Trip Report
Republic of Korea 21 – 28 October 2006

Map of the Republic of Korea, showing the location of the 5 National Nanofab facilities

A. Summary

The Republic of Korea is a country of 50 million people. Located to the west of Japan, it is the Koreans who literally view Japan as the "Land of the Rising Sun". Korean industry is dominated by large industrial conglomerates or Chaebol, like LG Goldstar whose origins are in toothpaste, and Samsung, created in the 1970's to make transistors. With few natural resources, Korea has fully embraced the "*knowledge economy*". Where steel production and ship building were formerly important, Korea now focuses on electronics and related information technologies. Korea has set a national goal to be one of the world's seven leading nations world-wide in science and technology by 2025, with emphasis on biotechnology and information technologies. The current total investment in R&D is about 35 billion euros, over 3% of GDP, with industry contributing 75% of the total.

In Korea people are driving mostly a Hyundai, a Kia, or a Daewoo. Little else can be seen on the road. The percentage of cars with LED lighting is very low, less than 1%. I saw only a few examples during my trip. This could be compared to the situation in Taiwan where more than 10% of the cars on the road are equipped with LED brake lighting.

Broadband internet is ubiquitous and free: like air or water. In everyplace I stayed, no-cost broadband connections by Ethernet cable operating at 10 Mbit/s up to 100Mbit/s were available. In contrast, wireless access appears to be rare.

EPIC is a partner in the European project MONA, a support action that works on merging optics and nanotechnologies. A major objective of the project is the creation of a roadmap for nanophotonics. EPIC was invited to Korea to make plenary presentations on the nanophotonics roadmap at two different meetings in Korea. Air travel and lodging were covered by a generous offering from my Korean hosts.

The major objectives of this trip were:

1. Identification of and meeting with people working on science and technology planning for nanophotonics and more generally nanotechnologies in Korea.

2. Discussions on key photonics technology developments in Korea involving lasers, IR-detectors and displays in order to answer questions from EPIC members.

3. Discussion about opportunities for European institutions to participate in Korean R&D programs.

The key results are:

1. Dr Jung-Il LEE of the Korean Institute of Science and Technology (KIST) has been identified as a leader in nanophotonics issues in Korea. He has agreed to participate in a MONA-sponsored workshop in January 2007, and to speak about the roadmap for nanophotonics in Korea.

2. Priorities for R&D investment in nanophotonics are emerging with new R&D results in this area. This is still very much a bottom-up development. The Korean nanophotonics roadmap project remains to be developed.

3. As a result of bi-lateral negotiations, Korean research teams can participate in Commission R&D programs. The evaluation of the project proposal by the Commission will be accepted by the Koreans, and the R&D budget of the Korean researchers will be paid from Korean government funds.

4. A similar reciprocal action that would permit European researchers to participate in Korean R&D programmes has not yet been implemented. The key contact is Dr Hanjo LIM who coordinates R&D funding for KOSEF, the Korean Science and Engineering Foundation.

5. ETRI, the Electronic and Telecommunications Research Institute is perhaps the leading institution for applied R&D in Korea. ETRI seeks collaboration with industry and I learned that ETRI would welcome collaboration with European companies. ETRI has a leading position with respect to European R&D in several areas, notably photonics on silicon, a subject of interest to many EPIC members.

6. Specific requests from EPIC members have been answered directly.

B. Thanks and Acknowledgements

My time in Korea was very short, and without the help of my colleagues in Korea, it would not have been possible to make the number of visits and meetings that I was able to accomplish during my stay. Many people were involved, and in particular I would like to thank the organizing committee of the IEEE Nanotechnology Materials and Device Conference for an invitation to present the MONA project and for their generous support of my travel expenses. Dr. “Andy” CHUNG helped at every step of the way, even assuring that I travelled to the right city! Professor Yoon-ha JEONG, a friend and colleague for many years helped make arrangements for the visits to KOSEF and to ETRI in Daejeon, following the Conference. I would like to thank Minkyung JUNG for accompanying me from Gyeongju to Daejeon. I owe a debt of special thanks to Dr. Jung-Il LEE who arranged meetings with Dr. OH at ETRI, Dr. LIM and Dr. EOM at KOSEF, and Dr. KIM at MoST. These visits have been crucial to creating a network of exchange between MONA and science and engineering organizations in Korea. I would also like to thank my host at INHA University, Prof. El-Hang LEE, especially for inviting me to participate in the 3rd International Symposium on VLSI Photonics, where I learned about breakthrough developments in Si-nanoclusters in a SiNx matrix, and other developments in silicon-related photonics.

Dr. Jung-Il LEE of KIST, who is organising the nanophotonics roadmapping effort in Korea.
jil@kist.re.kr

C. Specific Visits: Schedule and Summary

My schedule is summarized below:
Days 1 &2, Gyeongju
Plenary presentation and participation at the IEEE Nanotechnology and Devices Conference
I met:

- Simon DELEONIBUS of the CEA-LETI in Grenoble, sdeleonibus@cea.fr
- Chennupati JAGADISH, Professor at the Australian National University, chennupati.jagadish@anu.edu.au
- Hee-Gook LEE, President and CTO LG Electronics, heegooklee@lge.com
- Yoon-Soo PARK, Naval Research Laboratory, yoonsoopark@msn.com
- Takao SUGANO Chairman of Board, Toyo University, sugano@hakusrv.toyo.ac.jp

The NMDC conference program has been included as a file in the CD-ROM issued by EPIC and MONA.

Day 3, Pohang, Korea
Tour of the newly opened National Center for Nanomaterials Technology at Postech University, one of five national centers for nanotechnology, in planning or newly opened in Korea.

Day 4, Daejeong, Korea: ETRI and KOSEF

C-1 ETRI Laboratories

The Electronics and Telecommunications Research Institute, ETRI, was founded 30 years ago to support The National Telecommunications company KTT. ETRI is now the largest government-funded ICT laboratory in Korea with over 2000 researchers. Following the world-wide privatisation of telecommunications, ETRI is seeking support funds from other sources. This may represent an interesting opportunity for European companies.

Major areas of R&D activity are:

- Digital broadcast routers
- IT
- Embedded Systems
- Internet Security
- Mobile telecommunications
- Broadband convergence

I visited the IT Convergence and Components Laboratory, where I met with the Director Dr. Dae Kon OH. Dr. OH gave an excellent overview of the activity in this laboratory, which includes communications, Silicon systems on a chip, high-speed electronics and photonics, biophotonics, flexible displays, electronics, and photovoltaics and nanotechnologies. Materials and technologies are studied in the context of their relationship to IT. Development of new materials is an important part of the technology development. Two technical discussions that stand out in particular are LEDs based on silicon nanoclusters embedded in silicon nitride, and flexible photovoltaic cells deposited on stainless-steel substrates.

Dr. Dae Kon OH, Director of the IT Convergence and Components Laboratory at ETRI.
dkoh@etri.re.kr

The IT Convergence Laboratory is divided into seven sub-groups:

- Silicon ICs: System on a Chip
- Nanotechnology and IT
- Biotechnology and IT
- RF ICs
- Optical components
- New devices and materials
- Photovoltaic devices

Looking in particular at optical components, devices and materials, some of the R&D activities that appear to me to be quite competitive with European work are:

- Semiconductor-based optical devices for PON, E-PON and FTTH. Here ETRI aims to have the best results in the world
- Polymer-silica optical devices. ETRI is developing a very-high-speed polymer optical modulator. They are also working on planar silica lightwave devices like arrayed waveguides multiplexers, and special optical fibres for amplifiers and other applications
- Polymer technology is also being used to develop flexible displays, flexible optical waveguide interconnects using roll-to-roll processing (for use inside mobile telephones).
- Nano-plasmonic optical devices
- Considering materials and processing, ETRI has 6 MO-CVD and 2 MBE reactors. There are 2 semiconductor fab facilities and one pilot fabrication line.

I was impressed by the working to develop prototype components for 40 Gbit/s communications. The ETRI is proposing evaluation samples of 40Gbit/s transceivers, a 40 Gbit/s electro-absorption modulator and laser, tunable dispersion compensator, and an integrated detector/ transimpedence amplifier.

Dr. Man Gu KANG (10009kang@etri.re.kr) demonstrated a number of photovoltaic cells based on organic thin-film technology developed by Michael Grätzel at EPFL in Switzerland. This material is processed and deposited on thin stainless steel substrates, both inexpensive and flexible. Power conversion efficiency is about 5%. [Man Gu Kang, et al, Chemistry Letters, Vol. 34, pp. 804-805 (2005)]

Dr. Gun Yong SUNG (gysung@etri.re.kr) reported on the synthesis of LEDs based on quantum dots of silicon embedded in SiN. The radiative recombination is truly characteristic of the quantum-dot size. This gives complete continuous tunability using the quantum size effect. [G.Y. Sung, N-M. Park, J-H. Shin, K-H. Kim, T-Y. Kim, K.S. Cho, and C. Huh, IEEE Journal of Selected Topics in Quantum Electronics, Silicon Photonics Issue, Nov/Dec, 2006 (in press)]

Please contact me for more information on either of these developments.

C-2 Visit to KOSEF, the Korean Science and Engineering Foundation, the national funding agency.

Subject: Funding of R&D on nanotechnologies by the Korean government.

Funding of R&D is carried out principally by two ministries in Korea. Each has a budget of about 2 billion euros in 2006, up more than 10% from 2005.

MoCIE = Ministry of Commerce Industry and Energy and MoST, the Ministry of Science and Technology (budget = 1 billion €). There is a third one, the Ministry of Education. However they fund the work of individual university professors.

The MoCIE, and the name implies is a major supporter of industrial R&D. They provide the principal support for three of the national nanofabrication facilities in Korea. The MoST is oriented more toward the support of fundamental research and ideas. The MoST supports two of the national nanofabrication facilities.

KOSEF, the Korean Science and Technology Foundation is the operational branch of the MoST. KOSEF actually decides on the attribution of R&D funds based on the outcome of peer evaluation

Dr. Hanjo LIM, Director in charge of photonics R&D at KOSEF. hanjolim@kosef.re.kr

I met with Hanjo LIM who heads the General Directorate for Basic research at KOSEF. He has responsibility for attributing and overseeing 250 million € per year of R&D funding. Last year the R&D pie was divided as follows:

30%	Biosciences
40%	Engineering
20%	Materials Science and Chemistry
10%	Physics, Mathematics and Astrophysics

Most of the nanophotonics work is being funded in the physics or in engineering areas.

The choice of R&D subject is really "bottom-up". That is to say that the proposals are coming from research groups, and KOSEF does not try to impose objectives or even a call for proposals.

However, inside of KOSEF there is a Bureau of National Projects. This Bureau gives money to specifically identified fields in a top-down process. There are three identified areas:

- Improvement of National Productivity
- Enhancement of Social Security , and in particular, Health, Construction, Environment and Energy
- Enhancement of National Creativity: emerging science and technology.

KOSEF International Programmes

Travelling from Daejeon to Seoul on the French TGV high-speed train (300 km/hr) I was able to meet with Dr. Cheon-Il EOM who is responsible for supervising nanotechnology R&D programmes at KOSEF and is also responsible for national programmes and international relations.

Dr. Cheon-Il EOM, Director at KOSEF for Nanotechnologies. cieom@kosef.re.kr

Dr. EOM confirmed that there is no national R&D programme focussed on nanotechnologies. As a result there is not yet any coordination support in the form of a roadmap. He strongly supported to begin such an activity and he has asked Dr Jong-Il LEE to initiate this action.

Day 5, Incheon, Korea

Plenary presentation on the MONA project at the International Symposium on the VLSI Silicon Photonics

C-3 Visit to the MoST, the Ministry of Science and Technology to discuss European Cooperation

Dr. Cha-Dong KIM, Director General of the Science and Technology Cooperation Bureau – Europe at the MoST. kimcd@most.go.kr

During this visit, I sought information related to exchanges and cooperation between Korean and European Scientist. I was able to meet with members of Dr. KIM's staff in Gwacheon-City, and with Dr. KIM in Paris two weeks later. I learned that the Korean government has signed an agreement with the European Commission that allows Korean laboratories to participate in European projects. Korean scientists are paid by the Korean government for their part of the budget in a project approved for funding.

The MoST is actively pursuing greater interactions and involvement of European scientists in Korean R&D. The exchange budget exceeds 60 million € for 2006, up 25% from last year. International exchange is a key part of the "Korea in the Top-7" strategy. Networking is the first step. That is, there must be relationships formed between European and Korean research teams. The R&D work program can be found on the MoST website.
(http://park.org/Korea/Pavilions/PublicPavilions/Government/most/policye2.html)

If a collaboration is functioning, R&D funding of European-based laboratories by Korean programs is entirely possible.

D. Korean Investment in Nanotechnology R&D at the National Level

Main themes:

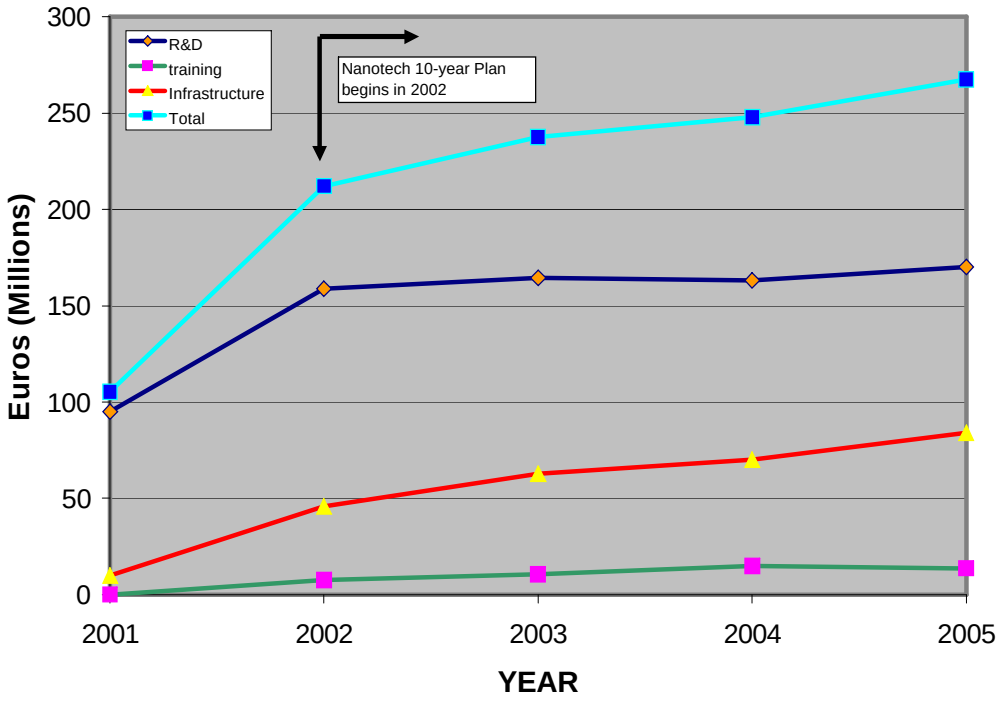
- Electronics and communications
- Materials
- Medical Science / Bio
- Security
- Environment and energy

The Nanotechnology Promotion legislation was passed in 2001. A 10-year rolling plan with 5-year reviews.

Strategy roadmap 2005 – 2010

I Assure expansion of necessary operational infrastructure
Identify fields where there is a comparative advantage. Expand these fields
Pursue industrial utilization of technology development results
Develop application technologies then commercialisation

2. Investment in R&D, Training and Infrastructure



Korean investment in nanotechnologies, according to the "10-year Rolling Plan" with 5-year reviews and extensions. The base level of funding for all nanotechnology areas at the present time is about 150 Million euros per year.

E. IEEE Nanotechnology and Devices Conference 2006

This meeting was a conventional scientific conference, with a significant difference: breakfast, lunch and dinner were organised to provide the maximum opportunity for networking. This opportunity made a big difference to the success of my trip. The conference program is included on the Korea CD-ROM.

Plenary Talks

1. Emerging Nanotechnology and its Impact on Technology Innovations in Industry", Takuo SUGANO, Toyo University, Japan

2. "The Trends and Future Prospects of Nanotechnology Development and Deployment in Korea", Hee-Gook LEE, CTO of LG Electronics, Korea

3. "Perspective of Nano Technology in the Semiconductor Industry", Kwang-Pyuk SUH, Samsung Electronics, Korea

4. "Self-Organisation and Self-Assembly in Nano/micro Systems", Toru MAEKAWA, Toyo University, Japan

5. "The MONA Project: The Nanophotonics Roadmap", Thomas P. PEARSALL, European Photonics Industry Consortium

6. "Computing at the Nanoscale", H. Stanley WILLIAMS, Hewlett-Packard Labs, USA

A complete listing of the programme is contained in the CD-ROM. I have hard-copy summaries of many of the presentations and posters. Please contact with any questions or requests.

F. 3rd VLSI Photonics Symposium at INHA University

On Days 4 and 5 I visited the INHA University in Incheon in order to participate in the 3rd Annual VLSI photonics Symposium. The meeting was organised by Professor El-Hang LEE, former director of

ETRI, and a national leader for photonics in Korea. INHA is also the home of the OPERA Photonics R&D Center.

Prof. El-Hang LEE of INHA University. Professor LEE is the Director of the OPERA Photonics Center, located at INHA, ehlee@inha.ac.kr

Dr. Gun Yong SUNG of the IT Convergence and Components Lab, ETRI. Dr. SUNG presented work on visible light sources using Si quantum dots. gysung@etri.re.kr

A summary of plenary presentations is given below. A copy of the program is contained the CD-ROM, and I have hard copies of most of the presentations if you would like additional details.

1. T.P. PEARSALL, EPIC, The MONA Roadmap for nanophotonics
2. Eung-Sug LEE, Korea Institute of Machinery and Materials, 3UV Nano-imprint Lithography using a Large-area Stamp"
3. Gun Yong SUNG, ETRI, "Nanocrystal Silicon Light Emitting Devices"
4. Alfred DRIESSEN, Univ. Twente "Optical Micro-ring Resonators for VLSI Photonics"
5. Yang-ku CHOI, KAIST, "Nanofabrication Technologies for Nano Bio-sensors"
6. Kazuo FURUYA, National Institute for Materials Science, Japan, "In-situ Fabrication and Analysis of Si-nanoclusters by Ultrahigh Vacuum Electron Microscopy"
7. O'Dae KWON, POSTECH, "Photonic Quantum-Ring Laser for Displays and Lighting"
8. El-Hang LEE, OPERA, INHA, "VLSI Photonics on Optical Printed Circuit Boards"

For more details about the complete program, please contact EPIC.

I toured the nano fabrication laboratory facility at INHA, and I was able to see a demonstration of nano-imprint lithography equipment made by EPIC member **Obducat.**

The 6" NIL Imprint Lithography station from Obducat. Left: as shown in the catalogue, and Right: While operating in INHA University.

G. National Nanotechnology Centres

There are five main national nanofabrication technology centres in Korea: KANC, NNFC, NNIC, NCNT, and GNIC. About half of these centres are not yet operational. If the NCNT can be taken as an example, then about ½ the annual funding is provided by government ministries (MoCIE and MoST) . The rest is coming from industry.

These centres are supported by three key research bases. This constellation forms the basis of the so-called ***21st Century Frontier R&D*** program.

Research Base 1. Center for TERA-level Nanodevices web site www.nanotech.re.kr
TERA means small and fast integrated circuits.

Research Base 2. Center for Nanostructured Materials Technology
10 million euros per year for 10 years
Support from MoST
Located at KIST
39-1 Hawolgokdong,
Seongbuku
Seoul
http://Cnmt.kist.re.kr

3 main areas

- High strength materials such as metal-ceramic nanocomposites. Hard coating are sought
- Nanostructured materials for energy applications. New catalysts, batteries, are sought
- Nanostructured optical materials for IT applications: optical amplifiers

In a 2nd phase biomaterials, bone tooth replacements will be studied.

Research Base 3. Center for Nanoscale Mechatronics and Manufacturing, www.nanomecca.re.kr

Plus 9 nanotechnology research Institutes and OPERA for photonics technologies.

G-1 National NanoFab Center, NNFC

I did not visit this center

Purpose:	Silicon-based nano fab. Focussed on very high speed (TERA) integrated circuits
Clean-room facilities:	2370 m², 300mm CMOS process line
Where:	Kaist in Daejeon
In service since	March 2005
Supported by	MOST
Web site:	www.nnfc.com

National NanoFab Center at KAIST in Daejeon. This center is operational since March 2005.

G-2. Korean Advanced Nanotechnology Center, KANC

I did not visit this center

Purpose:	Compound Semiconductors and Photonics
Clean-room facilities:	3368m², 150mm line and 200mm lines
Where:	East Suwon, Kyunggi province, 40km away from Seoul in Korea
In service since:	May 2006
Supported by	MOST
Web site	www.kanc.re.kr

Center Director is LEE, Joongwon

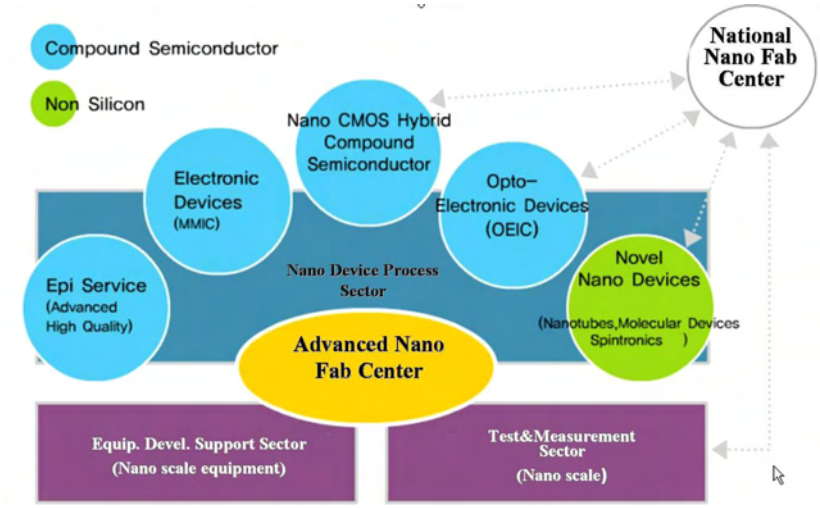
The KANC Center in Joongwon

This center specialises in processing only, treating compound semiconductors and other non-silicon materials. hey perform no film epitaxy, although one MO-CVD is on order for R&D purposes.

Major activities are:

- Patterning
- Industrialisation/Foundry
- Nano R&D
- Measurement and Analysis

KANC Complex (11,880 ㎡ including 3368 ㎡ clean room), R&D Building (19,800 ㎡), Industrial Building for Venture Companies (19,800 ㎡). The center opened this year in May, 2006. ***(This view is rotated 90° clockwise with respect to the orientation of the previous figure)***



Organisation at the KANC. It specialises in processing and characterisation, but does not yet participate in epitaxial services or in processing of microwave circuits (MMIC)

G-3. National Center for Nanomaterials Technology, NCNT

I visited this center.

Purpose:	Deposition and analysis of novel nano materials of all kinds
Clean-room facilities:	3111 m², 300 mm processing line
Where	Pohang
In Service:	October 2006
Supported by	Ministry of Commerce Industry and Energy (MOCIE)
Web site	www.nano.or.kr

Center Director is JEONG Yoon-ha
Specialises in materials synthesis and analysis
Budget for start-up is $110 million for the first five-year period that started in 2004.
- 30 million for building
- 30 million for equipment
- 50 million for operating expenses for 5 years

My photo of the recently-opened nanomaterials center at POSTECH in Pohang. The building was completed in July 2006. They are just starting to install equipment.

Government funding (national regional and local) contributed $46 million out of $110 million for the first five-year period. The remainder is coming from industrial support

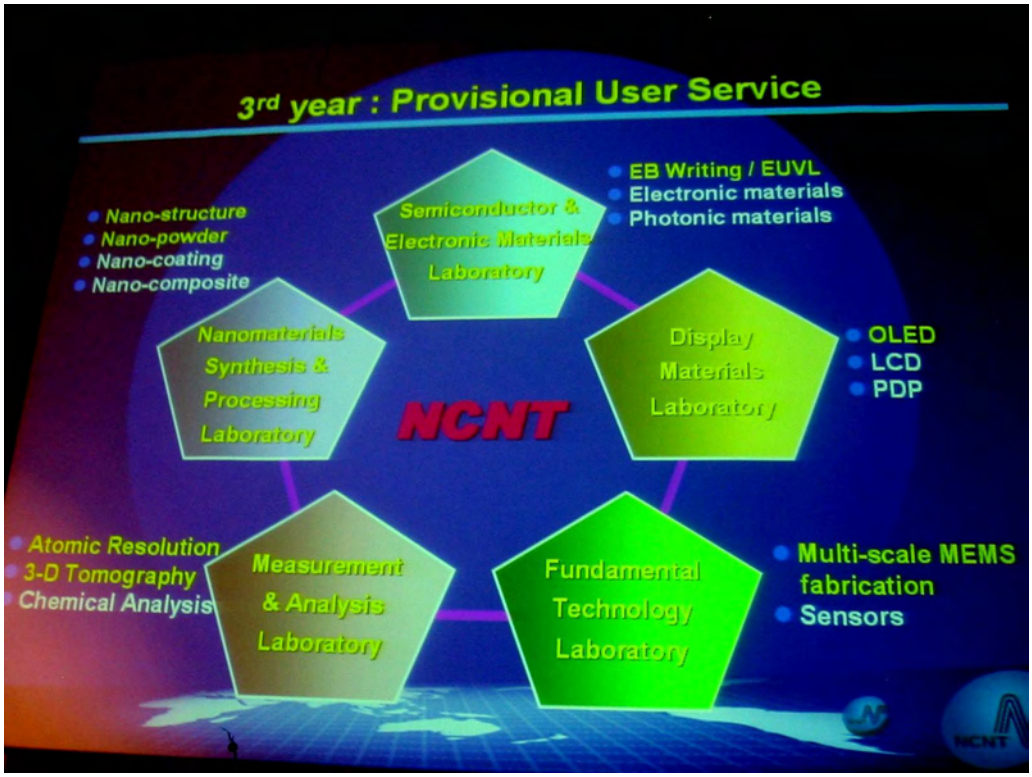
The Principal Companies supporting the center are:

- POSCO
- LG-Philips
- LG Electronics
- LG Chemistry
- Samsung SDI
- Samsung electronics

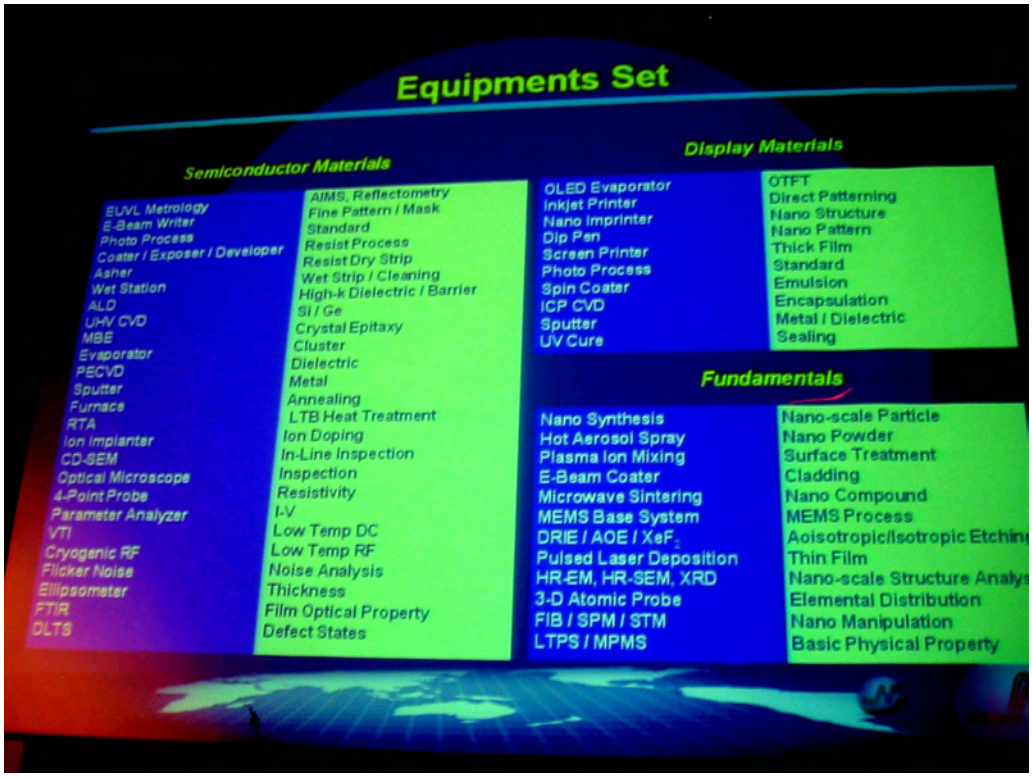
Building

$30 million
Time 13 months
3111 Fab
3365 Central Utilities Building
5183 R&D

The following figures were shown during a presentation of the center.



The center has just opened, but no equipment has been installed. The key areas envisaged are nanocomposites, including ceramics, electron beam and deep-UV lithography, and OLED materials.



A résumé of equipment to be installed in the POSTECH center.

G-4. National Nano Integration Center

I did not visit this center.

Purpose:	Nano process and integration. Establish module-oriented process, equipment, and procedures
Clean-room facilities:	2346m²
Where:	Jeonju
In Service:	planned for Dec. 2007
Supported by	Ministry of Commerce Industry and Energy MOCIE
Web site:	www.nnic.re.kr

The NNIC in Jeonju is under construction. The purpose of this center is to develop industrial manufacturing methods.

G-5. Gwangju Nanotechnology Integration Center

I did not visit this center

Purpose:	Nano process and integration : Establish module-oriented process equipment and procedures
Clean-room Facilities	1195m²
Where:	Gwangju
In Service:	planned for November 2006
Supported by	Ministry of Commerce Industry and Energy MOCIE
Web site:	www.gnic.kitech.re.kr

The Gwangju Center should be completed by the end of 2006. The purpose of this center is to develop industrial manufacturing methods.

Gwangju is known as the LED Valley in Korea. There are significant LED demonstration projects running here of most kinds of LED applications related to lighting and signalling. A list of projects is given below.

- LED Valley (Nat'l Growth Engineering)
  U$100M, 05-08, LED, Semiconductor Lighting

- FTTH Service Model City
  U$80M, 05-08, FTTH 20k Households

- Photonics Industry Promotion
  U$350M, 04-08, HB LED, Opt. Com

Photonics Support clusters in Gwangju:
- KOPTI: full scale direct tech support for companies
- ETRI-OCC: FTTH deployment support
- KAPID: marketing and information support
- APRI: basic R&D support
- Kitech: manufacturing & process support
- GJTP: business incubator
- Universities: GIST, Chosun, Chonnal Nat'l University

End of Report