Small Stuff in Search of the Big Bucks: Nanotechnology Commercialization Activities by Sector

Kristin Abkemeier, Analyst
Lux Research Inc.
December 18, 2007

Agenda

- Introduction
- Where does nanotechnology commercialization stand?
- Focus on nanotech in electronics and IT
- Nanotech activities – a couple of examples

Lux Research profile

- Introduced nanotech to Wall Street in 2001
- Lux Research spun off from VC firm Lux Capital in 2004
- Active in current U.S. nanotech public policy
  - Testimony before Congress twice
  - Trained FDA on nano in 2006
  - ANSI Nanotechnology Standards Panel
- Retained clients are primarily global 1000 organizations, but also include startups, investors, universities, and government
- Strong international connections – regular travels to Asia (China, Japan, Korea, Taiwan, etc.) and Europe
- Extensively cited in the press, including the Wall Street Journal, Forbes, Business Week, the Economist, Technology Review, Discover, etc.
- Rigorous methodologies based on:
  - Primary research: Hundreds of conversations annually with start-up CEOs, corporate executives, researchers, policymakers and thought leaders
  - Secondary research: Patent analyses, business and trade press, scientific literature

George W. Bush, U.S. President

Josh Wolfe, Director, Lux Research

21st Century Nanotech R&D Act Signing

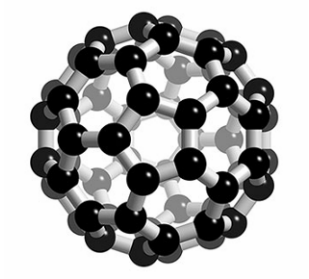
Lux Research CEO Peter Hebert on CNBC

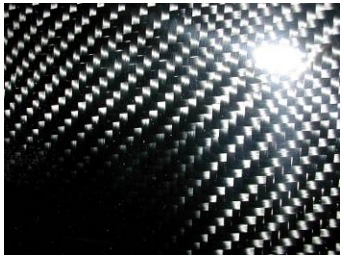
Lux Research President Matthew Nordan testifying before U.S. Congress

Lux Research offers advisory programs in ten technology domains

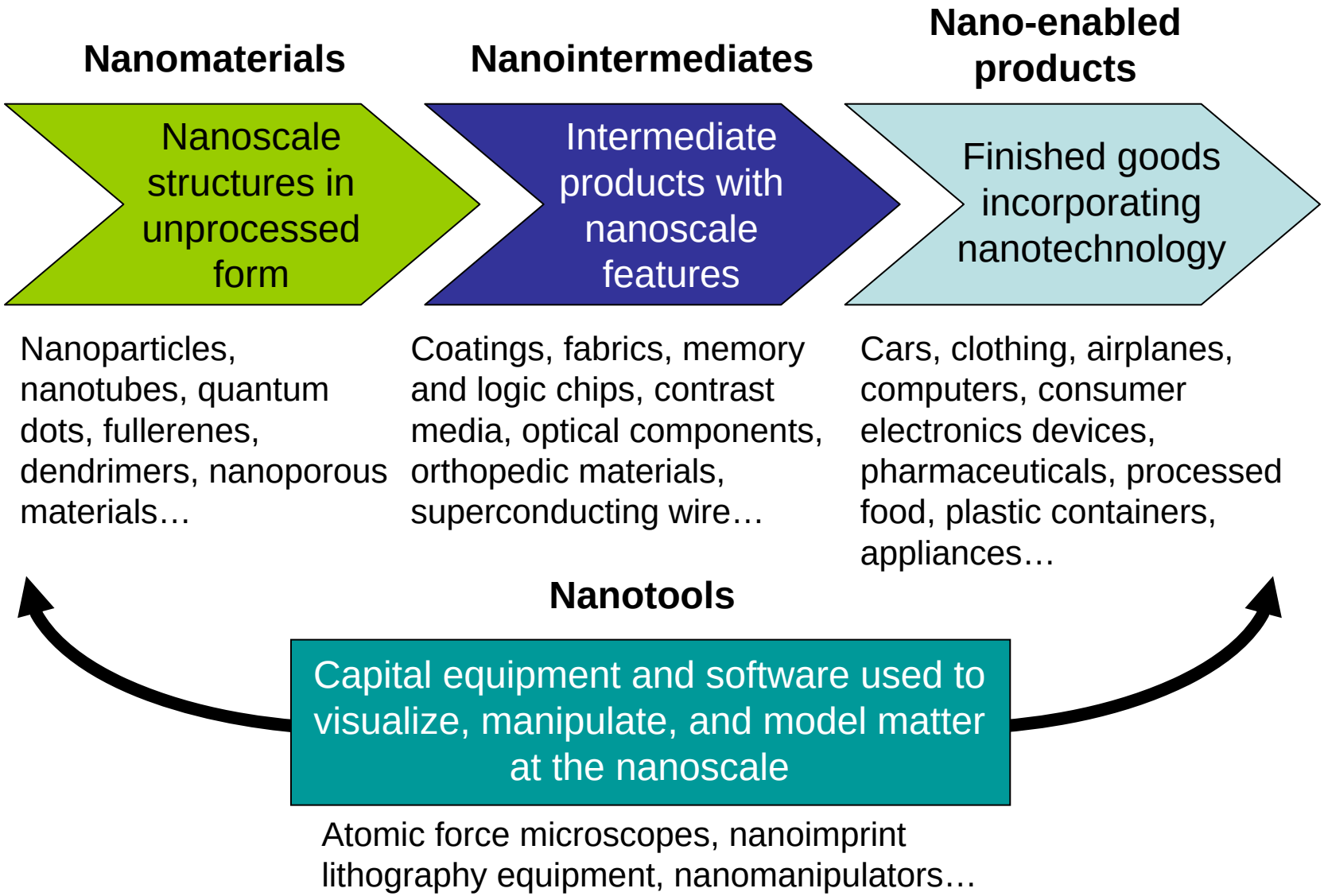
- Nanomaterials
- Solar
- Alternative power and energy storage
- Printable electronics
- Water technologies
- Advanced composites
- Alternative fuels
- Displays
- Waste technologies
- Memory technologies

- To come: synthetic biology, drug-device convergence, robotics…?



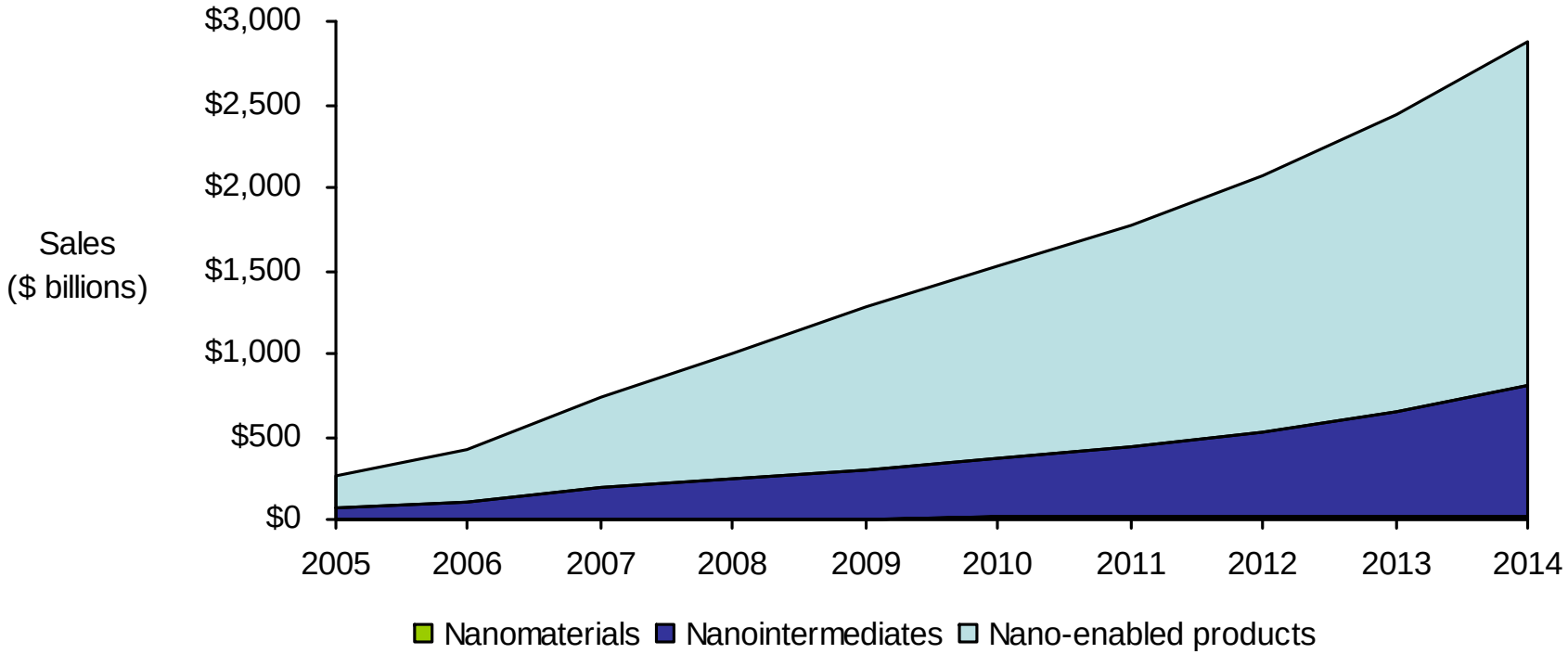


The nanotechnology value chain



Nanotechnology will impact $2.9 trillion worth of products across the value chain by 2014

Sales of products incorporating nanotechnology, 2005 to 2014



Forecast based on Lux Research's value chain ontology, secondary research, and more than 100 interviews with executives, thought leaders, and academics. Projections were triangulated from bottom-up, top-down, analogical, and third-party market estimates, as well as advanced evolutionary models.

Source: Lux Research Report "Sizing Nanotechnology's Value Chain"

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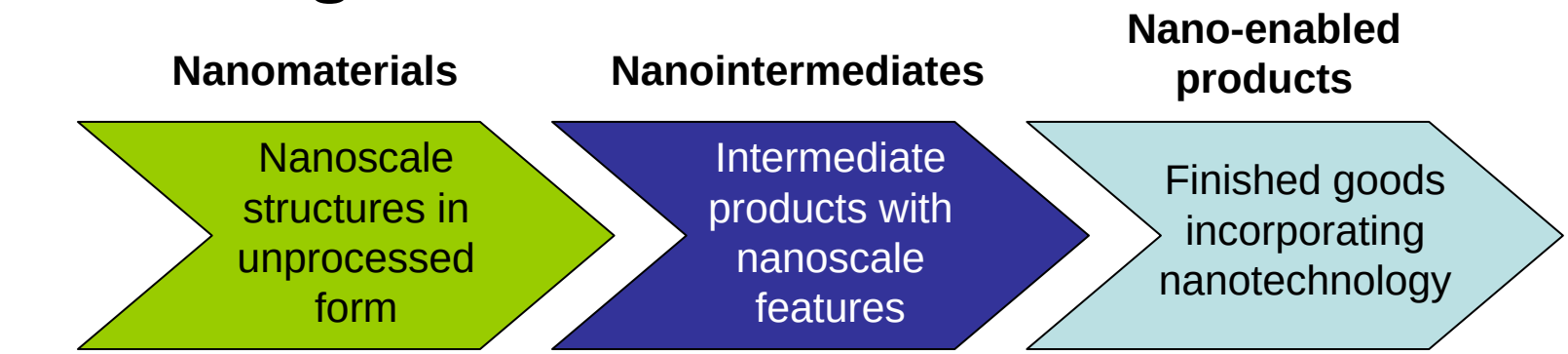
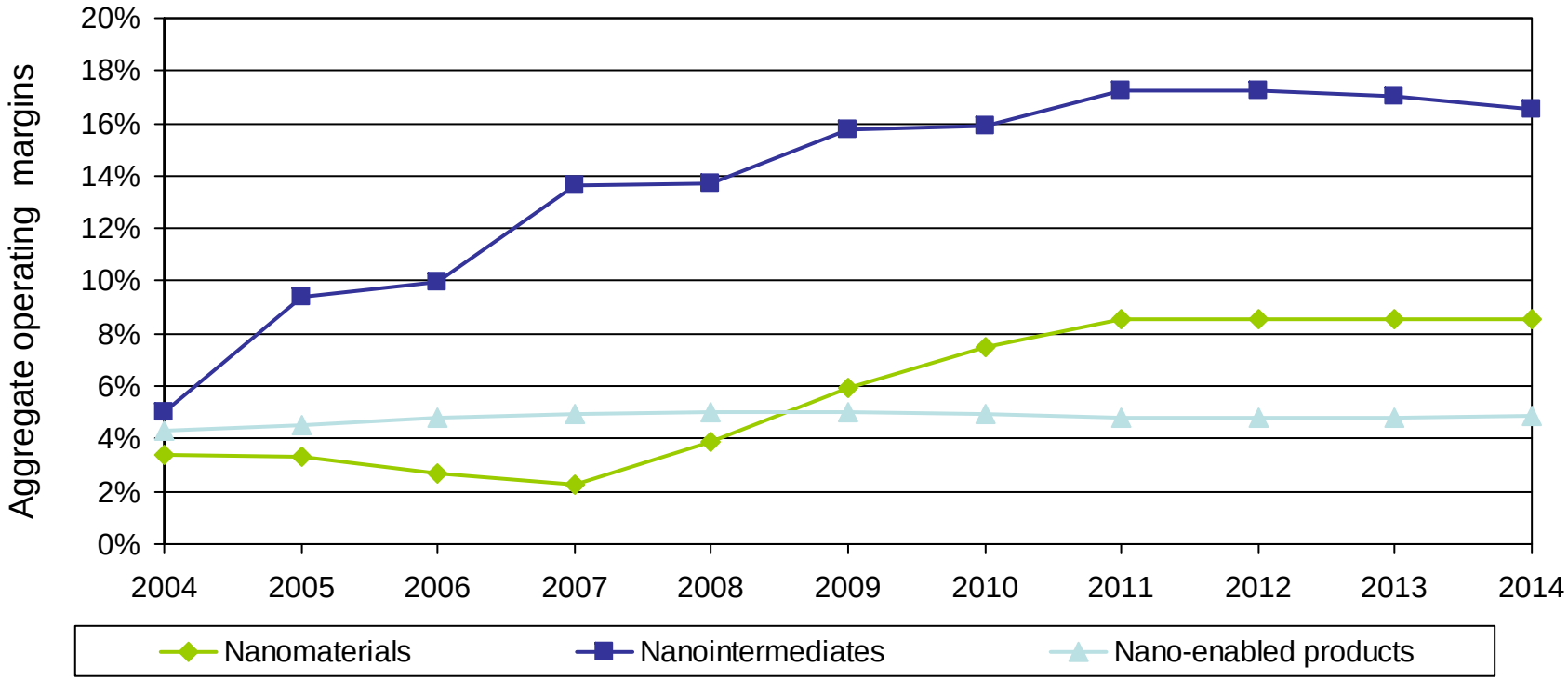
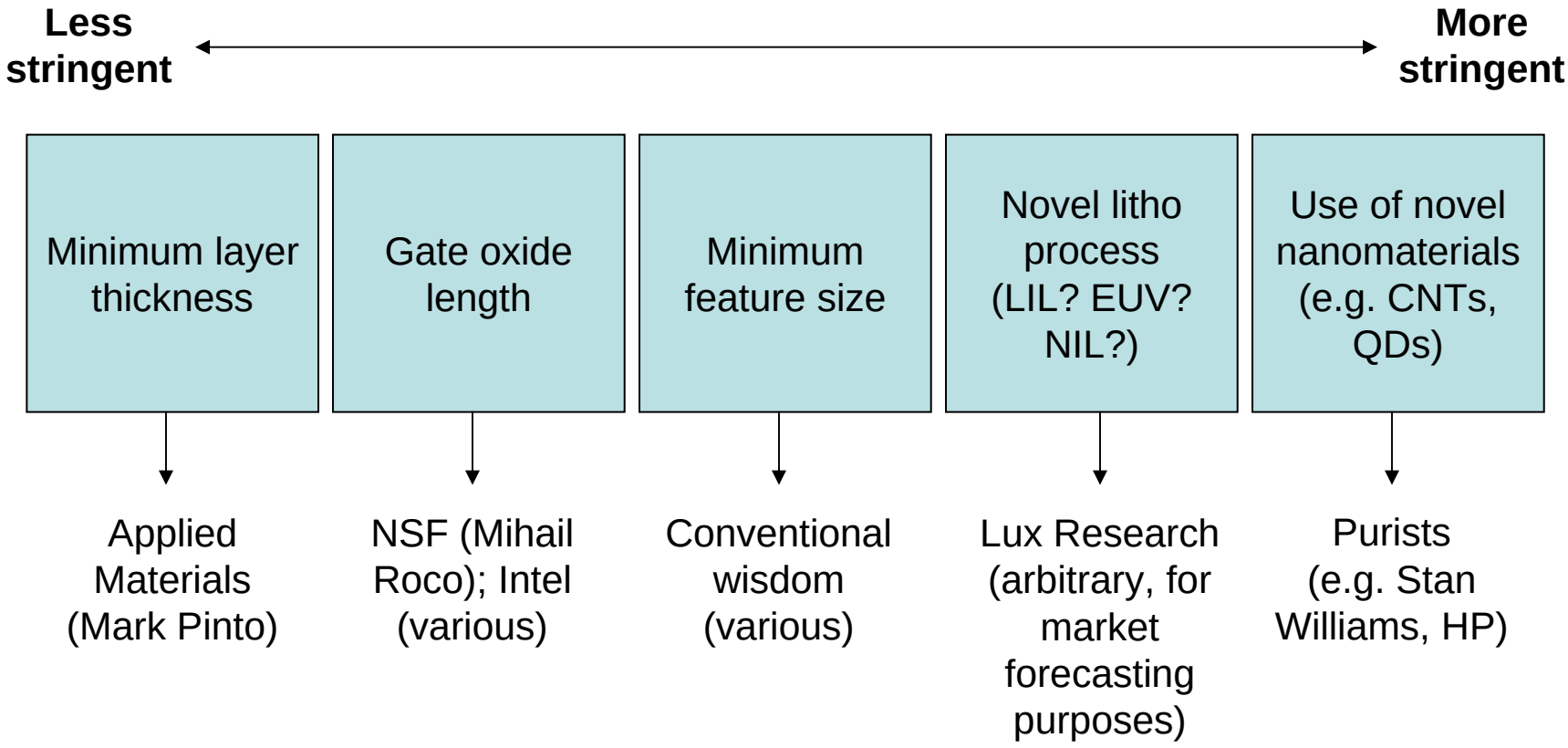
Profits along the value chain

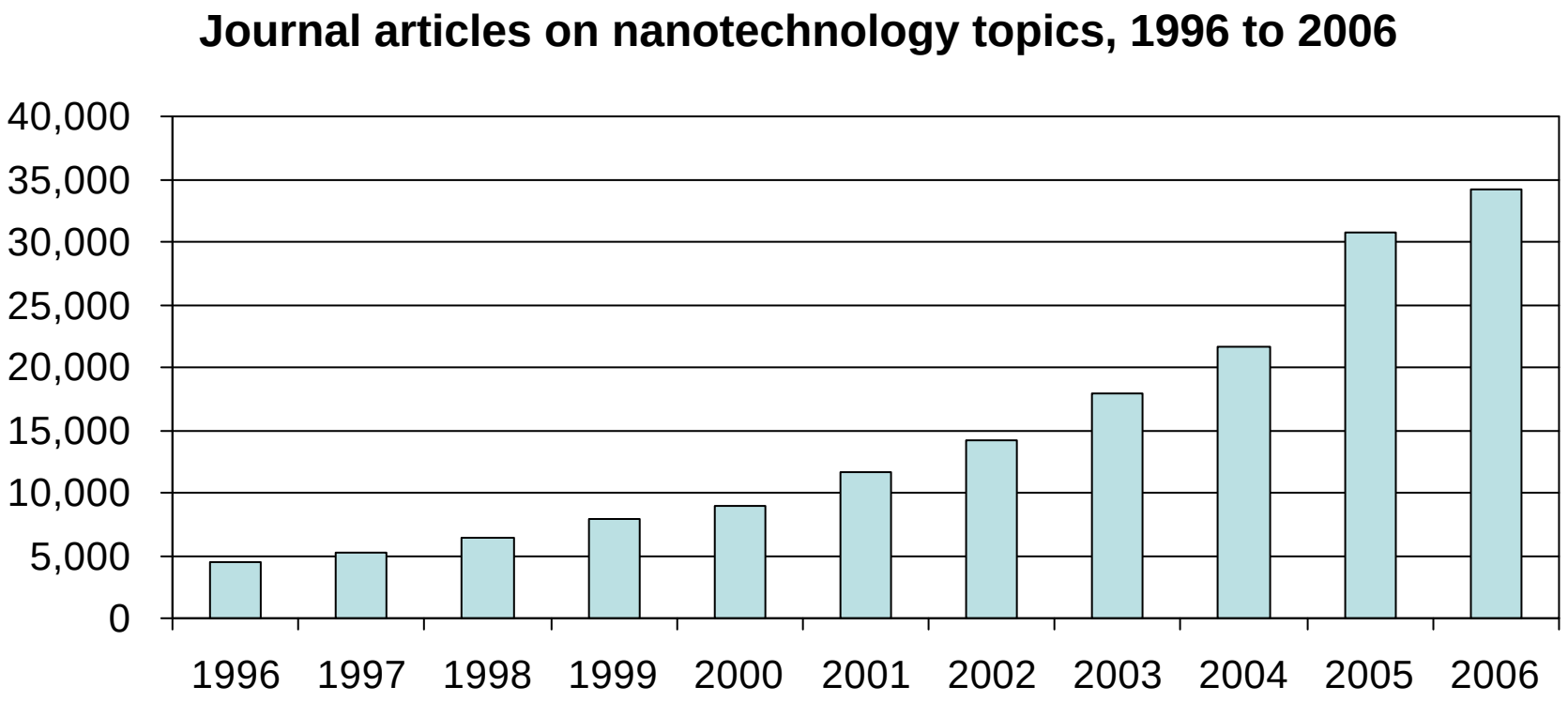




The definition of "what's nanotech" in the electronics & semiconductor industries is semantic and unproductive



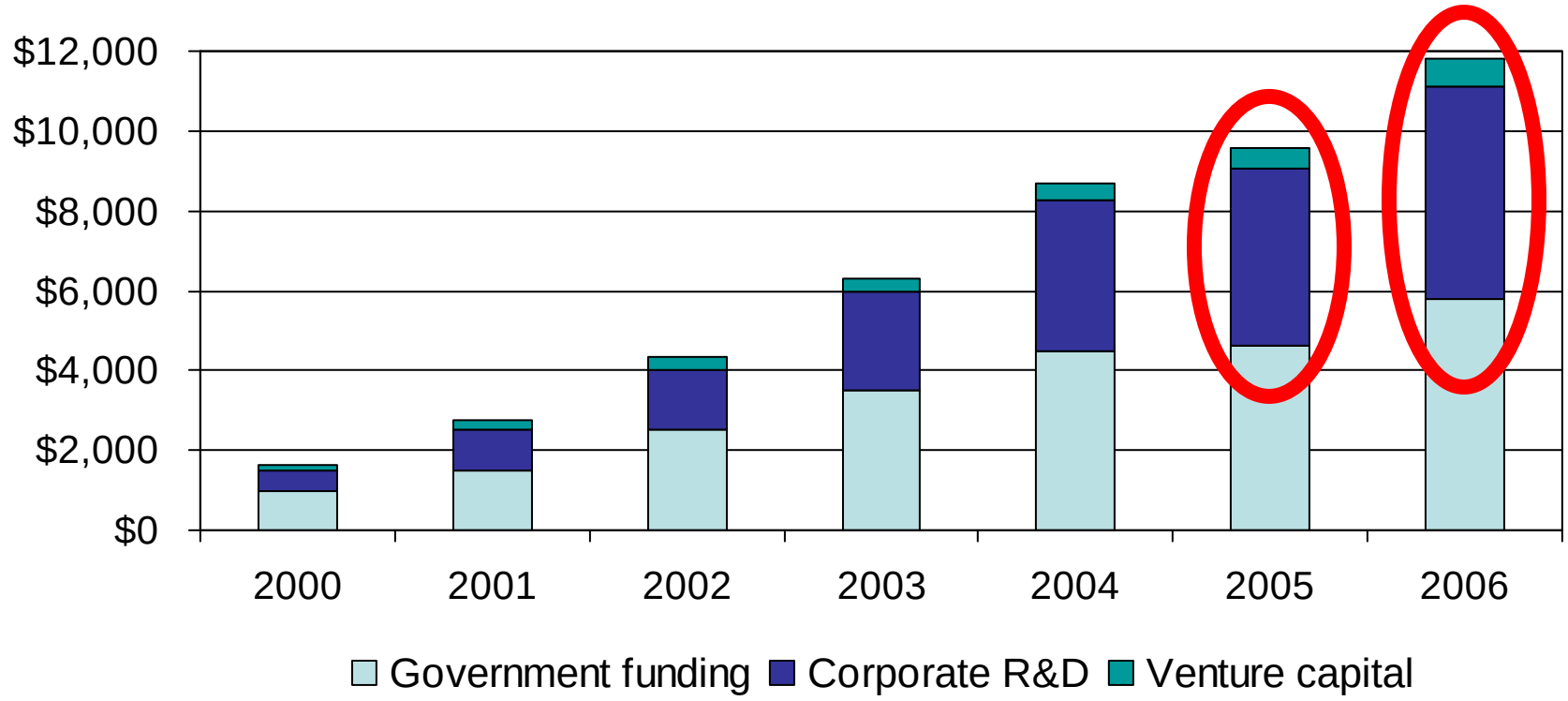
Discovery keeps growing…



Source: Science Citation Index searches. Search string: TS=(quantum dot OR nanostruc* OR nanopartic* OR nanotub* OR fulleren* OR nanomaterial* OR nanofib* OR nanotech* OR nanocryst* OR nanocomposit* OR nanohorn* OR nanowir* OR nanobel* OR nanopor* OR dendrimer* OR nanolith* OR nanoimp* OR nano-imp* OR dip-pen)

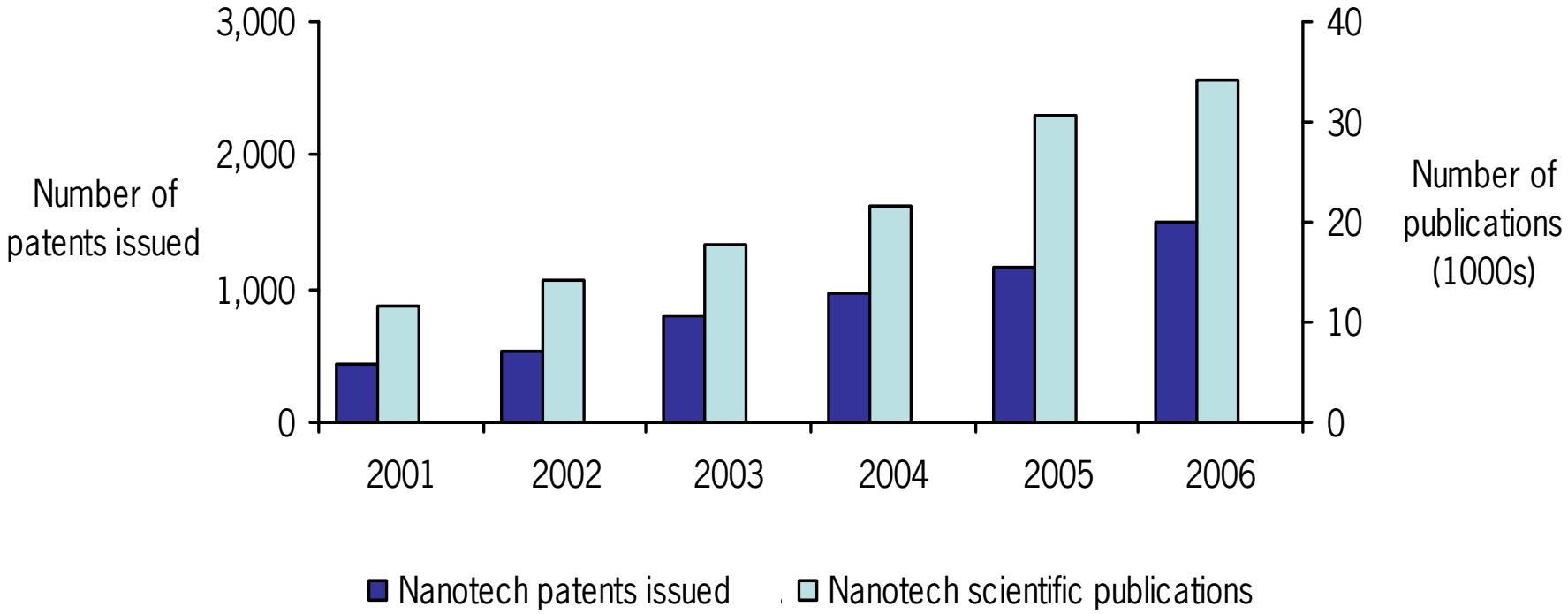
…but gets eclipsed by commercialization

Global nanotech funding, 2000 to 2006, fixed exchange rates (US$ millions)



Source: Lux Research data and projections.

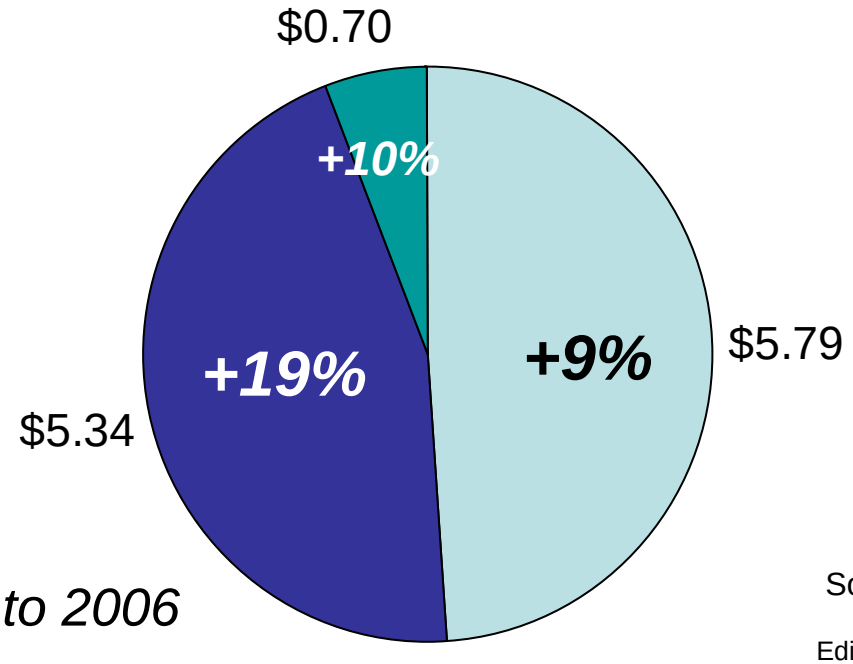
Nanotech research efforts worldwide continue to drive publications and patents



Source: September 2007 Lux Research Report "Bringing Nanotechnology Applications to Market"

Funding for nanotechnology R&D totaled $11.8 billion worldwide in 2006, up ~13% from 2005

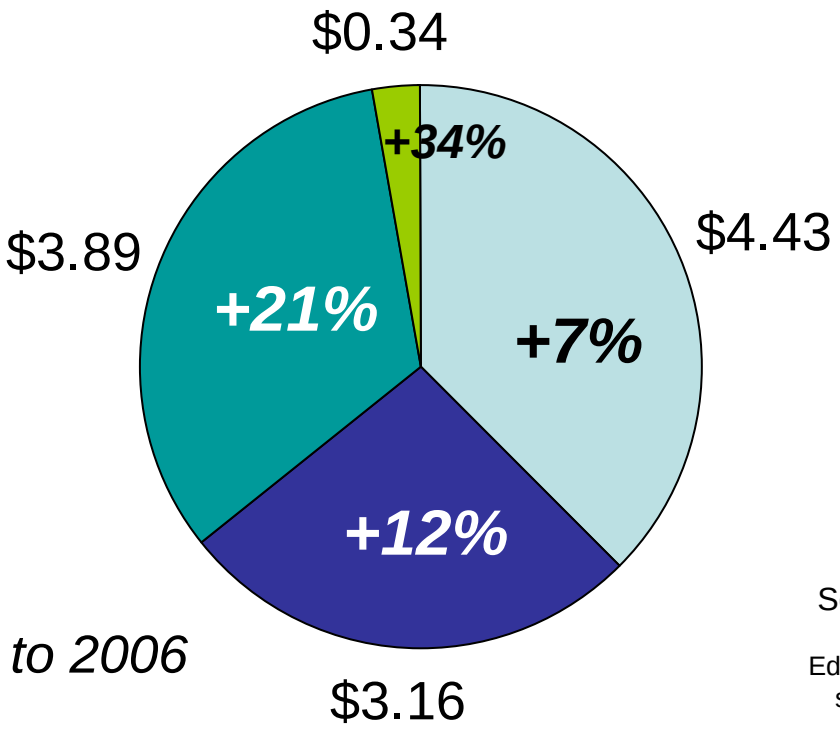
Global nanotechnology investment by source, 2006 ($ billions)



Source: Lux Research Reference Study "The Nanotech Report, 5th Edition," December 2007; published spending allocations, government statistics, Lux Research analysis

Funding for nanotechnology R&D totaled $11.8 billion worldwide in 2006, up ~13% from 2005

Global nanotechnology investment by region, 2006 ($ billions)

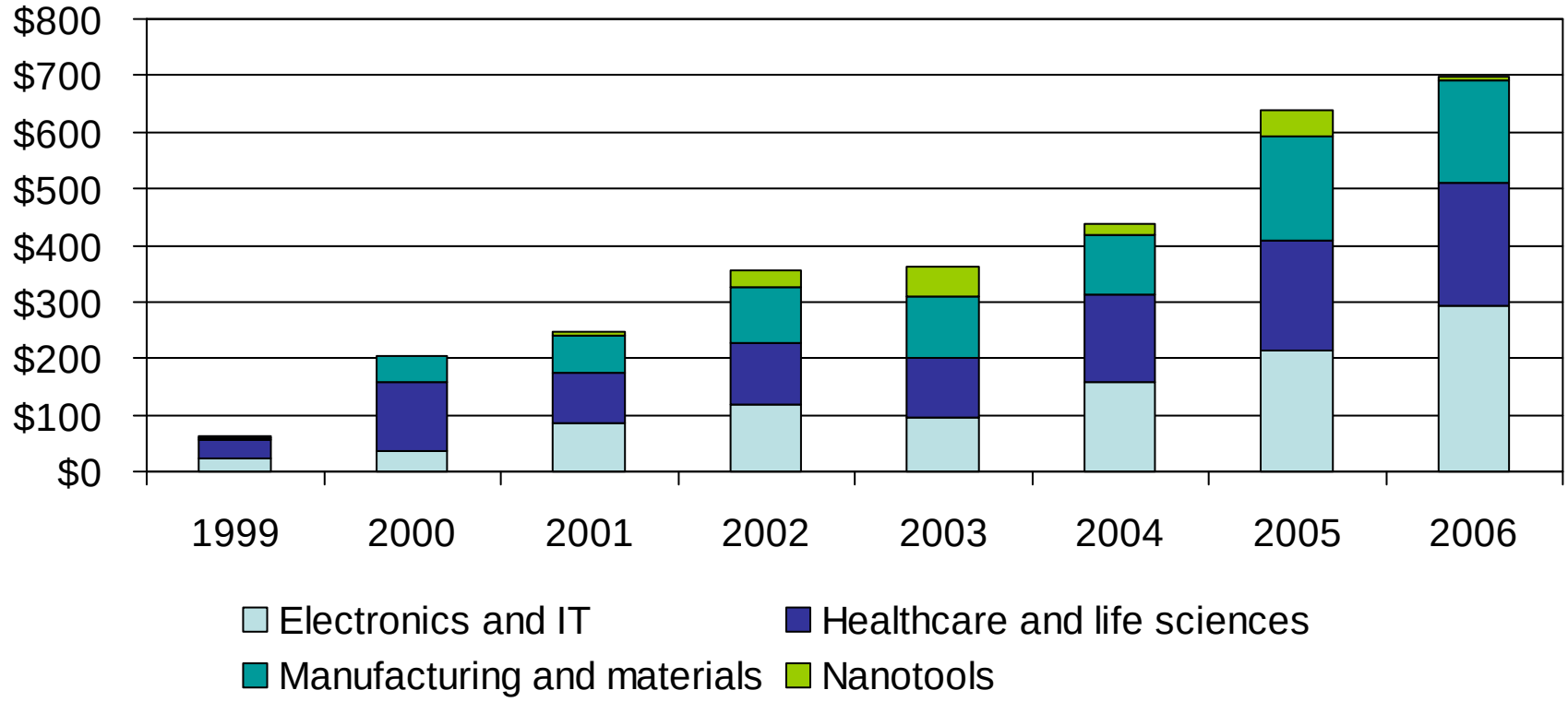


Growth from 2005 to 2006

Source: Lux Research Reference Study "The Nanotech Report, 5th Edition," December 2007; published spending allocations, government statistics, Lux Research analysis

Nanotech venture capital spending is maturing with a strong focus on electronics applications

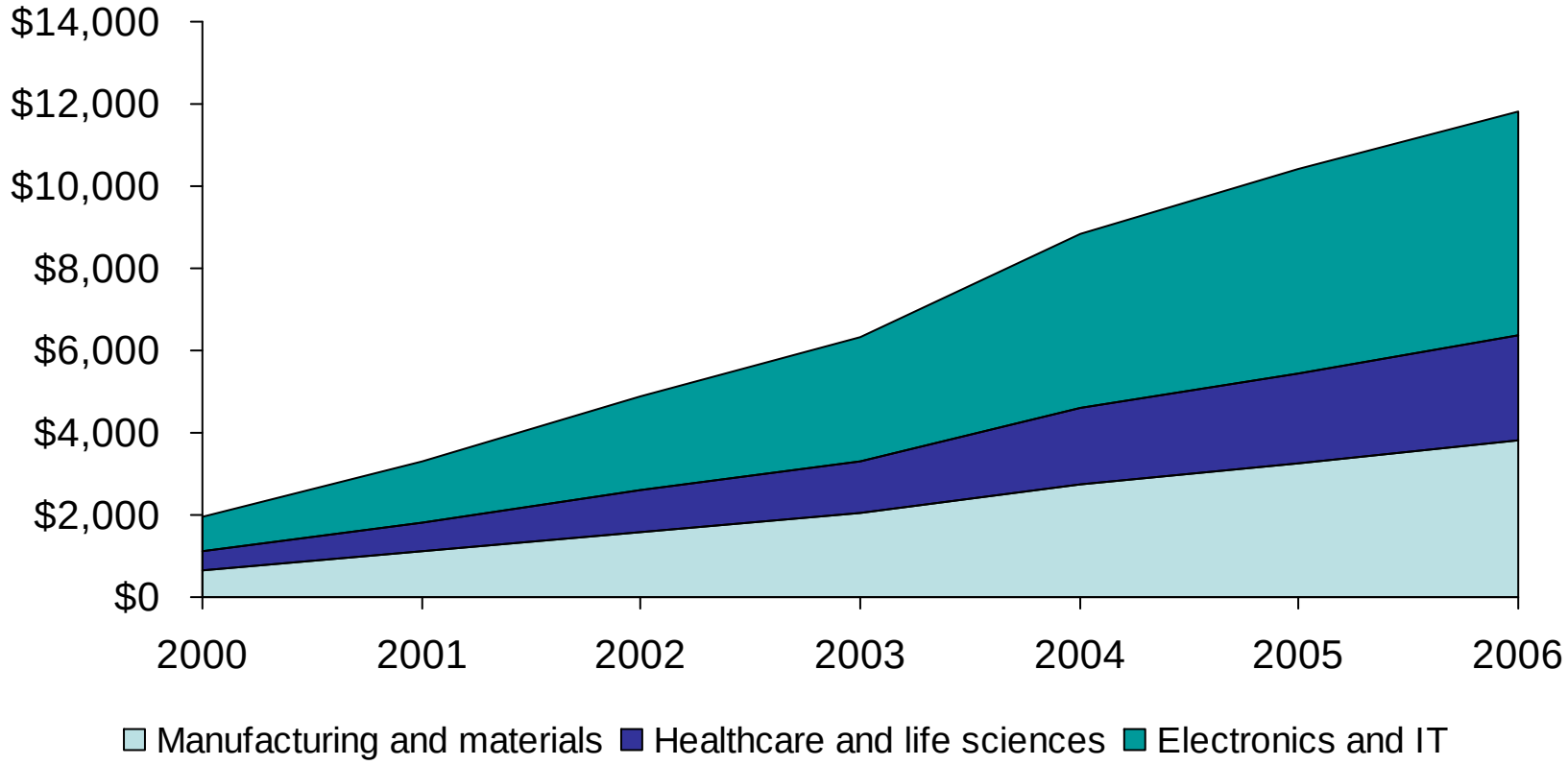
Nanotechnology venture capital funding, 1999 to 2006 (US$ millions)



Source: Lux Research data and projections.

Nanotech funding by sector

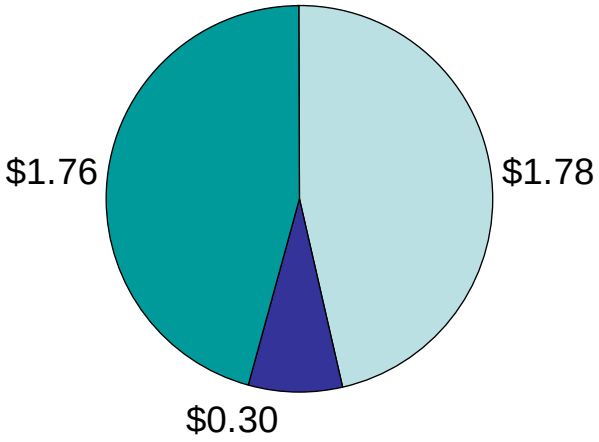
- **EIT sector spending in nanotech represents 46% of total in 2006, and has received $22.3 billion out of a total of $47.5 billion**



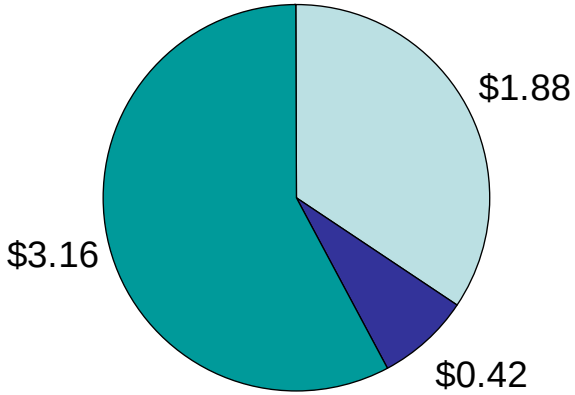
Funding is spent differently across the three sectors

Nanotech spending by sector and organization, 2006

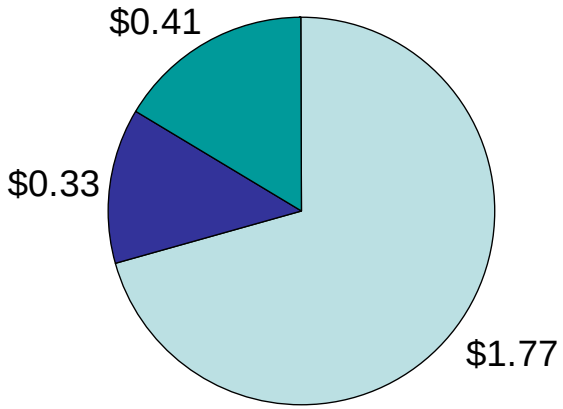
Materials and Manufacturing:
$3.84 billion



Electronics and IT:
$5.46 billion



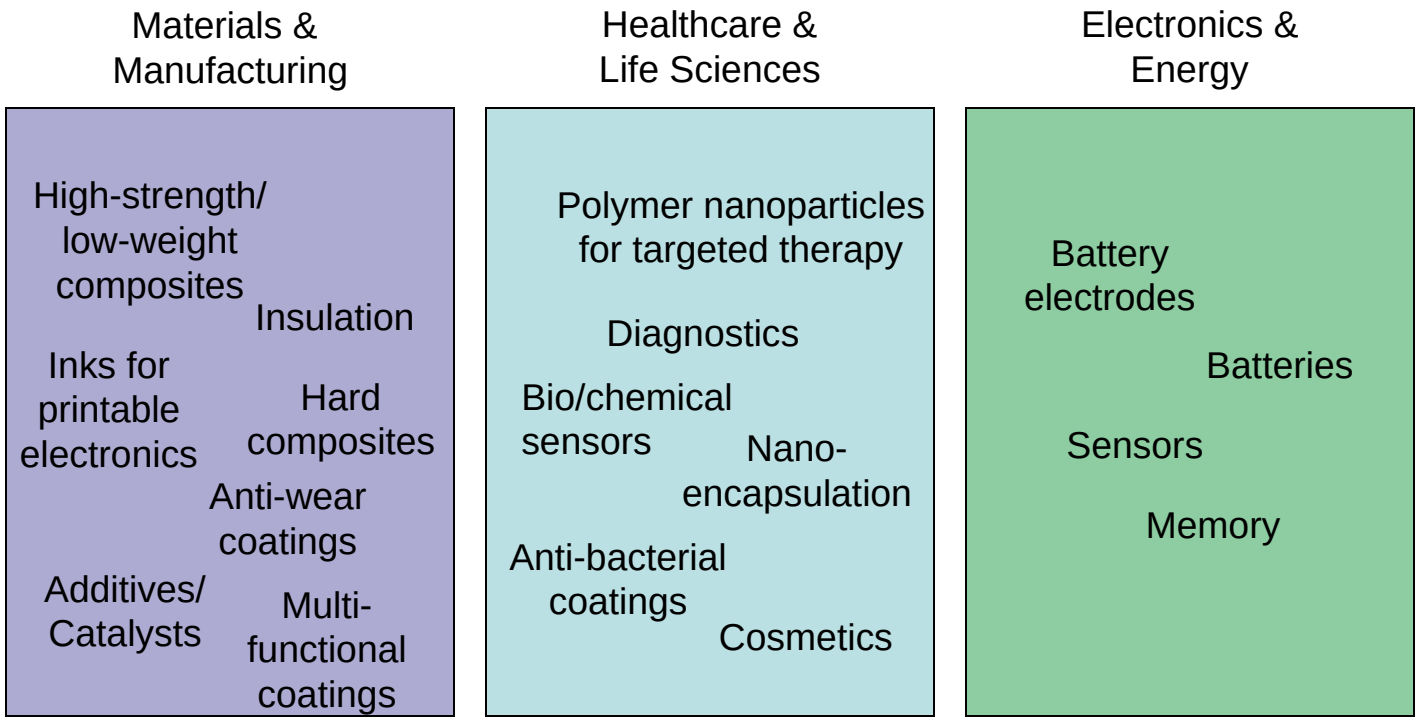
Healthcare and Life sciences:
$2.51 billion



Academic and government labs | Start-ups | Corporations

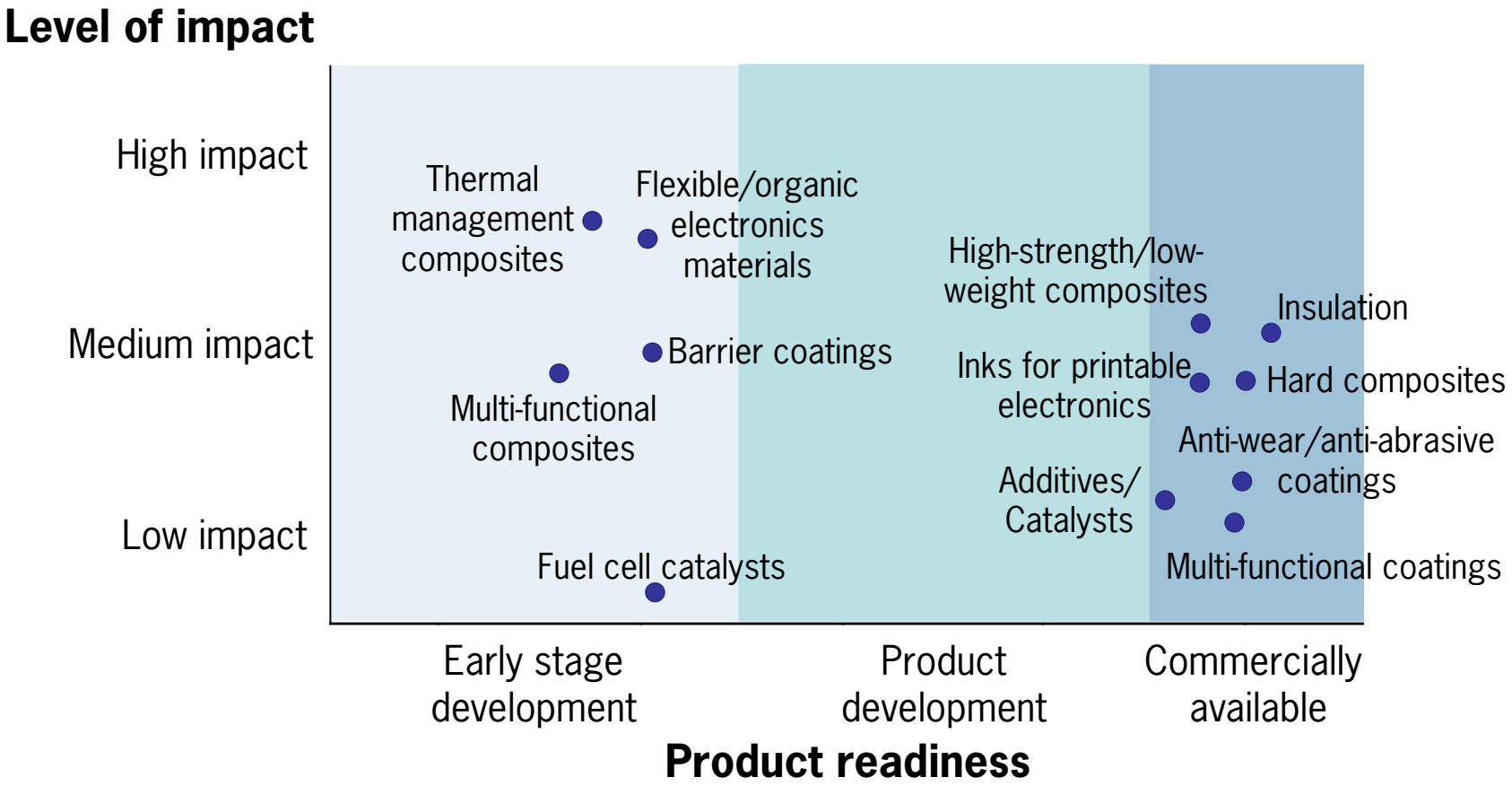
Sources: Lux Research Reference Study "The Nanotech Report, 5th Edition," December 2007; Lux Research Report "How Industry Leaders Organize for Nanotech Innovation"; Lux Research Report "Ranking the Nations: Nanotech's Shifting Global Leaders"; Lux Research Report "Making Sense of Nanotech Venture Capital"

The Best Evidence of Nanotech Maturity: Multiple Applications In-Market



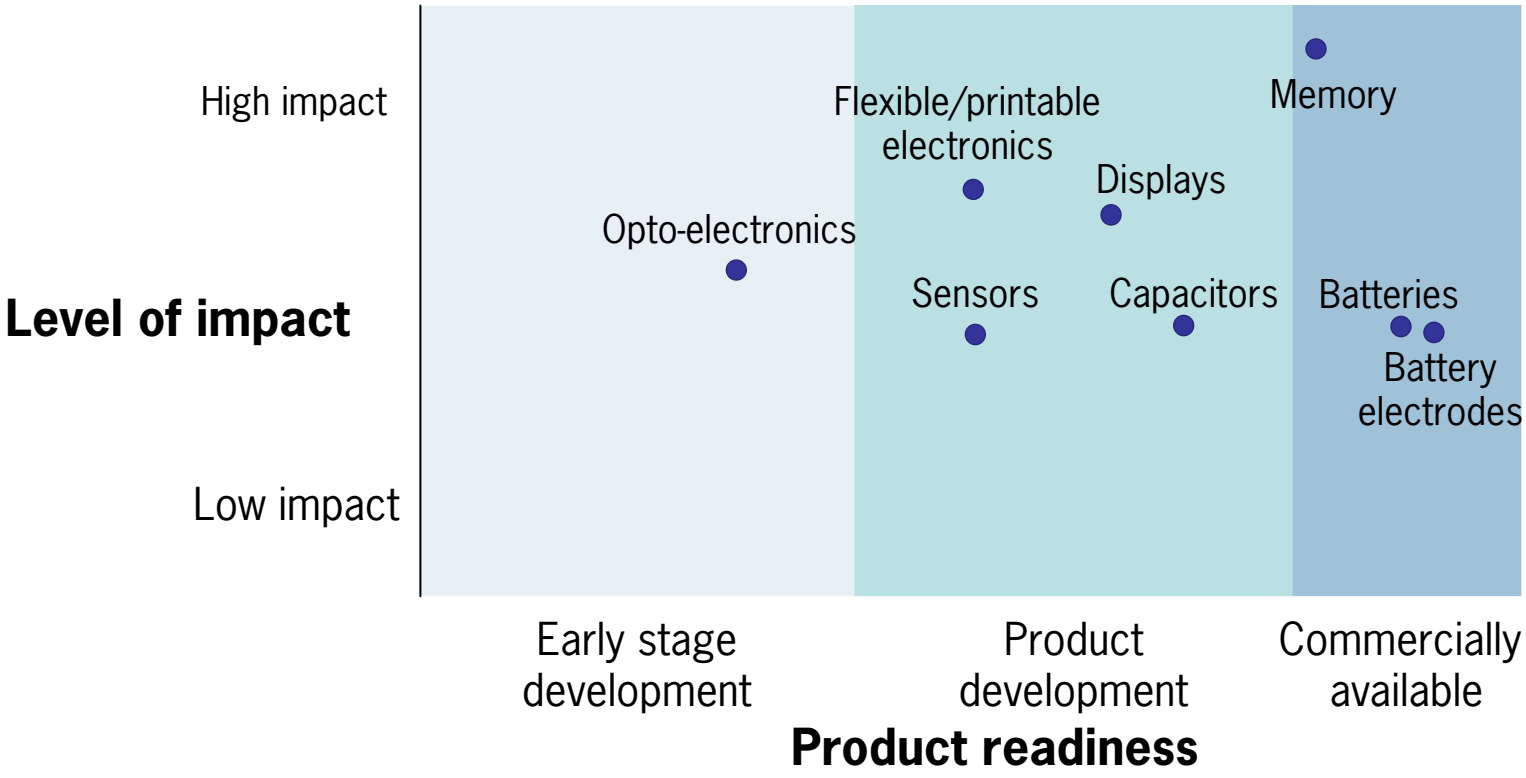
Source: September 2007 Lux Research Report "Bringing Nanotechnology Applications to Market"

Product readiness vs. level of impact: Materials & Manufacturing



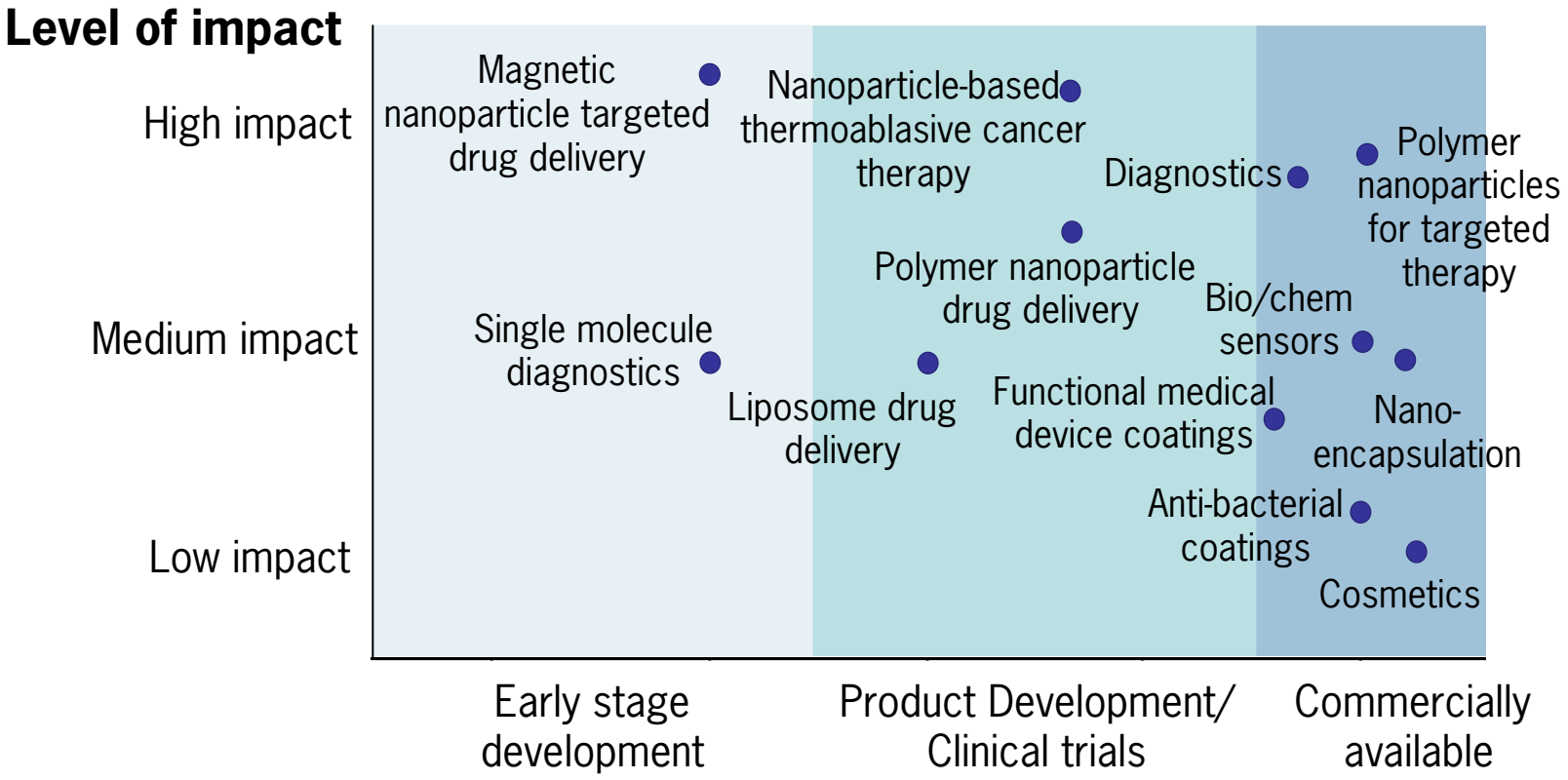
Source: September 2007 Lux Research Report "Bringing Nanotechnology Applications to Market"

Product readiness vs. level of impact: Electronics & Energy



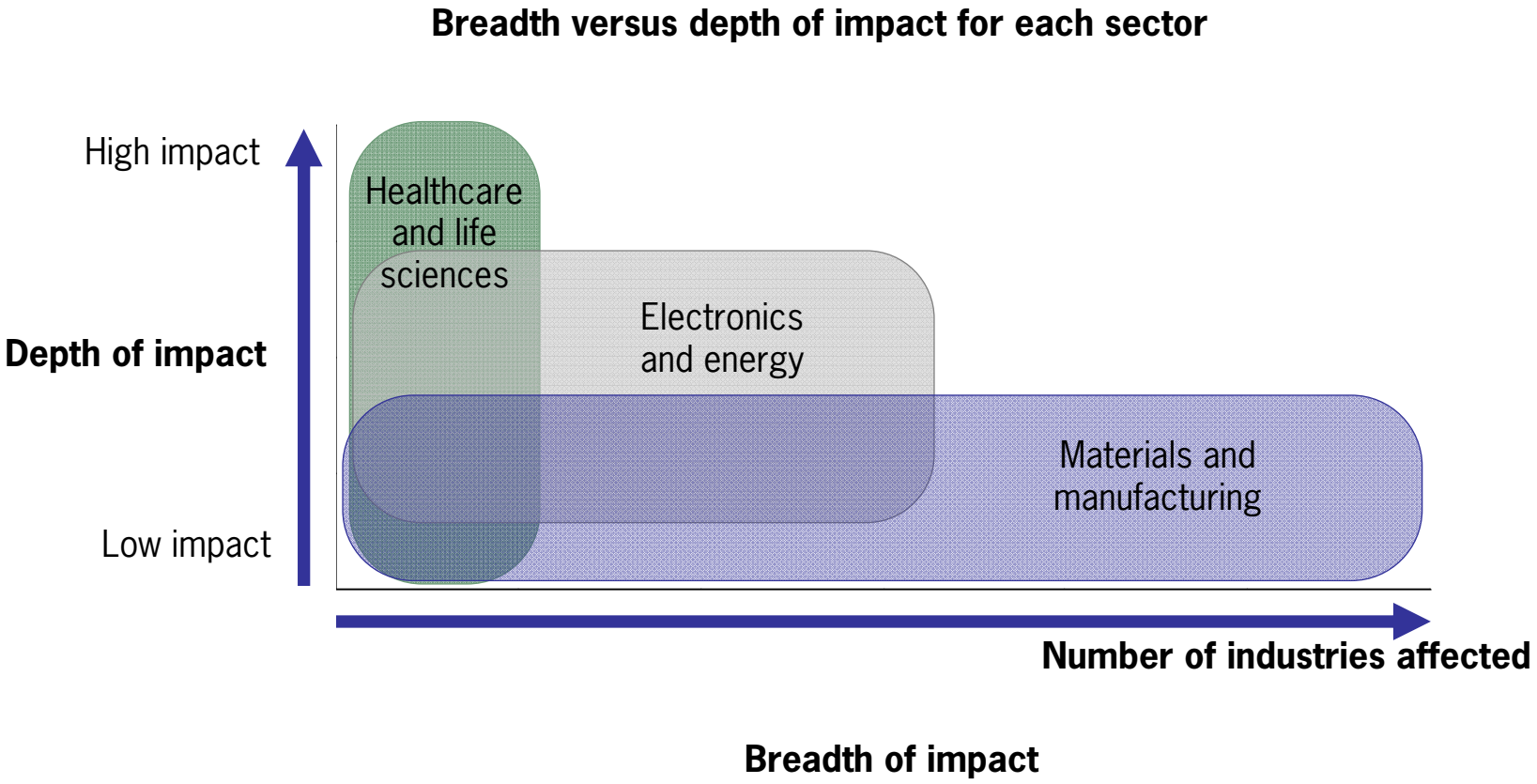
Source: September 2007 Lux Research Report "Bringing Nanotechnology Applications to Market"

Product readiness vs. level of impact: Healthcare & Life Sciences



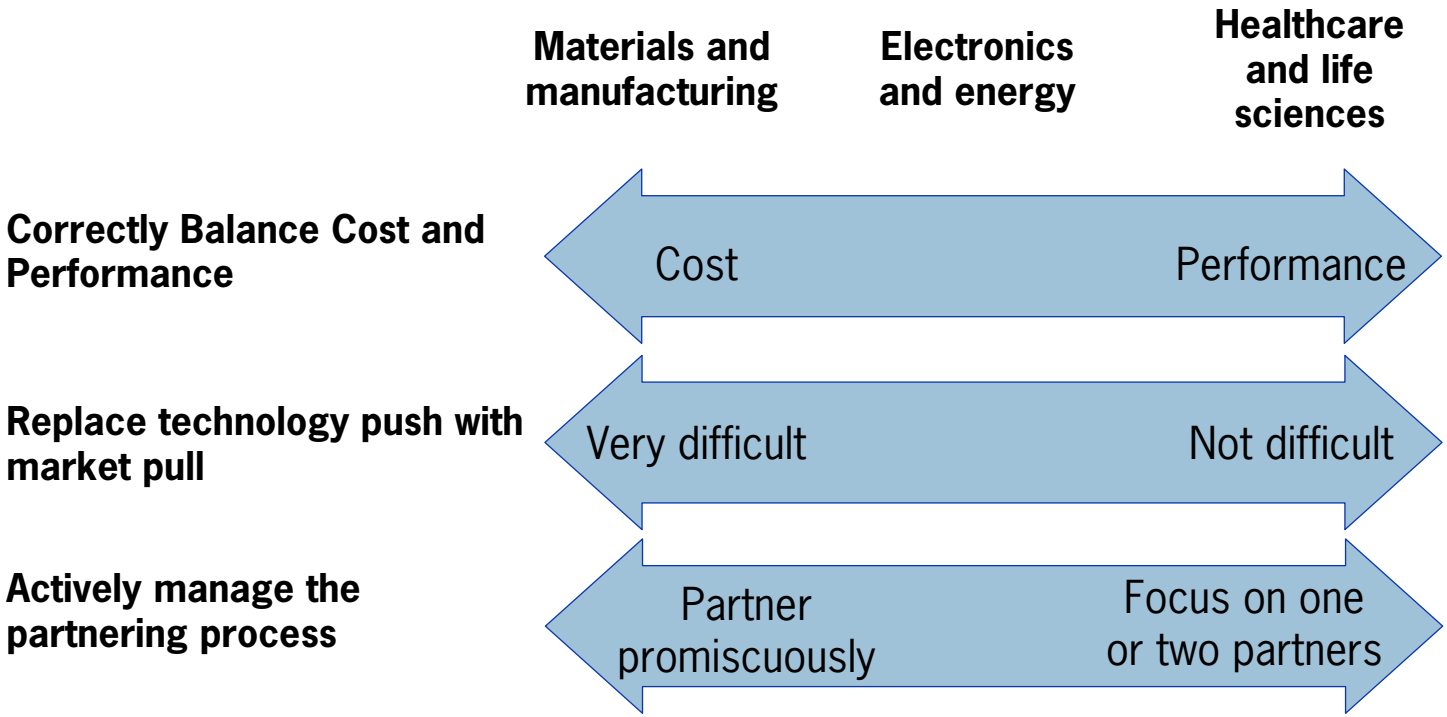
Source: September 2007 Lux Research Report "Bringing Nanotechnology Applications to Market"

Nanotechnology Impact is Different in Each Sector



Source: September 2007 Lux Research Report "Bringing Nanotechnology Applications to Market"

Commercialization strategies need to be driven by sector-specific factors



Source: September 2007 Lux Research Report "Bringing Nanotechnology Applications to Market"

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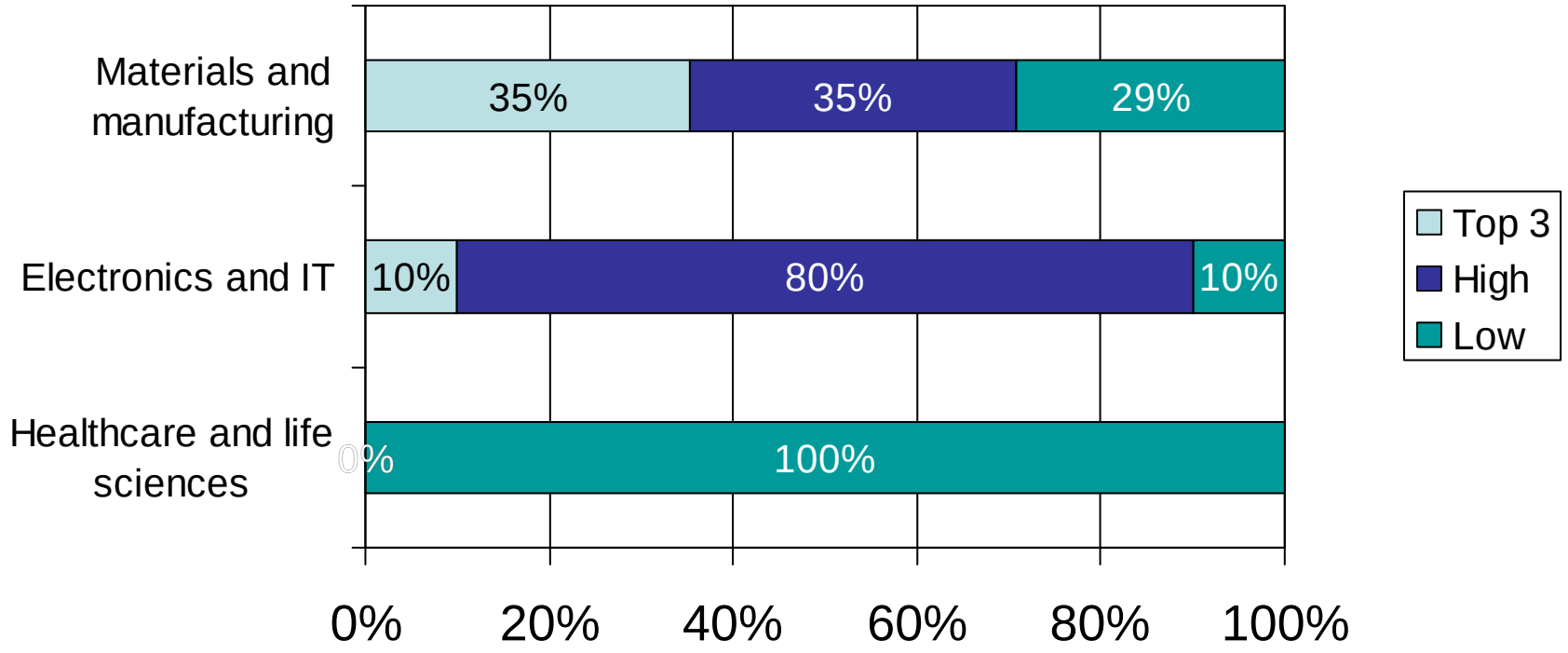
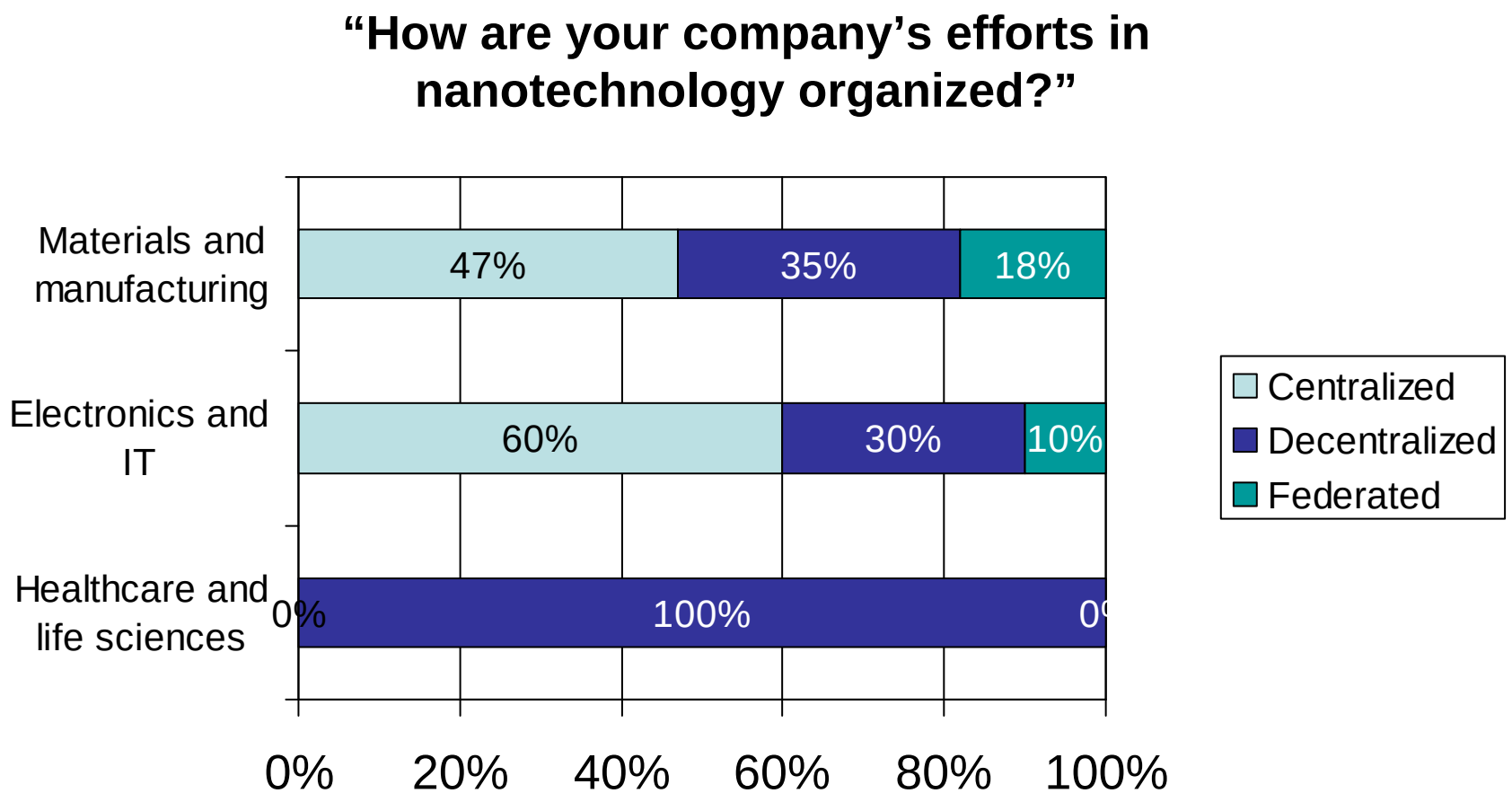
Electronics and IT companies see nanotech as a big, but not a top three, priority

"How big a priority is nanotechnology at your company today?"



Source: December 2004 Lux Research Report "The CEO's Nanotechnology Playbook"

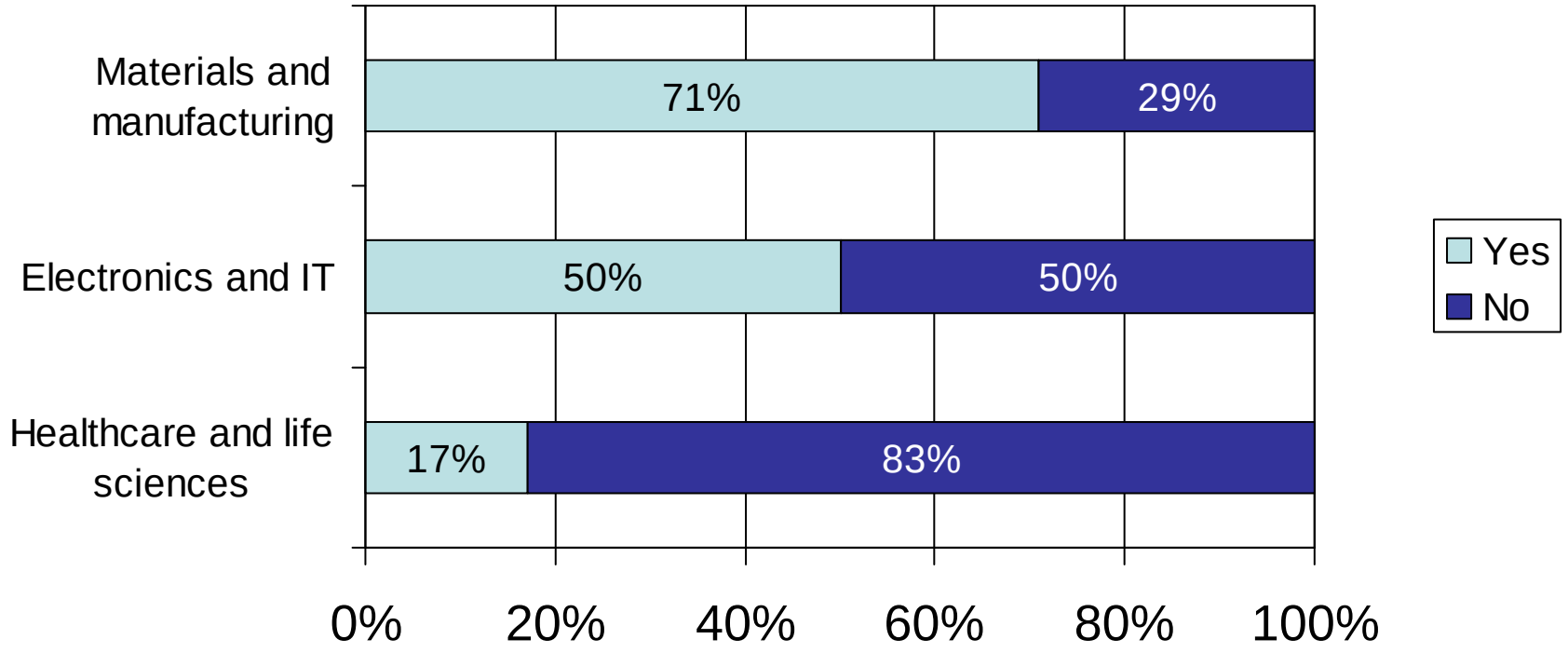
Most electronics and IT companies have a dedicated nanotechnology effort



Source: December 2004 Lux Research Report "The CEO's Nanotechnology Playbook"

Half of electronics companies claim to have an explicit nanotechnology strategy

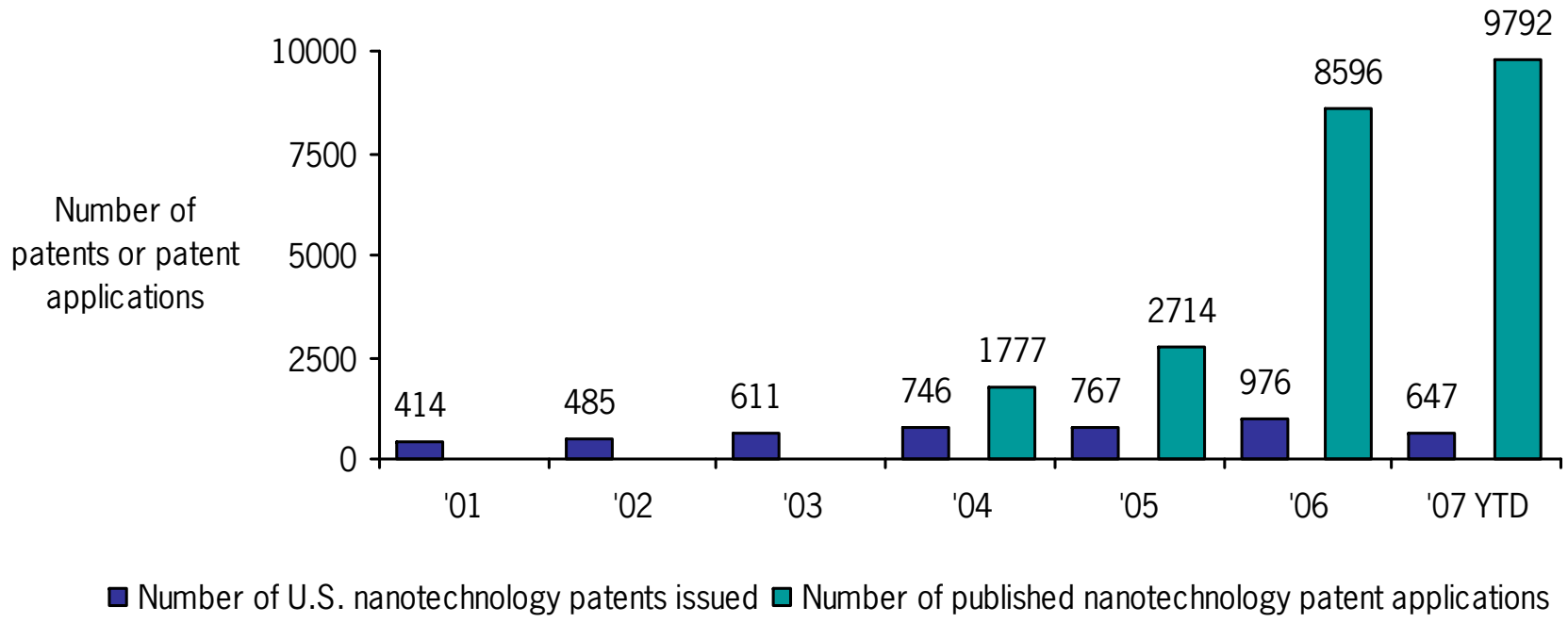
"Does your company have an explicit strategy for exploiting nanotechnology innovations?"



Source: December 2004 Lux Research Report "The CEO's Nanotechnology Playbook"

Nanotechnology IP Landscape: Rising pendency is creating a significant backlog

- Backlogged pub. patent applications tops 20,000 dating back to 2004

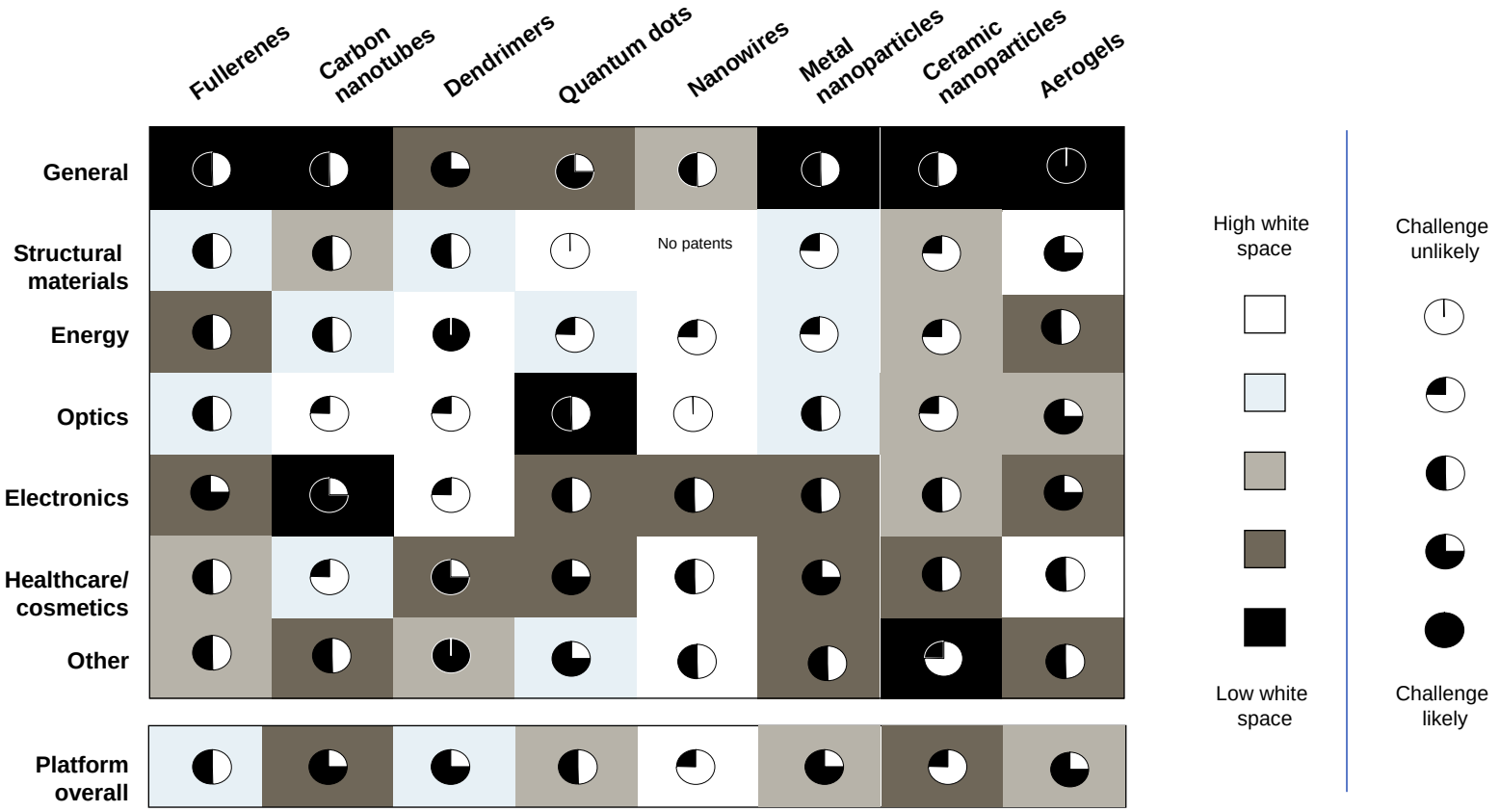


Source: Lux Research patent analysis as of July 2007

Nanotechnology IP Landscape

Lux Research found 4,986 nanotechnology patents covering 102,651 claims, and did claim-by-claim analysis of eight nanomaterials covering 2,646 patents and 49,807 claims.

- It's messy – detailed analysis required for each particle and application
- However, judicious firms can find freedom to operate

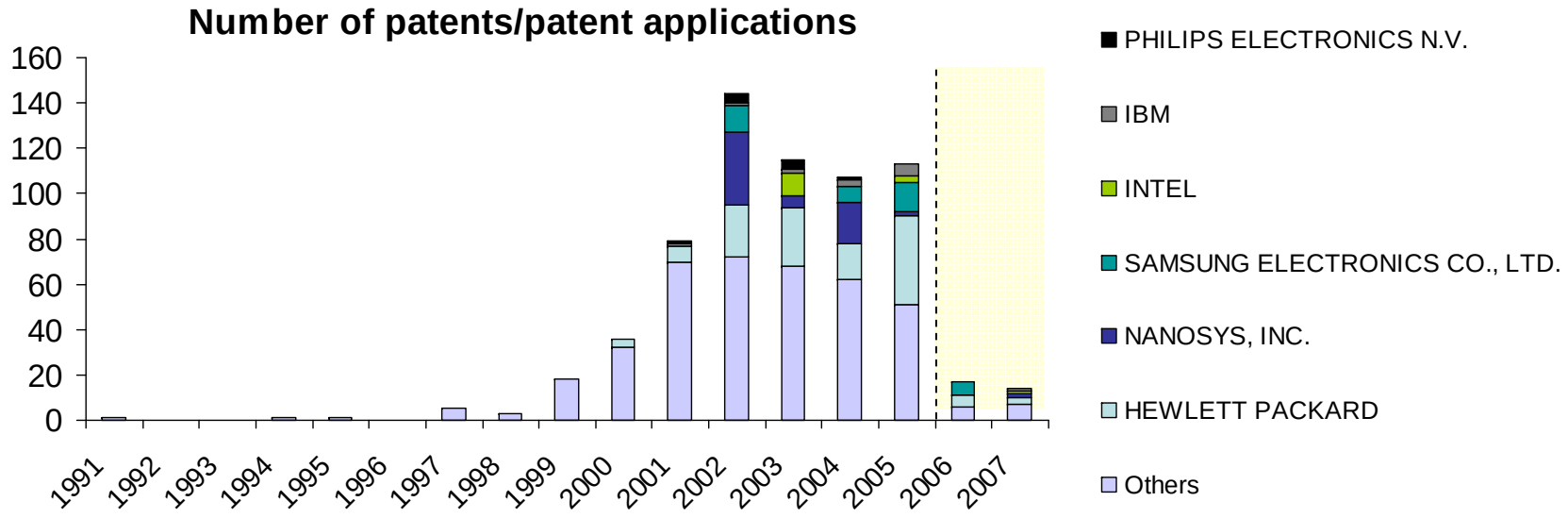


Source: June 2006 Lux Research Report "Nanotech IP Battles Worth Fighting"

Nanowires – Commercialization (1)

Application activity: Leading developers

- Based on an analysis of 654 issued patents and published patent applications from the USPTO
- Activity is mapped by year of earliest filing to remove USPTO processing lag, although data is complete only through 2005
- Leading applications developers
  - Hewlett Packard accounting for 19% of the total activity
  - Nanosys accounting for 9% of the total activity, but also holds licenses to significant university work

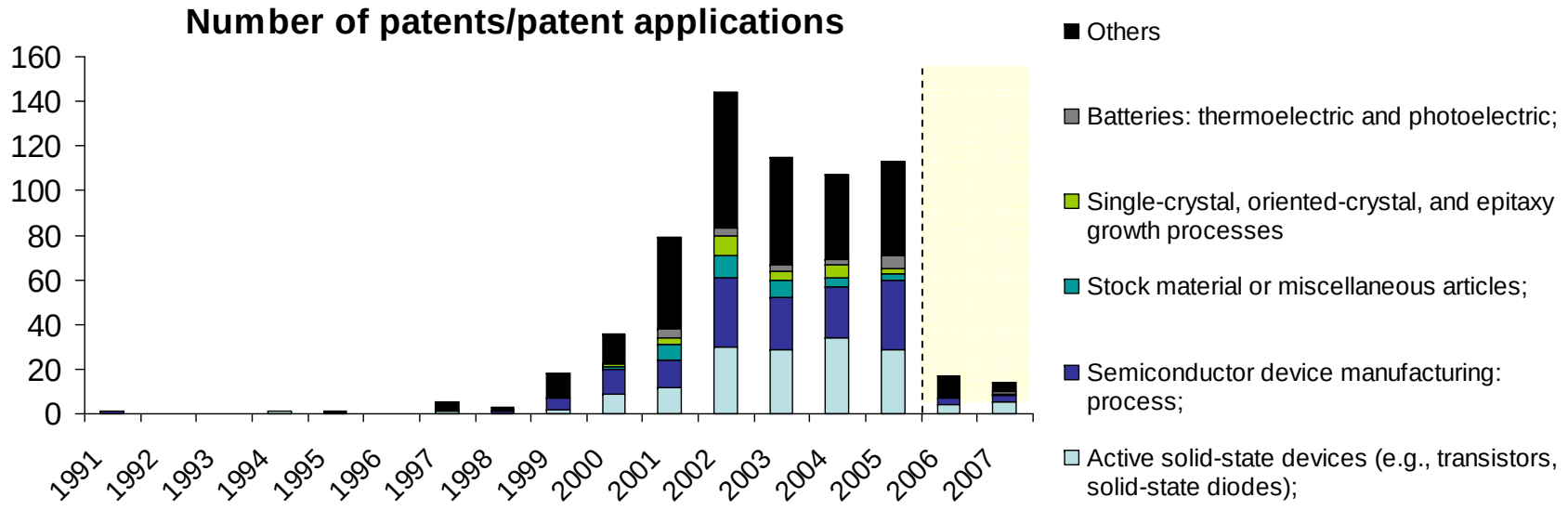


Source: Lux Research patent analysis as of July 2007

Nanowires – Commercialization (2)

Application activity: Leading applications

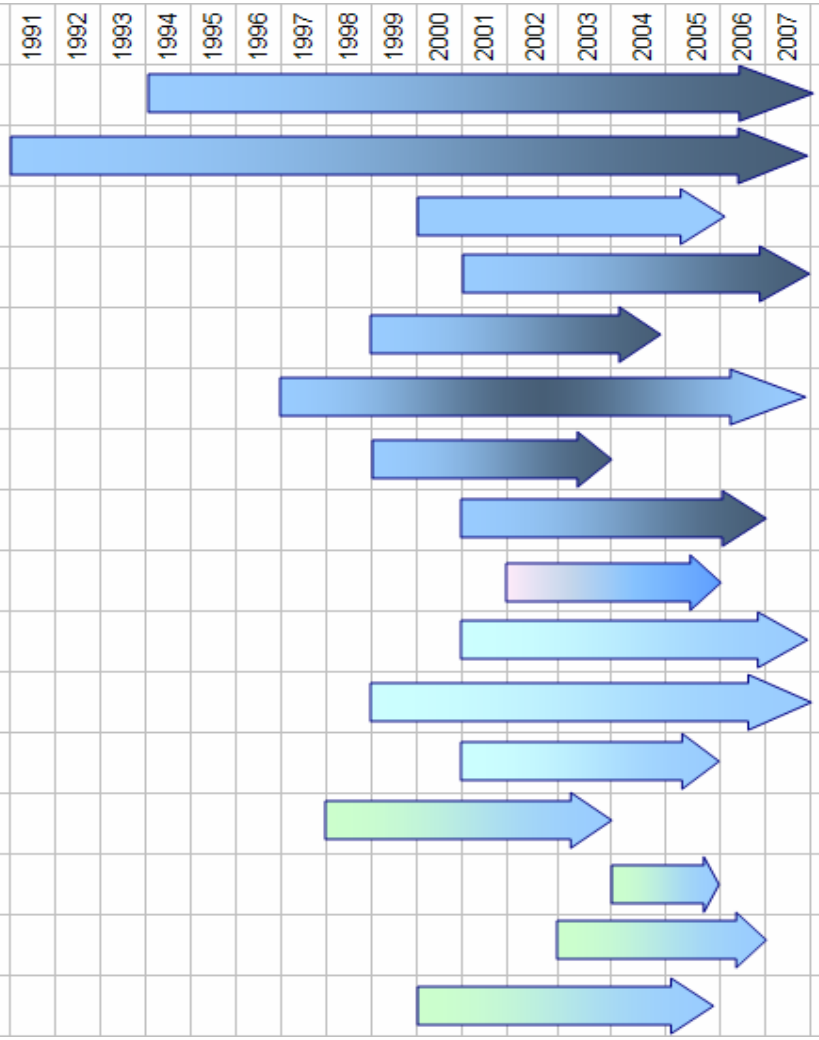
- Based on an analysis of 654 issued patents and published patent applications from the USPTO
- Activity is mapped by year of earliest filing to remove USPTO processing lag, although data is complete only through 2005
- Leading applications are in two areas:
  - Active solid-state devices (e.g., transistors and diodes) accounting for 24% of the current activity
  - Semiconductor device manufacturing accounting for 22% of the current activity



Source: Lux Research patent analysis as of July 2007

Nanowires – Commercialization (3)

Description	Year of introduction	Activity lev	Momentum
Active solid-state devices (e.g., transistors, solid-state diodes);	2010	High	High
Semiconductor device manufacturing: process;	2009	High	High
Single-crystal, oriented-crystal, and epitaxy growth processes;	n/a	Med	Low
Batteries: thermoelectric and photoelectric;	2012	Med	High
Electric lamp and discharge devices;	2015	Med	High
Chemistry: electrical and wave energy;	n/a	Med	Low
Etching a substrate: processes;	n/a	Med	Low
Optics components	2013	Med	High
Data processing: design and analysis of circuit or semiconductor mask;	2017	Med	High
Electronic digital logic circuitry;	2015	Low	High
Chemistry: electrical current producing apparatus, product, and process;	2015	Low	High
Nanotechnology;	2020	Low	High
Electricity: measuring and testing;	n/a	Low	Low
Data processing: measuring, calibrating, or testing;	n/a	Low	Low
Dynamic magnetic information storage or retrieval;	n/a	Low	Neutral
Electricity: electrical systems and devices;	2020	Low	Neutral



Source: Lux Research patent analysis as of July 2007

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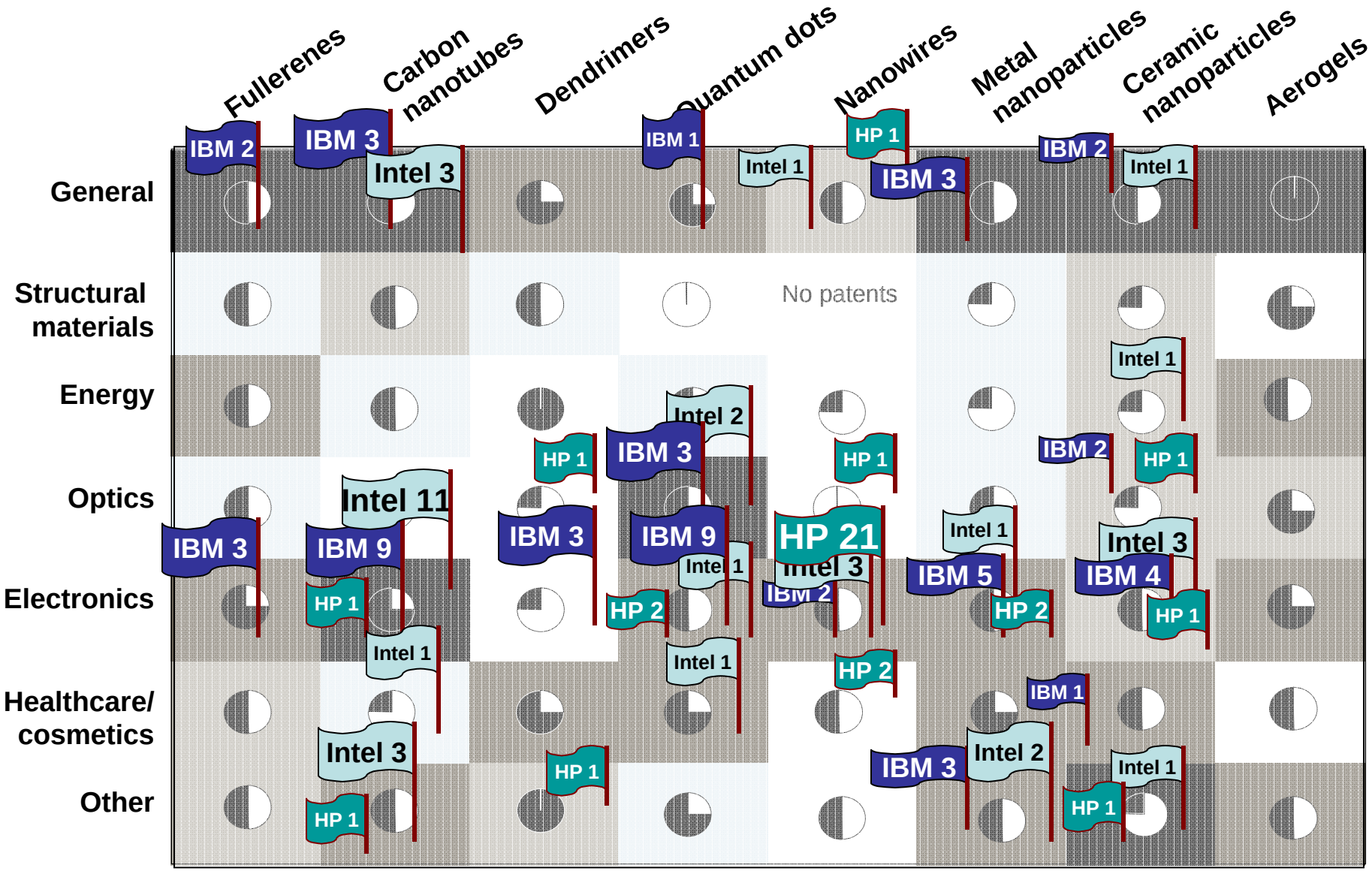
Nanotechnology IP Landscape: Activity of IBM, Intel, & HP



Source: Lux Research patent analysis as of July 2007

Overview

- Nanotech activities from IBM, Intel and HP contribute significantly to the scientific research in nanoelectronics.
  - Despite leading efforts in fundamental research on materials and applications, IBM's nanotech efforts fall mostly into the realm of interesting science. Innovations that hold commercial potential will likely be licensed off rather than produced
    - **IBM follows an internal research and development protocol**
  - Intel must incorporate many of its innovations into products to maintain its leadership position in the semiconductor industry. Many advances in nanotech will be critical to continuing Moore's Law
    - **Intel utilizes internal R&D, but more importantly its VC group**
  - HP holds out considerable commercialization potential, but a lack of a focused/targeted effort for its research makes it an unlikely champion
    - **HP focuses on universities and start-ups to complement internal R&D**

IBM's Nanotech Activities

- **Background:** IBM's core business is increasingly focused on services, but the company's research labs conduct investigation into nanoelectronics with applications in semiconductors, memory devices, and photonic ICs

- **Nanotech funding:** Since 2004 0.5% to 1% of its R&D budget to nanotech, $35 million in 2006

- **Nanotech headcount:** 150+ employees are dedicated to research in nanotech, estimates from Tom Theis but may not represent fulltime activities in nanotech (note: at $200,000/year salary for a full time equivalent (FTE), 150 employees draws $30 million/year); the likely FTE at IBM is 75 to 100 people with other funds earmarked for equipment purchases

- **Summary:** IBM's work in nanoelectronics is diverse and ultimately targeted for commercial integration, however, the current status of many of the projects that IBM has undertaken is considerably **earlier stage** –in many cases either concept stage or lab stage. IBM is likely to choose only the most promising areas and license out other innovations along its services business model.

- **Projects:** Millipede, silicon nanophotonics, CNT electronics (oscillator)

Intel's Nanotech Activities

- **Background:** As a leader in semiconductor process technology, Intel's activities in nanotechnology look at harnessing nanoscale innovation to further Moore's Law in scaling devices
- **Nanotech funding:** estimated at 10% of total R&D
- **Nanotech headcount:** estimated at 100s of people spanning various R&D facilities
- Key areas of focus:
  - **Quantum dot memory**: Targeting a floating gate flash memory replacement, Intel is in a 3-way collaboration with technology partner, Micron, and nanotech startup Nanosys to develop a novel charge trap memory device that uses metal quantum dots of SiGe(5nm in diameter) as the charge storage medium. The quantum dots are synthesized offline and functionalized such that the nanomaterials can be coated onto the silicon wafer substrate in an ordered array. Likely incorporation at the 22nm technology node
  - **Carbon nanotube interconnects**: While few nanomaterials are listed on Intel's technology roadmap, the company continues efforts to research the potential use of carbon nanotubes as an interconnect material in ICs. Currently lagging in the conceptual stage, Intel anticipates potential commercial incorporation by 2012, and likely use of this technology will take the form of printable interconnects with CNT-based inks in chip package.
  - **Thermal interface media**: Using metal nanoparticles and carbon nanotubes, Since 2002, Intel has been investigating the potential use of novel materials to improve thermal interface between chip and heat spreaders.
- **Summary:** With the most to gain from implementing novel technologies to maintain its technology leadership position, **Intel is likely to lead commercialization of nanoscale innovations** that move beyond simple scaling of existing materials and architectures used in its IC products. With significant issues arising from processor heat generation, material innovations could appear here first, but it is unlikely that Intel will be vocal in publicizing these breakthroughs.

HP's Nanotech Activities

- **Background:** Driven by a need to find new applications for its ink jet core competency, HP's activities in nanotechnology tend towards innovations that will enable printed electronics capability.
- **Nanotech funding:** ~0.5% of R&D spending is allocated to nanotech research, $30 million in 2006
- **Nanotech headcount:** 65 employees are dedicated to nanotech research
- Key areas of focus:
  - **Nanoimprint lithography (NIL):** Using equipment developed in-house, as well as from NIL equipment suppliers like Molecular Imprints, HP puts considerable manpower to developing NIL expertise looking at all aspects including equipment, stamp, surface prep materials, patterning materials, and lift-off techniques.
  - **Nanowire arrays:** Stemming from research in nanoimprint lithography, HP has been able to develop ordered arrays of silicon nanowires
  - **Carbon nanotube-enable printed electronics:** A recent development at HP has been the undertaking of developing a carbon nanotube-based ink with noted CNT-based memory developer, Nantero. HP and Nantero are targeting the development of an ink-jet printable memory device based on carbon nanotubes explicitly for RFID. Other developments that will like stem from this collaboration are CNT-based conductive inks for other RFID tag components like the antenna.
- **Summary:** HP's nanotech efforts are diverse and uncoordinated. The company has great potential to bring innovations to market given its broad product portfolio in electronics ranging from computers and printers to digital cameras. Despite this potential, **the random assortment of innovations that the company has pursued in earnest to date are far from commercialization**. With a focused partnership with Nantero, HP could advance its printed electronics activities.

Thank you

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