Future of Indo-Korea Collaborative Activities in Nanotechnology

Sivaram Arepalli
Department of Energy Science
Sungkyunkwan University, Suwon, Korea
sivaram.arepalli@gmail.com

When I googled for 'Nanotechnology Collaboration India Korea', not much came out, but one news item stood out: Dec. 8th, 2009; "The Nano Science & Technology Consortium (NSTC) located at NOIDA, India, announced a tie-up with Midas Systems, Korea to supply high-end nanofabrication equipment in India". Midas Systems, Korea develops and produces various high end equipments such as Spin Coaters, Nano Imprint equipment and Mask Aligners.

Interestingly NSTC in India and Midas in Korea are not household names for nanotechnology!

Nanotechnology (NT) involves controlled manipulation of materials at the nanoscopic level to achieve remarkable properties at the macroscopic bulk level. Recently, the International Organization for Standards (ISO) defined nanomaterial to have at least one dimension less than 100 nm (nanometer is a billionth of a meter). According to US Interagency Working Group on Nano Science, Engineering and Technology (IWGN) on NT Research Directions (Sept. '99): "*Nanotechnology will be a strategic branch of science and engineering for the 21st century, one that will fundamentally restructure the technologies currently used for manufacturing, medicine, defence, energy production, environmental management, transportation, communication, computation and education".*

Following the US lead of "National Nanotechnology Initiatives (NNI)" in 2001, several countries adopted NT as a prime area of focus for the national development. Because of the tremendous potential and realizable economic impacts, investments have been on increase for the last several years. The proposed NNI budget in US for FY2010 is $1.64 billion (Cumulative investment of $12 billion since 2001). This includes NT-based bio research and "Environment, Health and Safety (EHS)" research. Projected world-wide market for NT enabled products will be between $500 billion and $2 trillion by 2015.

Both India and South Korea have recognized nanotechnology as crucial for economical growth and therefore implemented programs to support this.

Here is a list of programs, facilities, universities and companies in India & South Korea focusing on NT. I hope that this will provide additional useful information for establishing and continuing active long range collaborations between the two countries in the exciting field of NT.

KOREA

In Korea, the Korea NT Initiative (2001-2010) has been implemented with the latest revision for the period 2006-2015. ***The "NT Development Plan" included the investment of 1,485 billion Korean Wons (about 1billion US dollars) in R&D over a period of 10 years from 2001 till 2010.*** Five years after the establishment of the Phase-1 NT Development Plan during which NT

development was actively conducted throughout the country, the Phase-2 plan (2006-2015) was formulated as a new national policy of NT development, and revealed the government's aggressive intention to develop NT keeping environmental and societal impacts as priorities. Many NT-related research projects are being conducted by various groups in the government, academia, and industrial laboratories. Basic research on nanodevices (CNT-FET, single-electron transistor, nano-bio device, etc.), nanoanalysis (scanning probe microscopy, atomic force microscopy, etc.), nanomaterials (nanoparticles, nanowires, nanotubes applied to semiconductor, energy, and nanoprocessing technology (including top-down and bottom-up processing technologies) are investigated with support of government project funding and infrastructure supplied through the Korea NT Initiative. Active universities include Seoul National University (SNU), Sungkyunkwan University (SKKU), Korea University, Korea Advanced Institute of Science and Technology (KAIST), Yonsei University and Pohang University of Science and Technology (POSTECH). Several industries maintain internal R&D in NT and the notables are Samsung, and LG. Other institutions that conduct basic and applied research include Gwangju Institute of Science and Technology (GIST) and Korea Institute of Science and Technology (KIST). The level of Korea's NT is evaluated to have improved much from about 25% of the US, the strongest in NT, in 2001 to 66% in 2005, and the number of SCI papers and patents ranks 5th in the world. A report published by Lux Research, a US consulting company specialized in NT industry, evaluated Korea as one of the top four countries in the area of NT in 2005.

Korea has three NT Frontier Programs

1) “Tera-level Nanodevice Development Program” for ultra high speed, ultra large scale integration (ULSI), and ultra low voltage nanodevices
2) “Nanostructured Materials Technology Development Program” aims at developing environment-friendly and high-efficient nanomaterials
3) "Nanoscale Mechatronics & Manufacturing Technology Development Program” for process technologies and manufacturing nano-scale ultrafine industrial parts as well as analysis, design, control and measurement technologies

There are five National NT Fabrication Facilities:

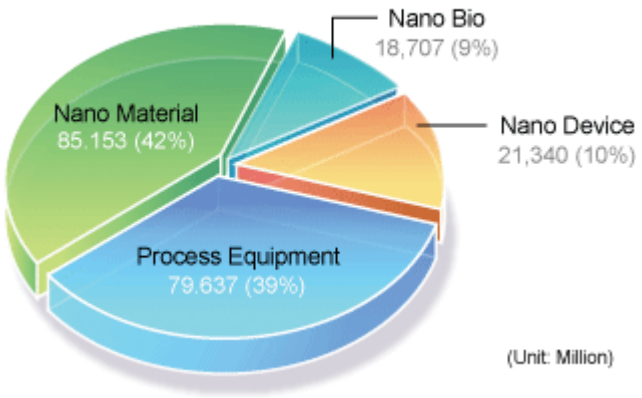
1) National NanoFab Center (NNFC) in Daejon has silicon-based facilities include Patterning Lab, Device Lab, Pie Lab and measurement & analysis devices.
2) Korea Advanced Nano Fab Center (KANC) in Suwon supports nano device research equipment and facilities, measurement, test and inspection
3) National Center for Nanomaterials Technology (NCNT) in Pohang supports nanomaterials for semiconductor display
4) National Nano Printed Electronics Center (NNPEC) in Jeonju to support nanoprocesses.
5) Gwangju NT Integration Center (GNIC) in Gwangju also to support nanoprocesses.

The NT work is carried out in several Korean universities such as Seoul National University, and Sungkyunkwan University and research institutes such as Korea Institute of Science and Technology (KIST), Korea Institute of Energy Research (KIER), Korea Advanced Institute of Science and Technology (KAIST), and SKKU Advanced Institute of NT (SAINT).

From Phase I investment, the following are achieved:

1) Devices (World's first tera-level flash memory device, Photonic crystal laser, one millionth of a meter scale)
2) Materials (World's first synthesis of CNT at room temperature, and world's highest purity semiconductor nanorod)
3) Nano-Bio (Chips for diagnosis of hepatitis or cancers, Nano-bio sensors for cell use)
4) Processes/Tools (100 nm level soft lithography technology, Manipulation of block co-polymer for semiconductor devices)
5) Products (16 giga NAND flash memory, Sterilizing air conditioner/washing machine using nanosilver, Next-generation AFM)

Investment by R&D area of Nanotechnology in 2006



Investment Plan for the 2nd-phase Nanotechnology Development

In the Phase-2 NT Development Plan, R&D effort is divided into two stages. The first (2006-2010) purses basic prerequisite activities that lay the groundwork for commercialization, and the second (2011-2015) pursues advanced technologies for commercialization and international collaboration.

(Unit: 100mil KRW)

	R&D	Infrastructure	Human Resources	Total
1st Stage(2006~2010)	14,330	5,370	660	20,360
2nd Stage(2011~2015)	19,620	7,580	990	28,190
Total	33,950	12,950	1,650	48,550

By 2014, Korea wants to capture a 20% of the global nanomarket (equivalent to $500 billion in amount).

INDIA

Lux Research in 2005: “Ranking the Nations: Nanotech's Shifting Global Leaders” mentions that the assessment ranks the US, Japan, South Korea and Germany as "dominant" and Taiwan, Israel and Singapore as "niche players", with a low score on absolute nanotech activity but a high score for technology development strength. The UK and France came out as "Ivory Tower" nations, with a low score for technology development strength but a high rating for NT activity. And the report ranked China, Canada, Australia, Russia and India as in NT's "minor league"!

In October 2001, Department of Science and Technology (DST) India launched a modest program in Nano Science and Technology, called the Nano Science and Technology Initiative (NSTI); has identified nanaomaterials science & technology as an important thrust area of research and supporting some basic research projects in this field some goal-oriented projects on use of nanomaterials in drug-delivery systems, synthesis of Titanium dioxide from ilmenite ore etc.. By 2007, more than 450 Ph D students and four globally competitive basic and applied research centers came out of the NSTI program; completed projects covered topics such as “organic light emitting diodes (OLED), solar cells, nanophosphors, carbon nanotube (CNT) based sensors, nanocomposites, printable nanoelectronics, designed drug delivery, nanostructured magnetic materials” and developed 11 clusters of nanoscience center facilities with “Nanocluster & Ion Beam Sources, Field Emission TEM with CCD, Nano Indenter, PPMS with 7 T Magnet & VSM, Nanomanipulator with SPM, Optical Tweezer, Nanolithography, etc.”. Based on the success of NSTI, the Government of India has mounted a Nano Mission in May 2007.

The primary objectives of the Nano-Mission are:

1) **Basic Research Promotion** – Development of fundamental understanding of matter that enables control and manipulation at the nanoscale. Creation of Centers of Excellence.
2) **Infrastructure Development for Nano Science & Technology Research** – Chain of shared facilities across the country for TEM, SPM, etc.
3) **Public Private Partnerships and Nano Applications and Technology Development** Institute activities like Public Private R&D Projects, Nano Applications and Technology Development Centers, Nano-Technology Business Incubators etc.
4) **Human Resource Development** –Provide interdisciplinary training as a part of education for the nanoscale science, engineering and technology students.
5) **International Collaborations** – Priority for Nano-Science and Technology collaborations with many countries. Academia-Industry partnerships will also be nurtured.

Steps were initiated for recommended the establishment of three Institutes of Nano Science & Technology (INSTs) as part of the existing active centers in nano science and technology. These INSTs will be at

(i) Mohali, co-located with IISER, Mohali, as a centre of ARCI, Hyderabad,
(ii) JNCASR, Bangalore as a joint centre of JNCASR and IISc and
(iii) IACS, Kolkata

In addition, the INSTs, special support was given to the "Public-Private-Partnership" projects including *Nano Functional Materials Technology Centre (NFMTC) at the Institute of Technology Madras, Chennai; Development of High performance rubber nanocomposites for tire engineering at MG University, Kottayam; and Research program on Smart and Innovative Textiles (SMITA) at the Indian Institute of Technology Delhi*.

The 11 clusters of nanoscience are located at Univ. of Pune, Pune; IIT Madras, Chennai; JNCASR, Bangalore, BHU, Varanasi; IIT Kanpur, Kanpur; IISc, Bangalore; SINP, Kolkata; IIT Delhi, New Delhi; IACS, Kolkata; National Chemical Laboratory, Pune and SNBNC, Kolkata.

There are seven centers of NT:

1) Amrita Institute of Medical Sciences, Kochi, Kerala (Implants, Tissue Engineering, Stem Cell Research)
2) S.N. Bose National Centre for Basic Sciences, Kolkata (NEMS & MEMS / Nano products)
3) Tata Institute of Fundamental Research (Nanoscale phenomena in biological systems & materials)
4) IIT-Bombay, Mumbai
   (Nanoelectronics, polymer nanosensors, nanobiotechnology)
5) Indian Institute of Science, Bangalore (Nanodevices, Nanocomposites, Nanobiosensors)
6) IIT, Kanpur (Printable Electronics, Nanopatterning)
7) Indian Association for the Cultivation of Science (Photovoltaics & Sensor Devices)

Achievements:

1) Synthesized Nanocrystals of pure CoO and ReO3 for the first time
2) Inorganic nanowires and nanotubes using alumina membranes and hydoregels
3) GaS and GaSe nanowalls and nanotubes; ZnO nano pyramids
4) Sensors with high sensitivity and low recovery time for humidity, H2, ethanol, carbon monoxide, LPG, NO2, NO and N2O have been fabricated using various metal oxides nanostructures
5) Development of two novel soft lithography techniques, namely, elastic contact and adhesive force lithography based on self organization of polymer thin films
6) Prepared a rectangular lattice of CoPt squares on NbN super conducting films using the technique of focused ion beam milling for magnetic studies.
7) Magnetic nanoparticles for hyperthermia treatment of cancer and MRI contrast agent
8) High throughput and high content RNAi screens to study nanoscale cellular processes
9) Si wafer arrays of Si/Si3N4 structures
10) Design and synthesis of core-shell and quantum well structures based on group II-VI semiconductors with high efficiency for photovoltaic applications.

I believe there are several areas of interest that could compliment several collaborative areas in nanoelectronics (Korea leads); nanocomposites (India leads); photovoltaics (equal); nanobio applications (India leads) and future is very bright for these two emerging nations!

References

1) ISO Technical Committee TC229 on Nanotechnologies : http://www.iso.org/iso/iso_technical_committee?commid=381983
2) US Nanotechnology Initiative: http://www.nano.gov/
3) Lux Research: http://www.luxresearchinc.com/
4) Korea Nanotechnology Gateway: http://www.k-nano.kr/
5) India Nano Mission: http://nanomission.gov.in/