Nanotechnology Commercialization in Oregon

February 27, 2012
Portland State University
Physics Seminar

Robert D. “Skip” Rung
President and Executive Director
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.
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

Therefore, “nano” and micro are key for national and regional prosperity.
Yes, You Can Lose Your Economic Base

The 10 Richest US Cities

Newport Beach, CA
Newton, MA
Pleasanton, CA
Arlington, VA
Santa Monica, CA
Mountain View, CA
Thousand Oaks, CA
San Francisco, CA
Sandy Spring, GA
Sunnyvale, CA

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

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

“Those Jobs Aren’t Coming Back”

(2010, ranked by average income)
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
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

- Grow research and talent development at Oregon universities
  
  **Metric: Federal and private awards and contracts**

- Support Oregon industry and start-ups with accessible shared high-tech facilities and tools
  
  **Metric: # of external clients, service revenue**

- Attract capital to Oregon start-ups 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

ONAMI Starts Operations
end of $10M in earmarks
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.

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.
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.

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.

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.
**ONAMI High Tech Extension**

### External Organizations Using SUF (Cumulative)

- **Users up >3x since inception**

### Clients by Market

- **Materials/Geo/chemicals**
- **Semi/solar/energy**
- **Bio/health**
- **University**
- **Government**
- **Other**

#### 1Q2012

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

### First-time user grants:

- Vitriflex, AI SThesis, Oral Biotech, Trimble, Inspired Light, Triquint, Microchip
## ONAMI Commercialization Gap Fund

<table>
<thead>
<tr>
<th>Technology Stage</th>
<th>Company Stage</th>
<th>Funding Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Result</td>
<td>(NA)</td>
<td>NNI Grants</td>
</tr>
<tr>
<td><strong>Proven Prototype</strong></td>
<td><strong>Formation</strong></td>
<td><strong>Gap Grants (state + federal)</strong></td>
</tr>
<tr>
<td>Products, Sales</td>
<td>Development</td>
<td>Early Stage Investors</td>
</tr>
<tr>
<td>Product Line Expansion</td>
<td>Growth</td>
<td>Various (private)</td>
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</tbody>
</table>

### 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

- ONAMI /Government Grants
- Research
- ONAMI Gap Grants
- Proof of Concept
- Early Stage Funds
- Product Proof
- Investor funded
- Revenue Generation
- Investor funded
- Growth / Cash Generation

Focus on interfaces and operations
# The ONAMI Gap Fund Portfolio, February 2012


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

$103M leverage to date, more pending
ONAMI Entrepreneurs In Residence

Team, Network, Market and 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
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
Sure, we’re all for innovation and job creation, but what about the downside/risks of “nano”?

Start Worrying -- Details to Follow!

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

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 functional 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

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1.</td>
<td>Prevent waste</td>
</tr>
<tr>
<td>P2.</td>
<td>Atom economy</td>
</tr>
<tr>
<td>P3.</td>
<td>Less hazardous chemical synthesis</td>
</tr>
<tr>
<td>P4.</td>
<td>Designing safer chemicals</td>
</tr>
<tr>
<td>P5.</td>
<td>Safer solvents/reaction media</td>
</tr>
<tr>
<td>P6.</td>
<td>Design for energy efficiency</td>
</tr>
<tr>
<td>P7.</td>
<td>Renewable feedstocks</td>
</tr>
<tr>
<td>P8.</td>
<td>Reduce derivatives</td>
</tr>
<tr>
<td>P9.</td>
<td>Catalysis</td>
</tr>
<tr>
<td>P10.</td>
<td>Design for degradation/Design for end of life</td>
</tr>
<tr>
<td>P11.</td>
<td>Real-time monitoring and process control</td>
</tr>
<tr>
<td>P12.</td>
<td>Inherently safer chemistry</td>
</tr>
</tbody>
</table>

### 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)

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Coupling Applications and Implications:
An integrative and prioritizing approach

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

<table>
<thead>
<tr>
<th>Safer Design</th>
<th>Green Nano-Material</th>
<th>Green Nano-Manufacture</th>
<th>Green Nano Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DUNE SCIENCES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce e-impact</td>
<td></td>
<td><strong>PERPETUA</strong></td>
<td></td>
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<tr>
<td>Waste Reduction</td>
<td></td>
<td><strong>ZAPS TECHNOLOGIES</strong></td>
<td></td>
</tr>
<tr>
<td>Process Safety</td>
<td></td>
<td><strong>CSD Nano, Inc.</strong></td>
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<tr>
<td>Materials Efficiency</td>
<td></td>
<td><strong>ESS, LLC</strong></td>
<td></td>
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<tr>
<td>Energy/ H2O Efficiency</td>
<td></td>
<td><strong>Puralytics</strong></td>
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</table>

[Image of logos and company names]
Inpria develops materials that enable vacuum-quality metal oxide thin films with the speed and low cost of solution processing.

Inpria Corporation (Corvallis, OR)

![Diagram of materials layers]

**Al Dielectric**
- 325 nm

**Thermal SiO₂**

**150 nm IGZO**

**1.6 nm TiO₂**

**Hf dielectric**

**Al dielectric**

**Polyacrylate**

**Mo**

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

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
  - Reduced Waste
  - Increased Yield
  - Elimination of Heavy Metals (Pb, Hg, Cd)

- Business Aspects
  - Reduced Cost
  - Increased Process Control
    (Particles of known size, shape and chemistry)

- Green Performance and Business Success are compatible.
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)
The World Needs Solid State Lighting

Worldwide Electricity Consumption

Lighting: 27%
4.7B KWh in 2009

Other: 73%

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 CO2 emissions by 8B tons (equal to the emissions from all of the passenger cars in the world)

Source: Canaccord Genuity
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”)
LED
NANOTECHNOLOGY
WATER
PURIFICATION

Green, Lean, and Mean

Mark Owen, CEO
Beaverton, OR

www.puralytics.com
Puralytics Solution

- 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

**Shield 500** – world’s first solid state water purification system

*Clean Tech Open 2010 Winner*
LEDs excite a nanotechnology coated mesh which destroys germs and chemicals

4 Patent Apps Filed, 3 Grants, Field tests successful
Shield #113 Performance

Fraction Removed at 500 gal/day

0% 20% 40% 60% 80% 100%

Caffeine (4 ppm) MTBE (1 ppm)
Photocatalytic Oxidation

Photocatalytic Reduction

Photolysis

Photoadsorption

Photo Disinfection
ARC* Moth-eye Structure

Moth-eye Structure

Synthesis + Deposition

SiO₂ Stochastic Tapered Structure

* Anti-Reflective Coating

Molecule

μCh. Heat Exch.

Nanoparticle

μChannel mixer

permeate

ligands

Homegenous Nanoparticle film

substrate

info@csdnano.com
* 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

- ARC glass
- Bare glass
- Solar Spectrum

1% Glass
3% Solar Cells
Organizational roles/needs in technology commercialization:

**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