89年10月27日繳交 本案請指微縮片

行政院國家科學委員會
補助國內專家學者出席國際學術會議報告

89 年 4 月 17 日

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會議時間地點	2000 年 4 月 10 日 ~ 4 月 14 日 日本 Hiroshima	本會核定補助文號	NSC 89-2217-E-002-006
會議名稱	（中文）2000 年第六屆世界微機電高峰會議 （英文）2000 World Micromachine Summit		
發表論文題目	（中文） (See Attached) （英文）		

報告內容包括下列各項：

一、參加會議經過

二、與會心得

三、考察參觀活動（無是項活動者省略）

四、建議

五、攜回資料名稱及內容

六、其它

List of Paper Published

1. M. S. Lin, and C. K. Lee, "MEMS in Taiwan: Year 2000 Status," The 6th World Micromachine Summit, Section 1: Country Review, Hiroshima, Japan (April 10-14, 2000).
2. M. S. Lin, and C. K. Lee, "Taiwan's Approach to MEMS Technology Transfer," The 6th World Micromachine Summit, Section 5: Technology Transfer, Hiroshima, Japan (April 10-14, 2000).
3. M. S. Lin, and C. K. Lee, "MEMS Commercialization: Taiwan's Foundry Role," The 6th World Micromachine Summit, Section 6: Industrial Infrastructure, Hiroshima, Japan (April 10-14, 2000).

2000 年第六屆世界微機電高峰會議

(2000 World Micromachine Summit)

報告人：李世光

國立臺灣大學應用力學研究所

一. 參加會議經過

會議於 4 月 10 日報到，4 月 11 日開始論文報告。共計 15 個國家(地區)代表參加，各國代表及觀察員分別為：

Australia:	Prof. Ian Bates, Mr. Jason Chaffey, Prof. Clive Davenport, Prof. Erol Harvey
觀察員:	Mr. Egon Vetter
Benelux (Belgium, The Netherlands):	Prof. Albert Van den Berg, Dr. KrisBaert, Dr. Kees Kykel,
Canada:	Mr. Dan Gale, Mr. Chris Lumb, Dr. Marc Nantel
China:	Prof. Zhaoying Zhou, Prof. Henggao Ding, Prof. Yog Qin, Prof. Zhenging Zhao
觀察員:	Mr. Yong Huang, Dr. Yong Li, Dr. Zuwu Yuan, Prof. Wendong Zhang
France:	Prof. Daniel Hauden, Dr. Jean-Christophe Eloy
Germany:	Prof. Wolfgang Menz, Dr. Robert Bauer, Dr. Ralf Voss, Prof. Engelbert Westkaemper
觀察員:	Mr. Patric Salmon
Japan:	Prof. Naomasa Nakajima, Mr. Takayuki Hirano, Dr. Tsuneo Ishimaru, Mr. Toshiro Shimoyama
觀察員:	Mr. Tatsuaki Ataka, Dr. Kunihiko Hara, Mr. Masami Inada, Mr. Takao ishizaka, Dr. Hirotaka Itoh, Dr. Hideto Iwaoka, Mr. Akihiro Kaahara, Mr. Mitsuhiko Kawamura, Mr. Takashi Kurahashi, Dr. Takashi Mihara, Dr. Koji Namura, Mr. Yoshihiro Naruse, Dr. Kuniki Ohwad, Mr. Toshiyoshi Okazaki, Mr. Hideaki Oku, Mr. Ryo Ota, Dr. Toshihiko Sakuhara, Mr. Akinobu Satoh, Dr. Kiyoshi Sawada, Dr. Tadashi Sugihara, Dr. Hisaki Tarui, Dr. Osamu Tohyama
Korea:	Prof. Young-Ho Cho, Dr. Joong Won Lee, Dr. Suk-Han Lee, Dr. Sangmo Shin

觀察員: Dr. Jong-Uk Bu, Dr. Ci Moo Song

Mediterranean (Spain, Greece, Italy,):
Prof. Paolo Dario, Dr. Carles Cane, Prof. Dr. Androula Nassiopoulou, Dr. Mario Zen

觀察員: Eng. Giancarlo Alessandretti, Dr. Giouse Iseni

Nordic (Denmark, Finland, Norway, Sweden):
Prof. Jan-Ake Schweitz, Dr. Sami Franssila, Dr. Francois Grey, Dr. Stein-Ivar Hansen

觀察員: Prof. Klas Hjort

Singapore: Dr. Loke Chong Lee, Prof. Siaw Kiang Chou, Prof. Mong King Lim, Dr. Siak Lim

觀察員: Kwok Hong Lee

Switzerland: Prof. Nico de Rooij, Mr. Philippe Fischer,

Taiwan: Dr. Min-Shyong Lin, Prof. Yen-Hwei Chang, Prof. Chia-Lung Kuo, Prof. Chih-Kung Lee

UK: Prof. Geoff Beardmore, Prof. Richard Gentle, Dr. Malcolm Gower, Prof. Ronald Lawes

觀察員: Dr. Ayman El-Fatatry, Mr. Russell Noble, Kr. Katharina Otani

USA: Dr. Albert Pisano, Dr. Long-Sheng Fan, Dr. Nadim Maluf, Dr. William Tang

會議論文題目及重點為：

1. Review of Microtechnology Activities in Australia
   - MEMS Research Development Paradigm Changed.
     - Knowledge Development →Product Development
     - Device Development →System Development
     - Examples of the current micro-technology actives were:

       Sensors: Oxygen and Ozone sensors for high temperature applications, Light sensor for defect detection in wire cable, Pathogen recognition sensor, Environmental sensing arrays, Sensors for food condition monitoring and certification, etc..

       Micro-systems: Drug delivery system, Multiplex array

Bio-devices, etc.

- MEMS Resources
  - Academic Researchers →Researchers with Industry Experience
  - Silicon Chip Manufacturing Technologies →Double Sided UV Mask Aligner, Synchrotron, Micro embossing and micro injection molding
- MEMS Education
  - Ph.D. Univ. Research →Ph.D. Industry Projects
  - Specialist Microtechnology Course Modules →Microtechnology Coursework Degrees
- MEMS Commercialization
  - One-off Customer Projects →Product Targeted for Mass Production, Spin-off Companies and Joint Ventures

2. Region Review of Benelux (Belgium, The Netherlands, Luxembourg)
   - No dedicated program to promote MST R&D in Belgium.
     - Research: joint force between university and industry
     - Application Driven
     - Avantium Company: Target Lab on a Chip, high-throughput experimentation for chemical and pharmaceutical industry and with US$5Million investment from the incubating university
   - Dutch government stimulated MST R&D since the beginning of 80's.
     - Activities are to increase the assimilation of MST in university into industry
     - Avantium Company: Target Lab on a Chip, high-throughput experimentation for chemical and pharmaceutical industry and with US$5Million investment from the incubating university

   Typical application field were: Micro optics, RF-MEMS, X-ray detector and inspection, Micro displays etc..
3. Overview of Micromachining Activity in Canada
   - Rapid expanding national research infrastructure
   - Increased university research → more university-industry collaborations→boost in the supply of MEMS/micromachining graduates
   - The field was emphasized in optical micro-systems, Leadar Cronos etc.

4. Recent Status of MEMS Development in China
    - Extended and new programs for MEMS research in succession
        - Ministry of Science and Technology (MSTC) started a key fundamental research plan: "Integrated Micro Opto-electro-mechanical Systems" as one of the "10th Five-year Plan"
        - The MEMS project includes 9 topics: (1) micro-scale mechanical dynamics, (2) calorifics for micro systems, (3) mechanical properties of materials for micro machines, (4) vector optics for micro optical devices, (5) theoretical problems of RF MEMS, (6) micro fluids, (7) inter-disciplines for micro systems, (8) 3D fabrication, materials, packaging and reliability for MEMS, (9) design, modeling, database and simulation of MEMS.

5. The Five Last Year Period in Micro-Nano-technologies in French
    - Academic Education
        - 2 Engineering schools proposed a complete course→At least 8 universities and engineering schools proposed diplomas now
        - 300-400 new engineers per year in MEMS/MST, all of them are employed in Industry or in Res. Centers or Ph.D. Doctorants (50 per year)
    - Academic Research
        - 1997, the laboratories of le Centre National de la Recherche Scientifique (CNRS) created a four year MST research programs. Seventy-six research teams are working on 28 selected projects and the 5 demonstrators devoted to micro-robots, micro-airplane, micro-system for drug delivery, microlab on a chip. The main themes are (1) 8 projects in integrated sensors, (2) 5 projects in specific micro-technologies and nano-technologies, (3) 5 projects in micro-motors and micro-actuators, (4) 3 projects in MOEM, (5) 5 projects in Lab on a chip, (6) 2 projects in nano-instruments
        - 1999, Ministry of Research sponsored a new nano-structure program. Eight of the 25 proposals were selected, which are (1) new materials obtained from self assembly, (2) nano-optics, (3) nano-electronics (one electron transistor), (4) photonic band

gaps, (5) nano-biology, (6) near field micro-scopies.

- Cooperative Academic/Industry Research and Development
  - National Program I started in April 1999 with code name RMNT (Reseau en Microtechnologies et Nanotechnologies) and with budget larger than US$1.3 millions. Funded by Ministry of Research and many ministries. Initiated by consortia and Academic institutes. Scientific and technical goals include: (1) nano-technologies, nano-materials, nano-structures, nano-electronics; (2) advanced microelectronics and high-powered integrated electronics, opto-electronics; (3) micro-technologies, microsystems, micro-devices; (4) micro-connectors, micro-energetics, micro-packaging, (5) biotechnologies, lab on a chip; (6) ultra accurate milling, (7) CAD for microelectronics, nano-technologies, and microsystems.
  - Application fields include automotive, space, communications, life science, and environment.
- Main Industry Players
  - Automotive; aeronautic sensors; space applications; biotechnologies; micro-optics; electronic sensors; medical microsystems; domestic appliance systems; micro-fluids and micro-aerodynamics; DNA, Proteomic chips, Lab on a chip.
  - Start-ups such as Tronics, Teem Photonics, Osmoze, etc. are being created recently.

6. Micromachine Development in Germany
   - MEMS Programs are US$800Millions/10 years.
     - 50% Federal Ministry of R&D, 25% Industry, 12% University, 12% Fraunhaufer Institute of Technology, 1% others.
   - Collaborative Projects include: (1) intelligent cutting tools, (2) intelligent power outlet, (3) distributed intelligent micro-systems for home applications, (4) Microsystems technology for outlet, (5) wafer analysis, (6) environmental sensing. Typical examples were the online water analysis device.
   - New MEMS Program: MST 2000+
     - Goal: MST for high-tech products made in Germany
     - Funding Period: Jan. 1, 2000 – December 31, 2003

- Funding: EU$50M/year
- Perspectives: fostering the use of MST/MEMS in important fields of application, MST manufacturing – building up of a broad industrial infrastructure (modular MST), improving basic conditions for innovation with MST.
- The distribution of application areas was primarily focused in environment, machinery, medical, communication and automotive.

7. Country Review of Micromachine in Japan
   - Japanese Future Market

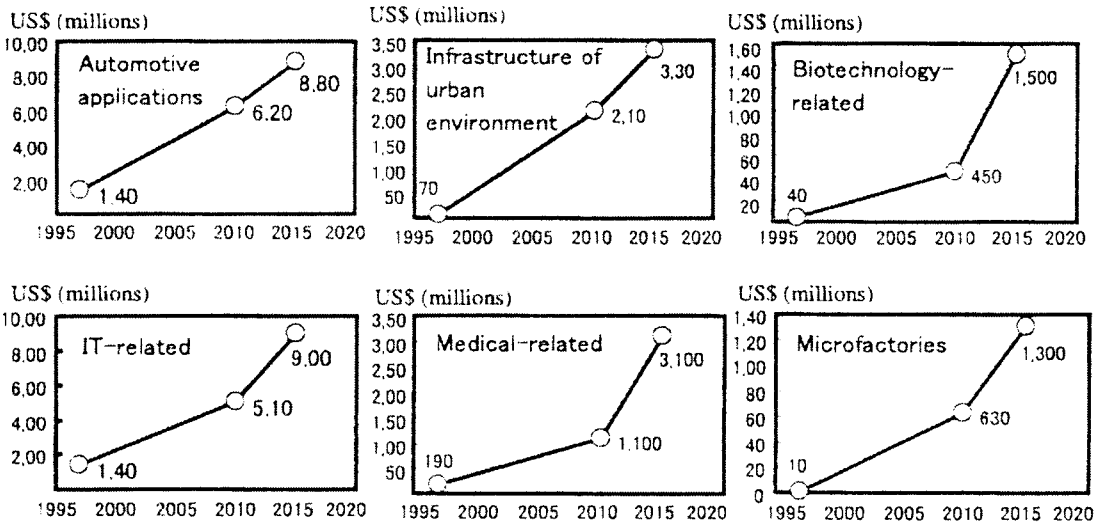
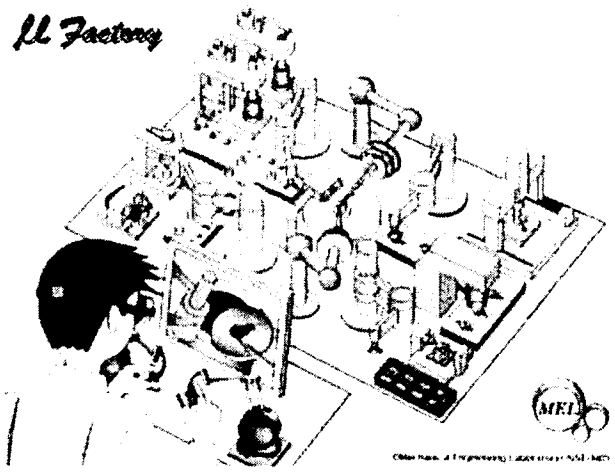


Figure 1. Japanese Market for Typical Application Area

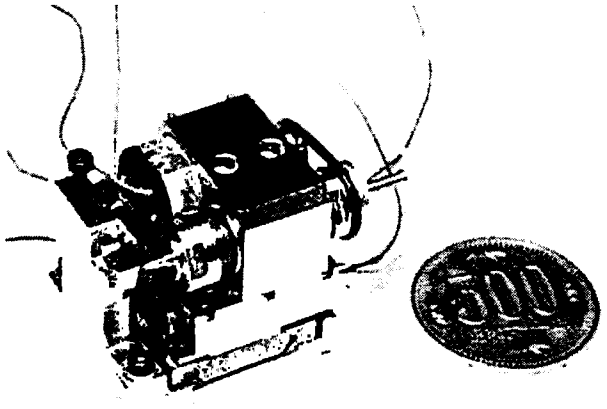
- MEMS National R&D Project: "Micromachine Technology"
  - 2nd Phase since 1996
  - Part of the Industrial Science and Technology Frontier (ISTF) program sponsored by the Agency of Industrial Science and Technology (AIST) of the Ministry of International Trade and Industry (MITI)
  - Goal: establish a technological paradigm for micro-machines
  - Main focus currently: (1) systematization technologies: fabrication of four experimental micromachine systems; (2) functional device technologies: actuators, micro-joints,

batteries, etc.; (3) common basic technologies: control, evaluations, etc.; (4) study of micromachine technology and systems.

- Demonstrations: (1) wireless micromachine, (2) chain-type micromachine, (3) catheter-type micromachine, (4) micro-factory, (5) laser catheter for medical applications.



機械加工によるマイクロファクトリ
Conceptual drawing of microfactory



マイクロ旋盤
Photograph showing microlathe

- A newly designed portable micro-factory (www.mel.go.jp) that includes micro-lathe, micro milling machine, micro press machine, micro transfer arm, micro two-fingered hand, etc. was constructed and fabricated. (See drawing/photo above.)

8. MEMS Summit Country Report of Korea
   - Launched a National Micro-system Project
     - Long-term basic research that uses micro-robots as the focal

point.

- Installed a National Level MEMS Lab

9. MEMS Regional Report of Mediterranean
   - Spain launched a New National Framework Program of Research, Development and innovation 2000-2004
     - 8 areas of interest
     - Total Budge: US$40 millions
     - Six new projects on the applications of MST on home appliance, agroalimentary industry, industrial control and biomedical applications.
   - Greece micromachine activities can be examined from 3 areas:
     - Institute of Microelectronics, National Center for Science Research "Demokritos" with an emphasis in silicon micromachining for microsystems and sensors such as bulk/ surface micromachining, wafer bonding and thinning techniques
     - Institute of Electronic Structure and Laser/Foundation for Research and Technology-Hellas with capabilities in excimer laser micromachining, materials processing, surface treatment and cleaning, and micro-structures of materials by laser etching.
     - CERECO (Company for Research and Development Ceramic and Refractory Materials) can perform excimer laser micromachining and laser processing.
   - Italy's Main National Microsystems Projects
     - Microsystems Project of US$ 3.5 millions.
     - Project on Special Materials and Advanced Technologies of US$1.0 millions.
   - Micromachining activity at IRST of Italy
     - Micro-calorimeters for high energy physics: beta-ray detector for neutrino mass experiment
     - Medical and biomedical micro-devices based on ISFET technology for cell activity measurement, and 3D microelectrodes array for neurological applications
     - Micro-heaters acts as low power sensors for methane detection,

fire protections, etc.

- Experimental devices such as quantum wires for gas detection
- Medical and biomedical micro-devices involves integrated pressure-flow sensor for urodynamic diagnostics
- Microphones based on capacitive silicon microphones for low cost/high volume applications
- Microshutter-micromirror array and micro-actuator array.

10.Nordic MEMS Region Review

- Several new MST initiatives were launched in Denmark.
  - Reorganize Microelectronics Center (MIC) at Danish University of Technology (DTU).
  - COM (Communication, Optics and Materials): combine MIC's photonics research program and telecommunication programs at other DTU institutes
  - CAT (Center for Advanced Technology): established as an industrial research center in 1998 with an emphasis in Microsystems and photonics packaging.
  - Sensor Initiative: initiated by the Council for Advancement of Industry (Erhversfremmestyrelsen), started at the summer of 1999 and will last for 4 years. Format is center-contract collaborations between service centers and industry, as well as industrial Ph.D. education.
  - Start-up companies: 4 start-up companies established at MIC between the summer of 1999 and the summer of 2000.
  - Major activities were focused on optoelectronic.
- Tekes (the National Technology Agency) of Finland has launched a new MEMS program called Presto.
  - Goals include: (1) create new components and solutions based on MEMS, (2) facilitate the large scale use of micromechanical components, (3) develop Finnish research in companies, research institutes and universities, (4) facilitate the implementation of micromechanical products in existing products, (5) create new business in the manufacturing, assembly and design of micromechanical products, (6) create an international network of partners to supplement the national know-how, to educate industrial/research personnel, and to

facilitate the information exchange.

- VTT developed the RF-MEMS, ultrasonic transducers and acoustic emission diagnostics systems.

- Norway has launched a new national initiative with a hope to put Norway among the best in industrializing research results within micro-technology.
  - SINTEF established Norwegian Microtechnology Center (NMC) and involved in research in universities and in industries. Norwegian Research Council (NFR) will contribute 150 millions NOK towards investments in NMC labs. Twenty (20) millions NOK/year for research programs at universities and SINTEF. Twenty five (25) to forty millions NOK per year are to be used to support for MEMS industrial development projects.
  - SensoNor offers foundry service based on the technologies used for their OEM micro-systems for volume production.
  - Eight companies were established in the past two years.
  - The sensors that were developed are: finger print sensors, glucose sensors, medical pressure sensors, lab-on-a-chip, gas sensors, optical modulators and dust sensors.
- Two MST-related start-up and one new MST institute were established in SWEDEN.
  - IMEGO Institute was inaugurated in 1999 at Gothenburg. IMEGO intend to apply micro-electronics, micro-mechanics, and new components in microsystems to produce demonstrators, prototypes, and products together with, and on behalf of companies and researchers. Initial focus will be systems based on sensors in the automotive industry, environmental projects, health care, safety/security, smart houses, IT/communications, and medicine.
  - RADI Medical Technology AB, a subsidiary of RADI Medical Systems AB in Uppsala, was established to prototype and to commercialize a micro-X-ray source with diamond cathode for very localized radiation therapy.
  - Gyros AB, a spin-off from Amersham Pharmacia Biotech AB in Uppsala, will develop lab-on-chip device in polymeric materials on a CD format. Has 25 employees to start with and expect to grow to 100 persons in 3 years. Life science,

diagnostics and environmental analysis systems were also the major field for development.

11. Progress and Development of MEMS Technology in Singapore

- A 3-year national strategic research program in MEMS launched in January 2000 by National Science & Technology Board (NSTB) to enhance MEMS application capabilities (Table 1)

Table 1. Targeted MEMS Technologies in Singapore National MEMS Program

	Devices/Systems	Technologies	Targeted Applications
1	Integrated DNA micro-devices	Simulation, design, fabrication, materials	DNA analysis, drug delivery system, biomedical industry
2	Biomedical micro-sensor arrays	Simulation, design, fabrication, materials	General biomedical industry
3	Microwave and millimeter wave MEMS	Mechanical and ASIC design, integration	Communication industry
4	MEMS for data storage	Micro-actuator simulation, design, fabrication, control	Data storage, information and communication industry

12. MEMS Summit Country Report of Switzerland

- Completed Swiss National Priority Programs: Microsystems and Nano-systems Technology (1996-1999)
  - Goal: (1) consolidate competence of university and industry in the field of technology and applications of micro-systems and nano-technology, (2) promote innovation in SME's (small and medium enterprises) and the creation of start-ups
  - Completed 56 projects and involved 31 university/institutes (56 millions CHF from the government) and 84 industrial partners (76 millions CHF from the industry)

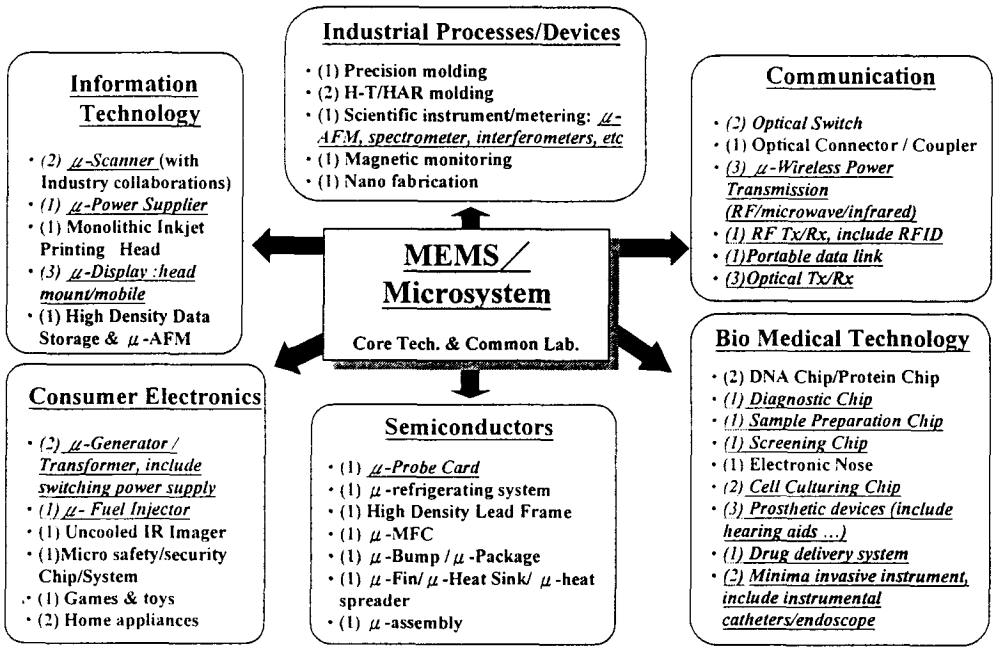
- Results 32 new products, 6 start-ups, 52 patent applications, 2 trademarks, and ~500 publications.

- Started Technology Oriented Programs (TOPs), TOP NANO 21 (2000-2003)
  - Budget: ~50 millions SFr from the government to be matched by industry
  - Objectives: (1) strengthen the Swiss economy through the development and application of new technologies based on the nanometer, (2) encourage the creation of new industries exploiting the nanometer, (3) integrate the subject of the nanometer in teaching.

13. MEMS in Taiwan: Year 2000 Status

- Manufacturing perspectives: (1) manufacture for the world, (2) cost/performance improves by a factor of 10, (3) market pull instead of technology push is the preferred field
- Possess 70% worldwide IC foundry service market→a good foundation to move into MEMS foundry
- Intend to integrate CMOS/MEMS to establish MEMS foundry services

Table 2. Potential Applications of MEMS in Taiwan



Note : 1. Recommendations of "Strategic Meeting on MEMS Industrial Technology Development", R.O.C., 1999
2. Survey of Marketing, Patents and Personal care instrument
3. Advisers from Industry, Academic Institute, and Government
4. Technical Analysis, Positioning, and SWOT Analysis

- Targeted MEMS area in Ministry of Economic Affairs (MOEA) listed in Table 2 is coherent with the *BASIC* (Biology, Automation, Semiconductor, Information technology, and Communications) strategy of the MEMS Technology Advancement Team at Taiwan's National Science Council (NSC).

14. MEMS Summit Country Report of UK

- Integrated Study Instrument System was used as the vehicle for MEMS development
  - Gyros, accelerometers, pressure sensors, etc. all integrated for critical flight safety assessment. Testing vehicle: Boeing 777.
- Single cell micro-biosensors is the main focus for Bio-MEMS research.

15. MEMS Technological Advances in US Industry

- DARPA defined Electronics, Photonics, and MEMS as the three core enabling technologies for all its projects.
  - Leverage IC fabrication technology
  - Build ultra-miniature system
- System needs will define research in device and fabrications. For example, the following projects was driven by system performance and platform needs.
  - Place pressure sensor belt on jet planes to measure the real-time air distributions/variations.
  - MEMS enhanced jet engine
  - MEMS actuators for data storage
  - MEMS replaceable transceiver components such as 92MHz free-free beam micro-resonator
  - Tunable RF filters for MEMS communication systems to enable advanced digital communication module
  - Potential satellite applications such as the demonstrations of the communications between the two Picosat micro-satellites.
- Expect the Inertial/Rate sensors in US alone will be US$6 millions by 2003
- MEMS packaging will be important for full system

implementations

- DERA μ-system and engineering--- inertial and acoustic sensors
- Smith Industries Company ----display and control systems in aerospace.
- Exitech Corp.---- biofactory on a chip, μ-biosensors (single cell)

結論：

1. 微機電系統已被確認為全球下一世代之重要科技與工業，為全球所有先進工業國家所重視
   - 美國 DARPA 定義其所有計畫之基本科技(Enabling Technology)為 Electronics，Phonotics，and MEMS。
   - 全球許多國家於過去幾年中建立微機電/微系統國家型計畫
   - 國際間所有先進國家均大幅增加 MEMS/MST 領域之研究計劃及研究金額
2. MEMS/MST 之發展策略及典範，已自 Device Fabrication 轉至 System Integration/Driven
   - 掌握平台科技及眼光之國家及團隊，將有最大利基
   - 以代工降低 MEMS/MST 進入門檻之策略，已逐漸風行
   - 以代工取得系統平台眼光，不失為一推動 MEMS/MST 之高度可行策略
3. MEMS/MST 之發展方向，日趨多元化
   - Silicon 加工，尤其是 CMOS 仍為量產及電子信號介面之最佳載具
   - 精密微加工，微電鑄/微電鍍，及微射出等多樣加工方式漸佔重要地位
   - 由於系統製造及應用日趨成熟，因 MEMS/MST 封裝技術及方法影響成本極大，故極受重視。

二. 與會心得與建議

此次參加會議諸國，在微系統領域之發展已由傳統之個別零組件，推進到以系統平台來驅動科技領域之發展，且其應用範圍包羅萬

象，包含至少有十個領域，由於我國傳統上並非以系統推動科技見長，因此目前這一新的微機電系統領域推動典範，勢將對我國萌芽中之微機電系統工業有所衝擊。於發展初期，若能不限制好的構想，不限制發展方向，則可有擴大具良好推動平台之核心思想的效果。但在考量我國有限之研發及系統開發資源下，我國似可考慮全力發展以下重點：

1. Information technology
   - Input device
   - Data storage
   - Output device: digital mirror, print head

2. Telecommunication
   - RF: power source, power transmission, SAW resonator, antenna
   - Optical: optical switch

3. Consumer product
   - Consumable
   - House appliance

4. Biochemical and biomedical
   - Fluidics
   - Biochemical sensors
   - Bio-factory on chip
   - Drug delivery system

5. Nanometerials like:
   - magnetic –for data storage and read /write head
   - diamond and SiC films for high temperature applications

6. Environment applications
   - chemical analysis systems
   - gas sensors and chemical sensors.

此一想法與我國國科會微機電推動小組，於去年年底所通過之微機電發展策略中所強調之"BASIC (Biology, Automation, Semiconductor, Information technology, Communications)"策略息息相關。

三. 攜回資料名稱及內容

Proceedings of the 6th World Micromachine Summit。論文集中收集28篇口頭報告論文與15篇各國現況報告論文。