**Auxiliary Information on 2011 Testimony**

**Commercialization and Potential for NanoScience Technology**
submitted to the
**Subcommittee on Science and Space**
of the
**Senate Committee on Commerce, Science, and Transportation**

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UNIVERSITY OF CENTRAL FLORIDA
RESEARCH & COMMERCIALIZATION

## NANOTECHNOLOGY IMPACT: Global, US, & Florida

**Nanotech Workforce:**

- The National Science Foundation estimates that **up to one million nanotechnology workers will be needed in the US itself** (Roco and Bainbridge, 2001)

- The referenced paper provides information on an interesting study on nanotechnology training programs previously implemented in NY, PA, CA and Mexico: "Training California's New Workforce for 21st Century Nanotechnology, MEMS, and Advanced Manufacturing Jobs" (Koehler, 2006)

**Global Trends:**

- Total worldwide sales revenues for nanotechnology were $11.6 billion in 2009, and are expected to increase to more than $26 billion in 2015, at a CAGR of 11.1% ("Nanotechnology: A Realistic Market Assessment", BCC Research, 2010)

- The largest nanotechnology segments in 2009 were nanomaterials, followed by nanotools (shows largest growth potential) and nanodevices ("Nanotechnology: A Realistic Market Assessment", BCC Research, 2010)

- Various governments **have appropriated $40 billion in global nanotechnology funding** over the last decade and **almost $10 billion more was added in 2010** ("Nanogeopolitics 2009: The Second Survey", ETC Group, 2009)

- In 2009, the **combined European Union member states spent 27% of the global nanotechnology funding, Russia spent 23%, US spent 19% and Japan spent 12%** ("Nanogeopolitics 2009: The Second Survey", ETC Group, 2009)

- The International Association of Nanotechnology (IANT), is a non-profit organization with the goals of fostering scientific research and business development in the area of Nanoscience and Nanotechnology
  http://www.ianano.org/

- Countries with extensive nanotech programs, both in private and government spending and research efforts include: Russia, Japan, Korea, Singapore, and UK

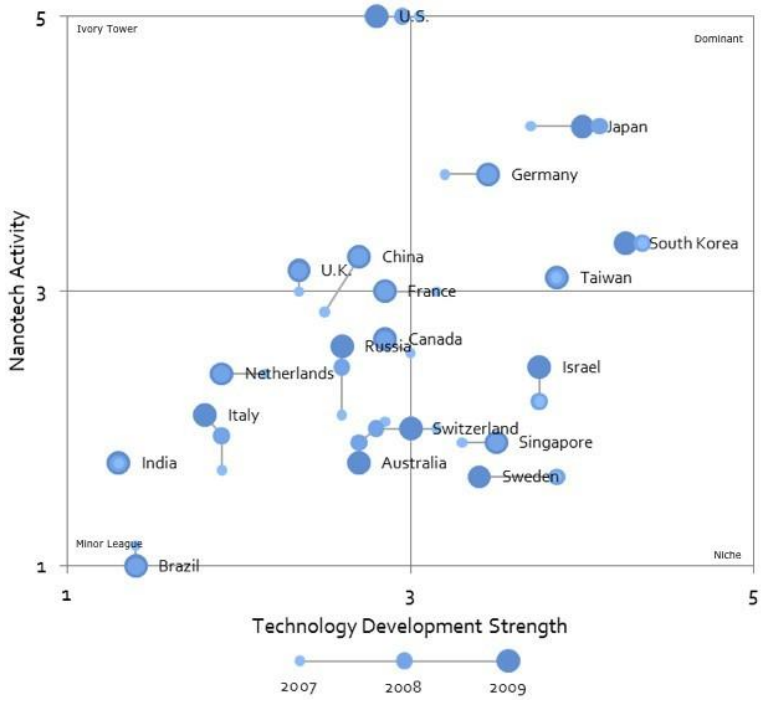
- **Russia**
  Rusnano, the state-sponsored nanotech investment arm founded in 2007, provides funding for research and commercialization of nanotechnology in an effort to revitalize the economy. As a direct result of the formation of Rusnano, Russia drastically improved its government funding, nanotech initiatives, nanotech R&D center scores, and publication counts. Rusnano has received more than 2,000 proposals for research products and centers, and approved 111 projects to date, in the categories of medicine and pharmaceuticals, energy efficiency and clean technologies, optics and electronics, coatings and surface modification, and nanomaterials.

Rusnano is **investing $500 million into Russian nanotechnology companies as well.** (DiChristina, 2011)

- **Japan**
  Though not as well coordinated or as well-funded as its US counterpart, Japan has a healthy government program and network of research centers for supporting nanotech, and its technology-oriented private sector helps to make up the funding gap. Patents and publication counts are healthy, and giant conglomerates like Toray and Sumitomo are very active in nanotech research and commercialization. Over 60 companies in nanotechnology are thriving throughout the country. These companies currently dominate in three markets – nanotubes, food, and semiconductors. The country and private sector **have invested over $1 billion** in funding towards nanotech (Haxton & Meade, 2009).
  http://www.nanonet.go.jp/english/aboutus/
  http://www.nanowerk.com/nanotechnology/Nanotechnology_Companies_in_Japan.php

- **China**
  Nanotech is a recurring theme in many of China's technology economic development plans, and both public and private funding has grown quickly over the years. The number of publications grew as an effort of Chinese scientists pursuing nanotechnology, but the patent count has remained similar to previous years. The nanotech companies that do exist in China are usually generic nanomaterial producers (such as Shanghai Huzheng Nano Technology Co. or developer Tianjin Tianhezhongxin Chemicals Co.), supporting the notion that China's research has produced little proprietary , and therefore, hardly commercial technology, to date.

- **India**
  India's Prime Minister has voiced concerns that India may be missing the nanotechnology wave (The Economic Times, 2011)




("Ranking the Nations on Nanotech: Hidden Havens and False Threats", LUX Research, 2010)

**US Trends:**

- The U.S. market is responsible **for more than 50% of the nanoproducts currently sold** throughout the world ("Nanogeopolitics 2009: The Second Survey", ETC Group, 2009)

- President **Obama's 2011 budget approved nearly $1.8 billion for the National Nanotechnology Initiative (NNI)** (Sargent, 2011)

- The **US Department of Energy is making the largest investment among the various NNI agencies, with $424 million** in 2011. (Harvey, 2011)

- **U.S. companies spent a total $3.2 billion** on nanotech-related research and development in recent efforts. (Harvey, 2011)

- From January 2008 to July 2010, **U.S. venture capitalists invested nearly $1.3 billion** in nanotech-related startups (Harvey, 2011)

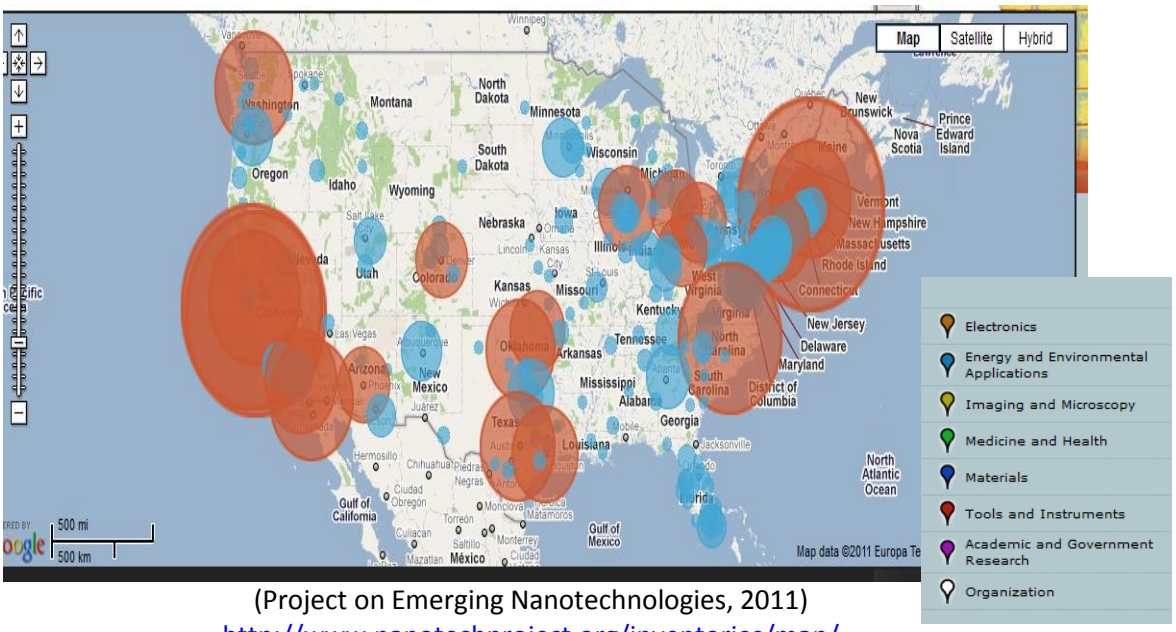
- Corporations (i.e. 3M and IBM), researchers, and private equity investors funded the National Nanotechnology Initiative, funneling billions of dollars into nanotech and attributing to thousands of patents filed on nanotechnology in 2009. ("Ranking the Nations on Nanotech: Hidden Havens and False Threats", LUX Research, 2010)

- The top 4 nanotechnology "economy-established" states, reported on parameters established by the Project on Emerging Nanotechnologies, are: California, Massachusetts, New York, and Texas. (Project on Emerging Nanotechnologies, 2011)

- All 50 states and the District of Columbia have at least one company, university, government laboratory, or organization working in the field of nanotechnology. (Project on Emerging Nanotechnologies, 2011)

- The top 6 Nano Metros (also based on criteria from the Project on Emerging Nanotechnologies) are: Boston; San Francisco; San Jose, Calif.; Raleigh; Middlesex-Essex, Mass.; and Oakland, Calif. (Project on Emerging Nanotechnologies, 2011)

- The number of US universities and government **laboratories working in nanotechnology is still substantial, with 182 identified as of 2011.** (Project on Emerging Nanotechnologies, 2011)




(Project on Emerging Nanotechnologies, 2011)
http://www.nanotechproject.org/inventories/map/

*STATE-SPECIFIC NANOTECH PROGRAMS*

- **Oklahoma NanoInitiative**
  The Oklahoma Nanotech Initiative (ONI) is a project coordinated by The State Chamber of Oklahoma and funded by the Oklahoma Center for the Advancement of Science and Technology (OCAST). In 2006, Oklahoma had over 50 scientists who were doing research in the nanotech field. The program appears weaker than its inception in 2005. Nearly all of the 50 Oklahoma-based companies with product lines involving nanotechnology are still in business since the initiative began. They cover a broad range of applications including medicine, sporting goods, cosmetics, textiles and optics.

  In 2006, state legislation pushed the Oklahoma Nanotechnology Sharing Incentive Act established the Oklahoma Nanotechnology Applications Project (ONAP) **which provides $2 million to state efforts** (Oklahoma Nanotech Initiative) to be used to promote and provide incentives to further "applications of nanotechnology". The ONI program has proved successful: "for the last three years, the return on the state's investment has been about 37 to one – **for every dollar the state spent, we brought $37 into the state**." (Fairchild, 2010). The state also

created “nano technician” jobs and education, as courses at universities and community colleges include: Nano Instrumentation, Nanotechnology and MEMS. The Oklahoma State Dept. of Career and Technology and OSU Okmulgee are partnered on an NSF grant to create the Oklahoma Nanotechnology Education Initiative that is currently being rolled out. Additionally, this nanotech initiative also has some of the most comprehensive K-12 education tools/multimedia in the country.

Notable, recently funded companies and research efforts include: Southwest Technologies (high-volume CNT production); Charlesson (improved eye disease drops); Amethyst Research (hydrogenation process for fire fighting, thermal mapping and border security); Caltech Global (hydrogen sulfide granular scavenging for oil/gas/landfill gas filtration); NanoBioMagnetics (drug delivery); University of Tulsa (nanobatteries); OK State U has **$51 million nanotech center,** 40 faculty/staff, and 100 grad students (nanofood/ag; nanowires, energy).

http://www.oknano.com/research.html
http://www.oknano.com/oklahoma_companies.html
http://www.ok.gov/ocast/Programs/Oklahoma_Nanotechnology_Applications_Project_%28ONAP%29/index.html

- **Texas NanoInitiative**

  Dallas/North Texas initiatives developed after donations to the University of Texas at Dallas to create the Alan G. MacDiarmid NanoTech Institute. The donor was the founder of Zyvex Labs, claimed the world’s first nanotech company. Several large corporations in the area have since started nanotech programs in the area including: Texas Instruments, Raytheon, and Lockheed Martin. These companies have initiated these programs in the local universities, rather than internally, to reduce R&D financial risks.

  VCs **invested $57 million in Texas-based nanotech companies** (Harvey, 2011). From April 2006 to October 2010, the state-run Texas Emerging Technology Fund (ETF) funded **about $22 million in grants** for nanotechnology-related research at Texas universities (Harvey, 2011). During the same period, the ETF **invested about $14.6 million in companies** (Harvey, 2011) looking to commercialize nanomedicine, nanoelectronics, and nanomaterials products.

  Major university players and associated projects/applications: U of Texas-Dallas (CNT airplane paint, superconductive power cables, Solarno PV spin-out, CNT artificial muscles); U of Texas – Arlignton (solar cell coatings, medicine toxicity/reaction biosensors).

  http://www.dmagazine.com/Home/D_CEO/2011/January_February/Technology_Issue/North_Texas_Research_Pushes_Future_of_Nanotechnology.aspx?p=1

- **Colorado Initiatives**

  The Colorado Nanotechnology Alliance is not-for-profit economic development organization governed by a strong board of directors whose core represents nanotechnology companies in the state. The Alliance **has more than 75 companies which employ 19,000 workers at an average salary $55,720.**

CU-Boulder has emerged as a significant academic nanotech player. The Nanoscale Science and Technology for Integrated Micro/Nano-Electromechanical Transducers (iMINT) was built on a DARPA grant and now has more than $2.5 million in research funding from the govt, Lockheed Martin, GE and Raytheon (Nanotechnology Now, 2008). More than 100 faculty in engineering, biology, chemistry, physics, dentistry, pharmacy, and medicine from CU-Boulder and the Anschutz Medical Campus in Denver are involved in micro/nano technology research in some way. (Nanotechnology Now, 2008).

Major university players and associated projects/applications: CU at Boulder (electronics thermal management, nanoscale characterization, melanoma detection); ITN Energy (solar); Colorado State University (extreme UV pulse lasers); CO School of Mines (works 100+ companies in materials processing research).

http://www.coloradonanotechnology.org/home/index.ph p
http://www.colorado.gov/cs/Satellite/OEDIT/OEDIT/1167928387048
http://ncf.colorado.edu/?p=news&sub=tinytech&id=63

- **California Initiatives**

The state has fragmented nanotechnology efforts. One of the state's main areas is in nanomaterial safety and hazards, under the California Department of Toxic Substances Control, which is partnering on these efforts with the US EPA. The Northern California Nanotechnology Initiative, NCnano, is an economic development initiative focused on developing the nanotechnology and the nano-bio-IT convergence technology economy of Northern California. Started in 2003, the Initiative's goals included bringing $6B in nanotechnology investment/grant money to the areas and to create 150,000 new local jobs (North California Nanotechnology Initiative).

The state's nanotech efforts are dominated by the universities. Every major state university has nanotechnology centers, as do notable private institutions. The California Institute of Nanotechnology offers training and commits research entirely in the nanotechnology field. The center works with the Cleantech Institute in the areas of renewable energy and clean tech. The Institute is primarily working in energy storage (novel batteries and fuel cells) as well as drug delivery mechanisms.

The national labs of Sandia and Lawrence Berkeley both have extensive nanotechnology programs in the particular areas of CNTs, nanocomposite alloys, and nanoporosity, and a molecular foundry focused on energy, respectively. Other university research efforts of note include: University of South CA (nanowires, graphene thin films); UC of Santa Barbara (NSF funded "nanotech in society" center which studies politics, economics, etc.); $100 million funded UCLA's NanoSystems Institute **has $350 million in research and development grants from industry** (nanotoxicology, carbon dioxide capture, drug delivery) (The New York Times, 2009); Librede (drug screening); NanoH2O (reverse osmosis/filtration); QuantumSphere (battery material enhancement); and CFX Battery Inc. (lithium ion batteries).

http://www.ncnano.org/
http://www.dtsc.ca.gov/TechnologyDevelopment/Nanotechnology/nanoport.cfm
http://www.dtsc.ca.gov/TechnologyDevelopment/Nanotechnology/nanopartners.cfm

http://www.cinano.com/Training/index.html
http://dealbook.nytimes.com/2009/07/16/californias-glimmer-of-hope-nanotechnology/
http://foundry.lbl.gov/

- **New York Initiatives**

In 2010, the Empire State Development (ESD) and the New York State Foundation for Science, Technology and Innovation (NYSTAR) today announced the merger of two of New York State's Centers of Excellence- Infotonics Technology Center (ITC) in Canandaigua and the Center of Excellence in Nanoelectronics and Nanotechnology at the College of Nanoscale Science and Engineering (CNSE) in Albany. Empire State Development and NYSTAR **will invest up to $10 million to the merged operation**, the Smart System Technology & Commercialization Center (STC), which will be managed and supported by CNSE.

CNSE's Albany NanoTech Complex has **$7 billion in investments** and is **an 800,000-square-foot** complex (College of Nano Science and Engineering, University of Albany). The UAlbany NanoCollege houses the only fully-integrated, 300mm wafer, computer chip pilot prototyping and demonstration line within 80,000 square feet of Class 1 capable cleanrooms ("New York State Announces…", Nanowerk, 2010).. **More than 2,500 staff the complex**, from companies including IBM, AMD, GlobalFoundries, SEMATECH, Toshiba, Applied Materials, Tokyo Electron, ASML, Novellus Systems, Vistec Lithography and Atotech. A new goal is to expand the complex to 1,250,000 square feet of next-generation infrastructure housing over 105,000 square feet of Class 1 capable cleanrooms and more than 3,750 staff. In a **$10 million joint development project**, Apic Inc.'s photonics systems and devices will be combined with the CNSE's nanoelectronics resources, to result in at **least 20 jobs over the next 18 months** (College of Nano Science and Engineering, University of Albany)**.** Moser Baer Technologies is investing more than **$17 million** at CNSE, acquiring state-of-the-art equipment for the pilot production line, creating more than **50 high-tech jobs by 2013** (Smart Systems Tech, 2011).

The Infotonics Technology Center of Excellence in Photonics & Microsystems is a technology commercialization center that maintains **140,000 square-foo**t with over 25,000 square feet of cleanrooms for MEMS fabrication and packaging ("New York State Announces…", Nanowerk, 2010). ITC works with industrial participants such as Corning Inc., Eastman Kodak Company, and Xerox Corporation. Academic participants include **approximately twenty New York State colleges and universities**, including the Rochester Institute of Technology and the University of Rochester.

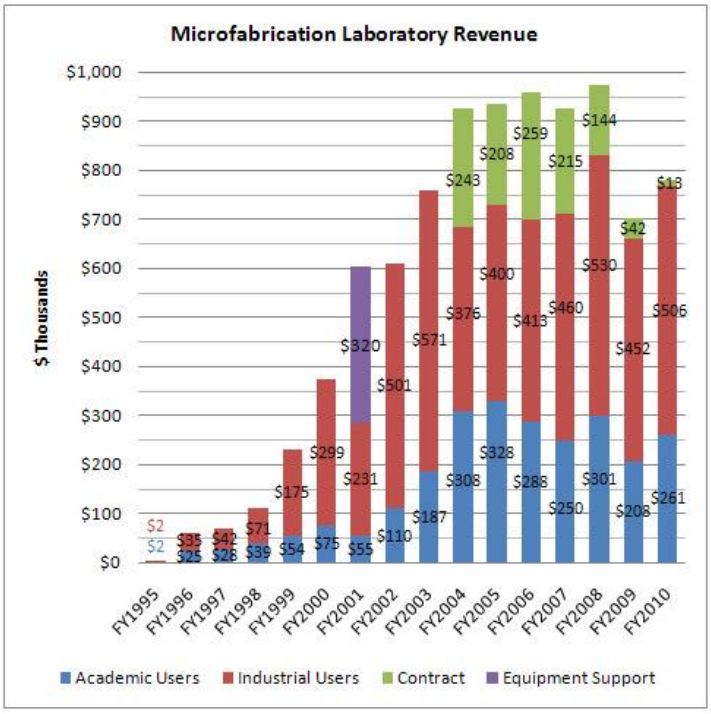
Notable research/commercial entities include: CNSE U of Albany (PV control/monitoring center, photonic integrated circuits, solid state lighting); IBM of Yorktown Heights (CNT); Rensselaer Polytechnic Institute (thin films novel planarization and metallization); Auterra/Applied Nanoworks (specialty inorganic compounds); NanoMas (nanoparticles for printed electronics).
Full database of NY research in nanotechnology:
http://www.nystar.state.ny.us/rsch/nanotech.htm

http://www.nanowerk.com/news/newsid=18133.php
http://www.nylovesnano.com/industry/industry.php?m=5
http://www.nynanobusiness.org/
http://www.research.ibm.com/nanoscience/

http://cnse.albany.edu/WorldClassResources.aspx
http://cnse.albany.edu/LeadingEdgeResearchandDevelopment/ResearchProfiles/ProfilesArchive.aspx
http://dpwsa.electroiq.com/index/display/photovoltaics-article-display/2478462125/articles/Photovoltaics-World/industry-news/2011/6/cnse-nanotech-complex-plans-pv-control-center.html
http://www.itcmems.com/news_June.html

- **Washington Initiatives**

The Washington Technology Center, Avogadro Partners, LLC, the University of Washington, Washington State University and Battelle's Pacific Northwest National Laboratory, with seed funding sponsored by Senator Maria Cantwell, have come together to launch the Washington Nanotechnology Initiative (WNI). The state has many expectations for a nanotechnology economy that are complementary to its current infrastructure. The graphs below show trends that exist or are anticipated in the state.




Microfabrication Lab Revenues (Washington Technology Center, 2005)

| KEY WASHINGTON SECTORS FOR NANOTECH | Location Quotients[3] | Jobs 2003[4] | Jobs 2012 est[5] |
|---|---|---|---|
| Transportation Equipment | 2.37 | 76,218 | 75,000 |
| Aerospace Manufacturing | 8.12 | 65,274 | 62,000 |
| Energy | 1.00 | 15,072 | 20,000 |
| Electronics | 1.00 | 22,238 | 28,000 |
| Instrumentation | 1.13 | 10,119 | 12,000 |
| Life Sciences | 1.09 | 18,706 | 25,000 |
| Agriculture | 3.29 | 71,038 | 70,000 |
| Software | 7.51 | 37,005 | 50,000 |
| Telecommunications | 1.19 | 23,477 | 28,000 |
| Other IT | 1.75 | 22,002 | 28,000 |
| TOTAL | | 361,149 | 398,000 |

(Washington Technology Center, 2005)

Notable research efforts: U of Washington (malaria testing, biomaterials, jointly work with PNNL).

http://www.watechcenter.org/resources/washington-nanotechnology-initiative
http://www.avogadro.us/news/2005/05/new-washington-state-nanotechnology.html

- **South US/Georgia/NC Initiatives**

  The National Science Foundation's National Nanotechnology Infrastructure Network has two facilities in the South: the Microelectronics Research Laboratory at Georgia Institute of Technology, and the Microelectronics Research Center at the University of Texas-Austin.

  The National Cancer Institute's Centers of Cancer Nanotechnology Excellence include the Nanotechnology Center for Personalized and Predictive Oncology, which is an Emory University-Georgia Tech partnership, and the Carolina Center of Cancer Nanotechnology Excellence at the University of North Carolina.

  http://www.techjournalsouth.com/2010/11/coin-seeks-materials-from-nc-nanotech-firms-for-dc-conference/

- **Ohio Initiatives**

  The Center for Multifunctional Polymer Nanomaterials and Devices (CMPND) was formed as a research and commercialization partnership in polymer nanotechnology. Centered at The Ohio State University, CMPND works with the University of Akron and the University of Dayton, three additional Ohio universities, 50 large and small Ohio companies, the National Composite Center,

polymer organizations and national labs, all situated in Ohio. **CMPND was awarded $22.5M from the State of Ohio Third Frontier Project and in return will contribute more than a total of $78M toward nanotechnology research and commercialization**. CMPND seeks to have a statewide economic impact by expanding existing business and creating and retaining **more than 5,000 high-paying 'white collar' jobs and 20,000 to 25,000 skilled manufacturing jobs** (Center for Multifunctional Polymer Nanomaterials and Devices).

Over 50 small and large companies, serving the industries of automotive, aerospace, biomedical, consumer products, electronics, and materials engineering**; have contributed nearly $49 million** of support to develop CMPND. The Universities (OSU, UD, UA, KSU , UT and WSU) have added **additional support of over $28 million, providing support to CMPND totaling more than $77 million, over three years** (Polymer Ohio, 2004). Along with names such as Honda, Delphi , Goodrich, Lockheed Martin, Goodyear Tire, MeadWestvaco, Boeing, Ashland , AES/Exxon Mobile, Milacron, Noveon, and Timken on the list, are the large companies of Ohio 's future: Applied Sciences, Cornerstone Research (R&D services), Nanosperse (design services), Maverick (hi-temp materials), Nanofilm (thin films for glass coatings and stain proofing), Sajar Plastics (injection micro-molding), Vector Composites (advanced composites), and WebCore Technologies (core composites).
http://www.polymerohio.org/download/pdf/NanoVer2.pdf
http://cmpnd.org/index.php?option=com_content&view=article&id=45:polymer-industry-is-ohios-largest-at-49-billion&catid=1:latest-news&Itemid=50

- **Pennsylvania Initiatives**

The Pennsylvania Initiative for Nanotechnology (PIN) is a statewide strategy that currently combines the efforts of the Pennsylvania Department of Community and Economic Development (DCED), the Commonwealth's research universities, the Pennsylvania State System of Higher Education, **over 125 companies**, and economic development organizations. PIN is leveraging Pennsylvania's clusters of research, industry, and workforce development assets to make Pennsylvania a global leader in nanotechnology research, commercialization and economic development activities. Using worldwide forecasts, Pennsylvania is projected to **produce at least $7.75 billion worth of nanotechnology products by 2015** (Pennsylvania Commonwealth)**.**

The Pennsylvania NanoMaterials Commercialization Center is **making available $700,000 in funds.** The Center invites Pennsylvania university researchers and companies to submit proposals for funding early-stage commercialization of nanomaterial research for energy applications. The Center is particularly interested in technology development focused on renewable, clean and efficient energy solutions. The Center was founded in 2006 under the auspices of the Pittsburgh Technology Council by a consortium of four western Pennsylvania companies; Alcoa Technology, Bayer MaterialScience, PPG Industries and US Steel. Today, the Center enjoys partnerships with Carnegie Mellon University, University of Pittsburgh, Penn State University, Lehigh University, the Department of Community and Economic Development for the Commonwealth of Pennsylvania, Air Force Research Labs and approximately 300 companies, organizations and individuals involved in nanotechnology.

Since 2007, the Pennsylvania NanoMaterials Commercialization Center has provided seed grants to 15 companies to support 19 early stage prototype development projects using nanotechnology and three pre-commercialization projects with universities. The total public investment has been $4,191,582, which has been matched by the recipient companies in the amount of $2,994,388. Recipients reported the following economic impact from this investment: **115 jobs created** and retained, **$43,219,000 leveraged investment by companies** due to the Center's funding, and **17 new patents filed** (NanoVIP, 2010).

Notable research projects include: U of Penn (monitoring molecular motions, single molecule probes, biomolecular optoelectronics); Penn State U (buckyballs, acoustic tweezers, nanodomes, strong in nano education); Carnegie Mellon (atom transfer radical polymerization, conductive organic materials, magnetic nanocrystals); Metalon Inc. (molecular inks); Illuminex (Si nanowire solar equipment).

http://www.gonano.psu.edu/facts/
http://www.newpa.com/build-your-business/key-industries/high-technology/nanotechnology
http://www.pananocenter.org/nano-center-about.aspx
http://www.nanovip.com/pa-nanocenter-awards-250k-to-pa-based-nanotechnology-companies-releases-industry-impact-data.html

- **Massachusetts Initiatives**
  Most data, groups and websites are available before 2005. Here is what they started their initiative with. Massachusetts had over **100 self-identified nanotechnology** firms and **over $110 million in venture capital** was invested in nanotechnology firms in 2003. The existing industries of bio/pharma, medical devices, semiconductor equipment, and material innovations drove clusters within the nanotech start-ups. The state also has major nanotechnology research centers at most university campuses, and three of these are National Nanotechnology Initiative Centers of Excellence: MIT Soldier Nanotechnology Center, Harvard Center for the Science of Nanoscale Systems and their Device Applications, and Northeastern University/UMass Lowell/ University of New Hampshire Nano Science & Engineering Center.

  http://www.masstech.org/mni/

**Florida Trends:**

Florida is also making strategic investments in the new and promising field of nanotechnology. The nanotechnology cluster in Florida includes at **least three dozen companies.** In addition, Florida universities are also busy building the infrastructure needed to conduct high-quality R&D in the field.
http://www.eflorida.com/ContentSubpage.aspx?id=316

**Why the nanotechnology market is not necessarily worth $1.5 trillion now: An article by Nanowerk regarding whether the market report numbers available on the industry thus far have been inflated.**

Estimates of the global **nanotechnology market** in 2010 ranged from about $15.7 billion to $1 trillion. By 2015, the market may be worth more than $2.4 trillion, according to different analysts. These differences reflect not only different analytical methods and assumptions, but also different definitions of the **nanotechnology market** (e.g., whether to include decades-old technologies such as carbon black rubber reinforcers and photographic silver, or whether to base the market value on nanotechnology inputs alone, as opposed to the total value of products that incorporate nanotechnology).

In the latest Lux report, a trusted source amongst the nanotechnology industry, a pragmatic decision was made to exclude certain types of materials and devices from the report that technically fit the definition of nanotechnology. These exceptions include carbon black nanoparticles used to reinforce tires and other rubber products; photographic silver and dye nanoparticles; and activated carbon used for water filtration. These materials were excluded because they have been used for decades, long before the concept of nanotechnology was born, and their huge volumes (especially carbon black and activated carbon) would tend to swamp the newer nanomaterials in the analysis.

Nanoscale semiconductors are also excluded from the study, although the tools used to create them are included. Unlike carbon black and activated carbon, nanoscale semiconductors are a relatively new development. However, they have been analyzed comprehensively elsewhere, and like carbon black and activated carbon, would tend to overwhelm other nanotechnologies by their sheer volume in the out-years towards 2015.
http://www.nanowerk.com/spotlight/spotid=1792.php

## MARKET OPPORTUNITIES

**APPLICATIONS OF MOST PROMISE:**

1.) Thin films in solid state devices (i.e. energy, lighting, semiconductors)

2.) Surface treatments/functionalizations (i.e. wet/stain proofing, improving cell/DNA/molecular particle adhesion)

3.) Drug delivery

4.) Semiconductors/memory devices

5.) Wireless sensor networks (i.e. dust nodes)

6.) Printed/flexible electronics

7.) Smart textiles

Other opinions – The following list provides applications of nanotechnology the Oklahoma Nano Initiative anticipated to be of great commercial success, by year ranges:

- 2004-7 burn and wound dressings, water filtration devices, paints, cosmetics, coatings, lubricants, textiles, memory/storage devices

- 2008-10 – medical diagnostics, displays, sensors, drug delivery, composite materials, solid state lighting, bio-materials, nano arrays, more powerful computers, protective armor, chem-bio suits, and chem-bio sensors

- 2011-15 -- nanobiomaterials, microprocessors, new catalysts, portable energy cells, solar cells, tissue/organ regeneration, smart implants

- 2016 and beyond – molecular circuitry, quantum computing, new materials, fast chemical analyses

  (Oklahoma Nano Initiative)

**BIG PLAYERS:**

Almost every technology based Fortune 100 company has some nanotechnology initiative. Several of these corporations have in-house venture arms or other mechanisms that would seek out nanoscale technology research from any source. Here are the larger players and what domain their nanotechnology programs belong to. That is then followed by specific profiles of companies with very specific, yet unique nanotechnology product lines.

*Defense/Security:*
- Lockheed Martin
- Raytheon

*Health/Food/Cosmetics:*
- Proctor & Gamble
- Kraft
- Nestle
- GlaxoSmithKline
- Johnson & Johnson
- Unilever
- Amgen
- Baxter

*Consumer Electronics:*
- NEC
- Xerox
- Microsoft
- Nokia
- Fujitsu
- HP
- Canon
- Philips

- Samsung
- HItachi

*Semiconductors/Mfg Equipment:*
- ST
- Intel
- Texas Instruments
- Lucent Technologies
- AMD
- ASML

*Chemicals:*
- Sumitomo
- BASF
- Dupont
- Dow
- Degussa
- Cabot
- Air Products
- Praxair

*Agriculture:*
- Monsanto

*Energy:*
- ExxonMobil
- ConocoPhillips
- ChevronTexaco
- Siemens
- GE
- Mitsubishi

*Consumer Products:*
- Wilson
- Easton

*Transportation:*
- GM
- DaimlerChrysler
- BMW
- Caterpillar
- Boeing

Specific Corporate Nanotechnology Product Profiles:

**Raytheon -** Along with partners, DuPont and Partners Healthcare, Raytheon currently sponsors the Institute for Soldier Nanotechnology at Massachusetts Institute of Technology. They act as liaison to the

Institute's Network Centric Systems group. The collective group is re-designing body armor materials to mimic the iron sulfide rich, uniquely structured shell of particular snails.
http://www.raytheon.com/newsroom/technology/rtn10_snail_armor/index.html

**ExxonMobil -** Sarnoff Corporation entered a five-year strategic agreement with ExxonMobil Research and Engineering Company (EMRE), in 2005, to commercialize EMRE's groundbreaking portfolio of mesoporous materials. Sarnoff was tasked to market outside of the petrochemical industry. The materials, which include novel high surface area silicas, were among the first nanomaterials ever created and have been commercialized by ExxonMobil for its own use.
http://www.nanotech-now.com/news.cgi?story_id=12688

**BMW -** BMW established a group of a dozen plus materials scientists to scan the field of nanotechnology and its applications in various industries. The idea was to initiate projects which would lead to the use of nanotechnology in BMW automobiles. That resulted in BMW applyings applications of nanotechnology in some models. There are now rear window systems in the 5 and 7 series cars which feature a "nanolayer laminate." This ultra thin layer helps reflect the heat of the sun while at the same time allowing in electromagnetic signals for telephone and other applications.

**Johnson & Johnson -** J&J concentrates on the areas of kidneys, diabetes, and cardiovascular systems and is looking towards nanotechnology for personalized medicine applications. J&J's biopharma interests include the areas of trophic, restore/replace, small molecules, and biological organisms. J&J recently invested in nanotech and in particular, start-up, Vesta Organano, though their partnership is not fully disclosed on all details.
http://organano.com/

**Kraft** - In 2000, Kraft Foods began sponsoring the NanoteK Consortium. The members of the Consortium include researchers from 15 universities, three national labs and three start-up companies. Harvard University, the University of Nebraska, the University of Connecticut, Los Alamos and Argonne National Laboratories, the Universities of Seville and Malaga in Spain and Uppsala University in Sweden are some of the institutions involved in this collaboration. Some of the research areas identified by the consortium members are the development of low cost sensors that detect the presence of foodborne pathogens, filters for removing undesirable compounds from foods and beverages, and nanoparticles to store flavors and nutrients inside food and release them at designated organs in the body when they are needed.

**Nestle** - Nestle's research center in Switzerland assigned a group of scientists to investigate the potential benefits of nanotechnology for food systems. Nestle was exploring nutraceuticals--nano-capsules that deliver nutrients and antioxidants to specific parts of the body at specific times. The technology turns previously insoluble nutrients into nano-sized particles that can be released into the body and properly absorbed, with big potential benefits for a whole new kind of health food.

**Lockheed –** Lockheed Martin has had a corporate focus on nanotechnology for the past 7 years which has helped shape the development of nanotechnology applications in all of its four Business Areas. Nanotechnology is one of 15 strategic technology threads in Lockheed Martin which focus on technologies that enable strategic growth. There is an on-going corporate funded project to develop ultra light weight structures. This project includes the development of processes for growing carbon nanotubes and testing new substrates and materials. The expected outcome is higher performance, lighter weight, and lower cost materials for many of our subsystems. Furthermore, the company is

hiring the best and the brightest in this space, creating job titles with “nanotechnology” in the name and job expectations.

**Caterpillar/Firefly Energy**

In 2006, in a hushed deal between Caterpillar and Firefly Energy, a joint venture was struck to develop a battery comprised of an electrical current collector constructed of carbon or lightweight graphite foam. This foam exhibited a sizeable increase in surface area for chemical reactions to take place and eliminated the need for heavy lead plates found in traditional batteries. The graphite material resists corrosion and sulfation build-up, thus contributing to longer battery life and is lighter in weight than today’s lead acid batteries. The nanotechnology application at Firefly Energy pertains to the battery’s grid coating process, which refers to the nanoscale nature of the coating.

## TECHNOLOGY BACKGROUND

**Nanotechnology 'Formats' Basics:**

While each format of nanotechnology harbors different mechanical, optical and electrical properties, their cost to produce and feasibility of scale-up varies just as much. These unique formats with different process procedures include:

1.) Nanotubes (i.e. Carbon Nanotubes [CNT])

2.) Nanoparticles

3.) Thin films

4.) Self-assembled monolayers

5.) Sol-gels

http://www.nanomagazine.co.uk/index.php?option=com_content&view=article&id=824&Itemid=139

6.) Nanocomposites

8.) Nanotools (i.e. nanolithography tools and scanning probe microscopes)

9.) Nanodevices (i.e. nanosensors and nanoelectronics)

**Commercialization Hurdles and Risks:**

- Manufacturing/scale-up is a challenge for nanotechnologies – Thin films/surface treatment deposition techniques are often expensive because they require large vacuum chambers and/or complex chemical/gas vapor management systems. In high volume, large surface area applications, the scale up of chambers and vapor systems can increase costs by at least one order of magnitude. Furthermore, such geometrically limited systems with low vacuum pressure requirements, cannot accommodate the cost-effective manufacturing that is afforded by roll-to-roll production. Other production complications are due to the sheer scale-up of producing nanoscale products. Lastly, metallic and ceramic nanoparticles are very difficult to produce in uniformity, and are especially difficult to uniformly produce in high volume manufacturing.

- Nanoscale devices operate in a new realm of physics. Known as "scaling phenomena", scientists cannot predict how these devices will operate when compared to macroscale systems. Simulations and modeling techniques are still under investigation as researchers delve further into nanotechnologies.

- There are a number of FDA hurdles for nanoparticles, as the only nanoparticles approved by the FDA for commercial use are Dendrimers, a particular type of polymer-based nanoparticle with a

limited scope of attributes. The main reason by the FDA for slow approval of all nanoparticles refers to the first complication of unreliable uniform production. Any metallic or ceramic nanoparticle is susceptible to poor uniformity in bulk production, and if these particles should be less than 100 nanometers in diameter, FDA staff are not sure of the consequences of live cells/tissue. The FDA fears that sub-100 nm particles could interact with DNA and/or cause cell damage.

- Because of many of the above hurdles regarding unknown information on the technology, nanotechnology product development cycles are very long.

- Venture capitalists, who typically invest in early stage start-ups, especially from university resources, are investing in nanotech, but not aggressively, due to the long cycles it takes from discovery to commercial viability.

- The US stronghold on R&D talent across all science and technology fields is diminishing. Compared to other developed countries, students in the areas of science and technology are not performing as well in their subjects are their peers in other nations. Also, the number of graduates with tertiary science and engineering degrees per capita in the US is among the lowest of the developed countries -- less than half of that of Taiwan, South Korea, and Singapore, and less than one-third the amount in Russia -- which is a grave concern for the US's technology development strength in the long-term. ("Ranking the Nations on Nanotech: Hidden Havens and False Threats", LUX Research, 2010)

**Additional Resources/Sites:**

http://science.house.gov/sites/republicans.science.house.gov/files/documents/hearings/Tour%20Testimony.pdf

http://www.nanotechproject.org/inventories/map/

http://www.nanotechproject.org/news/archive/putting_nanotechnology_on_map/

http://2020science.org/2011/01/04/us-national-nanotechnology-initiative-draft-ehs-strategy-good-in-part/

http://knowledge.wharton.upenn.edu/article.cfm?articleid=1413

http://crnano.typepad.com/crnblog/2007/02/nanotechnology_.html

*** http://www.electroiq.com/articles/stm/2010/08/ranking-the-nations.html

http://www.austrade.gov.au/Invest/Opportunities-by-Sector/Advanced-Manufacturing/Nanotechnology/default.aspx

http://grouper.ieee.org/groups/nano/**initiatives**.htm

http://www.technologyreview.com/computing/13533/

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