Global developments in nanotechnology commercialization

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Anticipating nanotechnology commercialization: Some questions which need better answers

- The shift from discovery to application in nanotechnology ..
  - But when? How?
  - What kinds of applications? (Passive v. active?)
- Who is turning nanoscience knowledge into nanotechnology innovations?
  - Type of companies? Locations?
- To what extent is a nanotechnology system of innovation developing?
  - Or is it multiple systems?
- How do companies address uncertainty in nanotechnology applications?
  - Technical? Regulatory? Market? Competitive?
- How can we feed insight about nanotechnology commercialization into the processes of anticipatory governance?

Nanotechnology commercialization

“Knowns” and “Unknowns”

“**Knowns” (or better “knowns”)**

- Corporate entry into nanotechnology through research publications and patenting
- Geographical concentration of corporate entrants in nanotechnology
- Linkages with public research and universities
- First generation consumer-oriented products

“Unknowns” (or mostly “unknowns”)

- Corporate strategy (in the face of uncertainty)
- Influence of contrasting regulatory environments on corporate strategies in nanotechnology
- Fit in the global supply chain v. inventive activity
- International boundaries, consumer values and demand
- Employment and labor market implications

Starting Point:
Base Analysis

CNS-ASU Program in Nanotechnology Research and Innovation at Georgia Tech

- Identified **more than 13,000 corporate establishments worldwide**, with either publications or patents

Data Sources

- ISI-WoS (1990-2008)
  - More than 500K publications
- Patstat (1990-July 2008)
  - 71K patent applications
  - 27K patent grants
- Corporate data:
  - Analysis at the establishment level (unique city, country locations)
  - Location data availability:
    - About 100% for publications
    - About 29% for patent app., 52% for patent grants
- Variations in the clean up process might increase coverage and counts (need to assume location for records with unreported location)

Country example 1:
US – leading-edge of nano commercialization

Companies

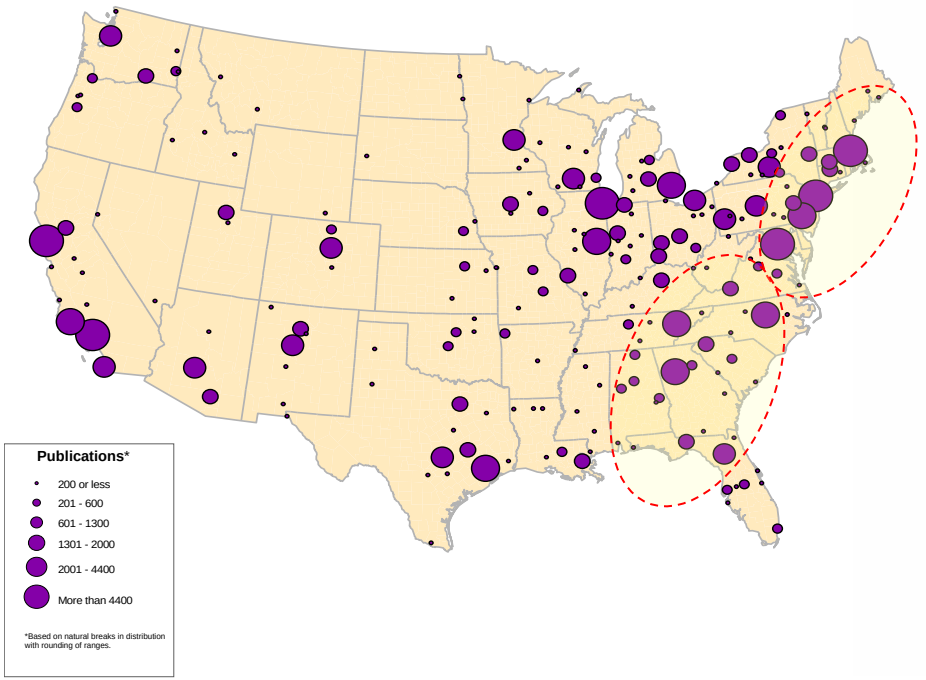
- Diverse: large established companies, SMEs, new start-ups; in high technology and more traditional industries.
- 53% of products in PEN dataset originated in the US
- Number of companies with engagement in nanotechnology through patents or publications is 5,600 in the US.
- Majority of assignees are companies rather than universities
  - IBM, HP , 3M, GE, EASTMAN KODAK
- Large companies (*Fortune 1000*): 154 with nano-patents.

Investment

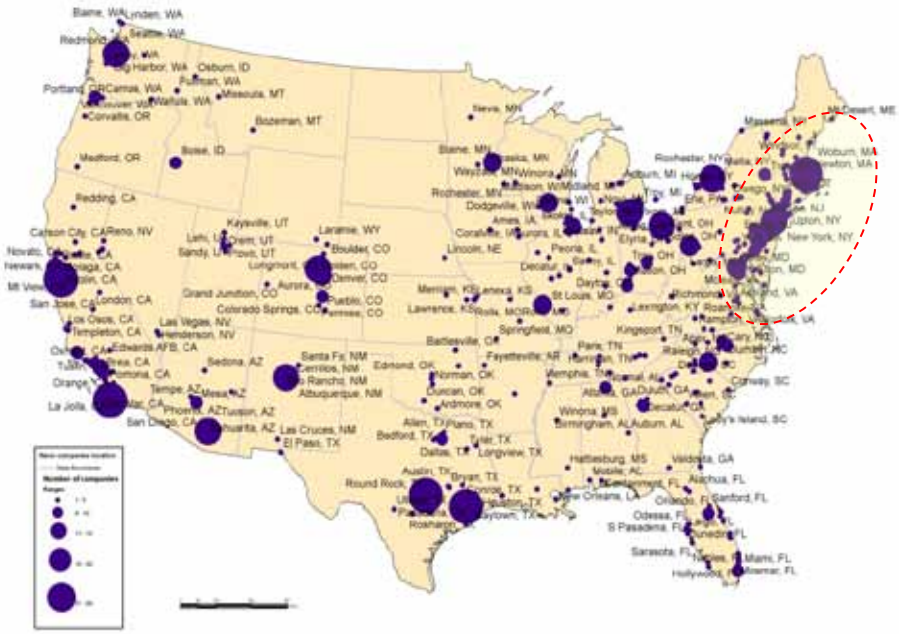
- VC investment in start-up enterprises engaged in nanotechnology ≈ $590 million in 2006 in US, or 84% of all global nanotechnology VC investment.
- Nanosphere – based in Illinois, spin-out from Chad Mirkin's research at Northwestern – received more than $100 million in VC investment, probably the largest nano VC deal to date.

See: Shapira, P., & Youtie, J., "United States", in Encyclopedia of Nanoscience and Society, Sage Publications, forthcoming.

Locations of Research Not Necessarily the Same as Commercialization



Nano Publications
1990-2006



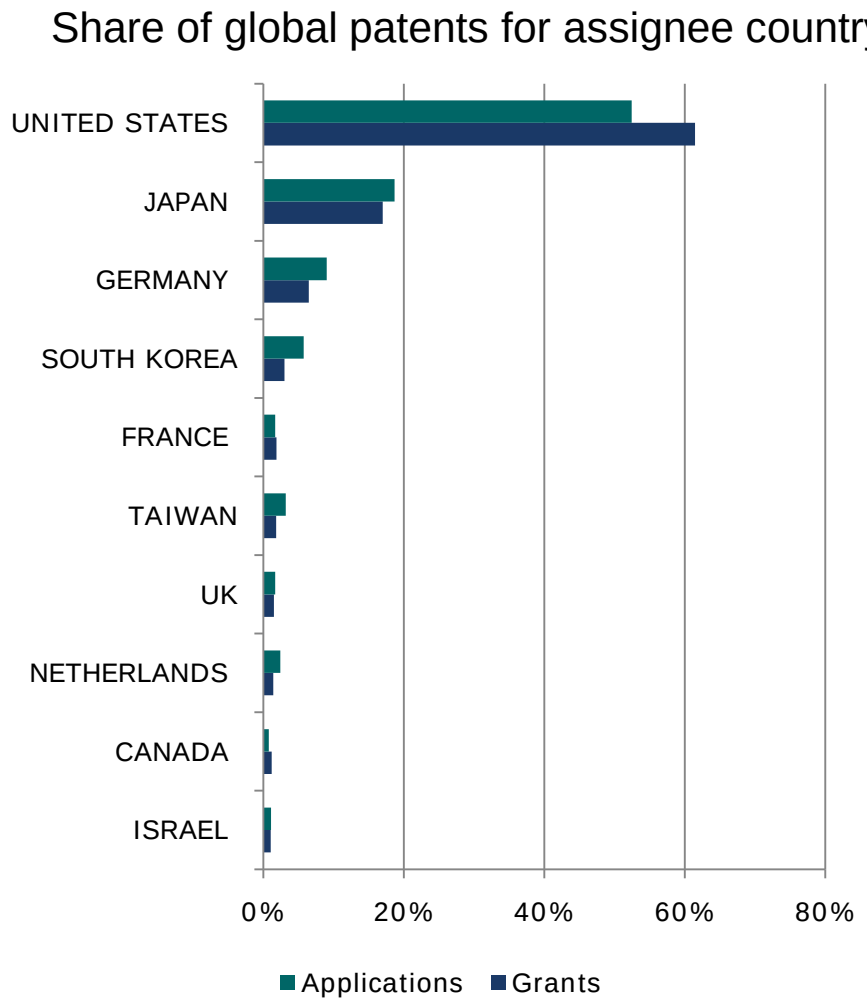
Nano Corporate Entry
as of 2009

Country example 2:
China – how will nano research power transition into commercialization?

- China = second largest producer of publications
  - Less cited
  - Fewer cross-national collaborations
- Yet only 14th in corp. patents world rank
  - Only 1% EPO patents assigned to Chinese 1990-2006
  - Universities have larger share of patents than do companies (59% v. 19%)
  - Greater emphasis on materials than nanobio
- Still, **more than 550 firms** with either nanotechnology publications or patents
  - 5th in world rank by number of firms

See: Shapira, P., Wang, J., & Tang, L. "China", in Encyclopedia of Nanoscience and Society, Sage Publications, forthcoming.

Early Nano Commercialization:
"Multi-player" rather than "global"



- Applications v. Awards 1990-2008 by country (chart to left)
- In USPTO:
  - patent grants for non-US assignees (33%) have lower share than US assignees (67%)
  - patent applications (after 2001), slightly higher share for non-US assignees (36%)
- Top foreign assignees in USPTO: Japan (16%), Germany (4%), South Korea (3%), Taiwan (2%)

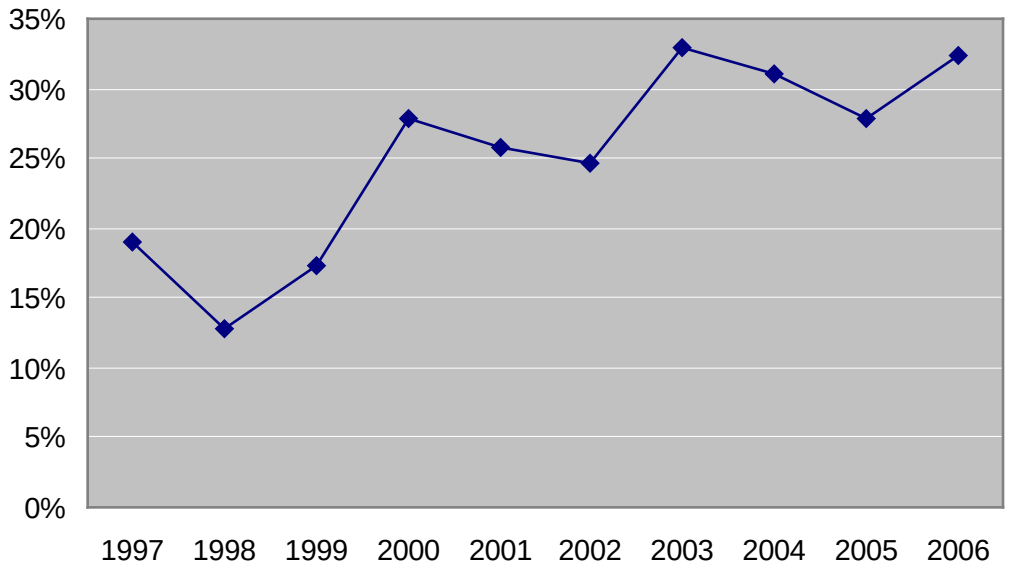
Nanotechnology Patenting Strategies of US Multi-National Enterprises (MNEs)

- Georgia Tech global nano patenting databases.
- 25 largest US MNEs active in patenting in nanotechnology
  - (13% of all USPTO, EPO, WIPO Patents)
  - 1997-2001 = 1187 patents; 17% co-invented abroad; 10% totally invented abroad
  - 2002-2006 = 2555 patents; 13% co-invented abroad; 8% totally invented abroad
- US MNEs not globalizing their nanotechnology patenting activities. US home advantages still evident.
- Find the importance of host country scientific strength, firm experience and technological capabilities, and technological diversity in patenting by host country. Market size and GDP/capita not significant.

Source: Andrea Fernandez-Ribas and Philip Shapira, Technological diversity, scientific excellence and the location of inventive activities abroad: the case of nanotechnology, *Journal of Technology Transfer* (2009) 34:286–303

International Nano Patent Strategies: Small Businesses are Increasingly Emerging

Proportion of U.S. SMEs* with WIPO PCT filings (relative to U.S. Large)



* SBA standard definition, less than 500 employees

Authors: Andrea Fernández-Ribas with research assistance Ronak Kamdar. Support obtained through CNS-ASU and the Kauffman Foundation and Georgia Research Alliance.

- Analysis of WIPO PTC nano-related applications 1997-2006 of 300+ US owned SMEs
- Increased geo-graphic breadth of patent protection; regional/ international (co-) invention patterns observed
- **Next Question**: What drives the growth of US SME international patenting?

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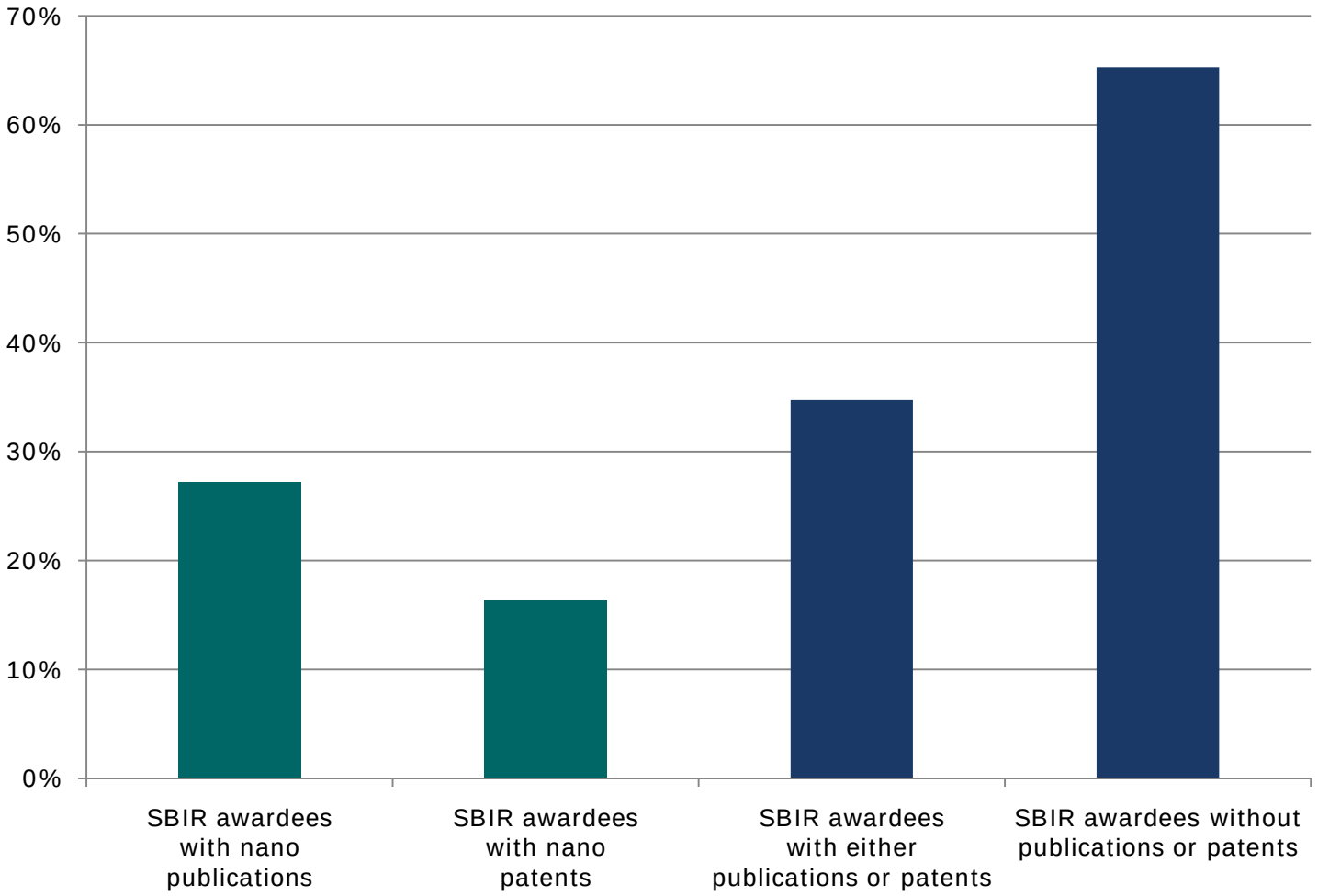
Not all of Corporate Activity is Patented



Total unique US companies in SBIR/STTR program between 1986 and 2009 is 478.
Source: Analysis of SBIR award databases (at NSF)

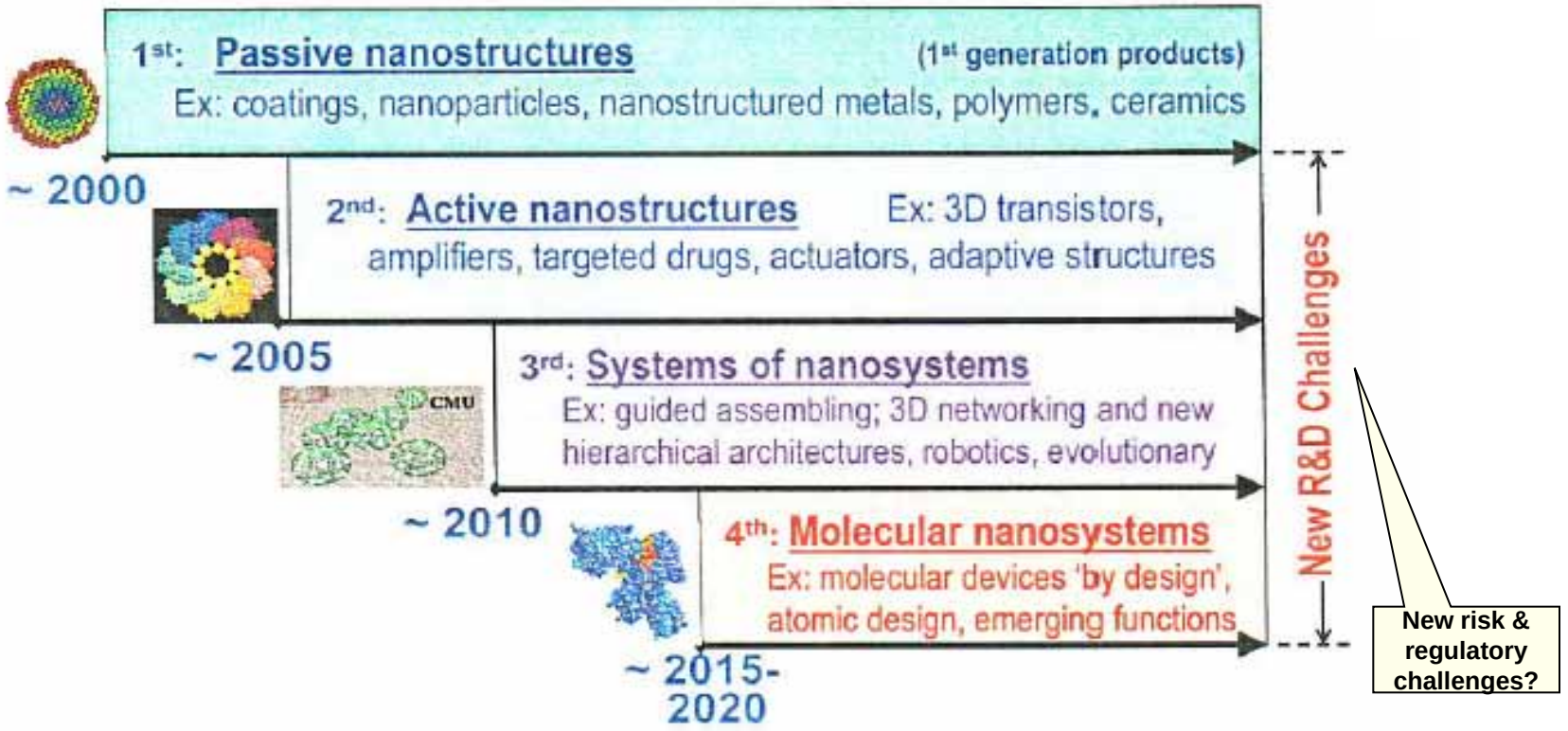
Opportunities for SMEs and Large companies are in contrasting applications

Use of nanotechnology (classes of technologies—IPC codes)**	Firm size*	
	SME	Large
Nano-raw material (e.g. carbon nanotubes, proteins)	21%	10%
Nano-intermediate (e.g. semiconductors, films)	76%	88%
Nano-products (e.g. solar cells, cosmetics, drugs)	11%	6%

* United States, Fortune 1000 vs. Non-Fortune 1000; all nano-patents since 1990.
** Technologies classified according to definition in Alencar et al. (2007); totals add up to more than 100% due to patents linked to more than one IPC class.
***Related IPC classes cover 57% of all nano-patent records in DB of nano-corp establishments.
Source: Patstat, USPTO patent applications and awards, 1990-2008.

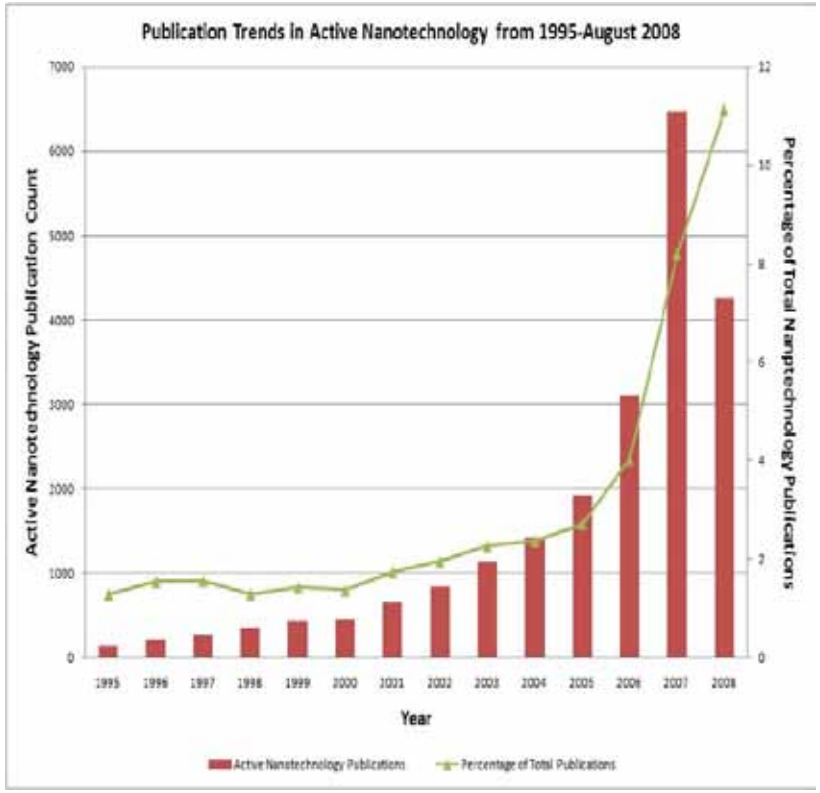
Nanotechnology commercialization

Can we anticipate direction over time?



Timeline for beginning of industrial prototyping and nanotechnology commercialization. Roco (2005).

Is there a shift to "active nanotechnology?"



- Active nanotechnology posited as 2nd generation, with important implications
- Filtered nano publication databases
  - Materials base (nano*, fullerene#, quantum dot#, dendri*, self assembl* and molecul*)
  - Active terms (motor, adaptive, self-healing, etc.)
- 21,000+ articles from WOS/SCI from 1995 to 2008
  - Shift? Yes, after 2006

Source: Vrishali Subramanian, Jan Youtie, Alan L. Porter, and Philip Shapira (2009). Is there a shift to "active nanostructures?" *Journal of Nanoparticle Research*,

Transition to active nanostructures:

What products can we expect?

- **Remote Actuated Active Nanostructures**: Nanotechnologies whose active principle is remotely activated or engaged.
  - Magnetic, electrical, light and wireless tagged nanotechnologies, used in light harvesting antenna, optoelectronics, remote-actuated drug delivery, wireless sensors, etc.
- **Environmentally Responsive Active Nanostructures**: Nanotechnologies that are sensitive to environmental stimuli like pH, temperature, light, oxidation-reduction, certain chemicals
  - Sensors, responsive drug delivery, environmentally responsive actuators, etc.
- **Miniaturized Active Nanostructures**: Nanotechnologies which are a conceptual scaling down of larger devices, technologies
  - Molecular electronics
- **Hybrid Active Nanostructures**: Nanotechnologies involving uncommon material combinations (biotic-abiotic, organic-inorganic)
  - DNA, protein, photosystem, etc. mobilized on a chip,silicon-organic hybrid nanotechnologies, etc.
- **Transforming Active Nanostructures**: Nanotechnologies that change irreversibly during some stage of its use or life
  - Self-healing materials like metal or plastic coatings, which on specific triggers, repair damage caused by corrosion, mechanical damage, etc.

Source: Vrishali Subramanian, Jan Youtie, Alan L. Porter, and Philip Shapira (2009). Is there a shift to "active nanostructures?" *Journal of Nanoparticle Research*,

Planned Corporate Panel

Focus (2010 through 2014)

- United States, Europe, Asia, L America (N = c. 500)
- Multinationals, and small and medium-sized enterprises (SMEs) – both incumbent and newly-established.
- Markets: (1) consumer oriented (e.g., food/packaging, clothing, cosmetics); (2) medical; and (3) industrial materials.

Data sources

- Publications and patents
- PEN DB of nano products
- Company websites (esp. SMEs)
- Award searches (e.g. NSF)
- Press releases (company website or other sources)
- Public companies: SEC filings (esp. Large; IPOs)
- Media coverage

Analyzing mined data

- Unobtrusive corporate analyses
  - Initial pilot with 5 US companies; analyzes of Brazilian co's)
- Potential for primary data collection (e.g., interviews)
  - Initial work in China (c. 20 companies interviewed)

Pilot companies

Company	Founded	Segment	Employees	Sales
3M Co.	1902	Industrial materials	79,183	$25B
Nantero, Inc.	2001	Industrial materials	11-50	$2M
SurModics, Inc.	1979	Medical markets	254	$137M
Merck & Co., Inc.	1891	Medical markets	59,800	$24B[2007]
International Cosmeceuticals, Inc.	1988	Consumer products	5	$620K

Source: multiple data sources online, as of 2008 otherwise indicated (e.g. Reference USA, BusinessWeek, Yahoo Finance)

3M Co.

St Paul, MN

Several applications of nanotechnology, for example:

- 3M Crystalline, sun protection film for cars
- Reflects UV and infrared more than 1,700 times compared to ordinary film

Positioning

- Multiple linkages with univ. (R&D collaborations, training, etc.)
- Globally distributed R&D centers
- Industrial, healthcare, transportation, consumer, communications, and specialty materials business segments

Company strategy (expect for nano)

- Innovation-based strategy, introduction of hundreds of new products
- Public funding (MMM, NYSE); significant cash flow of newly introduced products
- Large, vertically integrated company

LE

Merck & Co., Inc

Whitehouse Stn., NJ

MERCK

Nano-enabled products

- No products labeled “nano”
- Research in Biochemistry & Molecular Biology and patents related to pharmaceutical and ophthalmic nanoparticulate compositions

Positioning

- Multiple linkages with univ. (R&D collaborations, training, etc.)
- Globally distributed R&D centers
- Target final consumers and health care professionals

Company strategy

- Investing in nano-related startups through VC subsidiary?
- Public funding (MRK, NYSE)
- Research, manufacturing, and marketing of drugs and pharmaceuticals

LE

Nantero, Inc

Woburn, MA

Main product or technology

- Microelectronic-grade Carbon Nanotube Coating
- First of its kind, easy to apply and enables the removal of metallic and carbonaceous contaminants

Positioning

- Collaborations with MIT, Case-Southwest Missouri State University; partnerships with key semiconductor companies
- Main R&D facility in Springfield, MO (chosen due to costs and royalty agreement with local univ.)
- Provider to a wide range of electronics manufacturers

Company strategy

- Leading application of nano in semiconductors / memory chips
- VC-backed company ($31MM)
- Dynamic startup

SME

Surmodics, Inc

Eden Prairie, MN

Nano-enabled products

- Nano-structured carriers for drug delivery devices
- Improved drug incorporation, decreased dose size and products with longer shelf life

Positioning

- Key contacts with Univ. of Minnesota, collaborations with Univ. of Arizona and others, including companies
- Centralized R&D labs
- Provider of many large, diversified markets across the healthcare industry

Company strategy

- Growth based on acquisitions, licenses, and a well diversified product portfolio
- Public funding (SRDX, NASDAQ); strong cash flow from licensed products; SBIR program ($600K)
- Fast growing company

SME

International Cosmeceuticals, Inc

Miami, FL

Nano-enabled products

- Q-SunShade™ SPF 30+ Tinted Zinc Oxide Sunscreen listed in PEN database (not in company website)
- "Nanotechnology exploits structures smaller than a wavelength of light"

Positioning

- Founders affiliated with University of Miami
- Wholesale pharmaceutical distribution
- No research or patenting in nano DBs

Company strategy

- Nano-marketing strategy? Nanotechnology is not mentioned in company website anymore
- Private funding
- Single location, very small company

- *What is the role of this type of firm in nanotechnology product chains?*

SME

Pilot Cases

Contrasts in Positioning

Company	Segment	Strategy	R&D / Linkages	Marketing
3M Co.	Industrial materials	Multi-segment Multi-product	Global R&D Multi-university links	Nano" = USP
Nantero, Inc.	Industrial materials	Single-segment	Central R&D Multi-university	"Nano" = USP
SurModics, Inc.	Medical markets	Single-segment Multi-product	Central R&D University link	Nano" = USP
Merck & Co., Inc.	Medical markets	Products yet to appear? VC Invest in SMEs	Global R&D Multi-university links	No "nano" labeled products
International Cosmeceuticals, Inc.	Consumer products	Single-segment Intermediate user	No R&D University link	"Nano" downplayed

Source: multiple data sources online, as of 2008 otherwise indicated (e.g. Reference USA, BusinessWeek, Yahoo Finance)

Observations

- Corporate nanotechnology activity goes beyond research (i.e. publications) and technology development (i.e. patents)
  - Many companies are intermediate users (not developers) of nanotechnology applications
  - Differing national orientations, e.g. China: fast growing publications, low patenting level (use of trade secrets)
  - Challenges for regulation?
- Very diverse set of nano-companies: from large conglomerates and MNC, to very small companies with less clear roles / strategies
- Opportunities in nano for SMEs and large companies differ
- Nanotechnology production and consumption may be globalizing faster than nanotechnology research and invention
  - Challenges for regulation (as global nanotechnology supply chains emerge)

Research Challenges: Suggestions appreciated

- How to track corporate nanotechnology commercialization?
- How to classify and interpret the variety of corporate strategies?
- How to capture linkages between R&D/invention (concentrated) and production/use (more dispersed)?
- How to model influence of national innovation systems and regulatory environment on commercialization strategies?