.5 curve normalized



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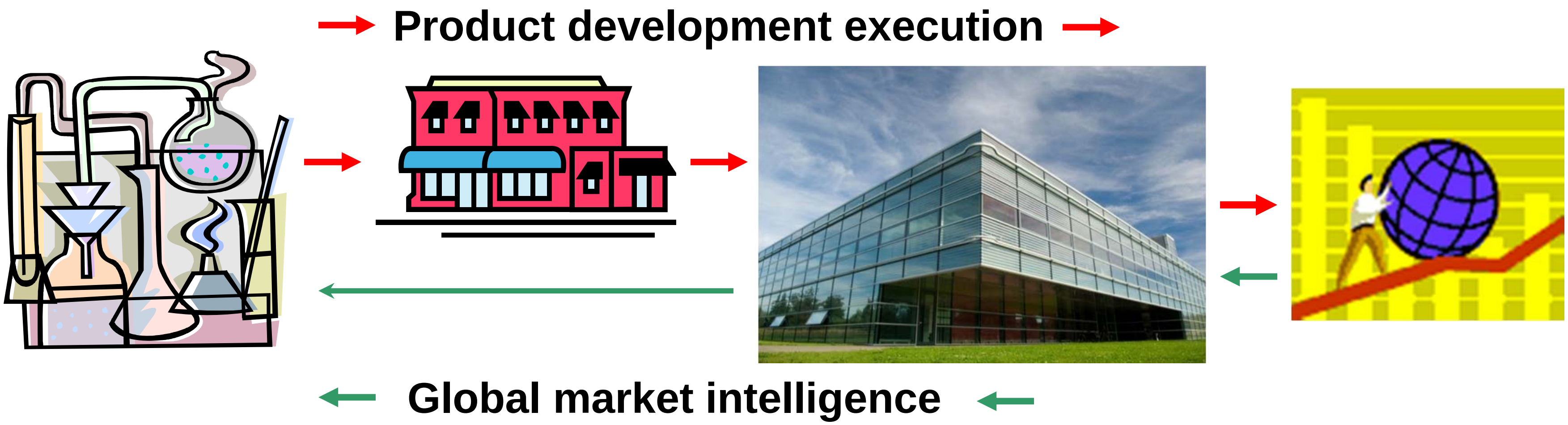

<u>Organizational roles/needs in technology commercialization:</u>

Research Institutions: scientific discovery, fundamental invention, talent development, shared user facilities. **Need:** public and philanthropic funding, enabling regulatory/legal environment

Startup companies: pioneering technology and market development of small - but disruptive – first opportunities. **Need:** equity/royalty licenses, large company customers/partners, high-risk (early stage) capital, minimal regulatory/legal burdens

Large companies: Manufacturing scale-up and global business development. **Need:** large & profitable “mainstream” markets, low-risk technology options

Summary: What it Takes

- Solid research base
- Successful industry cluster & workforce
- Locally and professionally managed gap & seed funding
- Local executive talent base and mentoring for new entrepreneurs and teams

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