# Asia Pacific Nanotechnology R&D and Commercialization Efforts

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## ABSTRACT

The unveiling of the National Nanotechnology Initiative in 2000 ignited a global race to develop nanotechnology. In the coming years, governments around the world will pour billions of dollars into the field. Perhaps the most promising region for nanotechnology R&D and commercialization is the Asia-Pacific. In this article, Dr. Lerwen Liu offers a detailed description of nanotechnology expenditures in the Asia-Pacific region. She discusses public commitments to R&D by Asian governments, with a focus on Japan, China, South Korea, and Taiwan. She also describes steps taken by Asian governments to facilitate commercialization of nanotechnology. The article then provides a summary of private investment in Asia as well as collaborate R&D and investment efforts. Finally, in the appendix, Dr. Liu provides detailed descriptions of nanotechnology funding in Australia, China, Hong Kong, India, Malaysia, New Zeland, Singapore, Taiwan, and Thailand.

## **INTRODUCTION**

The Asia Pacific (AP) region is advancing to become one of the most ambitious and dynamic nanotechnology regions in the world. There have been significant changes in the science and technology ("S&T") policy making in AP countries since the announcement of the US National Nanotechnology Initiative (NNI) in January 2000. Governments in the AP region have placed nanotechnology as one of the priority areas in S&T planning. The budgets for nanoscience and technology R&D, which include MEMs in most Asian countries, have been increased substantially and are more strategically allocated. Total public spending in the AP region is about US \$1.4 billion for 2003 (70% of which is from Japan), and private investments are on the rise. Appreciation of the importance of nanotechnology R&D has been growing in various industries and businesses in the region. The commercialization of microtechnology and nanotechnology has also become key in government and corporate strategy, particularly in advanced countries such as Japan. MEMS foundries are being established across Asian countries, including Japan, Korea, and Taiwan.

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## I. NANOTECHNOLOGY R&D IN ASIA

Japan, one of the most technologically advanced countries, has been investing in nanoscience since the mid-1980s through various national programs. Its government funding for nanotechnology per capita is the highest in the AP region and the world. Funding in 2002 increased by 20-30% from 2001. According to Japanese government data, the Nanotechnology and Materials Program R&D budget for 2003 is about US \$900 million,<sup>1</sup> which is about 11.5% of Japan's total S&T budget for the four priority areas (Life Science, Information Technology, Environment, and Nanotechnology). The other three priority areas also contain nanotechnology topics. If funding for those topics is included in the total estimate, Japan's total budget for nanotechnology is about US \$1.49 billion (with the supplementary budget included). The budget request for 2004, which was released at the end of August 2003, indicates that the Japanese government may increase the nanotech R&D budget for 2004 by over 20% compared to 2003.<sup>2</sup>

Countries such as the People's Republic of China, South Korea, and Taiwan have drastically increased their nanotechnology spending since 2001. China plans to spend 2-2.5 billion RMB (US \$250-300 million) in the current five-year plan (2001-2005). China is about to launch more aggressive initiatives because it wishes to match the funding of other advanced countries such as South Korea. China is currently building the National Nanotech R&D Center near Beijing University, TsingHua University, and the Chinese Academy of Sciences (CAS). The center is expected to be finished by 2004. The Nanotech Industry Base is also being built in Tianjin (about 100km east of Beijing) and is expected to be fully operational by the end of 2003.

South Korea has committed 2.391 trillion KRW (US \$2 billion) over a 10-year period (2001-2010). Government spending on nanotechnology for 2002 increased about 400% compared with 2000. One of the goals of its National Nanotechnology Initiative is to make Korea number one in the world in certain competitive areas and to develop niche markets for industry growth. Korea has a clear focus on a number of "core technologies" such as tera-level integration of electronic devices. Its "Year 2002 Plan for Implementing Nanotechnology Development" was launched with two new Frontier Research Programs, "Development of Nanostructured Materials Technologies" and "Development of Nanoscale Mechatronics & Manufacturing Technologies." Each of the programs has US \$100 million of funding for the next ten years. In addition to the Frontier Research Programs for Nanotechnology, the Korean government has launched "Core," "Basic," and "Fundamental" research programs whose total research budget is about US \$20 million every year for the next six to nine years. A Nanofabrication Centre was established last year with the main purpose of nanoscale device fabrication. It is located at the Korea Advanced Institute of Science and Technology (KAIST) in Daejoen Science City, where most government research labs are located. The Korean government has allocated US \$165 million for this center over nine years (2002-2010). The government has recently formulated the "2003 Action Plan for Nanotechnology Development," which includes the "Presidential Decree and Enforcing Regulation" for implementing the "Nanotechnology Development Promotion Act." The aim of this act is to prepare a solid research base for nanotechnology and to encourage industrialization of mature nanotechnology. The Korean government also allocated US \$380 million (19% of the total nanotechnology spending) to a "National Nano Industrialization Program," which includes an industrial R&D fund and a venture capital fund.

<sup>&</sup>lt;sup>1</sup> This estimate is based on an exchange rate of 100 yen to a dollar.

<sup>&</sup>lt;sup>2</sup> For more details about the latest Japanese nanotech budget, please visit the author's *Asia Pacific Nanotech Weekly* report at <u>www.nanoworld.jp/apnw</u>.

Taiwan's National Initiative on Nanoscience & Technology is a six-year plan with a total budget of US \$620 million from 2003 to 2008. Its structure in strategy and programs follows the US National Nanotechnology Initiative. It aims both to achieve academic excellence and to create innovative industrial applications through the establishment of common core facilities and education programs. The Academic Excellence Program covers the following topics: basic research on physical, chemical, and biological properties of nanostructures; synthesis, assembly, and processing of nanomaterials; research and development of probes and manipulation techniques; design and fabrication of interconnects, interfaces, and systems of functional nanodevices; development of MEMS/NEMS technology; and nanobiotechnology. Taiwan places important emphasis on nanotechnology education. Its education program aims to: establish interdisciplinary nanoscience and technology curricula at the university and high school level; enhance basic science knowledge education in high school, the mass media, and universities; promote international collaboration and personnel exchange; recruit talent from abroad, including personnel exchange.

Other countries in the AP region, such as Australia, Hong Kong, India, New Zealand, Singapore, Malaysia, and Thailand, have launched nanotechnology programs/initiatives. *Figure 1* is a global comparison of nanotechnology funding for Europe, Asia and the United States from 2001 to 2003. The units are in US dollars. It is assumed that 100 yen is equal to 1 US dollar, and 1 Euro is equal to 1 US dollar. Note the sharp rise in Asia nanotech funding in 2003.



## Figure 1: Funding Comparison for EU, Asia, and US for 2001-2003.

## II. NANOTECHNOLOGY COMMERCIALIZATION EFFORTS

The Japanese government has made a strong commitment to nanotechnology to create new industries and revitalize the Japanese economy. At the end of 2002, the government adopted the New Industry Development Strategy (NIDS) for Nanotechnology and Materials in the Council on Economic and Fiscal Policy (CEFP). The Ministry of Economy Trade and Industry (METI), which is the key ministry for sup-

porting Japanese industries, has launched the following R&D programs in 2003 for economic revitalization:

- Nanotechnology & Materials: 20 projects, 11.6 billion yen (US \$116 million)
- IT + Nanotech & Materials: 23 projects, 22.4 billion yen (US \$224 million)
- Life Science + Nanotech & Materials: 6 projects, 3.3 billion yen (US \$33 million)

Japan has been very strong in fine ceramics, occupying over half of the world market share, and in high-resolution electron microscopes, where it controls 60-70% of the world market shares. As for the new nanotechnology industry, Japan is expecting to lead the world in five key areas by 2010, as shown in *Table 1*.

Nano Industries	Trillion Yen	Billion USD
Innovation Materials	¥0.6-1.4	\$6-14
Nano Environment & Energy	¥0.9-1.7	\$9-17
Nano Bionic	¥0.6-0.8	\$6-8
Network & Nano Device	¥17-20	\$170-200
Nano Metrology & Manufacturing	¥0.8-2.2	\$8-22

Table 1: Japan Market Projections of Five Key Industries in 2010

MEMS technology R&D is included in nanotechnology programs in most Asian countries. In Japan, METI has just launched the New Manufacturing Technology Program—MEMS Project. The project, which is funded with US \$20 million for 2003-2005, focuses on creating devices of RF-MEMS, optical MEMS, and ultra-small MEMS sensors. The government has also established policies to overcome commercialization barrier, such as lack of MEMS engineers (several hundred in Japan compared to 5,000 in the European Union), lack of education programs, excessive focus on specialized industry, lack of venture companies, poor standardization, and poor networks. There are over ten MEMS foundries in Japan, including Olympus, Omron, Matsushita Electric, and Sumitomo Metal.

Taiwan is competitive with Japan in MEMS development. Taiwan has established the Taiwan MEMS Industry Alliance with about nine foundries and ten other MEMS start-ups. The Alliance aims to provide a platform to exchange technical and up-to-date market information, set industry standardization, integrate existing technologies, and provide road-mapping. It also provides IP management, legal services, and international trade services and advice. Its members include Asia Pacific Microsystems, Inc.; Walsin Lihwa Corp.; Micro Base Technology Corp.; and Neostones Microfabrication Co., Ltd.

Countries such as India have emerging MEMS industries, and Thailand, China, and Singapore have competitive MEMS facilities and research activities.

## **III. NANOTECHNOLOGY INVESTMENT IN PRIVATE SECTORS**

In the Japanese business sector, the two top trading houses in Japan—Mitsui & Co. and Mitsubishi Corporation—have established new nanotech business divisions. They are actively engaging in nanotech R&D and facilitating commercialization and investment in nanotechnology. Mitsui & Co in particular has started the process of building a global nanotech enterprise. Top Japanese companies such as NEC,

Hitachi, Fujitsu, NTT, Toshiba, Sony, Sumitomo Electric, and Fuji Xerox are continuing nanotech R&D efforts and taking more aggressive measures to accelerate commercialization of their R&D.

In Korea, Samsung, LG Group, and other Korean companies are aggressively investing in nanotech R&D and commercialization. Taiwanese semiconductor foundries such as TSMC and UMC are aggressively pursuing semiconductor nanoelectronics.

Venture capital firms such as Innovation Engine (Japan), Apax Globis Partners & Co (Japan), and Juniper Capital Ventures Pte Ltd (Singapore) have invested in nanotech start-ups in Asia. Listed firms such as Cranes Software International Ltd (India) and Good Fellow Group (HK) have invested in nanotech venture companies in Asia. The Australian Macquarie Bank and Pacific Dunlop are the main investors in AMBRI, the first nanotech company listed on the Australian Stock Exchange.

Investment hotspots in Asia include MEMS, optical electronics, memory, carbon materials, diagnostic tools, drug delivery systems, measurement and characterization tools, display technologies, and coatings.

## IV. COLLABORATION IN THE ASIA-PACIFIC

AP countries are showing strong ambition and efforts in pushing their countries into the "nano" future. The Asia Pacific region is becoming an exciting place for global partnerships and business opportunities in the nano space. Some advantages of collaborating with Asian companies are:

- Abundant human resources
- Excellent facilities (Japan and Korea)
- Advanced technology (Japan, Korea, and Taiwan)
- Dynamic technology and strong market growth

Unlike the European Union, these countries have not yet created an "Asian Commission" to coordinate Asian nanotech R&D and form networks. However, there has been increasing awareness of the need to collaborate. At the grass roots level, there have been various collaborations in research. For example, the Japanese government brought together representatives of various Asian governments during *Nanotech* 2003 + Future (held on February 26-28, 2003) to discuss the state of nanotech development in each country. The Japanese government is continuing to take the lead in building a stronger Asian network in nanotech R&D. An Asian Nano Summit is on its way!

The appendix provides additional information about nanotechnology policies and programs in Australia, China, Hong Kong, India, Malaysia, New Zealand, Singapore, Taiwan, Thailand, and Vietnam.

## APPENDIX

#### Australia

The Australia Research Council (ARC, at <u>www.arc.gov.au</u>), the key funding agency for Australian Science and Technology focusing on fundamental science, received an additional AU\$736.4 million over five years for doubling ARC competitive grants funding. Under the National Competitive Grants Program, four priority areas for ARC 2003 funding were announced in 2002, which include: (1) Nanomaterials and Biomaterials; (2) Genome-Phenome Research; (3) Photon Science and Technology; and (4) Complex/Intelligent Systems. AU\$170 million has been allocated from 2003 to support projects and centers for up to five years. AU\$90 has been allocated for five years for the ARC Center of Excellence (COE) program (starting 2003) for eight centers located around Australia. The Nanotechnology related COE include: (1) Quantum Computer Technology; (2) Quantum-Atom Optics; (3) Advanced Silicon Photovoltaics and Photonics; and (4) Ultrahigh-bandwidth Devices for Optical Systems. In addition, there are over AU\$45 million in investments committed by state governments, venture capitals, and other business investors.

#### China

According to a survey by the Chinese Ministry of Science and Technology (MOST), there are over 50 universities, 20 institutions within CAS, and 100 companies active in nanoscience and technology R&D in China. China's short-term strategy is to integrate nanotechnology with the traditional industries and develop products with competitive quality and performance that would improve consumers' daily lives. To provide a platform for the commercialization of nanotechnology, China is establishing the Industry Base and Engineering Center near Beijing and Shanghai. In particular, the Nanotechnology Industry Base is being built in Tianjin, a harbor city about 100 km from Beijing. Applied research in main R&D organizations around Beijing will move to Tianjin this year, when the Nanotechnology Industry Base becomes operational. China's long-term strategy is to strengthen basic science and enhance China's global competitiveness. The government has allocated 270 million RMB (US \$33 million) to building the National Research Center of Nano Science and Technology. The center will integrate China's top R&D institutions, such as the Chinese Academy of Sciences, Beijing University, Tsinghua University, Fudan University, Jiaotong University, Nanjing University, and the East China University of Science and Technology.

The Chinese Academy of Sciences (CAS) has the largest research institution network in China and the world. The CAS Nanotechnology Engineering Center Co., Ltd. (CASNEC) was founded in November 2002 as a platform for accelerating the commercialization of nanoscience and technology in the CAS. Its main investor is the Good Fellow Group (a HK-listed company), which owns 55% of the company's shares. The total amount of investment is about 50 million RMB (US \$6 million). The CAS has 20% of its shares, scientists at CAS have 15%, and YongFeng High Tech Park has 10%.

CASNEC was founded to reorganize the nanomaterials and nanotechnology industrialization within CAS using top-down management. The CASNEC is also viewed as a role model for promoting a national industrial base for nanomaterial and nanotechnology in Yongfeng High-Tech Park in Beijing. It will occupy 7,000 square meters of land in Yongfeng High-Tech Park, centrally located in Zhong-Guan-Cun area, which is the Beijing Science and Technology R&D and industry center.

The business concept of CASNEC is to provide a technology transfer platform for the CAS R&D. CASNEC's main revenue sources come from technology licensing, mid-scale production, and consulting services. For industrial scale production, CASNEC cooperates with large manufacturers which are well-

established in the related industries and market. CASNEC recently signed a technology licensing agreement with ERDOS Group, the biggest cashmere manufacturer in China, which represents about 30% of the national market. Its annual sales are about three billion RMB (US \$362 million). Compared with other venture business, CASNEC has the advantages of direct access to the R&D results of CAS, access to a pool of excellent experienced scientists and engineers, and stable financial support from the government. CASNEC consists of 26 PhDs, 112 master's graduates, three MBAs, and seven technicians.

## Hong Kong

In Hong Kong, nanotechnology R&D funding mainly comes from two major sources: the Research Grant Council (RGC), and the Innovation and Technology Fund (ITF). The RGC mainly funds basic research at universities, and the ITF funds mid-stream and downstream research at universities and industries to promote technology advancement and enhance competitiveness of existing industry. RGC and ITF administrators communicate with each other and coordinate their funding programs to avoid overlaps. The ITF started its strategic nanotech programs in 2001 after the Legislative Council approved the Development of Nanotechnology initiative on October 31, 2001. The total funding during 1998-2002 was about US \$20.6 million, plus 2.3% from industry. Funding of two key nanotech centers was recently approved. The Hong Kong University of Science and Technology (HKUST) received US \$7.3 million, and the Polytechnic University of Hong Kong (PolyU) received US \$1.6 million. The total funding for the two centers is US \$8.9 million for 2003-2004.

## India

India, a country with over one billion people, is making its way to the nanotechnology era. The Indian government has already started the Nano Science and Technology Initiative. Various funding agencies such as Department of Science and Technology (DST) and the University Grants Commission (UGC) have launched large nanoscience research programs. The main research has been conducted at institutions such as the Indian Institute of Science (Bangalore), Indian Institute of Technology (Madras, Chennai, Kharagpur, Bombay, Mumbai, and New Delhi), Central Electronics Engineering Research Institute (Pilani), University of Pune, Solid State Physics Laboratory (Delhi), and Tata Institute of Fundamental Research (Mumbai). Recently, some institutions have also started more coordinated nanoscience and technology research, including Raman Research Institute (Bangalore), National Chemical Laboratory (Pune), Central Glass and Ceramic Research Institute (Jadavpur), University of Delhi, and University of Hyderabad.

Three years ago, the government launched a US \$15 million/five-year National Program on Smart Materials coordinated by five government agencies and involving ten research centers across India, with a key focus on MEMS technology. The nanomaterials topic has been included, and more funding is expected to expanding the program. Last year the Department of Science and Technology launched the National Nanotech Program with total funding of US \$10 million committed over the next three years. The Indian Institute of Science (IISc) was awarded US \$1 million to its Nanoscience Research Center. IISc is known as the Knowledge Hub of India.

Indian nanoscience and technology covers a wide spectrum of topics, which include MEMS, nanostructure synthesis and characterizations, DNA chips, nanoelectronics (transistors, quantum computing, optoelectronics, etc.), and nanomaterials (CNT, nanoparticles, nanopowder, nanocomposites, etc.).

Similar to China, the Indian S&T and business network is worldwide. Unlike China, the fact that Indians speak English makes India much more accessible to the western world, drawing investment and global cooperation opportunities. For example, IndiaNano is a platform recently established by the India,

a country with over one billion people and Indian-American community in Silicon Valley to coordinate Indian academic, corporate, government, and private labs with entrepreneurs, early-stage companies, investors, IP counsel, joint ventures, service providers, start-up ventures, and strategic alliances.

There have been some interesting developments in the nanotechnology industry in India recently. Private companies have begun investing in R&D laboratories at university and government institutions. In the past, companies have largely refrained from investing in research. Universities and national research centers have worked in isolation. This lack of synergy and cooperation between the two sectors has prevented the growth of inventive technology. Private companies have, at best, worked with university labs in a consulting mode, where short-term interaction focuses on solving a well-defined problem, mostly in terms of troubleshooting. This sort of interaction has never blossomed into a relationship with a long-term vision for research-driven products or technology development.

However, the CranesSci MEMS Lab, India's first privately funded MEMS Research Laboratory, a joint venture between Indian Institute of Science and Cranes Software International Ltd (CSIL) in Bangalore, was established precisely to create a new culture in micro- and nanotechnology business in India. It aims to do so by coordinating a public research institution with private industry. The CSIL is listed on the Bombay stock exchange with market capital of about US \$20 million, and it is a leading player in the high-end scientific and engineering software products and solutions. The lab was created with a unique philosophy. It believes in science with a conscience. It has a vision of production based on business, so-cial obligations, and education. The lab not only transforms MEMS technology from the lab to the market place, but it also focuses on IP rights, strategic needs of the country and mankind in general, and providing other researchers with infrastructure knowledge management in MEMS technology.

#### Malaysia

In Malaysia, nanotechnology is categorized under Strategic Research (SR) of the Intensification of Priority Research Areas (IPRA) program in the Eight Malaysia Plan (2001-2005). It is funded by the Ministry of Science Technology and Environment (MOSTE). The SR projects must take place within 60 months.

A budget of RM 1 billion (US \$263 million) was allocated for IPRA in the Eight Malaysia Plan. Funding of the Strategic Research is 35% of the IPRA program and it includes four evenly distributed areas: Design and Software Technology, Specialty Fine Chemical Technology, Optical Technology, and Nanotechnology and Precision Engineering.Funding for Nanotechnology and Precision Engineering over the next five years is around US \$23 million—for a country with about twenty million people. (Note that Taiwan has a population of about 21.5 million, and its national committed spending for nanotechnology over the next six years is US \$620 million.)

Areas for nanoscience research include nanophotonics, nanobiosystems, nanoelectronics, nanostructured materials, and nanometrology. Malaysia's short-term strategy is to:

- Identify researchers in various areas of nanoscience with specific expertise,
- Upgrade and equip nanoscience laboratories with state-of-the-art facilities, and
- Prepare a comprehensive human resource development program for training nanoscientists.
- Malaysia's long-term strategy is to:
- Nurture a nanoscience research culture among researchers,
- Develop world-class national nanoscience laboratories in Malaysia, and

• Produce renown nanoscientists.

#### New Zealand

The main activities of nanoscience and technology in New Zealand have recently been coordinated in the MacDiarmid Institute for Advanced Materials and Nanotechnology, New Zealand's premier research organization concerned with high-quality research and research education in materials science and nanotechnology. It is founded upon principles of interdisciplinary cooperation. It is led by two universities, Victoria University at Wellington and the University of Canterbury, with partner organizations Industry Research Ltd (IRL) and Institute of Geological & Nuclear Sciences (IGNS) Ltd. Other research groups are at Massey and Otago Universities.

The Institute builds on pre-existing and dynamic research collaborations, exceptional scientific and engineering capability, outstanding leadership, unparalleled international networking, strong industry and business linkages, and expertise in training world-class graduate students. Of the Institute's principal investigators, nine are Fellows of the Royal Society of New Zealand, and six have been awarded prestigious RSNZ science medals. The MacDiarmid Institute is led by its Director, Professor Paul Callaghan FRS, and its Deputy Director, Dr. Richard Blaikie.

The Institute focuses on materials and technologies that are attracting worldwide attention, including: nano-engineered materials and devices, opto-electronic activity in semiconducting materials and devices, superconductors, conducting polymers, carbon nanotubes, sensing and imaging systems, functional materials and coatings, energy storage materials, light harvesting and photochemical materials, softmaterials, biomaterials, and complex fluids.

#### Singapore

The key funding agency in Singapore for nanoscience and technology is the Agency for Science, Technology & Research (A\*STAR). The A\*STAR Nanotechnology Initiative started in Sept 2001. Singapore's approach is to build on accumulated capabilities and promote innovations in areas that fuel Singapore's industries. A\*STAR develops nanotechnology research programs through existing capabilities development programs at the Institute of Materials Research and Engineering (photonics, advanced materials); the Institute of Microelectronics and Data Storage Institute (semiconductor, electronics, storage); and the Institute of Bioengineering and Nanotechnology (bionanotechnology). Their efforts are focused on pushing the technological envelope in industries key to Singapore, such as the electronics, chemical, and biomedical industries. The Singapore Economic Development Board is another funding agency for supporting industry applications of R&D, particularly funding nanotech start-ups and international joint ventures.

#### Taiwan

The Taiwan MEMS national programs started in 1996, funded by both the National Science Council (NSC) and the Ministry of Economic Affairs (MOEA). From 1998, NSC established three main national MEMS centers (the Northern, Central, and Southern Region MEMS Research Centers) to build up MEMS R&D common facilities and core technologies in Taiwan. From 2003, MEMS government programs have been imbedded in the National Science and Technology Program on Nanotechnology. Taiwan MEMS focuses on information technology, industrial processes/devices, communication, consumer electronics, semiconductors, and biomedical technology.

Taiwan MEMS has shifted from R&D to commercial production. The Taiwan MEMS foundry business started in 2000, and currently there are nine foundries in Taiwan. The accumulated investment in MEMS business in Taiwan is about half a billion US dollars. Asia Pacific Microsystems Inc. (APM) is a leading MEMS foundry, founded in August 2001 with over US \$50 million in capital. It currently has over 200 employees. The company is now pursuing MEMS fabrication technology and focusing on inkjet, smart transducer, wireless, optical, and bio-MEMS applications. It provides customers with one-stop shop services, including design support, process development, volume production, packaging, assembly, and testing. APM took over a 5-inch wafer foundry for making CMOS chips from Winbond Electronics Corp. and transformed it into an advanced 6-inch CMOS compatible MEMS fab in the Hsinchu Science-based industrial park. APM is targeting 8,000 wafers/month by 2003. The major shareholders of APM include Chi Mei Industrial Co., Mobiletron Electronics Co., Universal Microelectronics Co., Wintek Corp. (an affiliate of Acer Group), and a 30% venture capital investment. Details about APM can be found at www.apmsinc.com.

#### Thailand

The top funding organization for S&T is the Ministry of Science and Technology (MOST). The National Science Technology Development Agency (NSTDA), which is under the MOST, supports three main national centers, including the National Center for Genetic Engineering and Biotechnology (BIOTEC), the National Metal and Materials Technology Center (MTEC), and the National Economic and Computer Technology Center (NECTEC). The National Nanotechnology Center (NANOTEC) was approved in August 2003 by Thailand's government. The center aims to: (1) identify and focus on niche areas in nanotechnology; (2) assemble and produce a critical mass of researchers and educators on nanotechnology; (3) act as a national coordinating body between academia, industry, and government. The approved budget is about US \$25 million for the period of 2004-2008 with 300 personnel. The R&D areas of focus are advanced polymers, nanocarbon, nanoglass, nanometal, nanoparticles, nanocoatings, and nanosynthesis, with applications in automotives, food, energy, the environment, medicine and health.There are fourteen laboratories in six universities, and five laboratories under two government agencies, with about a hundred researchers total. The current research areas in nanoscience have been mainly in nanoparticles, quantum dot devices, carbon nanotubes, nanocoatings, and MEMS.

#### Vietnam

Vietnam, with a population of about 79 million, has very recently started its national nanotech program. The Vietnamese government has recognized that nanoscience is one of the most important S&T areas of the 21<sup>st</sup> century that will create new industries and high-tech products through technological breakthroughs. However, as a developing country, Vietnam is yet to build sufficient S&T infrastructures and create high-tech industries. Very recently the Ministry of Science and Technology (MOST) launched an infrastructure-building program on nanoscience and technology in Vietnam. It is a new priority program for the period of 2004-2006 under the National Program on Basic Research and Natural Sciences. It aims to:

a) identify researchers in various areas of nanoscience with specific expertise;

b) nurture a nanoscience research culture among researchers in Vietnam;

- c) prepare a comprehensive human resource development program for training scientists; and
- d) gradually upgrade and equip the nanoscience laboratories with state-of-the-art facilities.

The starting budget of this year for these activities is 5 billion VND (US \$ 0.35 million). Various institutions such as Institute of Materials Science, Institute of Chemistry, Institute of Physics of VAST and laboratories at the Hanoi National University, Hanoi University of Technology, International Institute for Materials Science, and others participate in this program.

The key R&D funding organizations in Vietnam are the Ministry of Science and Technology (MOST), Vietnamese Academy of Science and Technology (VAST) (formerly called National Center for Natural Science and Technology), and Ministry of Education and Training (MoET). There have been some research projects on nanoscience and technology in the past few years within various national programs. The total budget is about 4 billion VND for the period from 1999 to 2004. In addition, the Vietnamese government has put in considerable effort to upgrade the R&D infrastructure and facilities in selected areas of science and technology. There are now 18 national laboratories focusing on research in areas such as materials (three labs), biotechnology (four labs), and information technology (three labs). They are funded with about 50-60 billion VND (US \$ 3.5-4.0 million) per lab for a period of 3-4 years.

Current research and education activities on nanoscience and technology are mainly conducted by groups of physicists and chemists at the Institute of Materials Science (IMS), Institute of Physics (IP), Institute of Chemistry (IC) of the Vietnamese Academy of Science and Technology (VAST), and universities such as Hanoi National University (HNU), Hanoi University of Technology (HUT) and International Training Institute for Materials Science (ITIMS). The main research topics are physics and chemistry of nanostructured semiconductors, magnetic nanomaterials, nanocomposite materials, nanocatalyst materials, amorphous and crystalline phases, and multilayer nanostructures.

Education programs on nanoscience and technology (2-year MSc and 4-year PhD) have started in 2003 at Hanoi National University (HNU). The education programs emphasize the multidisciplinary nature of nanoscience from both theoretical and practical points of view. These programs involve participation by faculty of physics and faculty of technology of HNU, International Training Institute for Materials Science (ITIMS) and Institute of Engineering Physics on Hanoi University of Technology (HUT) as well as Institute of Physics and Institute of Materials Science of VAST.