T.P. Pearsall MONA Project Taiwan trip report, 18 to 28 April 2006

1. Summary:

Following an invitation to participate in a joint symposium sponsored by the European Commission (EC) and the National Science Commission (NSC) of Taiwan, I travelled to Taiwan where I presented the MONA project in Taipei and Hsinchu, distributing the MONA Frame-of-Reference study. In return, I received extensive quantitative information on the National Nanotechnology Programme in Taiwan. This information has been synthesised and organised in the CD-ROM, "MONA-Merging Optics and Nanotechnologies in Euope and Asia, vol.1". The meetings with the NSC and with the Nano Device Laboratory (NDL) were characterised by open and enthusiastic exchanges of information about ongoing projects and future opportunities. Both sides have agreed to schedule further discussions, with the next meeting to be held in Italy in September, 2006.

My travel expenses were covered by the generous support of the NSC and the NDL.

2. Introduction:

The Republic of China (ROC) is located on the island of Taiwan off the south-eastern coast of mainland China (PRC). The weather is sub tropical: very hot and humid in the summer, and warm and rainy in the winter. Taiwan is about 300 km in length. The centre of the island is alpine with peaks reaching 4000m. The eastern cost is less developed than the west coast. There are 23 million Taiwanese, and the population concentrated along the western coast exceeds a density of 10 000 habitants/km^2 in many areas from the north to the south of the island.

The first democratically-elected government was formed in 1996, only ten years ago. Prior to this the country was ruled for 40 years by the Kuomintang party of Generalissimo Chiang Kai-Shek. My impression is that the 40-year rule by the Kuomintang was an important factor in retarding the economic development of the ROC, and that it was a factor in encouraging the departure of the best and brightest students to western countries, mostly the US, for higher studies and careers in exile. With the birth of democracy in Taiwan and the development of a pragmatic approach toward its diplomatic situation, the economy has literally exploded, raising the GDP and per capita income by more than an order of magnitude in 10 years. High-level scientists and managers are now returning to Taiwan to help lead this development. They are benefiting from their knowledge and experience and close personal contacts with western businesses throughout the world. This influx of extraordinary talent promises to give development in Taiwan a further boost in the years to come.

The ROC is recognised diplomatically by only 25 countries. Nonetheless the ROC maintains trade and diplomatic offices throughout the world, including a mission to the European Commission in Brussels. Recognition is a sensitive and potent political issue. Despite the small number of governments that officially recognise the ROC, there is a thriving economic and intellectual exchange going on world-wide. For example, the ROC and the PRC are strong trading partners, and there are significant academic exchanges between the two countries. The relationship between the ROC in Taiwan and the PRC on the mainland has many facets, ranging from close collaboration and cooperation to outright hostility.

My mission to Taiwan had two components. The first was participation in a joint meeting between the National Science Council of Taiwan and the European Commission in Taipei in order to explore cooperation and the participation of Taiwanese scientists in the European Nanotechnology research programmes. The second part was my participation in the Symposium on Nano Device Technology in Hsinchu.

3. Investment in R&D: Budget Breakdown

Nanotechnology research is supported in Taiwan by a national program of over USD 600 million over 6 years. The Nanotechnology program is administered by the NSC. The program is now at its midway point, and review is being conducted this year to evaluate progress. The budget is shared between the NSC which supervises basic research, including the Nano Device Laboratory, and the Industrial Technology Research Institute (ITRI) which focuses on applications of nanotechnologies. The budget breakdown is shown below.

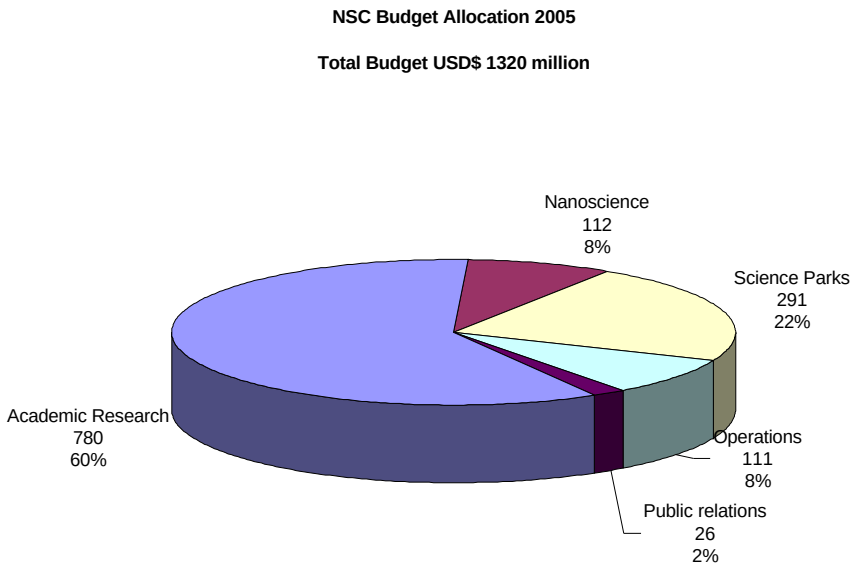

Figure 1. The annual budget of the NSC was US $1.32 billion in 2005. The National Nanotechnology Program is about 10% of all R&D expenditures.

The investment of the Taiwanese government is R&D has been growing at approximately 10% per annum compounded annually for the last decade, resulting in a cumulative increase of more than 200% during this time. The actual budgeted amounts are given in Figure 2.

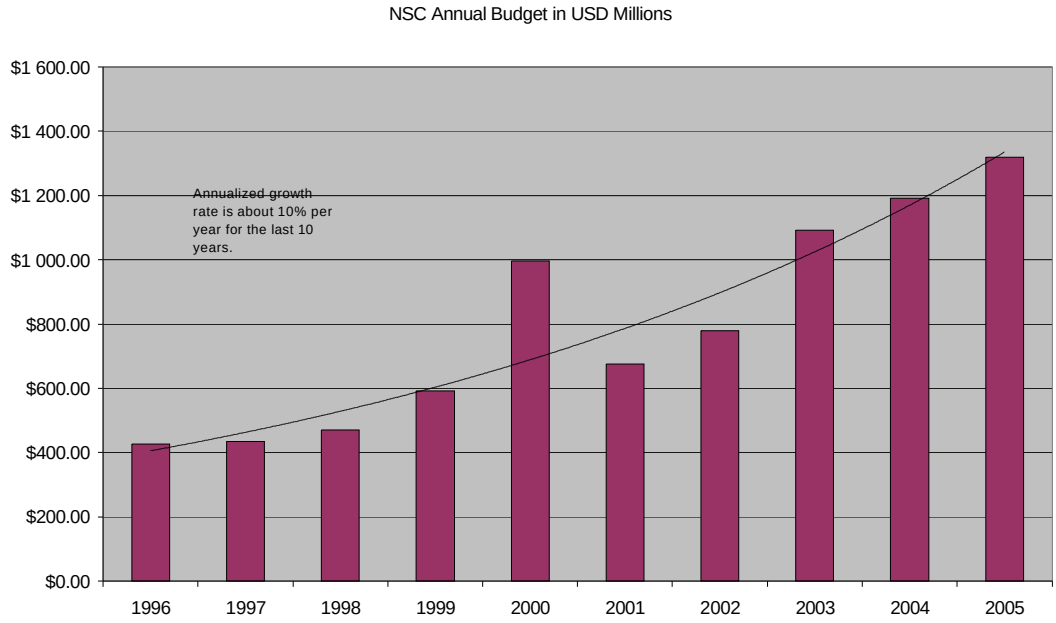

Figure 2. Investment in R&D in Taiwan 1995-2005

In addition, Taiwan has been working to increase its investment as a percentage of gross domestic product (GDP). The investment rate is now approaching 3%, and has increased by more than 60% since 1995.

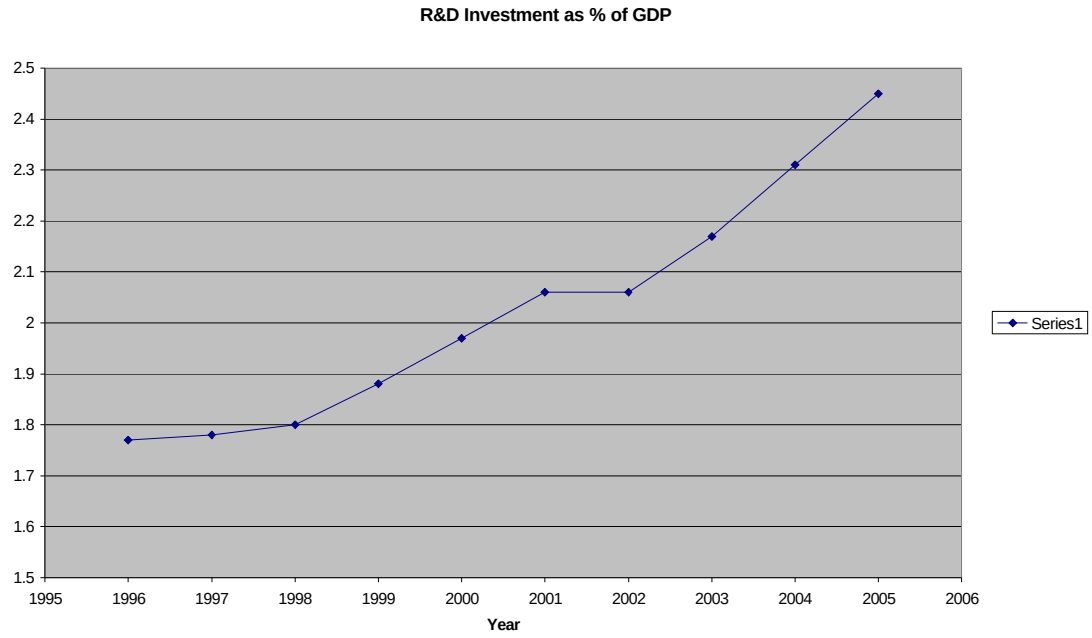

Figure 3. R&D investment in Taiwan as a percentage of GDP from 1995 to present.

A first conclusion is that the democratically-elected government of Taiwan has made a serious and strategic commitment over the long term to invest in and develop its capabilities in high-technology. There are valuable lessons to be learned here for European countries trying to reach the Lisbon goals.

The National Nanotechnology Program annual budget of US $112 million is divided between academic programs at universities and ITRI which develops industrial applications and which is expected to create spin-off companies. ITRI receives the lion's share with 5 times more budget that academic programs. The budget breakdown is shown in Figure 4.

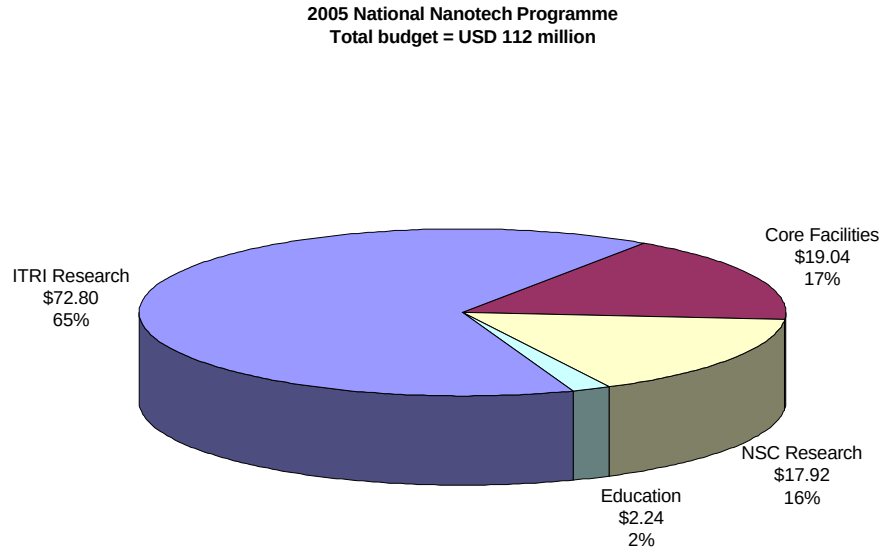

Figure 4. The National Nanotechnology Program: where the money goes

The educational component is US $2.2 million per year, and targets the introduction of nanotechnology to the science curriculum starting in the first level of primary education. I received 2 DVDs on the *Adventures of Nana and Nono* who introduce the opportunities presented by the nanotechnology frontier. The content is presented in a programmed learning format with questions and more details if

the answers are not correct. The target audience is children from 5 years and older. I have some copies of these CD which I would be pleased to share with anyone who indicates an interest.

4. The NSC-EC Joint Symposium on Nanotechnologies, Taipei, 19-21 April 2006

The first set of meeting was organised around a symposium on nanotechnology research with presentations by Taiwanese and European scientists. Results and work in progress were presented on subjects ranging from modelling and simulation, new materials, spintronics, in-vivo imaging of biological tissue on the micro or nano scale, and self assembly of molecular nanostructures. The level of presentations was very high, scientifically-speaking. And personally, I was amazed to see the technical capability and mastery that was presented by research groups from Europe and from Taiwan. The presentations have been made into a CD-ROM, and these can be consulted here in a separate folder.

European Commission representatives

Enrico Sabbioni, Joint Research Centre	Nanotoxicology	enrico.sabbioni@cec.eu.int
Oliver Panzer, DG-Research	European Commission	oliver.panzer@cec.eu.int
Axel Voigt, Caesar Research Centre	Molecular Modeling	axel.voigt@caesar.de
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Jeremy Baumberg, U. Southampton	Photonic Crystals	j.j.baumberg@soton.ac.uk
Thomas Pearsall, EPIC	EU MONA programme	pearsall@epic-assoc.com
James Callow, U. Birmingham	Biofouling	j.a.callow@bham.ac.uk
Jean-Louis Viovy, Institut Curie	Self Assembly in biology	Jean-louis.viovy@curie.fr
Bengt Svensson, Univ. Oslo	Nanotechnology at Univ. Oslo	b.g.svensson@fys.uio.no

Taiwanese Scientists

Ting-Kuo Lee, Exec Director NSC tklee@phys.sinica.edu.tw	Solid-state Theory
Ching-Ming Wei, Academia Sinica cmw@phys.sinica.edu.tw	Quantum size effect
Chung-Shi Wang, National Chi Nan Univ. cyang@ncnu.edu.tw	Nanoparticles in-vivo
Yuh-Lin Wang, Academia Sinica ylwang@pub.iams.sinica.edu.tw	Ordered Arrays of Monodispersed Nanostructures
Ing-Shouh Hwang, Academia Sinica ishwang@phys.sinica.edu.tw	Noble metal single atom tips
Chih-Chung Yang, Nat. Taiwan Univ ccy@cc.ee.ntu.edu.tw	Light emission from In-rich nanoclusters
Yeu-Kwang Hwu, Academia, Sinica phhwu@sinica.edu.tw	Nano-radiology with Synchrotron radiation
Jung-Chun Andrew Huang, Nat Cheng Kung U. jcahuang@mail.ncku.edu.tw	Detection of Co nanoclusters in Co-doped ZnO
Chia-Chun Chen, Nat. Taiwan Normal U. t42005@cc.ntnu.edu.tw	Applications of Functional Nanoparticles in Biological Labelling
Kung-Hwa Wei, Nat. Chiao Tung Univ. khwei@cc.nctu.edu.tw	Electrical transport by Gold Nanoparticles in Polystyrene
Ray-Nien Kwo, Nat Tsing Hua Univ. raynien@phys.nthu.edu.tw	High-K Dielectrics, A colleague with whom I worked for many years at Bell Labs

The presentation of TP Pearsall emphasised the MONA project. I gave a review of European R&D programmes in the nanotechnology and photonics areas. I discussed the opportunity for exchanges and participation of Taiwanese scientist in European R&D programs. I distributed copies of the MONA CD concerning the nanotechnology Frame of Reference to the audience.

Shared strengths: Academic research programs in Taiwan and Europe appear to be equally productive and creative. Many of the Taiwanese programs are led by senior scientists who have already spent 10 to 20 years working in the best research labs in the US or in Europe. Thus, research objectives in Taiwan and Europe are already well-coordinated, sharing similar objectives and priorities.

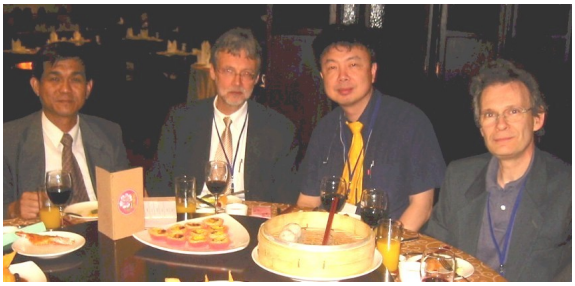
The scientific level of enquiry are high and well-developed on both sides, with the possibility that Taiwanese scientists benefit from a higher level of investment in capital equipment and in state-of-the-art resources for both nanofabrication and characterisation on the nano scale.

European strengths: Europe is rich in skilled human resources. The European university graduate education system produces more highly-trained scientists at the master's and PhD level than any other economic area in the world. For a number of reasons, European research programs excel in computational sciences, including the development of sophisticated and powerful modelling techniques which are applied to semiconductor design, molecular modelling, pharmaceutical drug design, weather analysis, and a large array of signal-processing applications like displays, communications, etc.

European needs: Europe lacks access to experimental and above all manufacturing facilities. The decline of cost-competitive manufacturing of high-tech products in Europe has important consequences. One is the shortage of jobs for highly-trained scientists and engineers.

Participants in the European Commission – National Science Council Meetings

From left to right:
- Hung-Duen Yang, Deputy Minister, NSC and co-host
- Bengt Gunnar Svensson, Univ. Oslo, Norway
- Wei-Xin Ni, National Nano Device Laboratory, Hsinchu
- Jean-Louis Viovy, Institut Curie, France



From left to right:
- James Callow, Univ. of Birmingham, UK
- Oliver Panzer, European Commission
- Axel Voight, Caesar, Germany

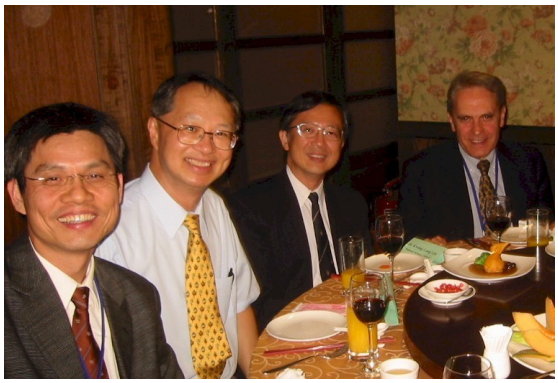
From left to right:
- Carlo Taliani, CNR, Italy
- Jeremy Baumberg, Univ. Southampton, UK
- Ching-Jyh Shieh, Deputy Minister, NSC and co-host

From left to right:
I. Lin, Director, Natural Sci. and Maths, NSC

Frédéric Laplanche, Deputy head European Economic and Trade Office

Ting-Kuo Lee, Executive Director, Nanoscale Research, NSC

From left to right:
Tsing-Tang Song
Executive Secretary NSC, meeting organiser
Andrew Kung, Inst. Atomic & Molecular Sciences, Acad. Sinica
Kwang-Lung Lin, Director General, Dept. of International Cooperation
Enrico Sabbioni, Leader of the European Delegation, EC Joint Research Centre, Nanotoxicology



Taiwanese strengths: Taiwan excels in the manufacture of high-technology products. The Taiwan Semiconductor Manufacturing Company (TSMC) was born out of ITRI (its most successful tech transfer project) under the leadership of Morris Chang, a Taiwanese who made his career and fortune in the US at Texas Instruments, and who was persuaded to return to Taiwan to build TSMC. The considerable investment required to build such companies is helped by substantial financing from the national government and a very high rate of internal savings.

Taiwanese needs: To keep its economy growing, Taiwan is searching for highly trained scientists. Having already repatriated a large proportion of its scientists working overseas, Taiwan is now facing a shortage of trained personnel, and this is a threat to continued economic growth.

Traditionally Taiwanese companies have engineered products by experiment, but the cost of experiment in micro and now nanotechnology is becoming prohibitive in cost of both time and equipment. There is a real need to develop modelling and simulation for nanotechnology manufacture. The NSC recognises that Taiwan has a weakness in this area.

5. Hsinchu Science Park and the Nano Device Laboratory, Hsinchu: 24-27 April

Hsinchu is a major science and technology centre in Taiwan. There are 4 major components:

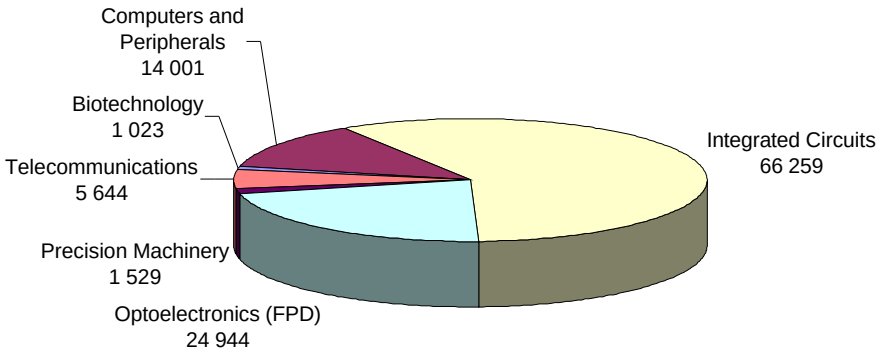
1. The Hsinchu Science Park, where major Taiwan high tech companies like TSMC, Macronix, EPISTAR, and AU Optronics are located
2. Chiao Tung and Tsing Hua National Universities
3. NDL, the Nano Device Laboratory
4. ITRI, the Industry Technology Research Institute

The Hsinchu Science Park is the largest of three such science parks in different parts of the island. All-in-all, these parks are home to companies with combined revenues of about $US 42 billion in 2004. Park revenues are increasing at 30% per year due in part to new installations as well as economic growth of established companies.

Data from the Hsinchu Park give a picture of the economic force represented by this tech development initiative.

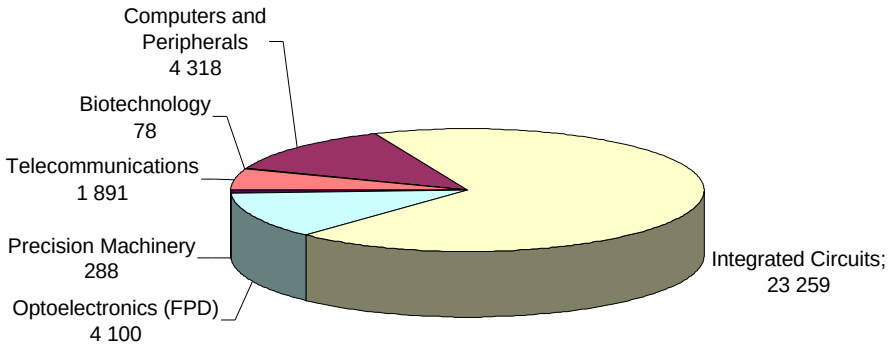
Thirty-three thousand people were employed by industries in the Hsinchu Park in 2004, The largest sector is IC fabrication, dominated by Taiwan Semiconductor Manufacturing Corp. TSMC.

113 400 Employees at Hsinchu Science Park in 2004



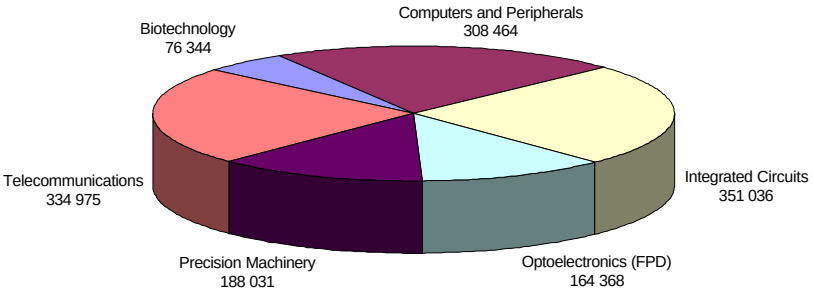
There are 45 optoelectronics companies, including LED fabrication, but the sector is dominated by flat-panel display production (for example AUO). The optoelectronics sector generated US $4.1 billion in the Hsinchu Park in 2004.

Revenues in $US Millions, Hsinchu Science Park 2004 (Total $US 34 Billion)



It is interesting to note the productivity per employee in each of these sectors, as summarised in the chart below. The average employee in computers, integrated circuits and telecommunications produced more than US $300 000 in revenues, while other sectors like optoelectronics, precision machinery and biotechnology produced less than half this amount. These are sectors that are disadvantaged by the cost of labour in Taiwan compared to lower rates on the mainland.

Revenues per Employee, $US/person Hsinchu Science Park, 2004



The Nano Device Laboratory is under the direction of Wei-Xin Ni, who also as been professor at Linköping University in Sweden for many years. The NDL laboratory is a department of the National Science Council, but is located adjacent to the National Chaio Tung and Tsing Hua Universities and the Hsinchu Science Park. The NDL is the coordination point for nanostructure synthesis in Taiwan. There is a second branch in the centre of the country in Taichung. The NDL lab in Hsinchu has its own 300-mm silicon CMOS fab as well as a full complement of patterning and characterisation tools. The lab has an annual budget of € 100 million.

NDL Facility

- Completed in 2004
- 3 300 m^2 of state of the art clean-room fabrication
- Total space = 13 200 m^2
- Nano fabrication capabilities
- 300 mm Si line

In this part of the visit, the emphasis was on industry technologies for nanostructure development and application. I was joined by Francis Balestra of the x university in Grenoble, and director of the SiNano network of excellence, and Eleanor Campbell of the Göteborg University, expert in carbon nanotubes. Each of us gave a short course during this week. My presentation covered planar photonic crystals. Copies of these presentations have been included in the CD-ROM.

6. High-level Panel Discussion

The programme consisted of a high-level technology exchange panel involving major industries in the park.

Francis Balestra, IMEP in Grenoble
Kent Chuang, IBM Yorktown Heights
Eleanor Campbell, Univ. of Göteborg,
Roger de Keersmaecker, IMEC
Gilbert Lecarpentier, Süss Microtec
Yuichi Nakamura, NEC, Kawasaki
Tom Pearsall, EPIC

From the Science Park, there were representatives from industry:

Liang-Gee Chen, General Director ITRI

John Chi, Director, Center for Nano-Science and Technology, University System of Taiwan
C.Y. Lu, Senior VP of Macronix
TSMC, Silicon Foundry
UMC, Silicon Foundry
T.K. Lee, National Science Council
Tan Fu Lei, National Chaio Tung University
Wei-Xin Ni, Nano Device Laboratory
Michael Tsai, Nano Device Laboratory

The focus of the panel was Silicon nanoelectronics. Both TSMC and UMC have lines running 45 nm and 32 nm nodes. The industry is searching for ways to continue shrinking the technology. R&D is looking extensively at emerging research devices and research materials. Follow-on topics are architectures, interconnect, and packaging technologies.

We discussed the problem of technology transfer: why does it take 20 years for an innovation to make it to the process line? After considerable discussion, it was agreed that universities and R&D labs should be working on topics that are at least 10 years out, while only industry can work meaningfully on production issues associated with the next 2 generations. There was obviously no proposal to speed up transfer from R&D to the factory floor. Companies actually seem pleased with the present situation.

Tool development was recognised a key element in progress. SEMATech in the US has been successful because it focuses on tool development, paid for by all the chip makers. Thus consortiums can help, but they need to focus on the roadblocks.

7. Short Courses

Short courses were largely tutorials on tools for nanotechnology, presented by experts or marketing specialists from all over the world.

? Advances in Device Characterization and Modeling Technologies

Dr. Min-Chie Jeng Cadence Design Systems, Inc	*MOSFET Modeling Now and Then*
Mr. Christian Eppers Agilent Technologies	*Breakthroughs in Device Modeling Speed and Efficiency*
Dr. Yuegang Zhao Keithley Instruments	*Characterizing Transient Device Behavior Using Pulse I-V Technique*
Dr. Yusuke Tajima, Auriga Measurement Systems LLC	*RF Modeling: from MESFETs to GaN PHEMTs*
Mr. David P. Menzer, Auriga Measurement Systems LLC	*Large Signal Device Characterization Solutions*
Mr. David P. Menzer, Auriga Measurement Systems LLC	*High Power Pulsed IV/RF Test and Device Modeling*
Mr. Arno Pettai Anritsu Company Inc.	*Microwave Multiport Testing Theory and Measurement*

? Nano-Patterning Technologies

Dr. L. Jay Guo University of Michigan	*Nanoimprint Lithography*
Dr. Chun-Kuang Chen TSMC	*Optical Lithography and Next Generation Lithographies*
Mr. Juergen Gramss Leica Microsystems Lithography GmbH	*Shaped Beam Technology for Nano Patterning*
Mr. Gilbert Lecarpentier SUSS MicroTec	*Cost effective Micro/Nano Replication Using a Step & Repeat Imprinting Approach*

Dr. Hiroyuki Ito
Hitachi High-Technologies Corporation

Large Field Deflection Errors due to Charging with the EB Lithography System

Mr. Toshiaki Fujii
SII NanoTechnology Inc.

Nano-Patterning Technology in FIB Applications

Mr. Ken Koseki
ELIONIX

Ebeam Lithography and Nano Fabrication

? **Advances in Nanoelectronics**

Prof. Francis Balestra
Coordinator of the EU Network of Excellence – Si-based Nano Devices (SINANO), Enserg, INPG, Grenoble, France.

Status and trends in Nanoscale SOI devices

Dr. Thomas Pearsall
General Secretary of European Photonic Industrial Consortium (EPIC), Paris, France.

Prof. Eleanor Campbell
Coordinator of the Swedish strategic research consortium on carbon nanotube materials, Göteborg University, Sweden.

Introduction to Carbon Nanotubes and Their Electronic Properties.

8. Visit with Chun-Yen Chang, President of National Chiao Tung University

From left to right:
Wei-Xin Ni, President of Nano Device Laboratory
Tom Pearsall, EPIC
Chun-Yen Chang, President, National Chaio Tung University
Francis Balestra, IMEP, Grenoble

The subject of this visit was the founding of the photonics technology platform Photonics[21], and the MONA programme. Through the MONA programme the European Commission is seeking to establish two-way exchange between nanotechnology programmes in Asian countries like Taiwan and European R&D. I personally conveyed a copy of the MONA CD concerning the nanotechnology Frame of Reference to President Chang.

9. Visit of ITRI and to EPISTAR

These visits have been covered in a separate trip report

10. Nanotechnology Symposium at NDL on the 27 and 28 APRIL 2006

TP Pearsall gave the first Keynote presentation in this symposium. I introduced EPIC, the Photonics Technology Platform Photonics 21, and the MONA project. The presentation emphasised the opportunity for participation by Taiwanese scientists and engineers in R&D projects of the European Commission. I distributed copies of the Photonics[21] Vision document and the MONA CD-ROM covering the Nanotechnology Frame of Reference to the audience.

From left to right:
T.K. Lee, Executive Director Nanoscale Research, NSC

Jyh-Hua Ting, Symposium Organiser, Nano Device Laboratory

Wei-Xin Ni, President Nano Device Laboratory

Eleanor Campbell, Dept. of Physics, Univ. of Göteborg

11. Visit with Deputy Minister Guo-Chung Chi, NSC, and Robert Lai, Chairman of the National Applied Research Laboratories

This was a special occasion to renew my acquaintance with Deputy Minister Gou-Chung Chi. We worked together for 10 years at Bell Labs in Murray Hill. Now he administers the distribution of the US $1.3 billion budget of the National Science Council. I gave a synthesis of my visit, highlighting the various proposals that were developed concerning mechanisms for exchanges and collaborative research programmes. I personally conveyed a copy of the Photonics[21] Vision document and a copy of the MONA CD concerning the nanotechnology Frame of Reference to Deputy Minister Chi.

From left to right:

Guo-Chung Chi , Deputy Minister, National Science Council

Tom Pearsall, General Secretary EPIC

I have had contact with the Service of Sciences and Technologies of the Taiwan representative to France in order to plan a follow-up visit with Dr. Chi during his forthcoming visit to France.

End of report

12. ANNEXE

Contact information for my principal visits in Taiwan

Name	Responsibility	e-mail address
Ministers		
Guo-Chung CHI, PhD Yale, Deputy Minister, NSC	Central Processing : Distributes money to projects	gcchi@nsc.gov.tw
Ching-Jyh SHIEH, Ph. D. Univ Mich., Deputy Minister, NSC	International Exchanges and relations	cshieh@nsc.gov.tw
Hung-Duen YANG, Deputy Minister, NSC	Co-host of NSC-EC meeting	hdyang@nsc.gov.tw
Directors		
Kwang-Lung LIN, Director General, NSC	International Cooperation	kllin@nsc.gov.tw
C.K. LEE, Director General, NSC	Director for nanoscience	cklee@nsc.gov.tw
I. LIN, Director General, NSC	Director for life Sciences	ilin@nsc.gov.tw
National Academy		
Ting Kuo LEE, Executive Director, Academia Sinica	National Program for Nanoscale Research	tklee@phys.sinica.edu.tw
Tsing-tang SONG, Executive Secretary, Academia Sinica	National Program for Nanoscale Research	ttsong@phys.sinica.edu.tw
Special personalities		
Chun-Yen CHANG, President, Chiao Tung University	President	
Wei-Xin NI, Ph. D. Linköping Univ.	President Nano Device Laboratory	wxni@mail.ndl.org.tw
Robert LAI, Chairman, National Applied Research Laboratories	Chairman of the Board National Nano Device Laboratory	rylai@narl.org.tw
C.Y. LU, Ph. D. Macronix International	Senior Vice President	cylu@mxic.com.tw
Jyuo-Min SHYU, Executive Vice President ITRI	Executive responsibility at ITRI Executive Director, National Nanotechnology Program	shyu@itri.org.tw