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第八屆世界微機電系統高峰會議並參訪鄰近研究機構與大學

(The 8th World Micromachine Summit 2002)

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一、前言

第八屆世界微機電系統高峰會議於 2002 年 5 月 1 日至 5 月 3 日，假荷蘭馬斯垂克（Maastricht）市會議中心舉行；與會人員分為會員（免繳註冊費）及觀察員（需繳費），我國為高峰會議之正式會員，本國代表由林敏雄博士（前工研院副院長，現任亞太優勢股份有限公司董事長）擔任首席代表兼團長，率領李世光教授（台大應力所），張所鉉教授（台大機械所），及蕭飛賓教授（成大航太所）等代表參加，並於本次會議發表三篇論文。國科會駐比利時科學組彭清次組長及工研院歐洲辦事處謝良翰博士為觀察員，全程參加本次會議。參加本次高峰會的國家與地區計有：Australia, Benelux (Belgium, The Netherlands and Luxemburg), Canada, China, France, Germany, Japan, Korea, Mediterranean (Italy, Spain, Portugal, etc), Nordic (Norway, Sweden, Denmark, Finland), Singapore, Switzerland, Taiwan, United Kingdom, and United States of America.

二、參加會議經過與參訪

本國四位代表於四月二十八日分別飛抵荷蘭阿姆斯特丹國際機場，由國科會駐比利時科學組彭清次組長安排接機，當日住宿於海牙。四月二十九日（週一），科學組彭組長安排拜會 Technical University of Delft，由 DIMES 研究中心的主任 Prof. A. Burghartz 接待，並聽取四位研究人員簡報，李世光教授簡報本國微機電／奈米科技策略現況。當日宿於布魯塞爾，並由我國駐比利時李大維代表招待晚宴。次日四月卅日（週二），由彭組長驅車拜會魯文大學(Catholic University of Leuven)內 PMA (Production engineering Machine design and Automation)，由 Dr. Ir. Hendrik Van Brussel 主任接待，及聽取簡報，並參觀實驗室。隨後拜會以微機電技術享譽歐洲的 IMEC 研究中心（網站 www.imec.be），當日繼續由彭組長驅車前往 Maastricht，參加微機電高峰會議的下午五點的會前接待會。

五月一日開始第一天的高峰會議，大會主席 Prof. Albert van den Berg (University of Twente) 首先作開幕致詞(Open Remarks)，然後開始第一場次 (session)『國家政策現況』的報告(Country/Region Review)，依英文字母的順序，

次由美、英、台、瑞士、新加坡、北歐國家、地中海國家、韓、日、德、法、中、加、比荷盧三國、澳洲等十五篇論文報告，我國的現況由李世光教授報告。第二、三場次『奈米基礎科學與技術』，計有日本、英國、比利時、加、台灣、澳洲、及法國等七篇論文報告，由張所銘教授報告本國奈米科技現況。第四場次『技術轉移』，有來自加拿大與比利時等兩篇論文。

次日共有四個場次，第五場次『微機電技術策略及新應用』，有五篇（日(兩篇)、西、美及中）論文，第六場次『微機電技術應用於化學、生化、醫、及偵測』有瑞士、法、韓等三篇論文，第七場次『企業之架構』有來自法（兩篇）、韓、台、中等五篇論文，台灣的論文再次由李世光教授報導；第八場次『未來展望』則由法國兩篇論文，結束本次高峰會議。

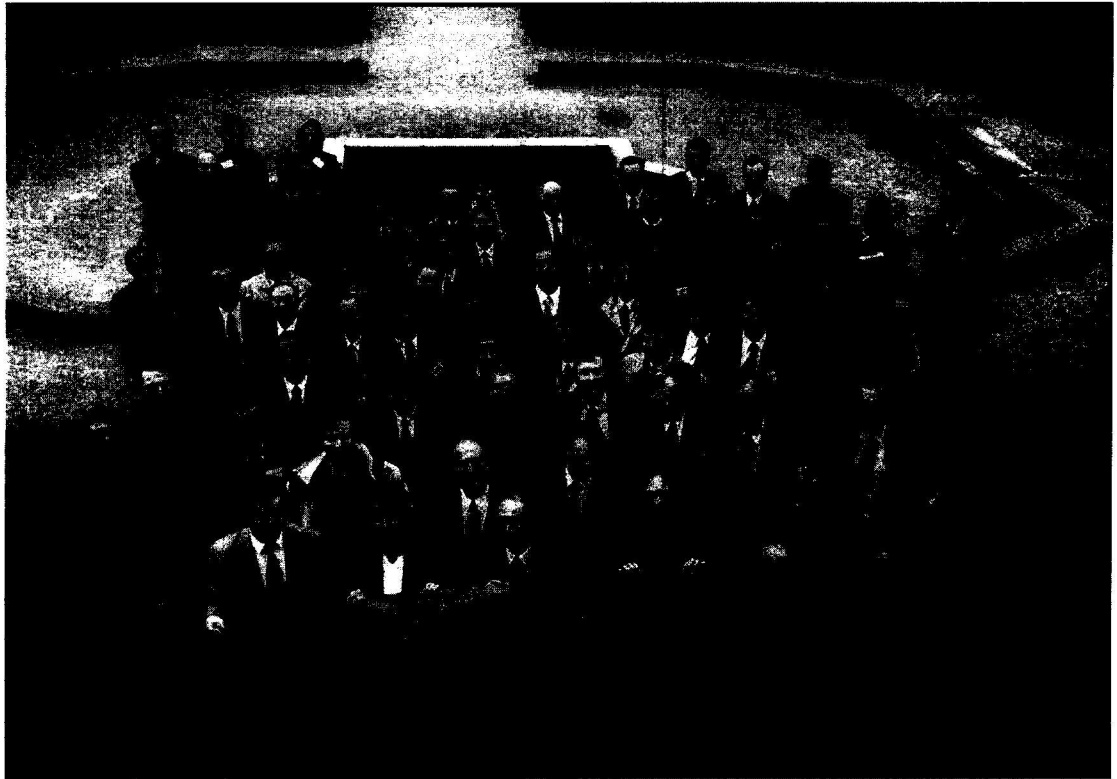
本日會議結束時，由大會主席宣告明年的高峰會議將於中國北京舉行。

五月三日，大會安排實地參觀，我國代表團選擇 The University of Twente 的 MESA 研究中心。會後當日搭乘火車至阿姆斯特丹過夜，次日（5 月 4 日）由阿姆斯特丹搭華航班機，途經曼谷返台灣，圓滿達成本次任務。

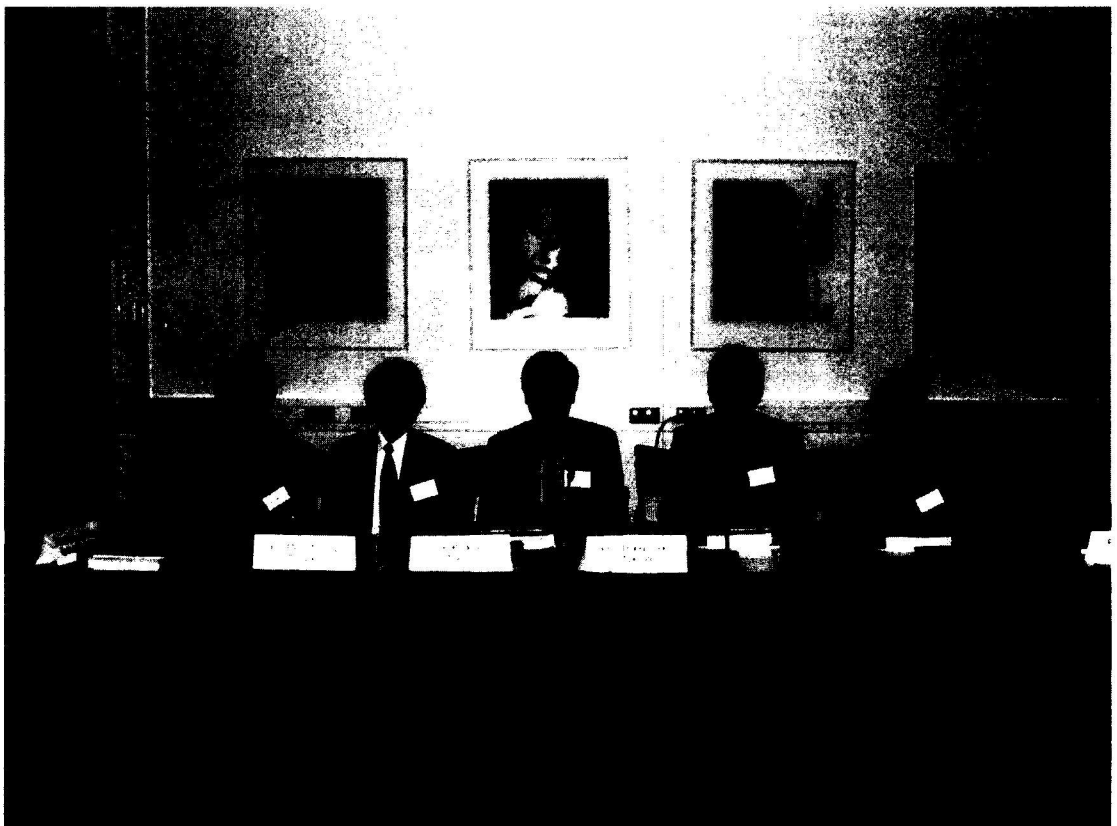
三、結論

1. 本次會議由荷蘭 MESA/Univ. of Twente 與 IMEC/Belgium 共同主辦本次高峰會，相當成功，各界給於相當好評與感激，受益匪淺，顯見主辦單位的用心。
2. 由大會各國的發展，顯而易見的是微機電的技術已漸漸地日漸成熟，商業公司與代工工廠也日益增加，對於微機電的技術開發與應用的蓬勃發展，將是指日可待的事了。同時，發現各國對於奈米科技的重要性日益顯著，並且投入相當經費、人力、設備等研發工作，因此大會對於這個轉變也給於相當重視，相信明年的高峰會將有明確的改變。
3. 不管微機電或是奈米科技，其所參與的人力與經費投資，都是非常龐大，尤其在技術研發與國際合作方面，都受到各界重視。我們所參訪的比利時 IMEC 研究機構，其與魯文大學關係密切，在理工科方面都有相當傑出成就。加以其在微機電技術、半導體、光電、通訊等科技研發，成果卓著，國科會以準備與 IMEC 簽約進行學術合作，尤其是在交換學生、博士後研究、教授，共同執行計劃等方面，都有相當的共識，非常歡迎與台灣學術界進行學術合作。其他如 Delft University 以及 Univ. of Twente 的 MESA 研究機構，也非常歡迎與台灣進行學術合作。
4. 明年微機電高峰會(2003)將移師北京舉辦，由北京清華大學負責，希望我國能繼續派員參加，並且希望台灣能在適當時機提出主辦意願，以增強我們的國際曝光度。

本次參訪團得以成行要感謝國科會的經費支持，尤其我駐外單位科學組彭清次組長與其同仁的細心安排與規劃，順利完成，特此致謝。



第八屆世界微機電系統高峰會議與會人員合影 (5-1-2002)



本國四位代表與國科會駐比利時科學組彭清次組長合影於高峰會議現場

April 28, 2002

The delegates arrived Holland at four different flights due to assignments and responsibilities of each delegate's organizations of the previous week. In fact, the delegates arrive from Taiwan, France, and USA separately. Dr. Charles Peng, Ms. Isabelle Chen and her husband Mr. Lai greeted all of them. Three of the delegates got the chance to visit Keukenhof (cook garden house) to see the tulip garden of Holland that open only once a month every year. The varieties and layout of the tulip garden is astonishing. The visit is an enjoyable and eye-opening experiences, which quickly make the delegates feel at home and ready for the extensive visiting and collaboration discussion programs.



Figure 1. Scene of Keukenhof, Holland

April 29, 2002

The whole delegates accompanied by Dr. Charles Peng stayed in Hotel Sofitel Den Haag (Fig. 2) near the train station and leave for the first day visit of TU Delft at 9:00 am of April 29, 2002.



Figure 2. View of Holland from Hotel Sofitel Den Haag

Technical visit at Delft University

Contact: Prof. Dr. Lina M. Sarro, Feldmannweg 17, Room 0.04, Delft, sarro@dimes.tudelft.nl, www.dimes.tudelft.nl, Tel: (+33) 15 278 7708, Fax: (+33) 15 278 7369.

Overview Presentations: Dr. Joachim N. Burghartz, Scientific Director DIMES Delft is a technical university with 7 departments of 18,000 students. DIMES was founded at 1987. Now, there are about 300 staff, with Class 100 Integrated Process Lab (ICP) and class 10000 nanotechnology Lab., and special applications labs (SAL). Total budget of DIMES is around 21M Euros per year. The four themes of the lab, including high frequency technology for communications, integrated smart Microsystems, large area electronics, nano-electronics, etc. DIMES abroad activities include a new training center in Tsinghua University of Beijing, China and various joint research activities all over the world. Base processes include 20nm e-beam lithography, nano and deep UV lithography, etc. The SAP labs were created to make more flexibility to the peripheral labs while trying to keep the fabrication capabilities stable in order to provide service and timely foundries to the research need and industrial service. Jointly develop the industrial processes IBM BiCMOS.5hp, IBM BiCMOS.6hp, IBM BiCMOS.7hp, UMC, National, etc., which DIMES sent the design to the various companies for fabrications and then came back for either post- processing or just testing. More than 100 Ph.D. students came more than 25 nationalities are involved, training is very strongly emphasized, and the growth is significantly with the strong market demand. The trends output is steadily increasing with time, however the dissertation needs in many cases are conflict with the market need. DIMES published around 500 papers annually.

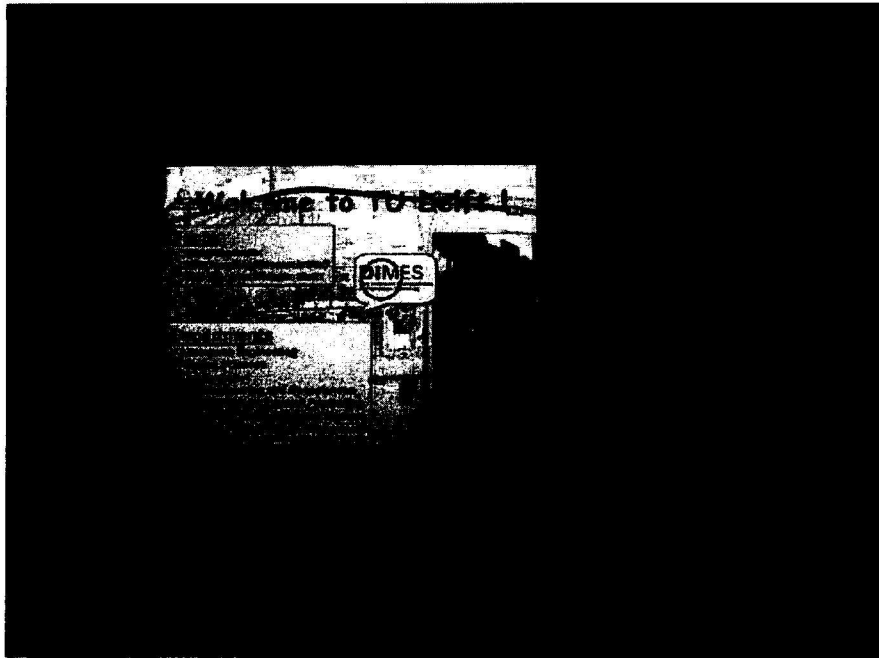


Figure 3. Presentations of Dr. Joachim N. Burghartz



Figure 4. DIMES' ICP Lab facilities.

DIMES Theme

I. High-frequency technology for communications

High frequency processes, modeling, design tools and test methodologies, etc.

Program 1: Exploratory HF devices on silicon on glass. The aim is trying to push high frequency applications and application horizon of silicon technologies. Micromachining for RF applications include through chip processing, etc. wafer level chip scale packaging, etc.

Program 2: compact transfer modeling, wireless transceiver and microsystem interface external system interface.

Program 3: Ubicom transceiver design of 70GHz design. The application vehicle is transceiver to be mounted on the sun-glasses.

II. Integrated Smart Microsystems

Full packaing, interaces, etc.

III. Nanoelectronics

Nano-scale electronics, materials, and also atomic scale electronics (atomic scale transfer, etc.) are some of the themes.

IV. Large area electronics

Thin-film solar cells (thin-film, flexible, tandem, transverse-junction, fast deposited), and large area electronics (thin-film Si crystallization, thin-film Si transistors) are some of the projects being pursued now. Uniform Si crystallization at specific areas are placed across the wafers.

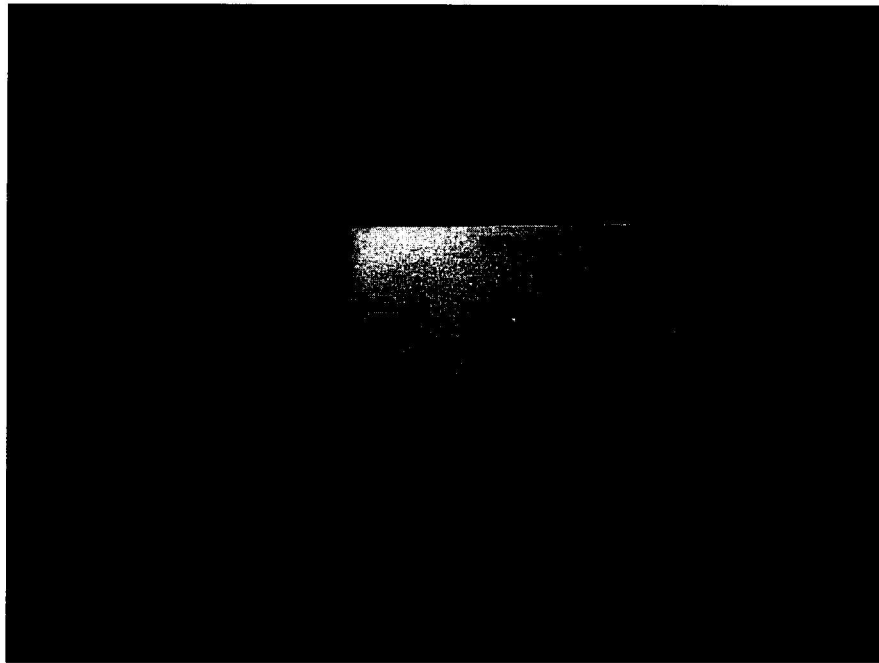


Figure 5. Presentations of Dr. Dr. Lina M. Sarro on microsystems

Integrated Smart Microsystems (theme II) presentations:

As both CMOS and BiCMOS processes are available in DIMES, the main targets are to have all the MEMS processes consistent with the electronics, which for example means that the processing temperatures are lower than 400 degrees C. More specifically, IC compatible, low cost, and low complexity. Some of the main areas of interest include MOEMS, RF MEMS, BioMEMS, 3-D electronics, wafer-scale packaging, NEMS, etc. One of the latest post-processing steps developed includes using polyimide as the sacrificial layer and all dry processes are needed for release in order to prevent stiction, etc. Wafer-to-wafer bonding is done with temperature less than 400 degrees. Anodic bonding processes of silicon-glass and glass-glass were developed. An European processing project includes high density through wafer interconnections, which include metal wires (DIMES) and molecular wires (other European organizations). A process called bottom-up plating involves Cu was used to make via connections and full area/partial area plating, which uses evaporation process to create seed layer first, then thickening by plating, then the whole wafer flipped up side down and then restart the through via plating. The lateral dimensions can be as small as 5 μm , and the thickness can be up to 200 μm , which corresponds to aspect ratio of 40. Inductor defined in electroplated photoresist for metal layers.

Presentation on BioMEMS by Prof. Paddy J. French:

A project includes multiple-parameter blood sensor which include pressure sensors, oxygen sensor, and flow sensors in order to give the surgeon the full pictures of the patient. The flow sensor was based on hot wire technology. Using 650 and 800 nm wavelengths light beams, which basically check the redness of the blood, did the oxygen saturation. The pressure sensor is basically a piezoresistive sensor. Using a deep structure to have the CO₂ diffused into a chamber did the CO₂ measurement. A 4.35 μm light beams was used to detect the presence and concentration of CO₂ as light beams of this wavelength is strongly absorbed with the presence of the CO₂. An integrated (sub) nano-liter array for high speed screening (HSS) biochips was developed. A nano-liter fluid cell was created by micromachining. The heater, photo-detector, fluid volume detector were made underneath the cell. Light source was shown from the side of the cell and the photo-detector was used to detect the light transmissions of the fluids, which makes this chip a complete optical processes. A micro-pillar based DNA separation chips was jointly developed with Mitsubishi Electronics.



Figure 6. Sample Presentations on BioMEMS

Presentation on Silicon Optical MEMS areas:

MOEMS in this group is trying to make “dumb optics” to become “smart optics” (silicon technologies). The applications include astronomy, ophthalmology, laser technology, optical instruments, etc. The main theme of the group is the adaptive optics, which includes wavefront sensor and an adaptive corrector. The first kind of wavefront corrector is basically a stretched membrane and electro-static force is used to modify the local deformation of the membrane. The operating voltage of the deformable membrane is around of 300 volts. The second kind of wavefront corrector is liquid crystal (LC) based, which modify the phase of each LC pixel. The operating voltage of LC is around of 5 volts. The wavefront sensor is

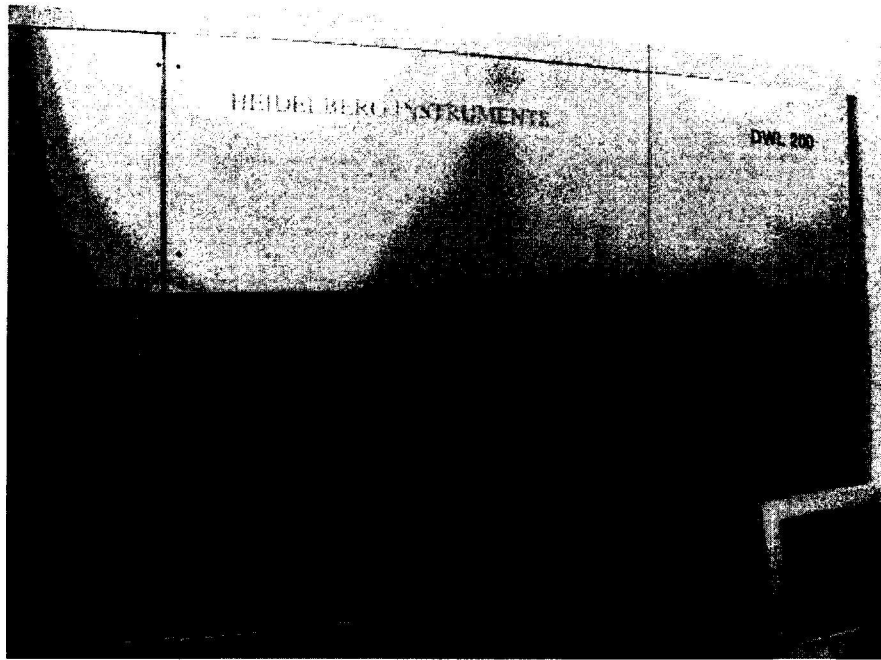
basically a Hartmann mask sensor (an array of 400 μ m diameter holes was placed on top of a corresponding array of position sensing detectors (PSD)). The local slope of the incoming wavefront was detected by using each matching pair of Hartmann mask (hole) and the corresponding PSD.

Presentation on NEMS areas:

This area has just been started. The NEMS is currently done with carbon nanotubes first. Silicon technologies are currently being pursued as well. Ref: D. W. Carr *et al*, *APL*, 75 (1999) 920. The data obtained does indicate that nanotube and silicon beam have about the same resonant frequencies. Nano-electromechanical SET (NEM-SET) single electron induced mechanical deformations is another research topic of interest that started 8 months ago. The alignment marks were done at the beginning of the process. The single wall carbon nanotube was spun onto the wafer. Once it is located, say by AFM, with respect to the alignment marks, the electrode was added to the located single wall nanotube. The release was done later on. A breath mode of 720 GHz of the CNT was found. In the future, NEMS with semiconducting inorganic nanowires will be pursued as it use same technology as for naotubes to generate contacts. It is concluded that nanotube technology may have major advantages such as smoother surfaces, better sensitivities, etc.



Figure 7. Lunch meeting with technical members of TU Delft (left: Dr. Joachim N. Burghartz, Scientific Director DIMES).



(a) Laser writer for masks



(b) Ion Implanters



(c) ASM stepper

Figure 8. Tour of the fabrications research facilities in TU Delft. Only the instruments not available in Taiwan's MEMS centers are shown.



Figure 9. Photos of Den Haag HS, where the delegates leave for Brussel

The Taiwan Delegates end the day with a dinner meeting hosted by Dr. David Lee (李大維代表, 駐歐盟兼駐比利時), Representative of Taipei Representative Office in Belgium on our European students activities, the public educational systems of Belgium, etc. The tax rate here in Belgium can be as high as 60%. Around 40 Taiwanese students studied here in Belgium now. The number of our graduate students here in Belgium has continued to decrease for the last few years. Part of the reasons may lie on the languages used here in Belgium are Dutch and French despites the tuition of the graduate school here per year for

students is less than NT\$20,000.



Figure 10. Dinner meeting with Dr. David Lee, Representative of Taipei Representative Office in Belgium (left: Dr. David Lee)



Figure 11. The Taiwan Delegates present a souvenir to Dr. David Lee, which is a laser engraved crystal of 3D Taiwan landscape on top of a high intensity LED light base. (left: Dr. M. S. Lin, Chief Delegate of Taiwan, right: Dr. David Lee, Representative of Taipei Representative Office in Belgium)

April 30, 2002

Technical visit at Production Engineering, Machine Design and Automation (PMA), Department of Mechanical Engineering, Catholic University of Leuven (KUL)

Contact: Prof. Van Brussel, Celestijnenlaan 300, 3001 Heverlee, Tel: (+33) 16 322 480, Fax: (+33) 16 322 987.

The delegates were greeted by Prof. Van Brussel in the university. Dr. Reynaerts gave an overview of the ME department as well as the PME division.



Figure 12. Presentations of Prof. Dominiek Reynaerts



Figure 13. Taiwanese Delegates, Professor Van Brussel (back right), and Professor Reynaerts (back left) at the PME division laboratory.

Overview presented by Prof. Dr. IR. Dominiek Reynaerts, Associate Professor:

K.U. Leuven has 27,000 students and is a complete university that offers all disciplines for higher educations. Education and R&D of mechanical engineering (ME) areas are production engineering, machine design, and mechatronics. There are 4 divisions within the ME department, with PME as the largest division. A total of 100 staffs are in the PME Division. For PME division, there are around 70 Engineering degree students (now is European engineering degree and will soon become the master program per new European regulations). The Dutch master program is around 3 per year, and an English master program for foreign students is also available now within PME. There are about 3 Ph.D. students per year in PME. There are quite a few spin-offs from PME as well as for ME departments. The research areas include production processes, computer integrated manufacturing, dimensional metrology and quality control, design of light weight structures, etc. For micro-precision engineering, the research involves the adoption of shape memory alloy (SMA) for airplane wing control, robotic hands control, etc. In addition, SMA is also used for many medical applications, including microgrippers, etc. Micro-hydraulic actuator systems, which were made of EDM process, were also being studied here. It should be noted that EDM (electro-discharge machining) is also an active research areas of this division. Hybrid technology, which includes Si processing, micro-milling, micro-EDM, injection molding, hot embossing, etc., is being developed to develop three-dimensional micro-machining process. Screen-printing process coupled with silicon micromachining to make conical shaped via holes were also being developed. It should be noted that conical shape was developed to make sure the silver screen printing paste will flow correctly into the via. Micro-power generation based on axial type turbine design and was made of micro-EDM on stainless steel will be pursued with a goal of 100 W as the specifications. The full integration of ME and EE is strongly pursued. For examples, piezoelectric actuators with configuration similar to the inch worm drive but with 4 spherical contacts, both 1 and 2 dimensional actuators are available, are being developed for processes such as ELID. Capacitance, eddy current, etc. were used as the sensing mechanism for feedback.



Figure 14. Grippers developed at the PME division of Catholic University of Leuven.

Technical visit at IMEC

Contact: Dr. Kris Baert, Kapeldreef 75, 3001 Leuven, Tel: (+33) 16 281 211,
Fax: (+33) 16 281 501.

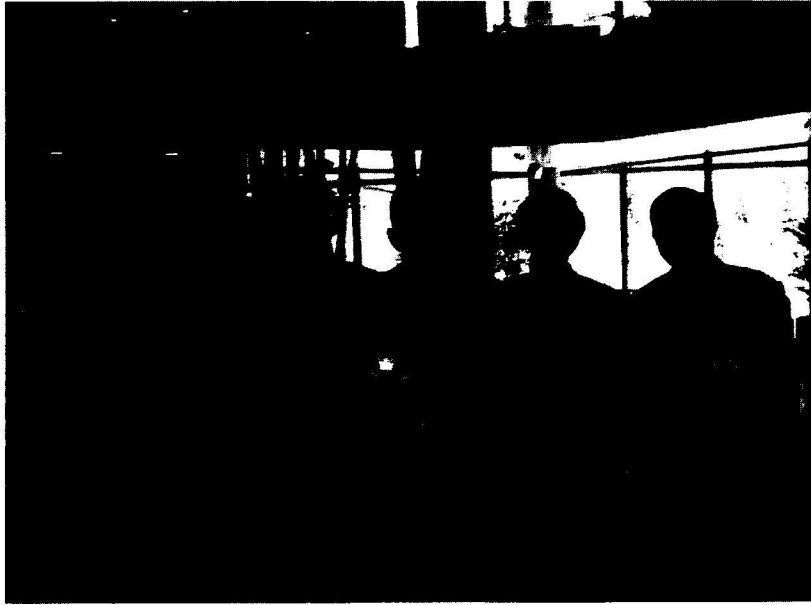


Figure 15. Photos of Taiwanese delegation at the front entrance of IMEC. The stature is the founding director of IMEC, who is a Stanford graduate and is a classmate of Dr. Morris Chang of TSMC.

Overview presentation of Dr. Robert Mertens (Senior Vice President, Microsystems, Components and Packaging Division and Professor of Katholieke Universiteit Leuven, Robert.Mertens@imec.be):

The original goal was to develop technology of 5 to 10 years. Due to the rapid change and applications of technology, the goal was changed to 3 to 10 years. The Microsystems, components & packaging (MCP) has the mission to develop (1) enabling technologies for ambient intelligence (require horizontal integration with heterogeneous conditions); (2) to provide packaging solution following the MEC CMOS technology road map (require vertical integration, stress on the performance, high power requirements); (3) and to develop photovoltaic systems. Competence centers are used to build up research programs, which through matrix organizations to handle primarily 4 programs include multimedia WPAN, wafer level packaging and interconnection, micro & nanotechnologies for health and comfort, and photovoltaic and powers. Dr. Mertens consider that the micro & nanotechnologies for health and comfort will be the most important part of the MCP division in 5 years. Inter-divisions or inter-universities, which include ESAT, etc., are involved in many of the research programs. Discussions for different programs are as follows:

Multimedia WPAN:

Challenges are to archive higher bandwidth for a given energy budget & miniaturization, which involves integration of high quality passives including antennas that adopts wider range of values for R, L, and C, and all must be done within ever smaller dimensions. Other topics include RF-MEMS, SIP (system in a package) and/or SOC, and GaN power amplifiers (deposit GaN through MOCVD on SiC substrate, which most other research institutes strives for light

beams applications) for base stations, etc.

For SIP, multiplayer thin film on SiC substrate (4 layers include ground, power, and two layers of inter-connections) with integrated passives for front end SIP for wireless (5GHz) and the active devices were mounted by flip chip technologies. The antenna integration program includes higher than 10GHz high-frequency small sized patch antennas, which are integrated on the glass substrate.

Wafer Level Packaging:

The main reasons of moving towards this area are (1) increasing compatibility of back end CMOS processing & packaging, (2) silicon chips for ambient intelligence will often be pad limited, (3) trend to flip-chip interconnections and to small pitch peripheral pads require wafer level redistribution layer, and (4) new functions for wafer level redistribution layer such as integration of passives and MEMS on chip (called "above CMOS" here). The wafer level packaging interconnection process is done after the CMOS process and due to the geometry, the pitch of the interconnects can be as high as 200 μ m, a much larger spacing than flip chip bumping, etc. The high Q on chip inductors are a project here as IMEC believes that the copper layer that can be used in the wafer level is much thicker than that can be achieved on the CMOS processes. For Micro & Nanotechnology for health and comfort monitoring:

Personal health & comfort tele-monitoring systems include real-time monitoring of temperature, heart rate, blood, etc. In addition, the smart pill program is being pursued. The 1st generation smart pill can sense, communicate, milli-sized, which basically is a miniature CMOS camera. The 2nd generation can sense, communicate, micro-sized, enact, which adopts semi-permeable membrane to allow body fluids to enter into the smart pills. Disposable plastic card with 30 sensor sites with each sensor is specific for different element is another project of interest. Technologies such as (1) ultra-low power CMOS: SPT/STDI; (2) mechanically flexible (disposable?) electronics such as ultra-thin and ultra-small Si chips, polymer electronics; (3) biomedical sensors such as MEMS, surface chemistry, self-assembling; (4) drug delivery such as microfluidics; (5) power sources replacing batteries (10... 100mW) such as MEMS based (kinetic, thermal or biochemical), plastic solar cells, super-capacitors (energy storage of 2 to 3 W-hours was recently achieved by using nanotechnologies); (6) wireless communications, and (7) intelligent signal processing.

Neuronic sensor for early warning system, which connects neuron signal to semiconductor technology, is currently being pursued even though it is considered a very far-reaching technology. Self-assembly monolayers for co-valent coupling were used as the base.

Discussions on Microsystems by Dr. Kris Baert:

Microsystems at IMEC had a very strong interface with users. The early research involves on IR-MEMS. Now it involves RF-MEMS, Bio-MES, etc. From design to package are parts of the strategy of IMEC. Two processing lines, P-line processes on 8' sub-micron Si, (D) UV-lithography and B-park processes on 6'-8' dedicated MEMS Si/Glass 1x lithography, are in IMEC. The 8' line is unique in the world for MEMS approach. Poly-silicon/Ge processes are used for IR-MEMS, which is standard and is targeted towards to low end applications, i.e., VO_x applications are not pursued. Surface micromachined poly-SiGe IR bolometers with U-shaped structure to support

large- area membrane is currently being pursued. The technology along the IR-MEMS line is fab compatible and this technology have been spun off to form XenIC, Inc. Bio-MEMS involves μ -calorimeter (microphysiometer) is a project being done, which basically is a thermopile on silicon wafers. The system is being positioned into an array for pharmaceutical applications. The microsystem for personal health and comfort applications includes monolithic blood gas sensor based on IsFETs, Pt, Ag(Cl), PI, etc. technologies. Affinity biosensors, which is a Si-based sub-micron IDE (Inter-Digital electrodes), was developed within the 8' processing line. To further improve cost-performance of biochips, an all polymer process is being pursued, where a flip chip was mounted to the biochips. In addition, SAW affinity biosensor including fluidic process is also being studied.

Discussions on MCMD with thin-film passives by Dr. Philip Pieters:

The main target of this line of research is to provide front-end for RF-MEMS applications. The requirement of RF-SIP technology includes glass substrate, copper electrode, etc. and can achieve Q of 150. A design library has been developed for fast implementations, which include more than 1000 models characterized by s-parameter measurement up to 50 GHz. The models include R, L, C, etc. For inductors, multi-turn circuit and coplanar layout configuration. The models within the library are scalable. Flip chip interconnect with 40 –1000 micrometers vias were developed. The WLAN BP-filter was implemented by using a MCM-D of q equals 125. Size reduction possible of DECT VCO is significant. For example, 300 mm² is shrunk to 2.54 mm² in this application. GSM dual band PA module for Bluetooth applications is also being studied. It was concluded that SIP has better cost/performance than SOCs.

Discussions on licensing this packaging library from IMEC to APM (Asia Pacific Microsystems) were one of the main topics of interests to the Taiwanese delegates and the IMEC representatives.

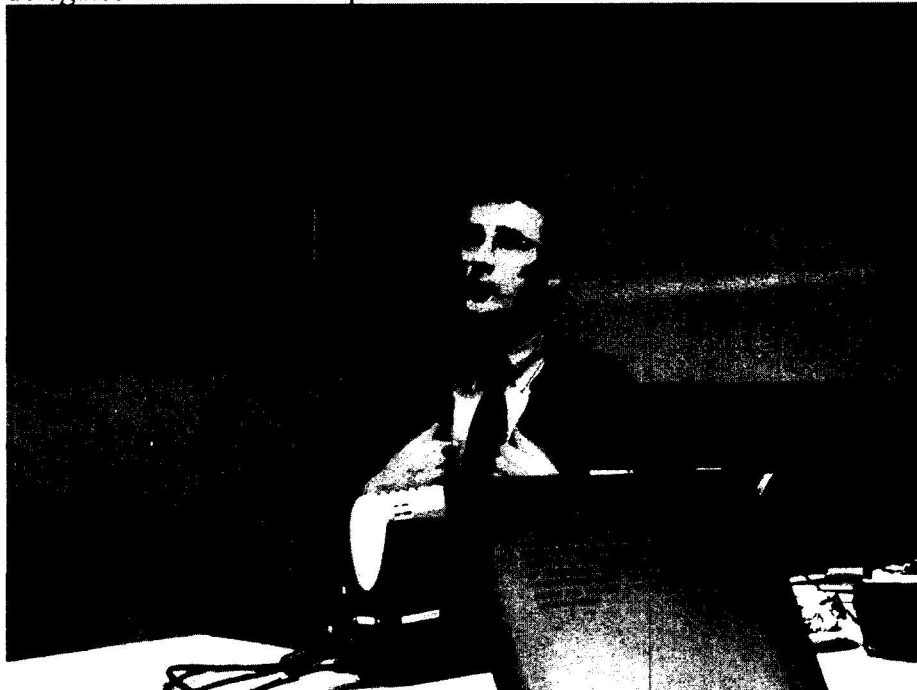


Figure 16. Presentations of Dr. Philip Pieters on MCMD with thin-film passives

Discussions on RF-MEMS by Kris Baert:

Capacitive shunt switch was one of the main emphases of RF-MEMS, with 10^6 times of operations in terms of reliabilities. The MEMS2TUNE project was being pursued with Phillips corp. MEMMS based integrated phase antennas is another project being studied now. RF-MMES 0-level packaging for solder and BCB sealing is a 250 degrees C low temperature process. Wafer level packaging process using BCB as sealing layer is another project being pursued. MOPS (MEMS reliability by Optical system methods) is the process used to study reliabilities. For example, interferometric analysis was used to study the deformation behavior of capacitive shut switches. Poly-SiGe was used as post-processed surface micro-machined layer.

Discussions on From ULSI to Microsystems and Nanotechnology by G.

Borghs:

Nano-fabrications seem eminent when examining from the Moore's law perspective, as we will be in the range of 1nm by 2002. The nanotechnology is trying to increase the control over material structures of nanoscale size 0.1 to 100 nm. The bottom-up refers to self-assembly which can be classified by (1) un-coded self-assembly include super-molecules, tension assembling, etc.; and (2) coded self-assembly such as biological self-assembly process. The quantum limits will be important when the device scale moves to smaller than 30nm when down scaling of transistors when considering from the top-down approach. The quantum limits are important. However, many of the nanodevices discussed mentioned that switching speed will be slower than that of the silicon processing if charge is being used. To handle this speed issue, spintronics and molecular electronics are being considered as alternatives to nano-electronic concepts. Room temperature spin-injection devices, magnetic semiconductors, magnetic quantum dots are part of the studies related to spintronics. The CNT based SET done at IBM (V. Derycke et al., IBM Research Division) was used as the first example that nano-fabrications can be integrated with top-down approaches. Self-assembly of polymers (jenekhe@che.rochester.edu) and works done at David H. Gracias, Joe Tien, etc. and George Whitesides, (Harvard University) are the main references used for bottom-up approaches. There are new opportunities for system in a package includes (1) wireless beyond 3G (silicon dust, small packages include small package, low power, high sensitivity, etc.) and (2) biology and electronics integrations. The main reason that NEMS can have better energy usage lies on the fact that higher Q factors are involved. More specifically, the high Q value of quantum mechanical structures will be pursued to reduce the high frequency switching loss. For electronics and biochemistry, biosensors of neutrons on a chip are a topic of interest. IMEC is pursuing the same trend as that of IBM and Max Plank. A hybrid transducer for molecular recognition events is trying to see if neuron transitions can be detected. In summary, the convergence of surface chemistry, nano-mechanical objects, and micro-electronics create new challenging opportunities. It is believed that energy and power considerations will be the driving force rather than scaling down.

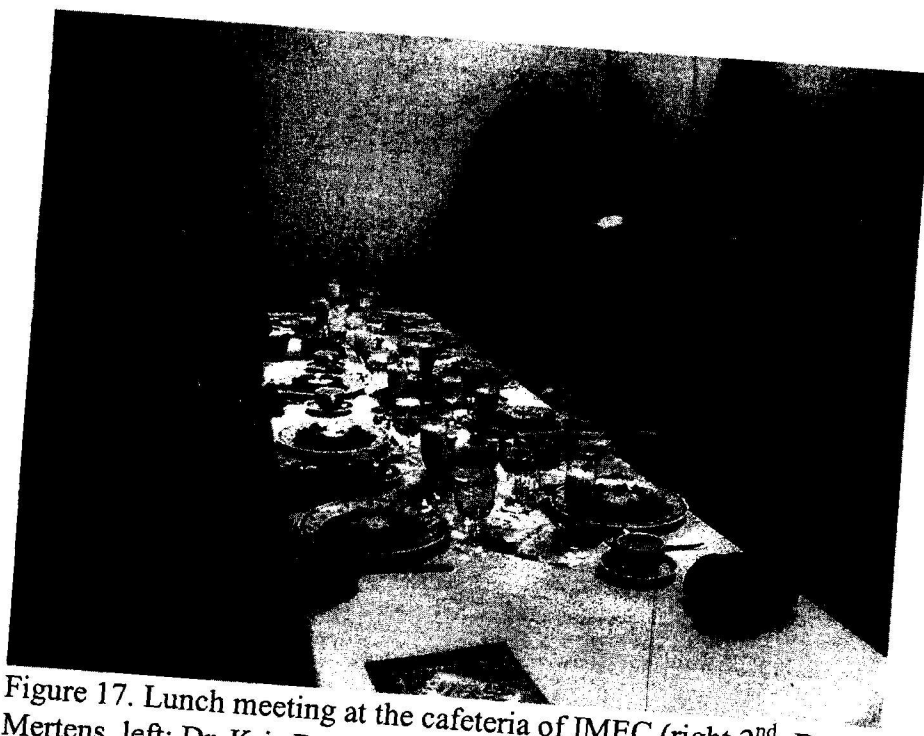


Figure 17. Lunch meeting at the cafeteria of IMEC (right 2nd: Dr. Robert Mertens, left: Dr. Kris Baert)

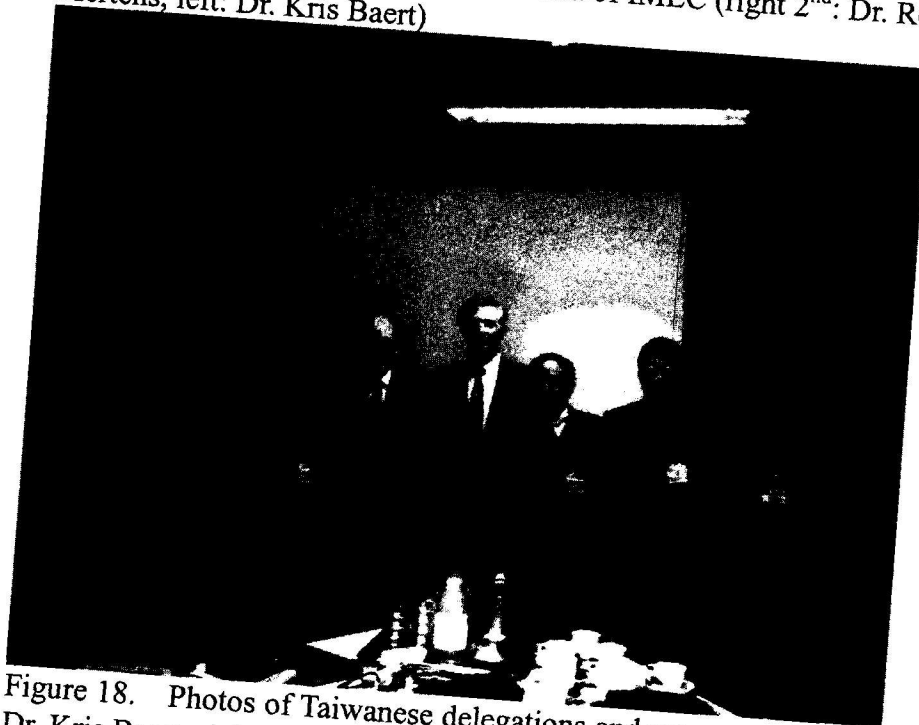


Figure 18. Photos of Taiwanese delegations and representatives of IMEC (left: Dr. Kris Baert, right 3rd: Dr. Robert Mertens, center: Dr. Dr. G. Borghs)

The delegates move from Leuven, Belgium to the conference site of the 8th World Micromachine Summit at Maastricht, The Netherlands after the meeting at IMEC. The registration and welcome reception start from the afternoon of April 30. The Taiwanese delegates were greeted by the host and delegates from many countries were happy to see each other (Figs. 19, 20).



Figure 19. Photos of Taiwanese, Japanese delegations, and the delegates from PROC (left 2nd: Chief Delegates of Japan, Mr. Toshio Shimoyama, left 3rd: 蔡炳初 of 上海交大, left 6th: 王曉浩 of 清華大學精密儀器與機械學系副教授&儀器科學與技術研究所, left 7th: 張文棟 of 華北工學院, right 5th: 袁祖武 of 中國工程院, right 4th: 丁衡高 of 中國工程院院士, right 2nd: chief delegates of PROC, 周兆英 of 北京清華大學, right: 王金山 of 重慶微系統科技股份有限公司)

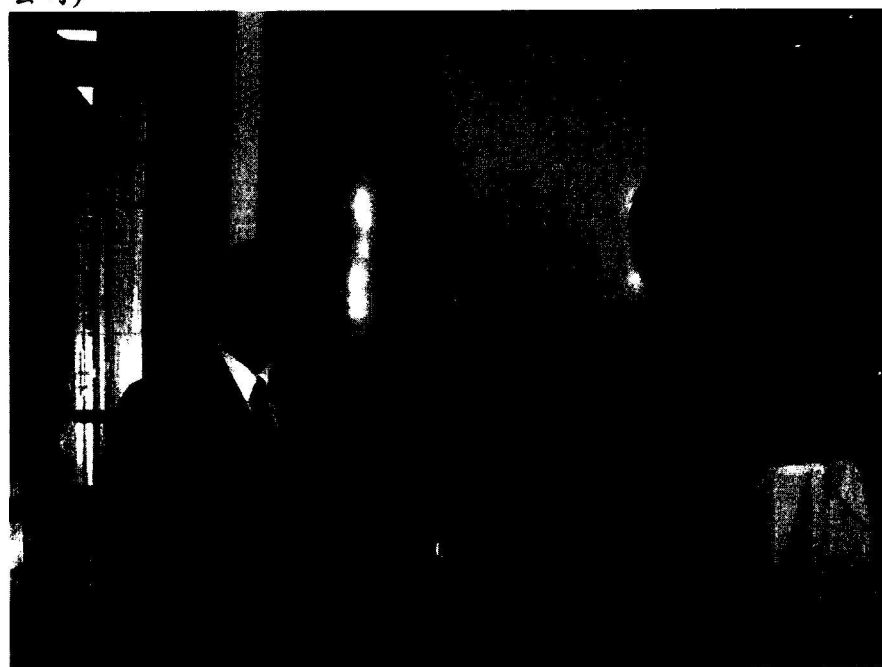


Figure 20. Discussions with Canadian delegate Dr. Thomas Jackman, Director of Materials Technologies of Canada NRC.
The delegates hosted a dinner party with the Benelux delegations at Restaurant Wen-Chow, which is located right across the street of the Maastricht train station (Fig. 21). Discussions concentrate on how to foster closer link of R&D activities in Taiwan and the Benelux areas went well (Figs. 22, 23).



Figure 21. The Taiwanese delegations in front of the Maastricht train station.



Figure 22. Welcome speech by Dr. Charles Peng (left: Dr. Kris Baert, right: Henk Leeuwis, Executive VP marketing & sales of LioniX, www.lionixbv.nl).



Figure 23. Dinner discussions with the Benelux delegations (left 2nd: Prof. Albert van den Berg, Chief delegates of the Benelux delegations and the Workshop Chairman; right: Dr. Kees Eijkel).

May 1, 2002

The 8th Micromachine Summit, Maastricht, The Netherlands (day 1)

The meeting was started with a greeting from the conference chair, Professor Albert van den Berg at 8:48 am. Review of the last 7th micromachine summit was detailed. It was stated that this conference was initiated by the Micromachine Center of Japan and had been hold all around the globe. This annual event has been very important to foster international collaborations.



Figure 24. Conference chair, Professor Albert van den Berg kicked off the 8th MEMS Summit.

Section 1. Country/Region Review

Presentation of the USA country overview by Dr. Michael Gaitan, Project Leader of NIST on MEMS systems. E-mail: gaitan@nist.gov):

There is no single MEMS program at NSF, USA. However, DARPA MEMS program manager Bill Tang, temporary on leave from Berkeley, had funded a series of program. Almost all major universities have R&D and teaching programs now. NIST is working on using AFM to measure the molecular interaction force. The molecules were attached to the chip and AFM interactions with those molecules were used to measure the force. MEMS standarization ASTM Task Group E08.05.08 is currently on going. International standarization forum has started now. Mr. Hirano is working on this effort. It is believed that optical MEMS and communication MEMS will be the next flag ship vehicle after the inertial sensor.



Figure 25. USA country overview presented by Dr. Michael Gaitan (NIST)

Presentation of the UK country overview by Prof. Geoff Beardmore:

A large world class of nanomaterial fabrication facility is being established at this moment. One of the main perspective is to have the R&D as well as the pilot program/capability in situ in order to speed up the development program. An inkjet printer head manufacturer, which is a spin off from a university, named Zhar is doing well with its innovative design. Many other SME's are working on MEMS projects.



Figure 26. Presentation made by Prof. Geoff Beardmore

Presentation of the Taiwan country overview by Prof. C.K. Lee:



Figure 27. Prof. C. K.Lee was giving the Taiwan overview presentation

Presentation of the Switzerland country overview by Prof. Nico de Rooi (University of Neuchatel,

Institute of Microtechnology):

Around 80 companies were founded in MNST during 1992 to 2002. The country tried to take advantage of the local industry excellent capabilities. Dense network of clean room facilities for MNST R&D (~10) and are distributed all over the world. A trend of seamless technology transfer from R&D towards manufacturing has shown. A new startup was awarded as the best start-ups within the Intel Star-Up funds. The drive moves from μ toward v is strong. The public funding program TOP Nano 21 will have around 60 millions CHF (~US\$30 millions) from year 2000 to 2003.



Figure 28. Photo of presentation on Switzerland country overview by Prof. Rooi

Presentations on Singapore Country Overview by Prof. Siak Lim (National University of Singapore, Mechanical Engineering, 10 Kent Ridge Crescent, 119260 Singapore, e-mail: mpelimsp@nus.edu.sg):

There is very little home grown industry in Singapore. The local economy is very dependent on the foreign investment. As the fund on establishing MEMS manufacturing services pulled out of Singapore, there are no MEMS manufacturing capabilities now. To provide enough and talented technical personnel so as to attractive foreign investment/industries, many of the R&D and educational programs are currently on going. The old funding mechanism NTSB was found to be not effective as many of the projects have too much overlaps. With the establishment of new A*STAR, the four institutes working on MEMS will now come to the same umbrella in order to establish more efficient funding mechanisms. Nevertheless, with so much dependency on foreign investment and no local industry at this economic recession period, it is indeed a very big problem for Singapore.



Figure 29. Photo of presentation on Singapore country overview by Prof. S. Lim

Presentation on Nordic Region overview by Prof. Sami Franssila (Helsinki University of Technology, Finland):

Using the inkjet process, the region is currently developing DNA technology. The consideration on cross-disciplinary is important especially that of the BioMEMS areas as how to customizer the 10 different genes within the MEMS mass production capability/nature. BioMEMS is a very important area here. One of the main problems lies on how to find a good funding mechanism to establish the very expensive clean rooms. It is considered that a sharing and an incubation mechanism are important. Various shared facilities are being established. The perspective is to integrate education needs with the volume manufacturing capabilities.

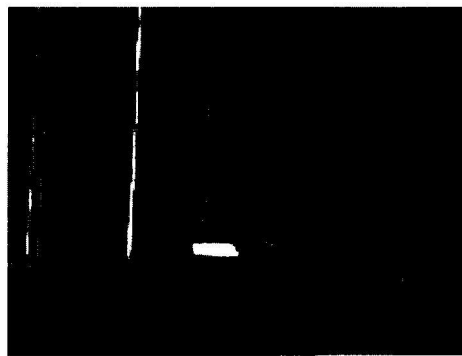


Figure 30. Nordic Region overview by Prof. Sami Franssila

Presentation on Mediterranean overview by Prof. Paolo Dario (Spain, Italy, Greece):

A new Spain start up was initiated with emphasis on the food industry and on artificial noses. Some additional Barcelona Science Park was established with the collaborations of three universities and the support of the local industries. The emphasis was on the bio-nanotechnology areas.

The MMN Greek network is moving forward as it has been.

The Italy activities include the 7th national conference on sensors and Microsystems, Bologna, Feb 4-6, 2002, which has around 120 participants with 20 from the industry. The project that triggers the most discussions is the electronic noses. The main features of the Italian national research programs are basic (curiosity driven) research projects, long term perspective is being emphasized. One of the strategic programs on nanotechnology, microtechnology, etc. with 40 millions Euros are in the call for proposal phase now. The lab-on-a-chip project is currently on going as well. Many of the laboratories in Italy concentrate their efforts on BioMEMS. The new facility on MEMS within the Italian university is finally open. Three new centers of excellence were established with two of them emphasized on (1) statistical mechanics and (2) enterprise on nanotechnologies.



Figure 31. Mediterranean overview by Prof. Paolo Dario

Presentations on Korean country overview by Dr. Young-Ho Cho:

The national R&D programs, which has emphasis on information technology (IT) and bio-technology, include a 10-year program on developing optical MEMS programs. The Korean president has asked the national technology advisory board to establish the nanotechnology program. The main reasons lie on the fact that Korea believes that nanotechnology may (1) bring new opportunities, (2) research and fusion with emerging technologies, and (3) added value and technology breakthrough. The master plan of Korea National nanotechnology program involves (1) R&D program for inter-ministry budget of US\$1.2B for the next 10 years, (2) Education & Training (E&T) of 12,600 people with budget of US\$ 83.5 millions, and (3) Facilities & Infrastructure (F&I) on establishing a National NanoFab Center with a budget of US\$189 millions. The main emphasis is to bring the industrial applications together with that of the academic research, which is mandatory for funding of projects. Multi-department collaborations are strongly encouraged. A new nano-bio science department of KAIST will be established with an emphasis on integrating electronics, biology, computer science, etc. The Korean government is developing a nanotechnology-manufacturing program to make sure R&D efforts will be commercialized. It is believed that MEMS will provide tools to advance nanotechnology and the nanotechnology will induce basic understanding/ advancement to MEMS. The budget to the Korean nanotechnology program per year budget is about the same as that of Taiwan. In addition, the Korean nanotechnology program runs on parallel with the on-going MEMS national programs with many overlaps between the two programs.

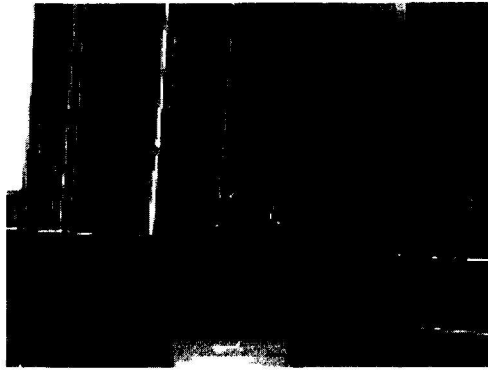


Figure 32. Korean country overview by Dr. Young-Ho Cho

Presentations on Japan country overview by Dr. T. Hirano:

The founder network for SME's (small and medium enterprises) are considered very important to realize the MEMS industry in Japan. The 10-year micro-machining industry has completed. A detailed review started two years ago with many outside experts, which indicates that commercialization, standarization, and infrastructures are important. The founder's network was considered a vehicle to foster collaborations on technological challenges, infrastructures, education and training. The standarization efforts in MMC include terminology definition (a draft to be submitted to IEC 47 soon), measurement method (many items are to be standardized include thin-film tensile and rubbing test, and a draft will be submitted to ISO/IEC in three years). These efforts are being submitted to the international forum, which will be available in the Internet. The micro-factories include 1 μm resolution positioning accuracy are commercialized with 16 orders in productions now. The CMOS camera developed in the program is being commercialized by Hitachi Corp. Some new initials are being instituted to resolve the gaps between the nanotechnology and MEMS. The gaps must be closed up soon.

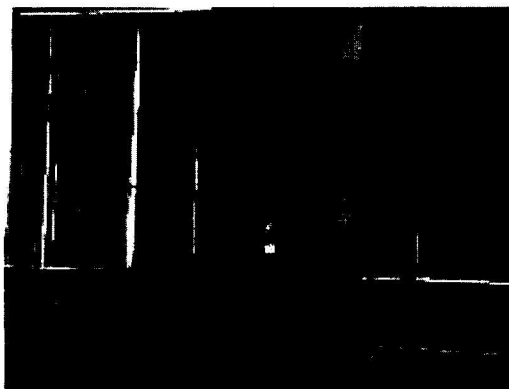


Figure 33. Presentation of Japanese country review by Dr. T. Hirano

Presentation on French country overview by Prof. Emmanuel Bigler:

RMNT is the French National Network in micro- and nano-technologies, which provides a network (<http://www.rmnt.org> and <http://www.technologie.gouv.fr>) to foster collaborations.

This project starts from a bottom approach, which has priorities such as (1) taking the industrial demand into account, (2) building a pool of competences, (3) help starting new projects with industrial applications, (4) solve new technological problems, and (5) being an incentive for SMEs in the field. As the original French system choose engineering students by their mathematical capabilities, which means a student with very little background in engineering can enter into the engineering discipline. This situation has a very strong impact on the development of MEMS. This system is being changed throughout the nation. A series of clean room facilities located in Lyon, Geneva of Switzerland, etc. are available to serve the MEMS fabrication needs. The Atomic Energy Commission represents 20,000 engineers, which has very strong efforts in silicon technologies, etc. The establishment of the laboratories in Grenoble and the MINATEC project will have a very strong impact on French efforts on MEMS. A question was raised on the emphasis of engineering discipline on MEMS and on the emphasis of science discipline in nanotechnology, will that modify the directives? The French emphasis on integrating science and engineering is considered to provide a niche.



Figure 34. French country overview by Prof. Emmanuel Bigle

Presentation on China's country overview by Prof. Zhaoying Zhou:

A recent review of MEMS development strategy was completed. The suggestions include (1) develop areas with priority in the areas of micro-sensors, information MEMS, and bioMEMS, (2) stress on the basis of MEMS fabrication and the related nanotechnology, and (3) develop a number of applied MEMS systems. Many key-labs were created across the whole nation. Two MEMS foundries were established in Beijing and Shang-Hai. Automatic testing of MEMS devices are being pursued. There are many MEMS companies established in China. For examples, (1) Chongqing (重慶) MEMS Scientific Company, Ltd. collaborates with IMEK, Belgium to develop product like micro pressure sensor, micro accelerometers, micro-mechanical gyros, and micro spectrometer, (2) Shanxi Kotel Nanotechnology Co. Ltd., founded in August 2001 and collaborates with CSEM, Switzerland to build up a production line for micro pressure sensors, biosensors, and MEMS integration applications, (3) MMESIC Co. Ltd., was founded in 1999 after having acquired the strategic venture investment from Analog Devices and TSMC of Taiwan, will concentrate its

product on integrated sensors and accelerometers based on standard CMOS and MEMS technologies for the measurements and control of movements for automobile, game machines and other industry areas, and (4) Nanjing Yi Lai Gene Medical Co. Ltd. was founded on Dec. 1999, which is joint venture established by Hong Kong enterprise Senzen enterprise. The company will work on research, development, production and sales of genetic diagnostic technology, different kinds of gene chips, medical diagnostic reagents, medical apparatus and measuring instruments.



Figure 35. China's country overview by Prof. Zhaoying Zhou:

Presentations on Canada country overview by Dr. Dan Gale (Canadian Microelectronics Corp.):

New infrastructure was established in McGill University with an expected opening date of August 2002. Synchrotron facility is available here for various R&D activities as well. The research infrastructure was being put into universities, research organizations, etc. across the whole nation. Rapid growth on MEMS activities is found now. The emphasis on industries is on the bioMEMS area. However, the size of the industry is much smaller than that of the communications, which is seriously impact by the current slump of the industry. Another emphasis is on the automobile applications.



Figure 36. Canada country overview by Dr. Dan Gale

Presentations on Benelux overview by Prof. Kees Eijkel (University of Twente, the Netherlands):

Representatives from DIMES and IMEC are present, the review of their activities are covered in the report of the first two days of the Taiwanese activities. Phillips is the company that must be mentioned here as it works on LCD, microelectronics, RF-MEMS, communications, etc. TI is

another company worth noting in this region. MESA⁺ is working with a Israel startup on lab-on-a-chip project for blood testing. The Holland form a cluster of companies in order to help built up on the European activities in the MEMS areas. A total of 12 flagship projects led by independent scientists will be used to pursue nanotechnology programs and the proposed fund to the government is 100 to 120 million Euros (with equal amount of funding from the local government and institutes) for 5 years. Both infrastructures (60%) and R&D activities (40%) will be part of the funding.



Figure 37. Benelux overview presented by Prof. Kees Eijkel

Presentations on Australian country review by Prof. Ian Bates (Rmit University, i.bates@mit.edu.au):

The government priorities on the kind of micro industry should be developed include nano- and bio-materials, the genome-phenome link, complex systems, photon science and technology. A new infrastructure is being instituted, which include a number of initiatives with government support. The infrastructure development scheme is (1) the Bandwidth foundry (national facility for the provision of photonic integrated circuits to Australian researchers and product developers in many industry sectors, (2) National networked tele-test facility for integrated systems, (3) Australian Synchrotron Research Program, (4) nanostructural analysis network organization (NANO), and (5) MiniFAB is a new fabrication facility planned to provide the basic equipment necessary for designing, prototyping, manufacturing (small scale), and testing of micro-devices such as bio-sensors, environmental sensors, in-vivo implantable devices, micro-analytical devices, microfluidics devices, and micro-photonic devices.

Section 2. Fundamental Science and Technology of Nanotechnology

The national R&D Strategy of Nanotechnology in Japan by Naomasa Nakajima.

The Council for Science and Technology dedicated to take up nanotechnology as one of the four important fields, which had to be allocated resources with the highest priority recognizing its importance in the future starting march 2001. As CNT (carbon nanotube) was discovered by a Japanese researcher, many advanced research and marketing activities related to nanotechnology is being pursued in Japan that includes detector based on CNT, etc. The market forecast

investigated by Mitsubishi Research Institute, Inc. and Nihon Keizai Shimbun, Inc. in Feb. 2001 shows some very astonishing figures*. The priorities in the nanotechnology programs include (1) nano-devices and the next generation information and communication systems, (2) micro-systems and materials for medical treatment & nano-biology making use of mechanism and control of living thing, and (3) generic technology and spread fields of measurement/evaluation, processing, numerical analysis and simulations (to extend healthy/longevity, utilize the structures and behaviors of bio-materials, a highly accurate measurement the evaluation and processing technology of one digit or more achieved for the demanded/processing level of nanotechnology). Some of the nanotechnologies are of primary interest include (1) one by one manipulation of atom, molecular, (2) ultimate micro-machine, (3) control of nano-structure by self-organization.



Figure 38. Japan strategy presented by Naomasa Nakajima.

Advanced Functional Materials Bridge the Nanotechnology-MST Divide by David Allen of Cranfield University of UK.

Security monitoring based on pyroelectric infrared detector is being developed. High-resolution hybrid arrays are being developed by BAE systems infrared Ltd. The processing temperature of depositing high quality ferroelectric thin films was kept below 450 degrees for survival of Al/Si metallization. This process is based on developing the process of fabrication PZT thin films from solutions (see Fig.).



Figure 39 Functional Materials Bridge the Nanotechnology-presented by professor David Allen (Cranfield University, UK)

* The Council for Science and Technology Policy, Promotion Strategy of nanotechnology and material (Sep. 2001).

Figure 40 Fabrication of PZT thin films from Solution (from the proceeding)

FBARs (thin film Bulk Acoustic Resonator) based on both ZnO (high Q, large peak depth) and PZT (large k^2 , large frequency width) are other topics of interest. Interests and a very large funding from a Japanese company (largest ever for the university) on non-volatile memory field have trigger some research works on nanoscale domain writing in PZT films, which involves a domain image on PZT/Pt/MgO written by using an AFM tip. Some of the research works, which is related to ferroelectrics, on virus separations are on going as a method to line up a group of viruses was found. A range of standards is desired to cover forces from 0.1nN to about 2000 nN. The accuracy required is better than 1%. Silicon Ferroelectrics offer a wide range of useful properties to be explored. The hysteretic properties of ferroelectrics offer an unique opportunity to pursue nonvolatile memory.

From ULSI to Microsystems and nanotechnology by Prof. G. Borghs, IMEC, Leuven, Belgium

This part of the presentations was a minor portion of the corresponding presentations/discussions at IMEC, Leuven at April 30, 2002. The mechanism to locate new materials and to find lower power consumptions is very important. With the decrease in critical dimension, the need to locate lower power electronics is significant. The MEMS can approach the mesoscopic part top-down and the surface chemistry/biology can approach it bottom up. It is believed that the integration of these two worlds are important to bring the technology forward. The wireless beyond 3G which was called “super sensitive sensing” in US and “ambient intelligence” in Europe. The smart dust, also part of the wireless 3G, involves low power electronics and low damping, etc. To achieve this goal, the RLC circuit is to be replaced by mechanical structures due to the large difference in quality factors. Electronics and biochemistry are being integrated through the neuro-chips. Max Plank institutes and many other European institutes including that of IMEC are working on this topic. It is believed at IMEC that the energy and power considerations will be the driving force rather than down scaling.

An overview of Canada's National Institute for Nanotechnology by Dr. Thomas Jackman.

NRC is a federally funded R&D organizations composed of more than 20 institutes located across the nations. The motivation is to bring people of different disciplinary together, which not only means that we must pass the language barriers and then the cultural barriers. The Microsystems structure division works on WDM transmission system work. However, the fundamental goal of NRC is the long-term research. The earlier work on WDM in 1988 was on the quantum information instead of the traditional communication approaches. For example, the artificial atoms and molecules are one of the major vehicles for research. The idea is to work on growing clusters with NRC (a top-down institute) located within the U. of Alberta (a bottom-up institute). There will be joint appointment between NRC and U. of Alberta, i.e., a university

faculty member will have the chance to influence the management of NRC, which was never heard before.

Two of the main areas to be pursued are programmable materials (establish relationships between the structures and function of nano-scale assemblies, develop platforms for the fabrication and assembly of nano-crystals, organic molecules and proteins into complex functional nano-systems, link biological information systems to traditional information systems) and adaptive materials (The porosity of the materials open and close according to the pH values of the solution developed by 3M can be used as the pH value balance mechanism).



Figure 41. Canada's National Institute for Nanotechnology presented by Dr. Thomas Jackman.
Impact of nanotechnology on micromachines: a NTU experience and perspective in Taiwan by Prof. S.H. Chang.

The main perspective and experiences of Taiwan in the MEMS and nanotechnologies are reviewed in detail in this talk. Introducing the status of Northern Region MEMS Center at National Taiwan University started the presentation. So far, a total of more than 680 peoples from 25 universities and 10 industries received the MEMS training. The success of the operation of the Northern Region MEMS Center mainly due to the internet based administration and technology established. By meeting the paradigm shift of technology, the MEMS Center has technology roadmap of migrating into NEMS and nanotechnology, with emphasis on communication applications. The second part of the presentation turns to Nanotechnology Research Center at National Taiwan University (NTU-NRC). Education programs have been established and planned in response to the nanotechnology trends. Special education programs focus on training students with strength in the science, engineering, business and intellectual properties.

Nanotechnology capabilities in Taiwanese universities and R&D institutes were reported. Achievements in nano-materials, such as Si oxide, gold and other nano-particles, nano-carbon tubes, nano-devices such as high temperature IR photo-detectors and lasers using quantum dots, filed emission diodes made from silicon oxide nano-particels, photonic crystals, photonic crystal fibers, nano-biotech., nano-metrology and nano-tools were all presented.



Figure 42. Status of MEMS and nanotechnology in Taiwan was presented by Prof. Shuo Hung Chang

Nanotechnology in Australia: A way forward by Mr. Jason Chaffey (Rmit University).

Australian pillars of strength of Australia include material science, surface science, biotechnology, medicine, photonics, etc. Nanotechnology is fundamentally a fabrication technology and also a marketing technology. The integration of science and business is very important. One of the major problems was the shortage of skilled personnel. It is believed the national nanotechnology research programs established in 1999 can be the bridge to bring the academic research and market opportunities. Some nanotechnology companies include (1) Ambri is commercializing a technology associated with point of care, critical care pathology systems for medical instrument testing, (2) Advanced Nano Technologies (ANT) is working to develop a new low cost process for manufacturing of a wide range of ultra fine and nanoscale powders, (3) GeneScan Australia Pty., Ltd. is a part of the GeneScan Europe AG group with two platform technologies with specializing in the analytic of food stuffs for the detection of DNA sequences indicative of genetically modified organisms supplying all components necessary for micro-array technology including production of custom-made biochips, and (4) Mimotopes found in 1988 is a chemistry based drug discovery company with a focus on lead finding and lead optimization for small molecule drugs.



Figure 43. Australia activities presented by Mr. Jason Chaffey

Analysis of European activities in the semiconductor and MEMS fields by J. C. Eloy (eloy@yole.fr)

A major investment in nanotechnology for nano-electronics by STM, Motorola, and Phillips is US\$ 2.8B in 5 years and in 2 phases. The MEMS field is growing fast with a very strong momentum. New applications are appearing (telecom, medical, etc.) The number of manufacturing facilities is growing fast with a very strong investment in Europe, Taiwan, and USA. A website (<http://www.yole.fr>) has been established and the information is updated every month.



Figure 44. European activities presented by J. C. Eloy

MEMS facility at the Canadian Light Source (CLS) Synchrotron by Prof. David M. Klymyshyn (TRLabs Scientists, Assoc. Prof. of EE, University of Saskatchewan)

A new synchrotron of Cdn\$ 175M of 30 beam lines will be fully operational by 2004. One beam line of CLS is dedicated to advanced electronics, MEMS, and nanotechnologies. The beam line is 2.9GeV, which is stronger than Taiwan's SRRC (1.8GeV).

IMEC Business operation model of MEMS by Raffaella Borzi (borzi@imec.be, San Jose, CA, USA, tel: (408) 551 4502)

The SIP (system in a packaging) concept of IMEC was presented and part of the presentations is similar to what the delegates discussed at IMEC. Micromachined poly-SiGe was studied due to its 5X lower thermal conductivity (important parameters for bolometers, thermopiles, etc.) and compatible with CMOS processing (lower deposition temperature allows post-processed CMOS-integrated devices). The research model is sharing cost, scientific knowledge, IP, and risks.



Figure 45. IMEC business model presented by IMEC Raffaella Borzi

MINATEC, a major French initiative in research and technology transfer for micro and nanotechnologies by Dr. Constant Axelrad (CEA, Grenoble, Leti, France).

CEA is a commission with staffs of 16,000 and budget of 3M Euros that provide R&D for nuclear energy, programmes of defense, research and technology for industry, and fundamental research. CEA evolves into three axes programme include (1) new technologies for information and communication, (2) new technologies for energy, and (3) biotechnologies. It relies heavily on generic scientific research basis of DRFMC, DBMS, DTP, etc.

MEMS Summit Banquet

After a whole day of meeting, the summit host sponsored a magnificent banquet at a near by castle which was built in the 17 century. The dinner started around 6:30 pm starting with the light drink and a special treat was the tradition fashion show and music (Fig. 46). Then a formal dinner with full meals and drinks was followed. By the time arriving hotel after dinner, it was around 12 pm. (Fig. 47). That concludes the first day of the MEMS Summit.



Figure 46. A traditional fashion show and music presented before the summit banquet held in a 17 century built castle near Masstricht.



Figure 47. A corner view of summit banquet held in a 17 century built castle near Masstricht.

May 2, 2002

The 8th Micromachine Summit, Maastricht, The Netherlands (day 2)

Section 5. Strategies, New Applications and Technical Aspects of Micromachines

Industrial Strategy on Micromachine Development Mr. Toshiro Shimoyama,
Supreme Advisor of Olympus Optical Co., Ltd.

Many new MEMS instrument have been developed. For example, a catheter type industrial endoscope capable of repairing (shape memory based actuator) and diagnosis was developed and commercialized. MIF was equipped with three built-in contact sensors and actuators can automatically prevent blood vessel contact. A single molecular fluorescence detection system based on confocal microscopy system and detects Brownian motion at the single molecular level was announced. A high-speed DNA computer that can perform molecular chemistry computations with highly parallel and very large memory characteristics. Geno-analysis including immuno assay and blood assay based on optical detection for DNA analysis was developed. Free flow electrophoresis was used. A MEMS based optical scanner was adopted in the laser scanning microscope product. For future strategy, fusion among nano, micro and optical technologies are considered the key. A MEMS foundry service was established to serve the customers. Many Internet inquiries was generated but no real business was materialized.

Lab-on-a-Chip of MESA+ by Prof. Albert van den Berg.

Lab-on-a-chip technology and advancement was discussed. Using the technology of MAFIAS, which has 4 micropumps, and various components, environmental monitoring was approached. Modular versus monolithic designs were compared. A MEMS blood extraction needle (nanoliter each taking) was developed by MEMS approach that has a very sharp tip and a 20 μm diameter hole to hold the blood. The needle was found to be strong enough to remain in the tip and not on the finger after use. A micro-machined dialysis membrane to measure the lithium in a buffer and blood was developed as well. This dialysis membrane will be integrated with the needle for further development. A vortex micro-mirror of the micro-tube form and similar to that of the rotating scanner, with rotation induced tip linear motion of 100 m/sec, was developed as well. A picoliter bubble dispenser was developed. Nano-channels of 40 by 100 nm were tried to prepare the team into nano-fabrications. Micro-engineering may not be enough to realize μTAS . Innovative systems with

micro-needles are developed.

Agro-alimentary applications of Microsystems in Spain by Carles Cane (Centre Nacional de Microelectronica, IMB-CSIC)

Even though a lot of industrial activities in Spain, very few MEMS activities exist. However, many interests appear recently from the application fields including that of the agricultures, food industries, etc. Emphasis is in the areas of pesticide/environmental monitoring, food qualities, etc. An example of using MEMS sensors for checking the quality of Iberian ham was presented.

Physical characterization of foundry fabricated scratch drive actuators by Deepak Uttamchandani of Microsystems Group, Dept. Electronic and Electrical Engineering, U. of Strathclyde, UK.

The tested physical characteristics of multiple dies with actuators in them from MUMP's foundry services were tested. Different sensitivities were found, which was attributed to environmental conditions. Through the experiences gain from the series of test, it is believed that more foundries imply wider technology selection, more micro-machine designs, and more R&D opportunities. Post-processing of foundry MEMS dies is a very interesting topic as it is possible to combine the best of the foundry (precise and reliable) and custom-made capabilities (eg. in university). Operate at the micro-nano interface is very important as integrating nano-particles into monolithic MEMS device may lead to technology forefront.

Research & Development of Microactuators by Prof. Bingchu Cai (蔡炳初 of 上海交通大學,微納米科學技術研究院院長,信息存儲研究中心主任)

The electromagnetic and SMA based actuators were chosen due to the availability of the facilities and past experiences. Various micro-motors (for micro-helicopter on guided wire, micro-vehicle, etc.) and micro-actuators (for optical switches) were presented.

Micro-technologies and Health Care by Claude Clement (PrecMediX, SA, Switerzland)

PreciMediX (**P**recision; **M**edical; **eX**change, network) is taking advantages of the Swiss capabilities. Pacemakers are very important as more than 3 millions (with inertial sensors) are embedded in human bodies. The reasons that health care need microtechnology are (1) there are many unmet medical needs, (2) there are many unsatisfactory solution there are more and more people in need, (3) moneys is the issue, (4) doctors and nurses are under stress, (5) may medical acts are automatable,

(6) quality of life is the demand, (7) new diseases are coming, and (8) chronic diseases: big challenges. It must be noted that health care is a special business as the deciders are not the customers, the emotion (nothing is good enough) involved, demand is larger than supply, not a free market, and technology professionals have poor understanding of the human body and health care.

Micro biomedical diagnostic system for endoscopic microcapsule by Dr. Jong Oh Park of Intelligent Microsystem Center, Seoul, Korea

This project was driven by a top-down approach as the final specifications were defined at the beginning and then each sub-module was developed according to the spec. A total of project of US\$130 millions for 10 years were funded. Many domestic and foreign committee members were involved in the evaluations and defining stages. Three phases of the project involve diagnosis, actuation, and sensing and diagnosis. Several sub-systems were developed and discussed in detail and photos were taken and attached below. A question from Mr. Shimoyama on the controllability from the external of the body as the question comes from the un-controllability (only single direction telemetry is done) of the Israel capsule. It was mentioned that bi-directional telemetry is currently being developed in the Korean project.

The Chief Delegates Meeting took place during the lunch.

This year's chairman, Prof. Albert der van Berg, did a countdown of the status of the workshop. A total of 75 delegates came to attend the meeting. It was proposed and approved by the Chief delegates that the next workshop will be located at Beijing, China around the first week of May. The meeting after next will be for US, Denmark, and Korea as the contenders. It was concluded that for regional balance, the US would give the highest priorities if a fund can be come out to host the workshop in US. The US delegate promised to check and look into the funding situations and get back to the next workshop chair, Prof. Zhao Ying Zhou of Tsinghua University, Beijing.

MEMSCAP: leader in MEMS-based innovative solutions by Gaetan Menozzi

There are a total of 240 employees in 8 countries. This company had an IPO in March, 2001 and raised 101 million Euros. It has 75 millions Euros in the bank at this moment.

Application of MEMS in BASIC-A Taiwan Perspective by Prof. C.K. Lee (National Taiwan University, Taipei, Taiwan) for Prof. Fon-Son Huang (National Tsing-Hua

University, Hsinchu, Taiwan)

A detailed countdown and reflection of Taiwan's MEMS strategy were given. An integrated foundry service was deemed as a very good driving vehicle for MEMS commercialization.

MEMS Industrialization: Current issues and future perspective by Suk-Han Lee of Samsung, Korea.

CNT color display program is moving forward. Scaling (from MEMS to nano) and functionality (improve cost/performance) are the two factors that can move the technologies forward. One of the questions is that "Why MEMS fails to create a major industry?" Many of the discussions on the time needed from discovery to full industrial maturity. The current market trend is promising but not exciting. The technical challenges are that "do we have clear understandings of the MEMS limitations for practical applications?" and "do we clear understand the critical technologies that should lead to product development?" and "do we have a clear understanding in terms its capability of value creation/innovation?" The technical access is to develop IP design blocks that can facilitate the product development. The market/business access is to active search for the values uniquely crated by MEMS as well as system approach to value creation, etc. It is concluded that MEMS will be the driver for the society of pervasive and mobile information and intelligence.

Efforts for MEMS Industrialization in KOTEL, Inc. by Prof. Wendong Zhang, China

One of the R&D centers of KOTEL (in 太原 of 山西省) is located within the campus of the NCIT (North China Institute of Technology), which holds 16.5% stock of KOTEL with 14.7% as the technology stock. Marketing channels were set up all across China. Many funding channels include combining with other partners, government budgets, university funding, etc. The capital is now US\$10 millions and it will invest US \$8 millions in R&D. This company is planning to develop 2 to 3 series of MEMS products this year. It is expected to invest over US\$100 millions in the industrialization of MEMS and move itself to the forefront of the MEMS industry.

Microsystems and microtechnologies in FW6 by Dirk Beenaert (European commission, Essential Inf. Society Techn. & Infrastr.)

It is expected that FP6 is not business as usual. The main emphasis will be on the major initiatives and not on independent projects. Ambient intelligence is the European MEMS terminology used to interface human and the environment. Seamless & rich connectivity, intelligent environment, are some of the important

issues for ambient intelligence. The equipment will become connected to each other, small in size, networked and everywhere, etc. The main perspective on Microsystems is not how small the devices are, it should be “added functionality.” The European perspective is that micro-system will not be driven by size alone; the driving force will be functionalities. Micro@Nano-technology is a young but dynamic field. In order to take advantage of nano-technologies for micro and macro systems and reverse we need fundamental R&D, but must emphasize more on applied research, etc. The problems today are lack of skilled personnel, re-use of competence and infrastructure, get critical masses and facilitate transfer of results, foster coordination, etc. The big challenges are economical (is it cheap enough), technical, social (will the society accept the technology advancements, e.g. biology and electronic interactions/interfaces), etc. Multi-disciplinary expertise is a key factor. In addition, industry and institute should focus to achieve critical mass.

NEXUS & EURIMUS: their role in the future EU 6th FWP (Frame Work Project) by G. Menozzi.

The new FWP 6 is detailed and the total funding will be around \$1.1 billions Euros for the next 5 years (2003-2008).

Chairman's summary:

Country and region reviews: (1) MEMS has further matured, (2) penetrates more markets, large and rich, (3) R&D programs, shift to nano.

Education: (1) MEMS embedded in regular curricula, (2) some international initiatives visible.

Nano: (1) centralized approach, (2) attracts the talent but also the money, micro is enabling process tool, platform, analysis tools, link to the world M@nano

Commercialization: (1) commercialization strategies mature, spin-offs steadily increasing, MEMS is a global effort, foundry system and strategies maturing and more effective fables, MUMPS, design houses, etc.

Next Year's meeting: Beijing, China, May 1-2, 2003, Prof. Z. Zhou.

Technical tours: Assembled tomorrow morning at 9:00 am at hotel reception

Bus for boat tour: leave at 16:45 from hotel entrance.

May 3, 2002

Technical visit at MESA+, Materials, Technologies and Systems for the Information Society, University of Twente, The Netherlands

Contact: Prof. Dr. Lina M. Sarro, Feldmannweg 17, Room 0.04, Delft, sarro@dimes.tudeflt.nl, Tel: (+33) 15 278 7708, Fax: (+33) 15 278 7369.

Figure 1. Presentations of Dr. Kees Eijket, Technical Commercial Director, MESA+ Institute

It is noted that MESA+, University of Twente has around 600 students which around half of Twente. A total of 420 personnel, and 320 researchers (include 200 Ph.D. students and post doc.) is in MESA. The 18 research groups were organized into 5 SRO's (strategic research organizations) and each has 35 full time equivalents. It has a budget of 25 millions Euros plus 35 millions Euro as the overhead. The 5 SRO's are μ TAS, nanolinks, low temperature/super-conducting circuitry, advanced photonic devices, material sciences and interfaces.

The sharing mechanism of the MEMS+ common facility was presented. The expenses include that of the utility, water (do not include the land and building), expenses, and investment to the future equipment. The incubation of new companies is taking very seriously at MEMA+. Technical shares were taken from the start-up, the patent rights can be owned or exclusively licensed to the start-ups. One good-sized start-up per year is being considered as part of the performance index of MESA. A total of thirty start-ups have been created with 2 to 3 per year recently.

The presentation by the CEO of LinoiX started beginning. It started January 2001 by Hans van den Vlekkert and Rene Heideman. It has venture capital funding and took the university as the technical share holders (April 2001), which is 33% at the beginning and reduced to 25% after the second round of financing. The current total capital is around 500 million Euros. The acquisition of business-unit MST of 3T BV (March 2002) was completed, which was active since 1988. It is almost broken even after only been in existence for slightly over a year. The core technologies lie on (1) integrated optics (SiON), and (2) microfluidics modular assembly technology for μ TAS. Development and production of micro-system for OEM customers is the main business area. Its strategy is based on design for manufacturing, rapid prototyping, small volume production, outsourcing for foundries, assembly houses for high volume. Optical sensor based Max Zender interferometer courtesy of Mierw Metro (do the electronic part and marketing), which can detect with sensitivity up to 10^{-9} moles, have been commercialized by using the

microstructures made by LinoiX. Microfluidics technologies developed to pursue lab-on-a-chip system is currently on going.