Innovation or Imitation? China's Bid to Become a Global Leader in Nanotechnology

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Data Sources

- **secondary:** publications, websites, recent reports (Demos, Lux, Council on Competitiveness)
- **fieldwork in China:** 30+ interviews with scientists, engineers, and policy-makers (summer 2006):
  - National Center for Nanoscience and Technology
  - Shanghai Nanotechnology Promotion Center
  - Nanotechnology Industrialization Base of China / China National Academy of Nanotechnology & Engineering (Tianjin)
  - Shanghai Jiao Tong University, Fudan and Peking Universities
  - Chinese Academy of Sciences
  - IMMS, IC-DFN meetings in Shanghai

Planning Environment For Nanotechnology

- *Nanomaterial and Nanostructure Basic Research Project:* funded by MOST, 1999 – present; basic research on nanotubes
- *10 Year "Climbing Up" Project* on nanomaterials (1990)
- *10th Five Year Plan* (2001-05): US$400 million invested in nanotechnology; calls for "bridging gap between research and marketplace," international collaboration
- *11th Five Year Plan* (2006-11): calls for development of "new materials;" "industrializing the technology for 90-nanometer and smaller integrated circuits"
- *National Long and Medium Term Scientific and Technological Development Plan, 2006-2020*
  - calls for "breakthroughs in the study of nanotechnology, which has been a strategic option for many countries to promote their competitiveness" – one of four "Science Megaprojects"
  - international collaboration = one of four policy instruments

International Collaboration

- **personal collaborations:** important and growing
- **institutionalized arrangements** involving international agreements (e.g., NSF-PIRE Program, http://pire-ecci.ucsb.edu/): growing
- **"100 Person Plan:"** lure back top researchers from overseas through lavish grants (~ millions of RMB) as startup funding for labs and research expenses
- Internet, relative ease of travel (but: **post 9-11 concerns**)

National Nanotech Platforms

- National Steering Committee for Nanoscience and Technology (2000) – to oversee national policy and planning
- National Engineering Research Centers for nanotechnology
  - Shanghai (SNERC): 10 major shareholders (CAS Institutes, universities, firms, Shanghai Nanotech Promotion Center)
  - Beijing: never got off the ground
- National Center for Nanoscience and Technology (NCNST) – Beijing

National Center for Nanoscience and Technology (NCNST)

- **founded (2003) under Chinese Academy of Sciences**, Tsinghua and Peking Universities; support from MOST, Min of Ed, National Development and Reform Commission
- **primary concerns:**
  - fund basic research, including funds for instrumentation (no product development)
  - enable nanotech scientists and engineers to work together
  - develop common standards for working at the nanoscale
- **four main in-house laboratory branches :**
  - nano-processing and nano-devices
  - nano-materials and nano-structures
  - nano-medicine and nano-biotechnology
  - nano-structure characterization and testing

Shanghai National Engineering Research Center (SNERC)

- proposal to create SNERC ratified by National Development and Reform Commission in 2003
- included in national high-tech development plan and 2005 Shanghai Key Project
- 10 major shareholders (Shanghai Nanotechnology Promotion Center, CAS Institutes, Shanghai Jiao Tong University, firms

  →"nano bomb" for liver cancer: 10 nm nanomagnetic heat treatment device; successful testing on rabbits (SNERC Director Gu Hongchen, Fudan University's Zhongshan Hospital, Shanghai Jiao Tong University)

Some Key Funding Sources

MINISTRY OF SCIENCE AND TECHNOLOGY PROGRAMS

- *863 program* (National High Technology Research and Development Program): nanotechnology singled out as a priority area for public funding
- *973 program* (National Basic Research Program): seeks to improve capacity for innovation, enabling China to "scale the peak of the world's science;" one project involves directional growth of long (2-3mm) carbon nanotubes

MINISTRY OF EDUCATION PROGRAMS

- *985 Project*: funds large university improvement grants; 30 top universities are recipients
- *211 Program*: aims to develop 100 "quality universities" for the 21st century

Additional Funding for Research, Development (including Nanotechnology)

NATIONAL NATURAL SCIENCE FOUNDATION

- increased importance as funding source (2005 total budget of US$337 million = 1/5 total gov't spending on research); growing 20% annually; peer review process

CHINESE ACADEMY OF SCIENCE

- *Knowledge Innovation Program* (2001-): gives priority to nanotechnology and other high-tech fields; calls for CAS incubation of high-tech startups by CAS-affiliated Institutes

How Much Government Funding for Nanotechnology? Estimates Vary….

- **$160 million in 2006** (Bai Chunli, Executive Vice-President CAS; Director, NCNST)
- **$250 million in 2005, up from $197 million in 2004** (Lux Nanotech report, 4th edition)

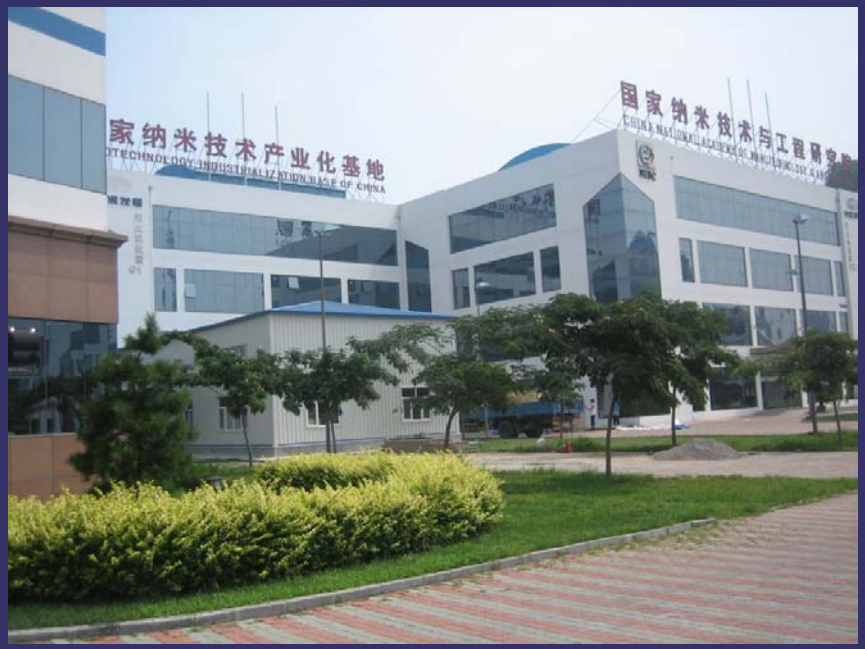
  = 1-2% of total gov't funding for "scientific and technological activities"

Nanoscale R&D: Multifaceted, Growing

- ~ 50 universities
- ~ 20 CAS Institutes
- ~ 300 industry enterprises
- ~ 3,000 researchers from different institutes, universities, enterprises

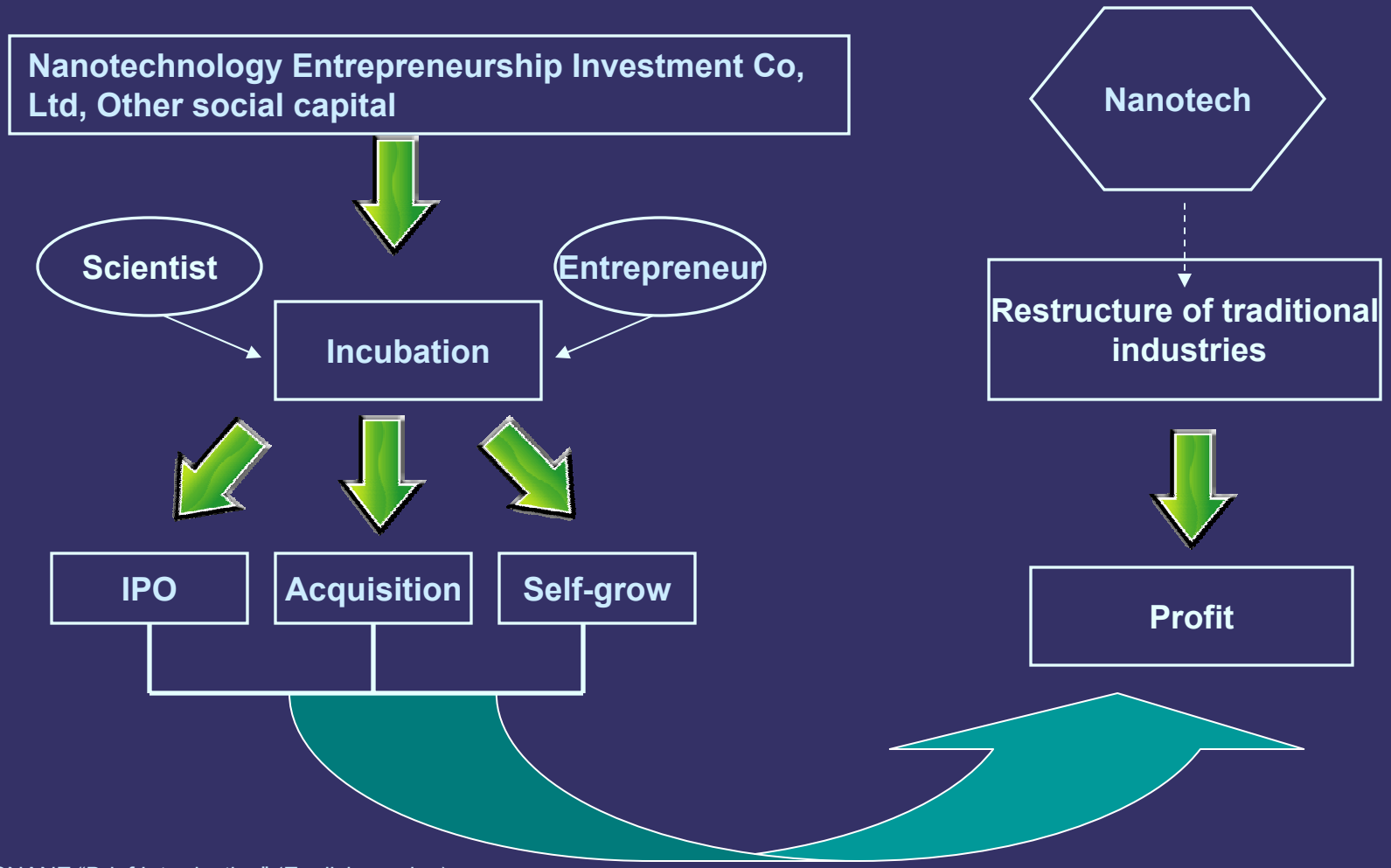
source: Bai Chunli, *Science* July 2005

Nanotechnology Industrialization Base of China (NIBC) / China National Academy of Nanotechnology & Engineering (CNANE)



- **CNANE** and **NIBC** in same facility, under same administration
- funding provided by Chinese Academy of Sciences, universities, and private enterprises
- **CNANE:** basic research, R&D
- **NIBC:** commercialization and profit-making; a principal incubator for Beijing area commercial spin-offs

NIBC/CNANE:
Nanotechnology Industry Increment Mode Chart



Adapted from CNANE "Brief Introduction" (English version)

NIBC/CNANE: Potential Applications

- **materials:** lighter, stronger; e.g. bullet proof vest, self-cleaning surfaces
- **medicine and health:** rapid and efficient genetic sequencing, diagnosis, and treatment technology; new drug delivery system (magnetic nanoparticles can be coated with anti-cancer drugs or antibiotics)
- **space craft and aviation:** super-light aircraft made of polymers
- **environment and energy:** clean energy, nanoporous material to clean water and air
  - Tianjin Alliance Technology: CNT-based super capacitor; provides uniform high-voltage power supply in the face of power fluctuations (pilot project)

Shanghai Nanotechnology Promotion Center (SNPC)

- funded by Shanghai Municipal Government, the State Development and Reform Commission, and local enterprises
- SNPC has several university-affiliated "industrialization bases" whose purpose is technology transfer
  - one of its core foci: development of nanomaterials for environmental reclamation
  - outreach program intended to raise public awareness about nanotechnology, including an exhibition at the Shanghai Expo Center

Shanghai Jiao Tong University

- adjacent to "Purple Bamboo" S&T industrial park (one of 53 throughout China; 30 more planned by 2010)

- College of Environmental Engineering: nanoporous materials for water filtration, environmental remediation

"Global Corporations Rank China as the Most Attractive Location for New Offshore R&D Facilities"
-US Council on Competitiveness, Nov. 2006

Shanghai's Dengshan ("Climbing Mountain") Action Plan

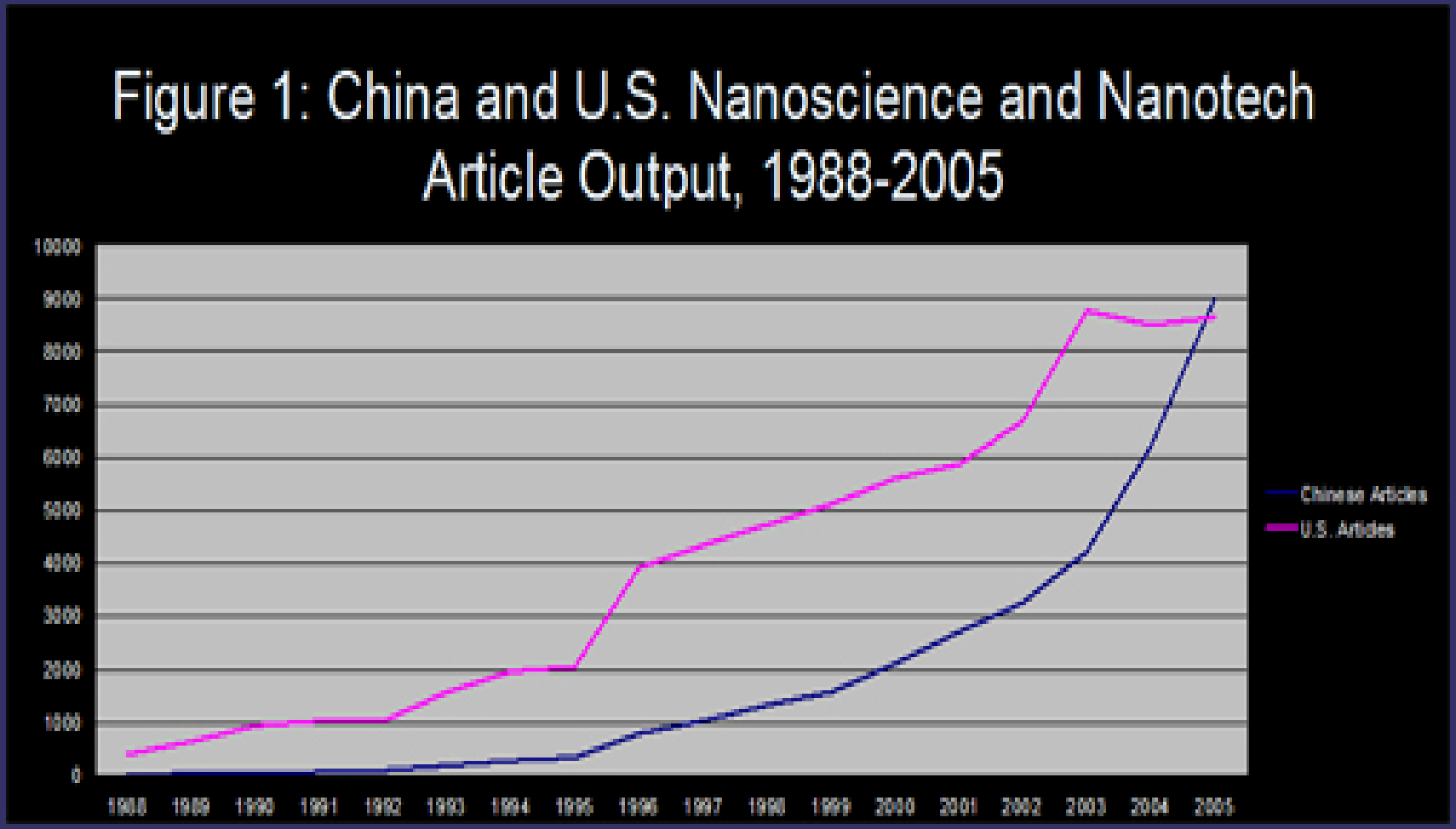
- funded by Shanghai Municipal Gov't
- nanotech component supports "frontier" and applied research (→ industrialization)
- examples of applied research:
  - low-energy cold lighting → high resolution large-size flat-screen displays
  - nano composites for construction uses
  - nano functional fiber and textile
  - nano materials for environmental purification, industrial catalysis

One Payoff: Scientific Publications

- 13% of all nano-related scientific papers in 2003 were from Chinese authors (U.S. = 24%); number of highly-cited "high impact" papers remains low (Zucker and Darby)

- 21-fold increase in nano-related publications 1994-2004 (Kostoff *et al*)

Nano-Related Publications, 2005



source: CNS analysis of database of more than 14,000 nanotechnology articles in 81 high-impact science and engineering journals

Scientific Impact: Weak, But Rising?

- Citations Per Paper, 2001-2003
  - China: 2.28
  - Japan: 3.70
  - Germany: 4.54
  - United States: 6.56
- U.S. Patents: negligible

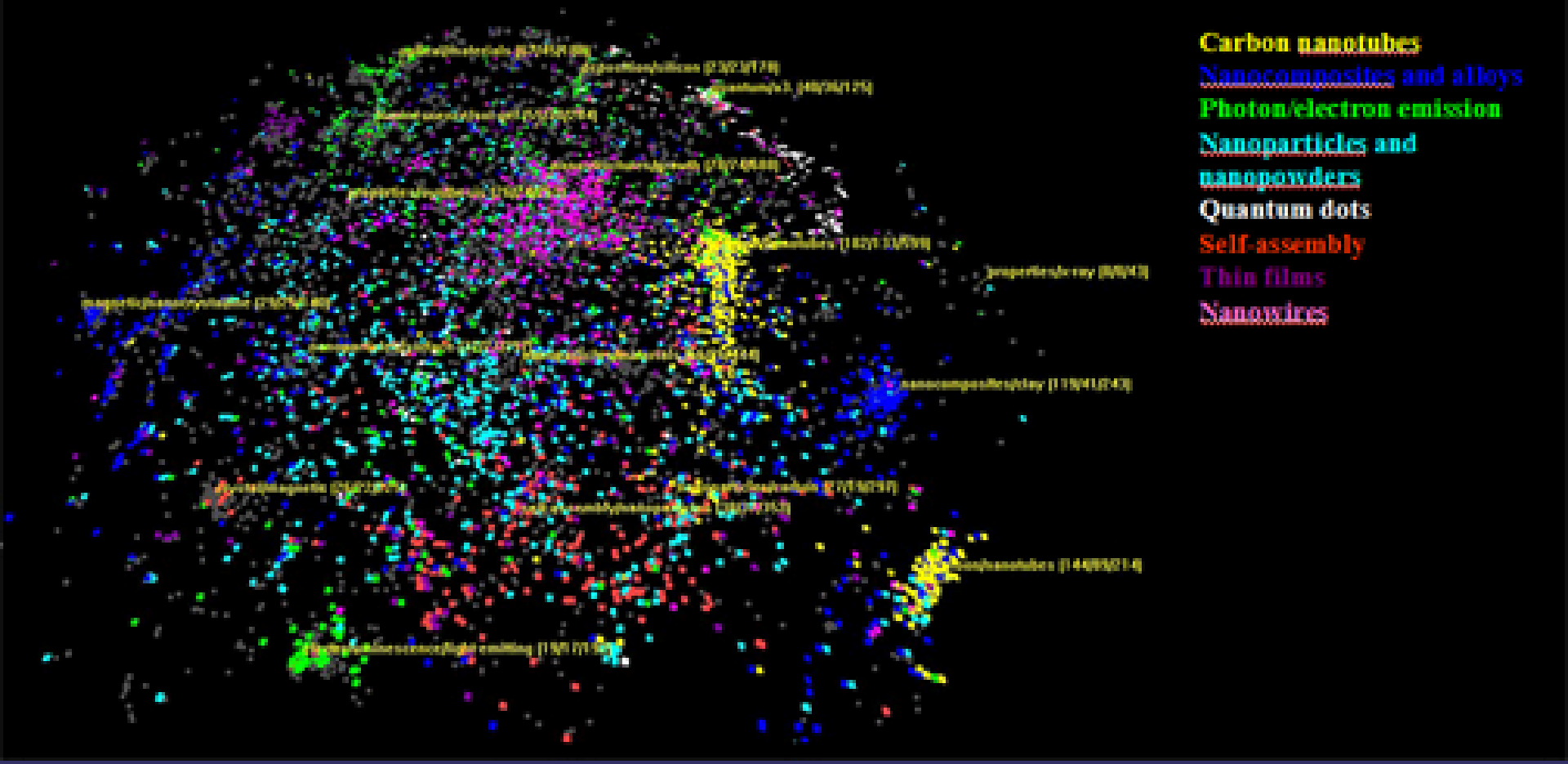
source: Bai Chunli, *Science* July 2005

Chinese scholarship is improving, thanks to international collaborations + growing number of returning overseas Chinese

- Esther Levy, editor of *Advanced Materials*

- ✓ **China is leading source of submissions to *Advanced Materials* with "nano" in title (31% of ~1,300 in 2005)**

Figure 2: Landscape of Chinese Nanoscience 2003-2005



source: CNS analysis of shared citations

Strengths of China Nanoscience

- **carbon nanotubes** → CNT yarns with great tensile strength (Fan Shushan, Tsinghua University)
- **nanoporous materials:** catalysts, environmental filtration (Zhao Dongyuan, Fudan University)
- **commercialization of basic nanomaterial applications**, such as coatings and composites
  - 30+ product lines employ nanomaterials, including textiles, plastics, porcelains, lubricants and rubbers

Commercialization: Some Examples

- **self-cleaning glass:** Beijing Concert Hall
- **"nano refrigerators"** with interior coatings that absorb odors
- **air conditioners** that filter out organic materials
- **camera lenses** with nano coatings that filter out glare
- **fabrics** that repel water and stains
- **conductive and anti-corrosive coatings** for oil tanks (Shenzhen Nanotech Port Company)
- **pavement coatings** that filter out vehicle exhaust (to be used in Olympic venue parking lots)

...and Some Weaknesses

- **commercialization remains limited:** nanotech largely in R&D phase
  - progress impeded by state-managed industries wary of innovations whose returns may lie in the distant future
  - major products 15+ years off?
- **intellectual property** issues/protections
- **pressure to produce/publish** (quality, fraud)
- **limited infrastructure** (e.g., nano fabrication facilities); **inadequate funding**
- **lack of private venture capital**

Some High-Level Reservations….

"Nano science is still very much occurring at the laboratory scale. There isn't an area that is near commercialization yet. Yet the future of nanotechnology in China is pretty bright." – Xie Sishen, Chief Scientist, NCNST

"Nanotechnology is not a commercially important technology yet. Scientific as well as investment and marketing efforts are needed to make nanotechnology more significant." – Wang Chen, Deputy Director, NCNST

…and some High-Level Optimism

"We let you know that serious science is being done in China."

-Cao Jinghua, Assistant Director General, Bureau of International Cooperation, Chinese Academy of Sciences, NSF-China Nanotech meeting, March 24,2006