



奈微系統技術的簡介與應用

Introductions and Applications of Micro System Technology

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What's MEMS

- Micro-Electro-Mechanical Systems (MEMS)
 - ▶ Integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro-fabrication technology
 - ▶ Size from micrometers to millimeters Electronics are fabricated using IC process sequences (CMOS, Bipolar, or BICMOS)
 - ▶ Micromechanical components are fabricated using compatible "micromachining" processes
 - Selectively etch away parts of the silicon wafer
 - Add new structural layers



Size of MEMS

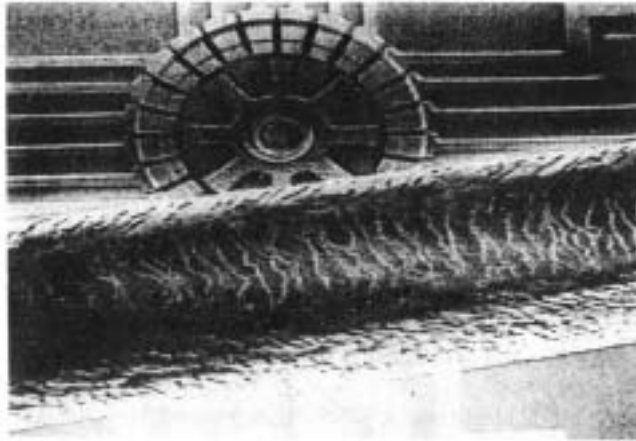


圖 1.2 複砂微馬達之尺寸與頭髮粗細之比較。感謝柏克萊加大之柏克萊感覺器與致動器中心。



微機電應用的發展歷程

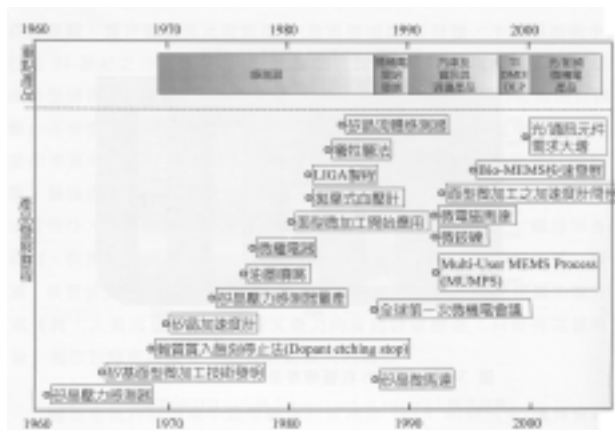


圖 3-28 微機電應用產品發展歷程 [2]

資料來源：華新圖書 - Prime Faraday Technology Watch 2002.01/全聯中心 ITIS 計畫整理

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Microsystem Structure

圖 1.4 微系統之單元

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Major Components in MEMS

- Sensors: Mechanical, Thermal, Magnetic, Chemical, Biological
- Actuators: Motors, Pumps, Valves, Gripper, Switches, Relays, etc.
- Interface:
 - ▶ Electric: A/D, D/A, for energy and information interface
 - ▶ Microfluidic: substance interface
 - ▶ Optical, Thermal, Acoustic

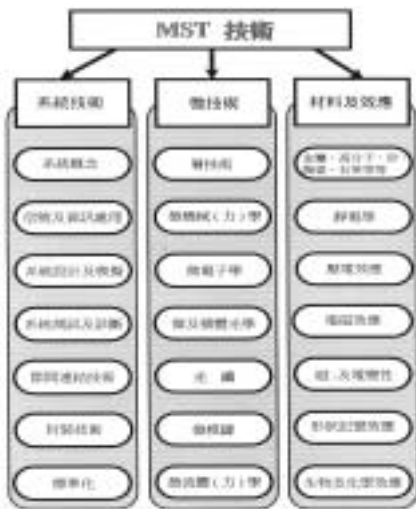
圖 1.5 微系統與它的環境間之界面

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MST Techniques



The diagram shows a hierarchy for MST (Micro System Technology) techniques. At the top is 'MST 技術'. It branches into three main categories: '系統技術' (System Technology), '微技術' (Micro Technology), and '材料及效應' (Materials and Effects). Each category contains a list of specific sub-techniques.

圖 1-6 基本的 MST 技術




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MST in Europe

表 4-1 歐洲 Europractice 的微系統製造群聚

群聚名稱	專精領域
法國製造群聚	集中在石英體型微加工技術、單晶矽體型微加工技術、絕緣矽面型微加工技術、智慧型感測元件製造。
德國製造群聚	專精於光通訊及微流體應用的深蝕刻技術、LIGA 技術、微結構薄膜及微系統封裝技術。
瑞士/荷蘭製造群聚	專精於微感測器、微致動器及微系統設計、體型及面型微加工技術、體型石英蝕刻、電鍍及封裝技術。
英國製造群聚	專精於各種輻射、化學及壓力微感測器，金屬氧化物的氣體感測器，製造失敗分析、可靠度及環境測試。
北歐製造群聚	這是最新成立的製造群聚，專精於微型光通訊元件製造、低單價的組裝及封裝、體型微加工技術上高寬深比蝕刻、高精度薄膜、壓阻計技術以及微系統應用的特殊用途 IC 製造。

資料來源：NEXUS(2000)/金屬中心 ITIS 計畫整理 [2]





MST in Europe

- European Community: NEXUS, UETP, Jessi, Jamie, MUST
- 學院與研究機構為主，應用著重在汽車、醫學與環保
- 每年相關經費約\$55-200 million (台幣20億 70億元)
- Germany
 - ▶ BMBF (德國聯邦教育、科學、研究暨技術部) 提倡微系統計畫(since 1990)
 - ▶ 主要研究機構：
 - Karlsruhe Research Center (FZK)
 - Fraunhofer Society for Applied Research in Munich (FhG)



MST in Europe

- Switzerland
 - ▶ CSEM (Swiss Centre for Electronics and Microtechnology)
 - Sensor research
 - Micro-mechanical components
 - Microrobots
 - ▶ Swiss Foundation for research in Microtechnology
 - ▶ National Foundation for Scientific Research
 - ▶ University of Neuchatel
 - Application-oriented research in Silicon based Sensors and actuators





MST in Europe

- France
 - ▶ Laboratoire d'Automatique et d'Analyse des System (LAAS)
 - ▶ Laboratoire d'Electronique, de Technologie et d'Instrumentation (LETI)
 - ▶ Institut des Microtechniques de Franche-Comte (IMFC)
 - 微機械人：控制器、結構、能源、高解析度定位系統
 - ▶ Centre Technique de l'Industrie Horlogere (CETEHOR)
- Netherlands
- United Kindom
- Belgium
 - ▶ University of Leuven
- Sweden



MST in Japan

- Intensive corporation between larger companies and university
 - ▶ University of Nagoya, Tokyo, Tohoku
- Ministry of International Trade and Industry (MITI) found Micromachine Center (MMC) in 1992
- MITI sponsor MST \$25-35 million (約10億台幣)
- National Research Facilities
 - ▶ Mechanical Engineering Laboratory (MEL)
 - ▶ Electrotechnical Laboratory (ETL)
 - ▶ National Research Laboratory of Metrology (NRLM)
- From industries: Advanced Machining Technology & Development Association (AMTDA) (來自企業贊助每年15-25億台幣)
- Focus on microsensors due to medical applications





MST in Japan

- MITI's Goal: Manufacture very small machines and instruments

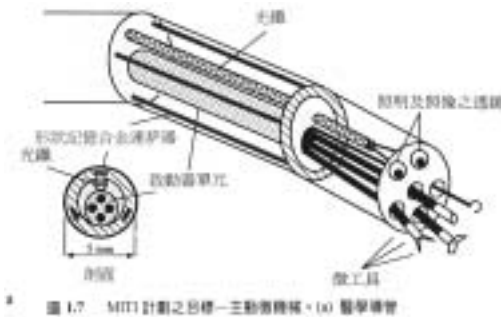


圖 1.7 MITI 計劃之日標—主動微機械。(a) 醫學導管

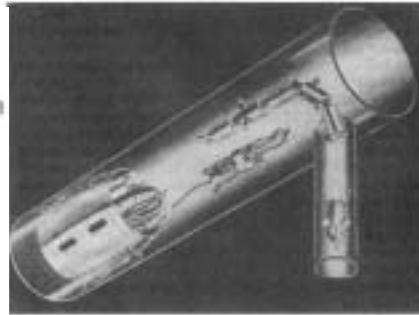


圖 1.7 MITI 計劃之日標—主動微機械。(b) 工業微機械人—梭梭 [MITI 91]



MST in USA

- Very active and application-oriented
- 18 MST centers from Engineering Research Center Program (ERC)
- NSF provides Solid State and Microstructures Program to support
 - ▶ National Nanofabrication Facility at the Cornell University
- Federal level:
 - ▶ Chamber of Commerce and the National Institute of Standards and Technology (NIST)
 - ▶ Advanced Research Projects Agency (ARPA) for Military application: \$8 million a year.
 - ▶ NASA, NHF, FCCSET





MST in USA

- University research
 - ▶ Cornell University
 - ▶ University of California, Berkeley
 - ▶ Massachusetts Institute of Technology (MIT)
 - ▶ University of Wisconsin at Madison
 - ▶ University of Michigan
 - ▶ Case Western Reserve University at Cleveland
 - ▶ North Carolina State University
 - ▶ Carnegie Mellon University
 - ▶ Louisiana Tech University
- Sandia National Laboratories
- Institute for Molecular Manufacturing (IMM) : Focus on Nanotechnology



MST in USA

- Industries: IBM, AT&T, Ford, Texas Instrument, Honeywell, Motorola, Nova-Sensor, HP, Analog Devices.
 - ▶ Developing components of microsensors and microactuators
 - ▶ Competition among companies.
 - ▶ Few collaborations.





MST in TAIWAN

- 每年投入相關研究經費：7 8億台幣
- 工研院：共用實驗室
- 中科院：國防、航太應用
- 國科會資助的研究中心
 - ▶ 北區奈微米中心（台大）
 - ▶ 中區奈微米中心（清大）
 - ▶ 南區奈微米中心（成大）
 - ▶ 國家奈米元件實驗室（交大）
 - ▶ 精儀中心：LIGA-like技術
 - ▶ 同步輻射中心（新竹工業園區）：LIGA技術



相關網站

- MEMS ISI技術情報交換站，加利福尼亞州美國
 - ▶ 美國的技術情報交換站 <http://mems.isi.edu>
- EMSTO德國柏林
 - ▶ 歐洲的技術情報交換站 www.nexus-emsto.com
- VDI/VDE-IT德國Teltow
 - ▶ 德國工程師學 www.vdivde-it.de/MST
- DARPA維吉尼亞州阿靈頓市
 - ▶ 資助美國政府的研究計畫 <http://web-ext2.darpa.mil/MTO>
- Nist馬里蘭州Gaitherburg
 - ▶ 資助美國政府的研究計畫 www.atp.nist.gov





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相關網站

- 國防分析學院維吉尼亞州Alexandria
 - ▶ www.ida.org/MEMS
- AIST-MITI日本東京
 - ▶ 日本的「微機器計畫」 www.aist.go.jp
- 美國Sandia國家實驗室
 - ▶ <http://www.sandia.gov/>
- 台灣網站
 - ▶ 北區奈微米中心 <http://nscmems.iam.ntu.edu.tw/>
 - ▶ 南區奈微米中心 <http://www.ncku.edu.tw/~nckumems/>
 - ▶ 國家奈微米實驗室 <http://www.ndl.gov.tw>

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MST Market Prognoses

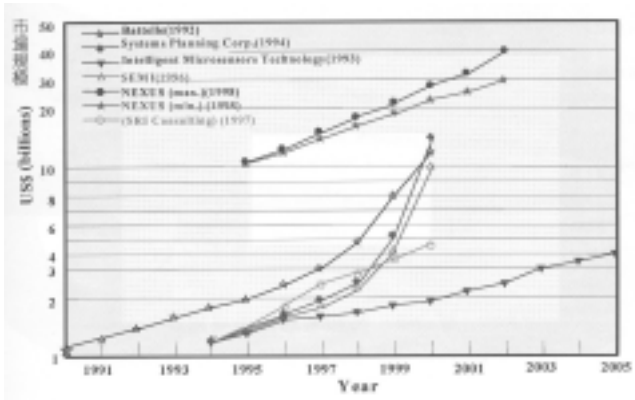



圖 3-1 全球微系統產品市場預測

資料來源：Micromachine Devices, Aug 1997/金屬中心 ITIS 計畫整理 [2]

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微機電系統的市場

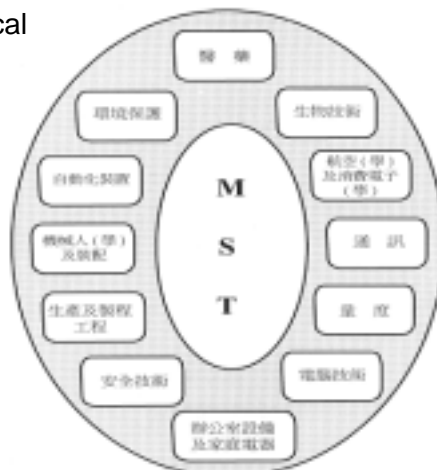
■ 微機電技術應用產品市場變化表[3]

2000年十大應用領域	市場佔有率	2005年十大應用領域	市場佔有率
汽車	26%	光開關	24.4%
工業設備	14.7%	投影系統	14.6%
噴墨印表頭	9.5%	繼電器	14.0%
投影系統	8.2%	汽車	11.6%
血壓計	4.4%	工業設備	6.9%
消費電子	4.0%	噴墨印表頭	6.0%
生物晶片	1.6%	生物晶片	4.0%
光開關	0.8%	通訊用濾波器	2.9%
醫療設備	0.6%	血壓計	2.2%
醫學儀器	0.4%	通訊用雷射	1.7%

資料來源：Cahners In-Stat Group

MST的應用

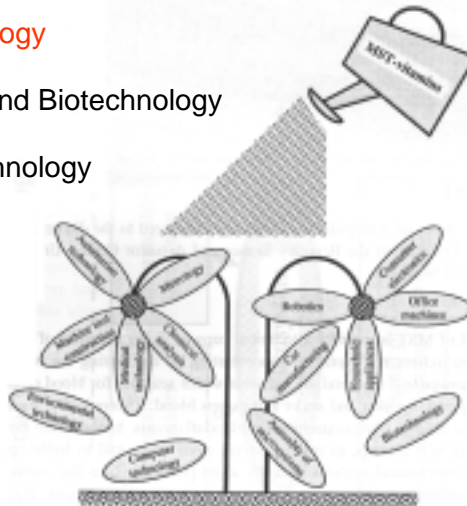
- Sensors to measure physical and chemical parameters
 - ▶ Temperature
 - ▶ Pressure
 - ▶ Acceleration
 - ▶ Chemical concentration
- Actuators interact with the real world
- Nanotechnology





Potential MEMS Market

- Medical Technology
- Environmental and Biotechnology
- Automotive Technology



Medical Technology

- Endoscopy (內視鏡)
- Implantable Dosing Systems (植入型投藥系統)
- Tele-microsurgery (遠距顯微手術)
- Artificial Prosthesis (人造替代品)
 - ▶ Pacemaker (心率調整器)
 - ▶ Hearing Aids (助聽器)
 - ▶ Neuronal Prosthesis (神經替代品)
 - ▶ 能源需求與來源?
- Implantable Sensor System (植入式感覺器)
 - ▶ 輻射量監測、血壓計、血液參數量測

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Micromachined Transducer
Applications for Medical Diagnostics & Treatment

Thursday, 10 May 2000 Microelectromechanical Systems (MEMS) Short Course © M. Adria Mihalek, 2000 Slide 9

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膠囊內視鏡


- 日本奧林巴斯（Olympus）研發出一種直徑1.1公分、長2.6公分可拋式膠囊內視鏡，預計2006上市，希望讓病人像吞藥丸似的把它吞下肚子後，就可讓醫師檢查身體內部，減輕做內視鏡檢查的痛苦。
- 這種膠囊內視鏡不用電池，它是以一種旋轉的磁場驅動，並以一種超敏感的顯像裝置顯示身體內部狀況，用一種超小型鏡片捕捉影像，同時有一支微小的天線把影像傳出體外。
【2004/12/29 民生報】

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Minimal-Invasive Surgery Spectrum

圖 2.3 小切口手術譜系

ab.  27

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Miniaturized Surgical Effectors

圖 2.4 不同的微小化外科器械。感謝 the Karlsruhe Research Center。

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醫學導管

圖 1.7 MITI 計劃之目標—主動微機械。(a) 醫學導管

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Implantable Fiber-Optic Dosimeter

圖 2.5 可植入人體的光纖計量器。感謝 the Julich Research Center。

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遙控的微感測器

■ 可植入式血壓計

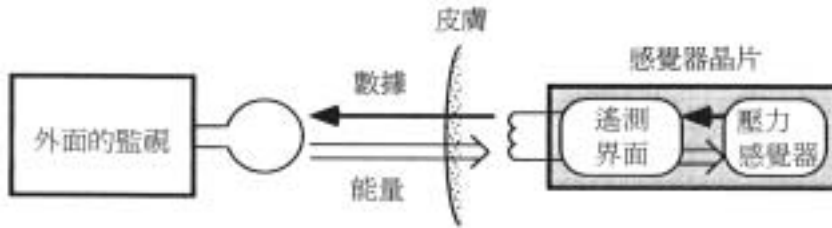


圖 2.6 遙控的微感測器系統之概念。根據 [Zache 95]。

神經替代品

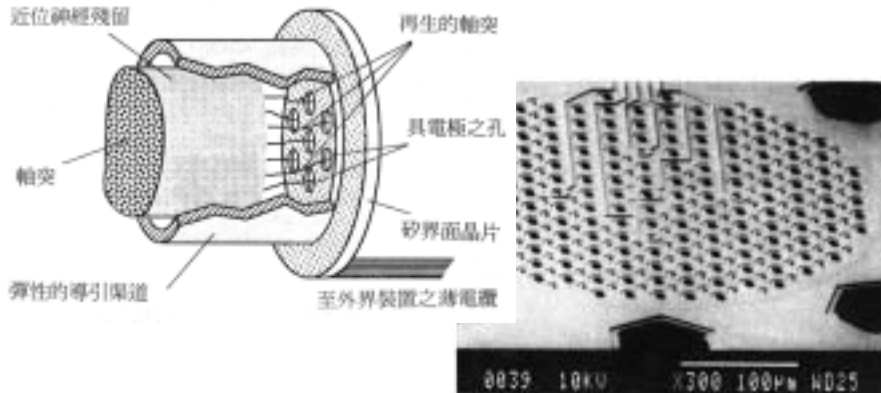


圖 2.8 矽界面“軸突控制電子”。感謝 the University of Michigan (Solid-State Electronics Laboratory)。

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Potential MEMS Market

- Medical Technology
- Environmental and Biotechnology
- Automotive Technology

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Environmental and Biotechnology

- Contaminant Analyzer (環境污染的監測) : 分析化學物質
 - ▶ 取樣
 - ▶ 參數量測
 - ▶ 訊號處理
 - ▶ 輸出控制
- Biotechnology
 - ▶ 遞送
 - ▶ 夾持
 - ▶ 輸送
 - ▶ 整理
 - ▶ 切割
 - ▶ 注射

Fig. 2.9: Contaminant analyzer using an optical principle. According to [Schum93]

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Microspectrometer

microParts

self-focusing reflection grating (0.2 μm x 1 μm)

Light input through optical fiber

Light output via reflecting edge

diode array

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Potential MEMS Market

- Medical Technology
- Environmental and Biotechnology
- Automotive Technology

MST-technology

MST-technology

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Automotive Technology

■ Sensors在汽車科技的應用



Courtesy of D. Thoma, Patru-Alu Applied Displays

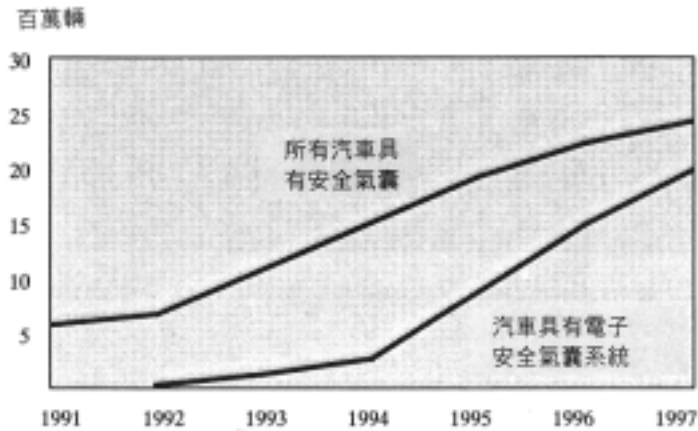
Micromachined Transducer
Applications for Automotive Operation & Safety

- Vertical Navigation Screens → Acceleration → New Rate
- Silicon Nozzles for Fuel Injection
- Fluid Phasor Sensor
- Micromachined Accelerometer for Airbag
- Microphones for Noise Control
- High Pressure → Leak → Ignition Pressure
- Gas Sensor
- High Temperature Sensor
- Micro Air Pressure Sensors
- Mass Air Flow Sensor
- Flow Sensor → Wind → Traffic People
- Pressure and Torque Sensors for Steering Control
- Tire Pressure Sensors
- Gas Sensor
- High Temperature Sensor

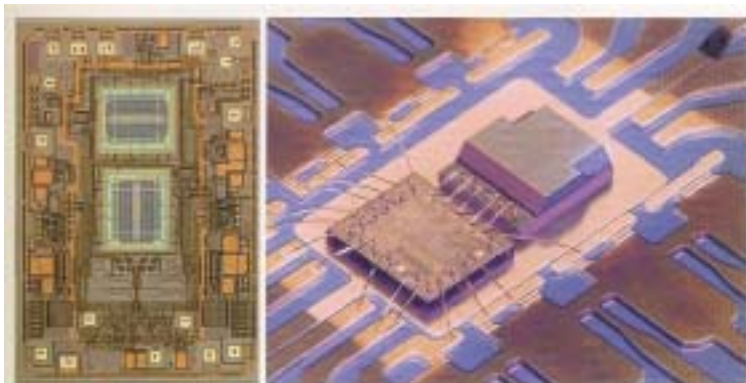
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微加速度計的應用

■ 安全氣囊的市場研究



Microaccelerometers



COLOR FIGURE 24.1 Examples of two high-volume accelerometer products. On the left is Analog Devices, Inc. ADXL230 two-axis lateral monolithically integrated accelerometers. On the right is a Motorola, Inc. wafer-scale packaged accelerometer and control chips mounted on a lead frame prior to plastic injection molding. (Photographs courtesy of Analog Devices, Inc. and Motorola, Inc.)



汽車微感測器的應用

- 微小化的角速度感測器：智慧導航與控制系統
- 壓力微感測器
 - ▶ 耗油最佳化
 - ▶ 燃油、機油、空氣、液壓系統、變速系統的壓力感測
- 距離感測器：倒車雷達陣列



Nanotechnology

- 奈米科技是什麼
 - ▶ 尺寸在0.1至100奈米間的材料結構的物理、化學性質研究，和材料結構的製造、操縱和量測等技術和儀器的研發皆可稱之（奈米科技，馬遠榮著，商周出版）
- 主要項目：
 - ▶ 奈米物理學
 - ▶ 奈米化學
 - ▶ 奈米材料學
 - ▶ 奈米生物學
 - ▶ 奈米電子學
 - ▶ 奈米加工學
 - ▶ 奈米力學





自然界的奈米科技

■ 蓮花出污泥而不染



自然界的奈米科技

■ 奈米防水層

- ▶ 鴨毛、鵝毛不沾水
- ▶ 毛細縫非常小水分子無法穿越，但極為透氣

■ 奈米塗料

- ▶ 植物、木材炭灰
- ▶ 附著力強、持久

■ 人體的奈米科技

- ▶ DNA排序



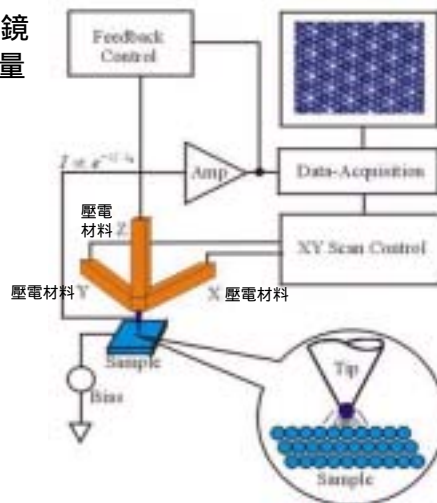
Scanning Probe Microscopy (SPM)

- 非接觸式掃描物質表面原子結構，解析度達 0.3nm
- Scanning Tunneling Microscopes (STM)掃描穿隧式顯微鏡
 - ▶ Tunneling effect：鎢探針在極接近樣品表面時（相距幾個奈米），加上低電壓在探針與樣品間，針尖與表面間會有電子的跳動，而穿隧電流(Tunneling current)受間距離影響
 - ▶ 觀測物需為金屬或半導體
- Scanning Force Microscopes (SFM)掃描力顯微鏡，又稱 Atomic Force Microscopes(AFM)原子力學顯微鏡
 - ▶ 探針在極接近樣品表面時（相距幾個奈米），探針與物體間產生原子力（低處吸引與高處排斥），再以電容或光學原理量測探針的震動量
 - ▶ 可量測導體與絕緣體



Scanning Tunneling Microscopes

- STM隧道掃描顯微鏡之壓電轉換器與度量原理





Scanning Force Microscopes

- SFM (使用雷射光束之SFM量測原理)

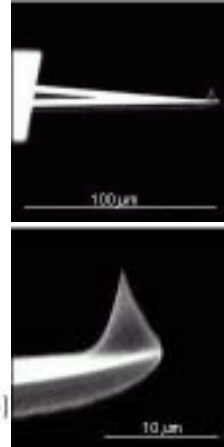
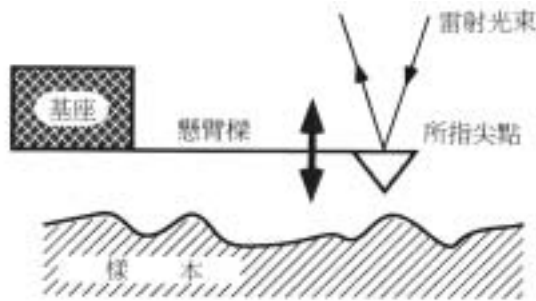


圖 2.15 使用雷射光束之 SFM 量測的原理。根據 [Torii 93]



Scanning Force Microscopes

- SFM (電容式)

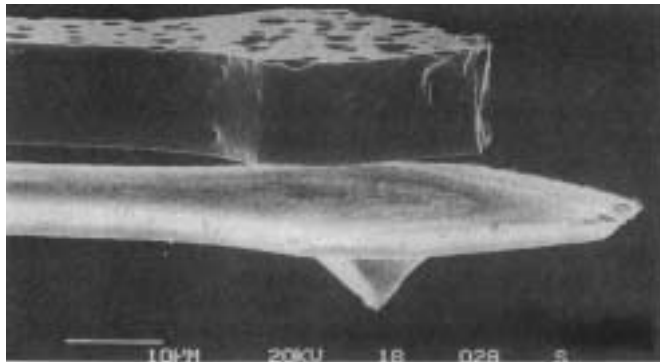


圖 2.16 使用電容量測原理的 SFM 之矽製探針相片。感謝 Neuchâtel 大學 (微科技研究所)。

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成列式SFM探針

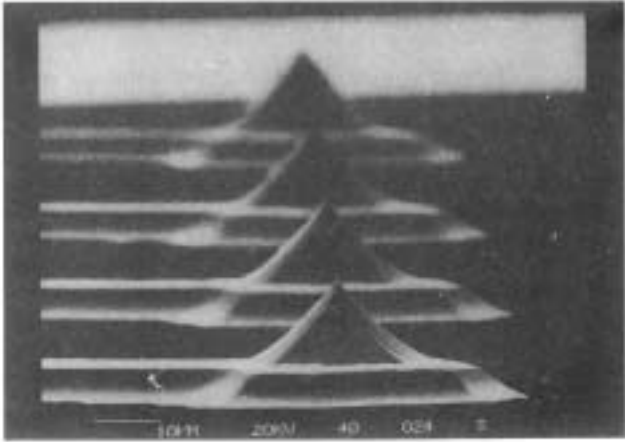


圖 2.17 成列的 SFM 探針 (感謝 Neuchâtel 大學 (微科技研究所))

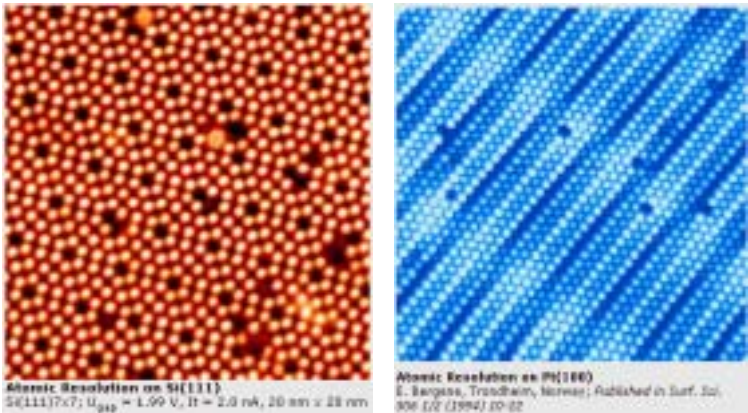
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SPM量測例

- 原子圖像



Atomic Resolution on Si(111)
Si(111)7x7; $U_{tip} = 1.99$ V, $I_t = 2.3$ nA, 20 nm x 28 nm

Atomic Resolution on Pt(110)
E. Bergens, Trondheim, Norway; Published in Surf. Sci. 306 (2) (1994) 10-22

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奈米科技的應用

- 奈米材料
- 奈米塗料
 - ▶ 隱形塗料奈米顆粒易吸收電磁波
 - ▶ 防污塗料
- 奈米機器人
- 生物醫學
 - ▶ 以奈米碳管製造的超小型膠囊
 - ▶ 奈米顆粒可穿透細胞膜
 - ▶ 生物晶片
- 光學積體電路
- 量子電腦



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