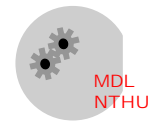


奈微米尺寸機器之製造及其應用

方維倫 教授
國立清華大學 動機系/微機電所

fang@pme.nthu.edu.tw
<http://mdl.pme.nthu.edu.tw>

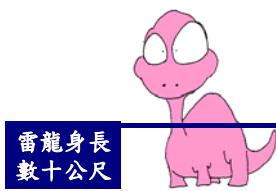


螞蟻與微結構

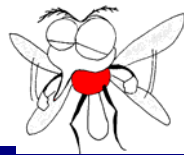


1 mm

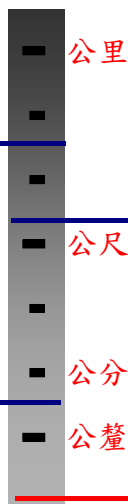




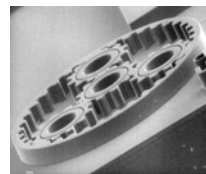
雷龍身長
數十公尺



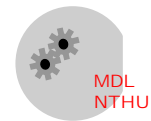
蚊子身長
約三公釐

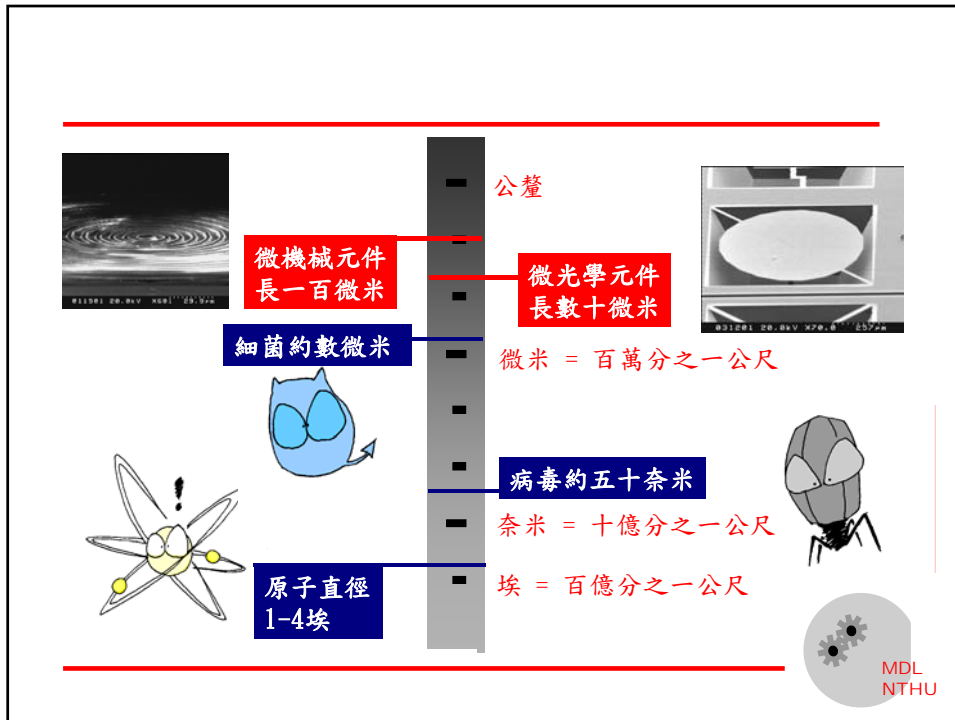


成年男子平均
身高 1.7 公尺



微機械元件
長一百微米



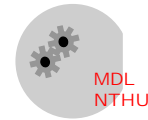


前言

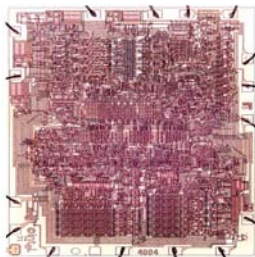
MDL
NTHU

歷史背景

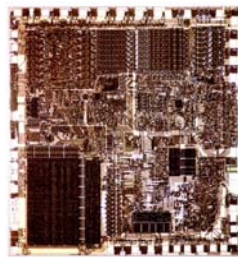
- 1947 : 1st Transistor (Bell lab)
- 1958 : **Planar technology (Fairchild)**
- 1959 : 1st IC (TI, Kilby)
- 1969 : 1st commercial RAM (Intel, 256 bit)
- 1971 : 1st Micro processor (Intel, **2300** transistors;
7.5M transistors for Pentium II at 1997)



微處理器



The 4004 - 2,300 transistors, 1971



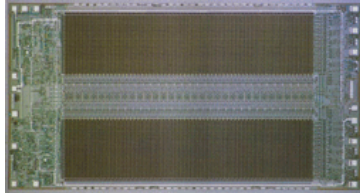
The 8088/8086 - 29,000 transistors, 1978



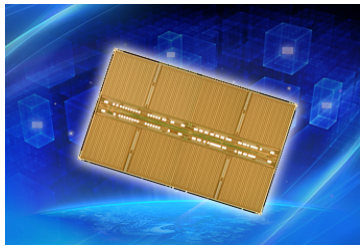
The Pentium IV - 42,000,000 transistors, 2000



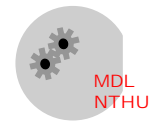
記憶體



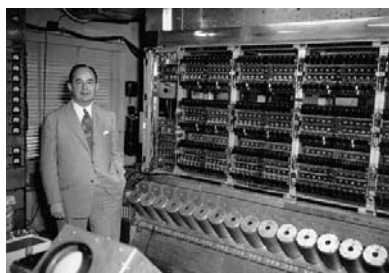
The 16kb DRAM, 1976



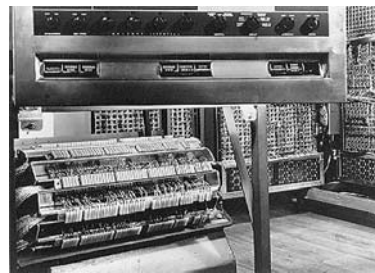
The 2Gb DRAM, 2011



電腦的演進 - I



von Neumann and his
“computer”, 1952



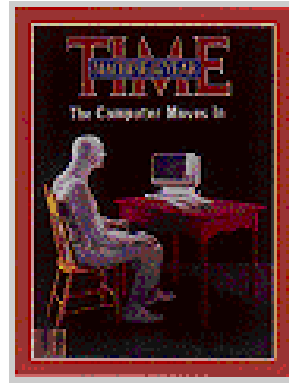
IBM 650, 1954



電腦的演進 - II



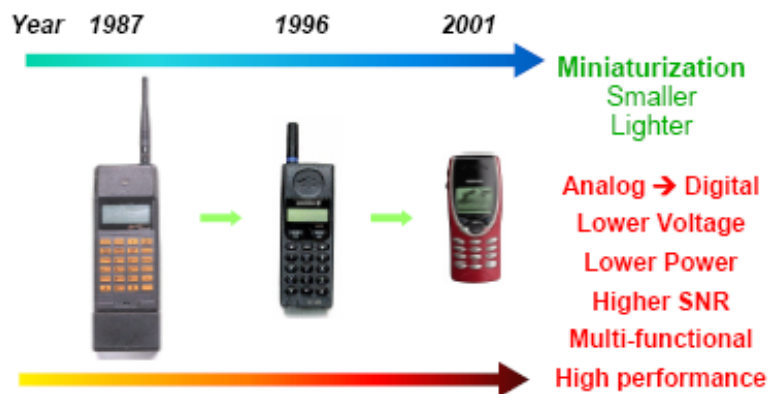
Jobs & Wozniak with Apple II - 1976



IBM PC - 1981/2

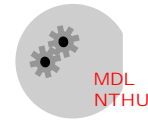


科技發展的趨勢



平面加工技術與高科技

- IC：台積電, 聯電, 華邦, ... (聯發科, 瑞昱, ...)
- Magnetic recording head：Seagate, Hitachi, ...
- LED/VCSEL/Diode laser：國聯, 光磊, 全磊, ...
- TFT-LCD：友達, 奇美, 廣輝, ...
- MEMS：探微, 亞太優勢, 台積電, ...



平面加工技術



Semiconductor processes

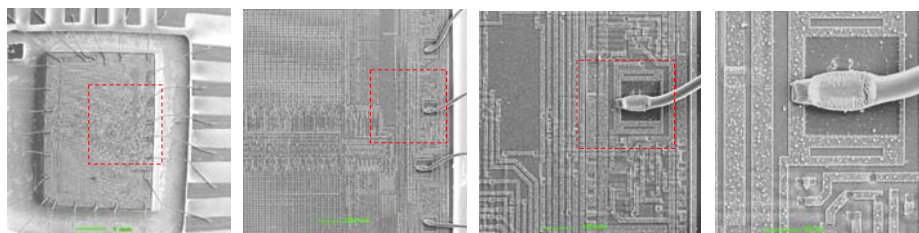
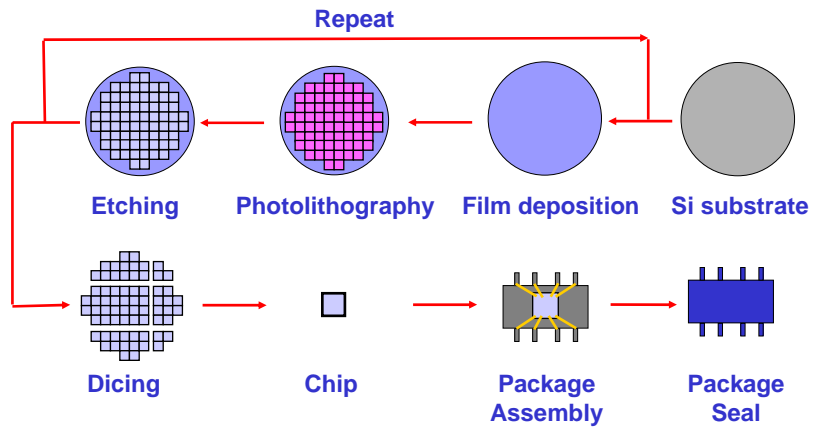
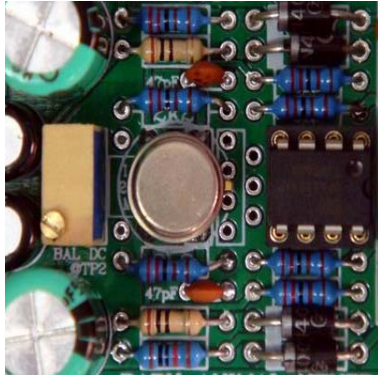


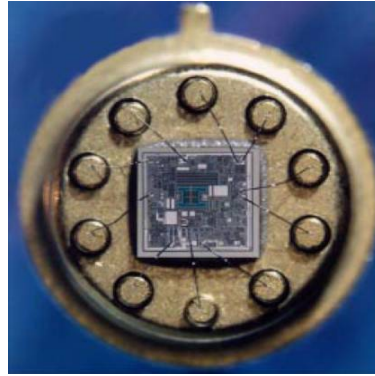
Photo source: Arizona State University



- **Discrete vs Integrated electronics components**



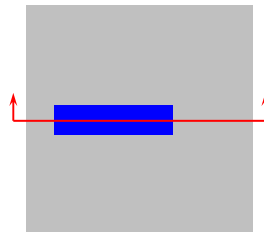
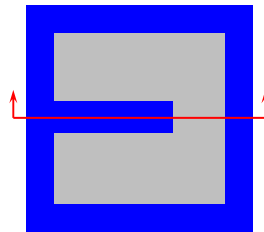
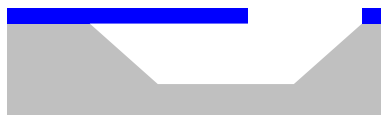
ATM Elektro, Czech Republic



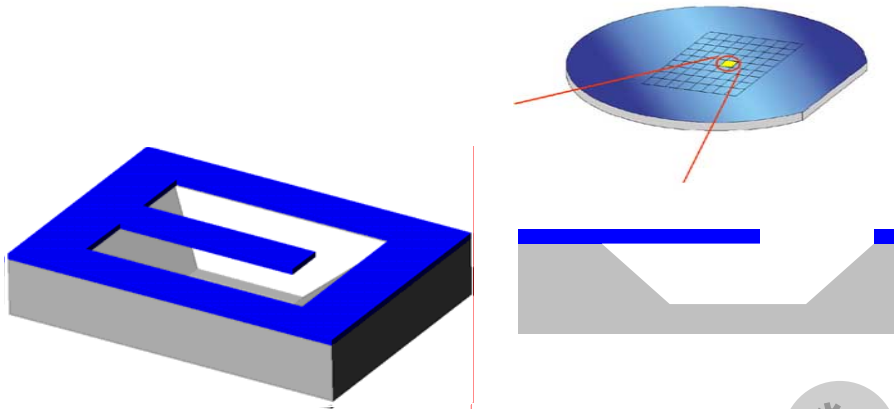
ADI, USA



懸浮微機械結構



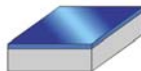
基本製程 I



空白矽晶片



長膜



微影

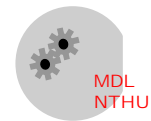
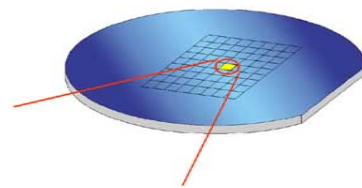
留下光阻以保護下層薄膜



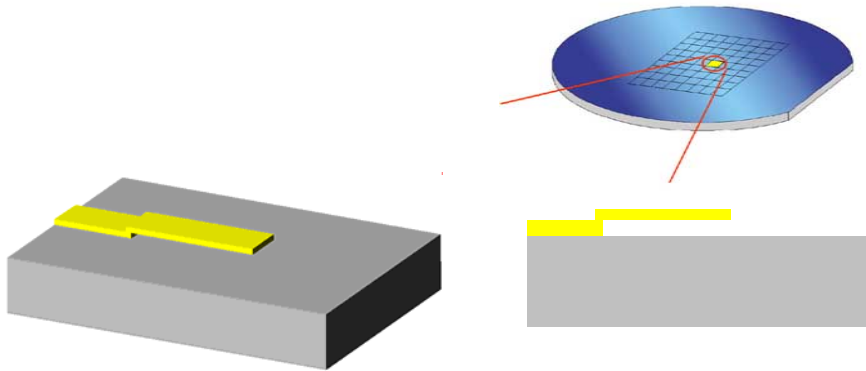
蝕刻薄膜、洗去光阻
此處的薄膜是結構層



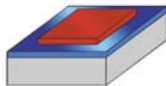
蝕刻矽底材
將結構懸浮



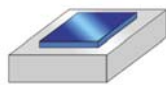
基本製程 II



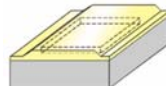
微影
留下光阻以保護下層薄膜



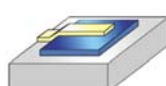
蝕刻薄膜、洗去光阻
此處的薄膜做為犧牲層



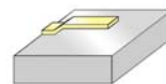
長第二層膜
作為結構層



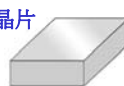
第二次微影、蝕刻
得到結構形狀



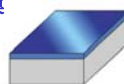
蝕刻犧牲層
得到懸浮結構



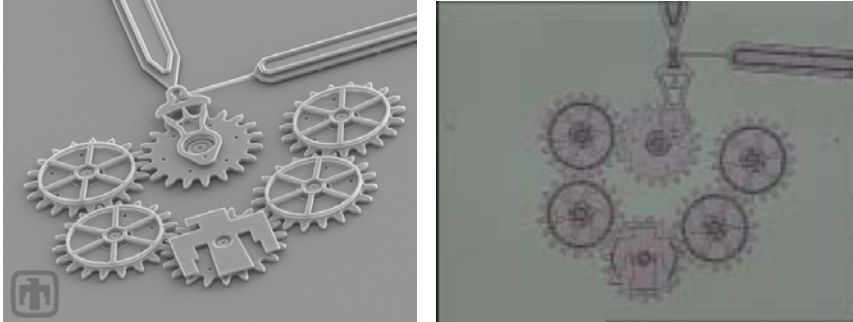
空白矽晶片



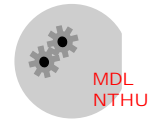
長膜



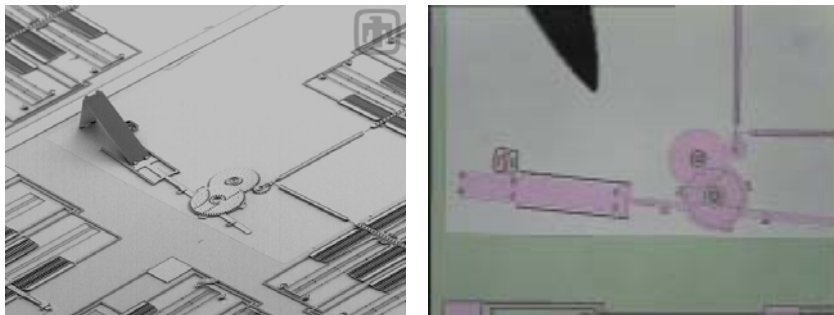
製程結果



Sandia National lab., USA



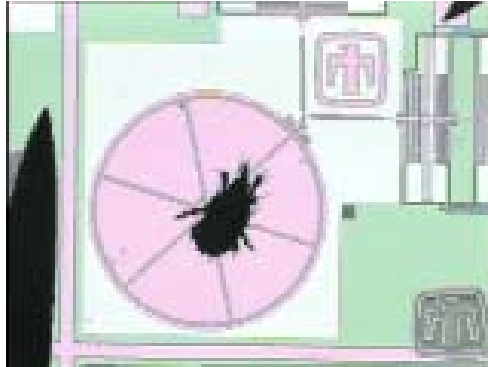
製程結果



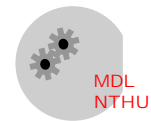
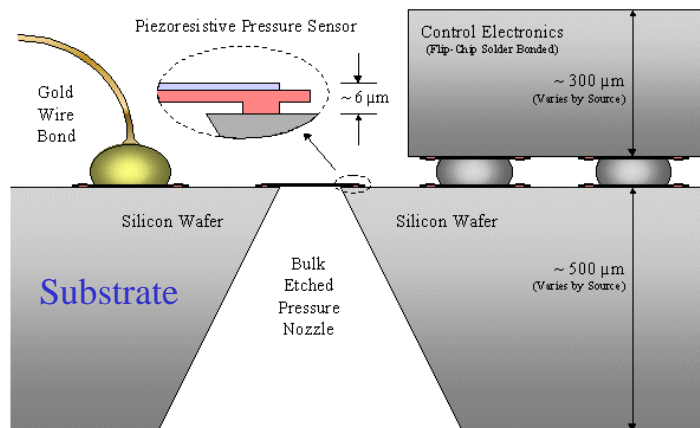
Sandia National lab., USA



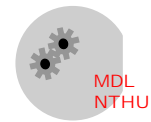
製程結果



Sandia National Lab, USA

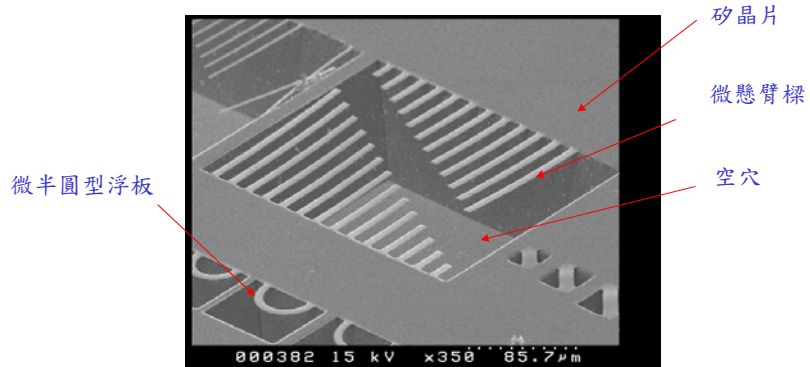


關鍵元件 – 被動元件



被動元件 – 樑

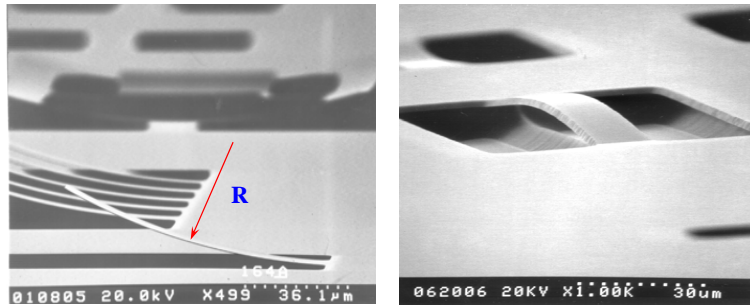
- 微機械結構 – 樑、浮板



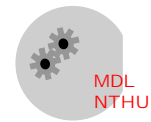
T. Tzou and W. Fang, 1999



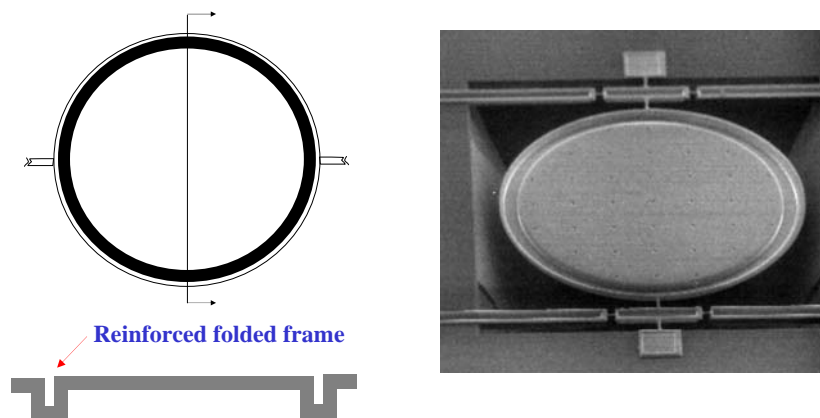
• 結構厚度與剛性



W. Fang, 1995



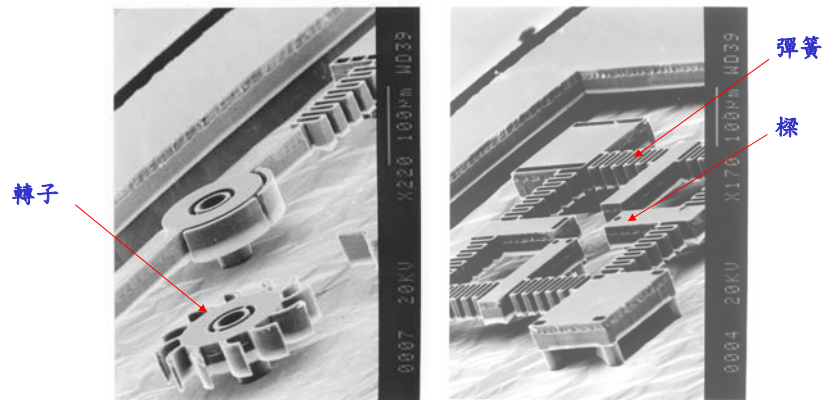
被動元件 - 平板



H.-Y. Lin and W. Fang, the ASME IMECE, Orlando, FL, 2000



被動元件 – 齒輪、彈簧



關鍵元件 – 致動元件



傳統主動元件

Motor



www.classictesla.com/photos/tesla/motor.jpg

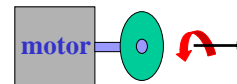
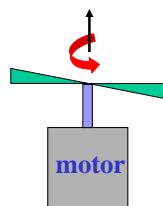
Engine



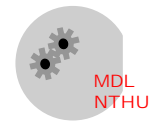
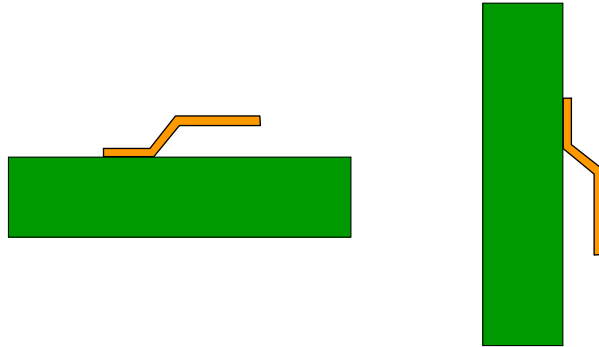
www.sportruck.com/feature/tangerine/engine.jpg



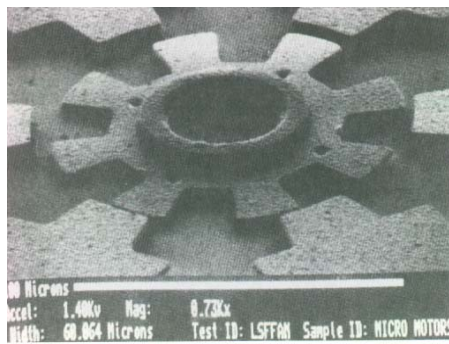
-
- 傳統致動元件之輸出 - 可由組裝調整



-
- 微致動元件附著於矽晶片 – 輸出無法由組裝調整



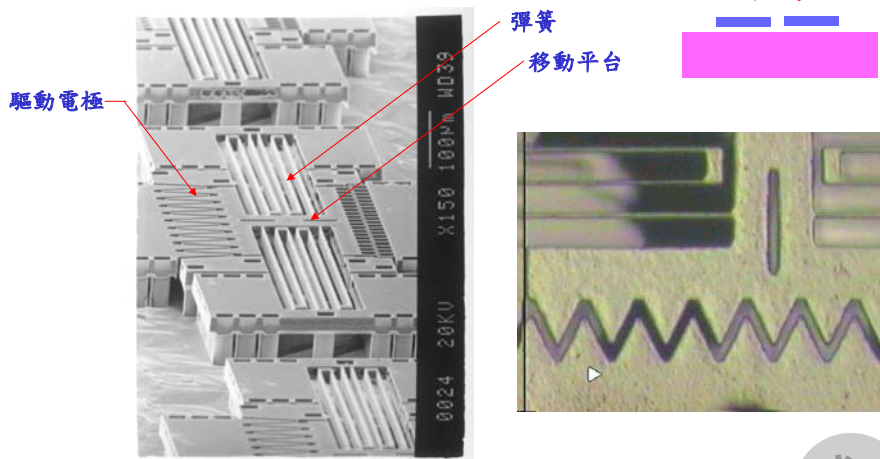
主動元件 – 轉動式靜電致動器



L.-S. Fan, Y.-C. Tai, and R.S. Muller, Int. Electron Devices meeting, 1988.

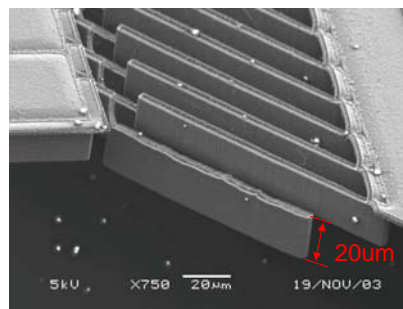
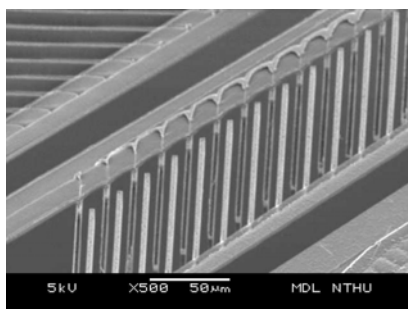
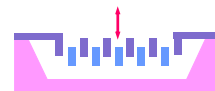


主動元件 - 線性運動靜電致動器

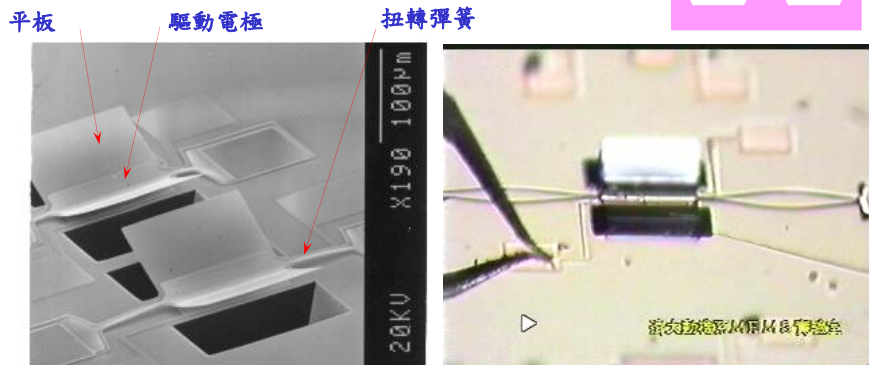


主動元件 - 靜電驅動致動器

- Vertical comb electrodes
 - + Comb thickness ~20um
 - + Travel stroke ~20um



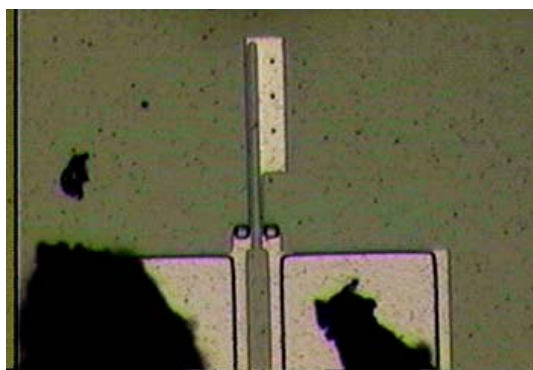
主動元件 – 扭轉式靜電致動器



J. Hsieh and W. Fang, *Transducers'99*, Sendai Japan, 1999

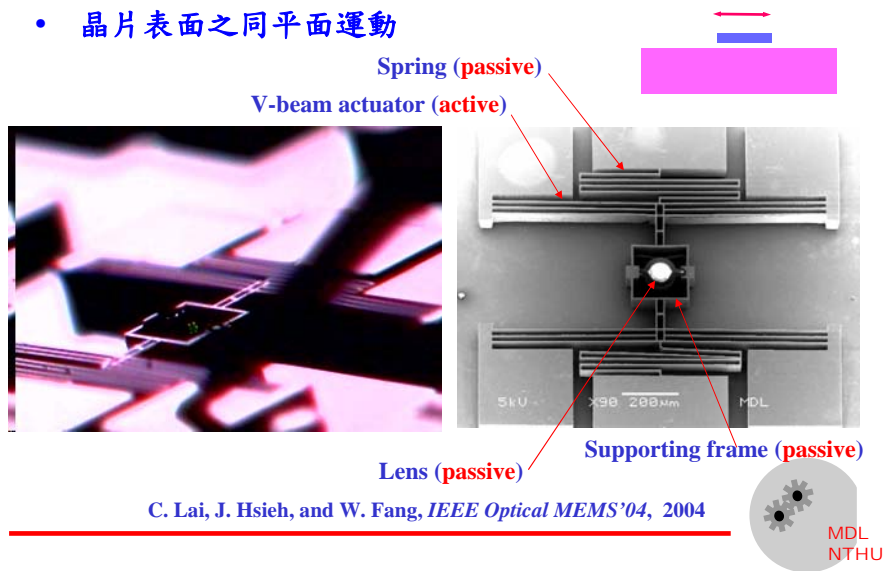
J. Hsieh and W. Fang, *Sensors and Actuators A*, 2000

主動元件 – 線性運動電熱致動器



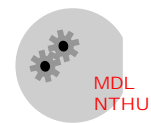
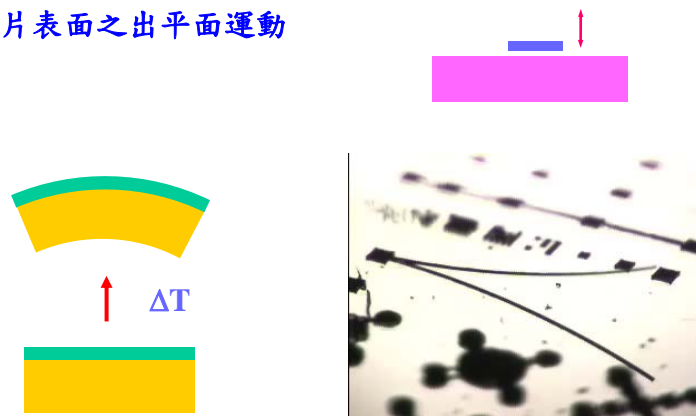
主動元件 – 線性運動電熱致動器

- 晶片表面之同平面運動



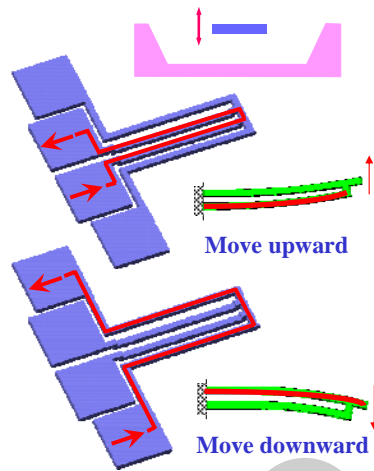
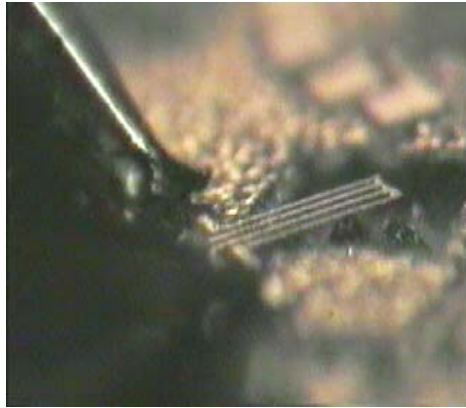
主動元件 – 線性運動電熱致動器

- 晶片表面之出平面運動



主動元件 – 線性運動電熱致動器

- 晶片表面之出平面運動



W.-C. Chen, J. Hsieh, and W. Fang, *IEEE MEMS'02*, Las Vegas, NV, 2002



組裝與整合



元件組裝



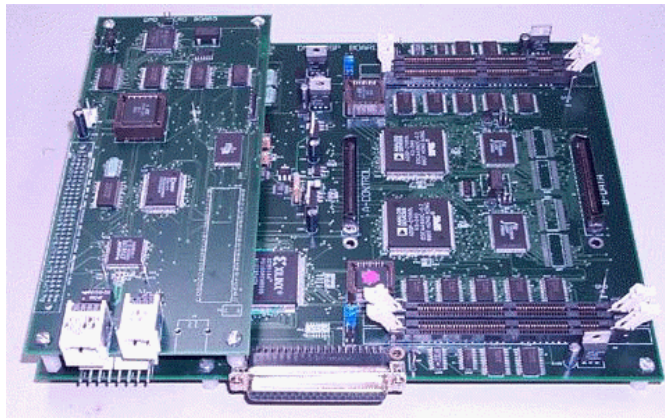
www.precisionscalereplicas.com



www.kukausa.com



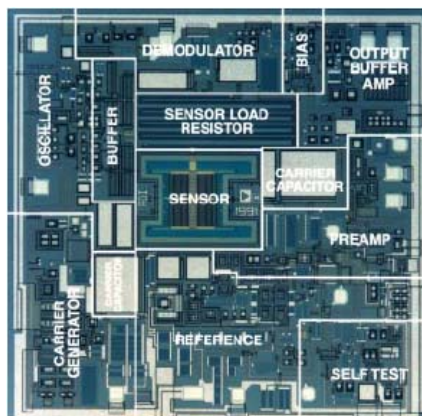
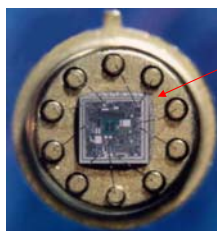
元件組裝



電腦主機板



製程整合

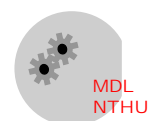
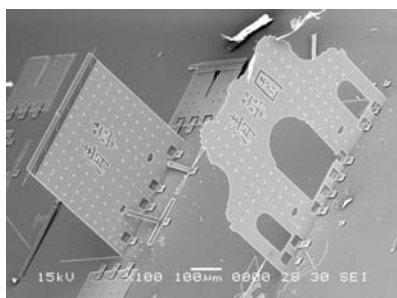


啟動汽車安全氣囊之加速度計 IC (ADI Inc.)



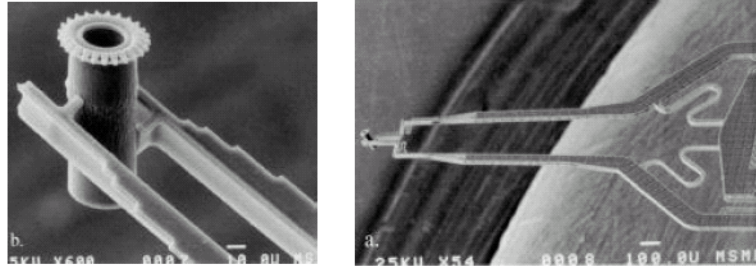
組裝 - 手工式

- 平面元件與直立元件



組裝 - 精密機械式

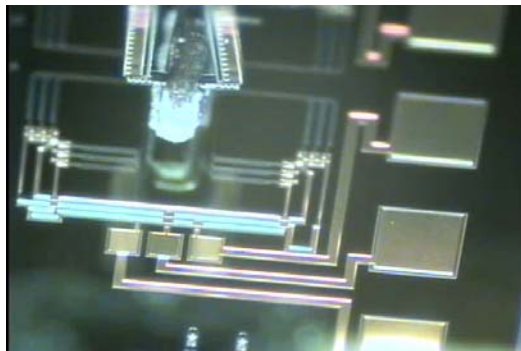
- Manually - Micro probe/gripper



Keller, UC Berkeley, 1998



組裝 - 精密機械式



Zyvex Inc.



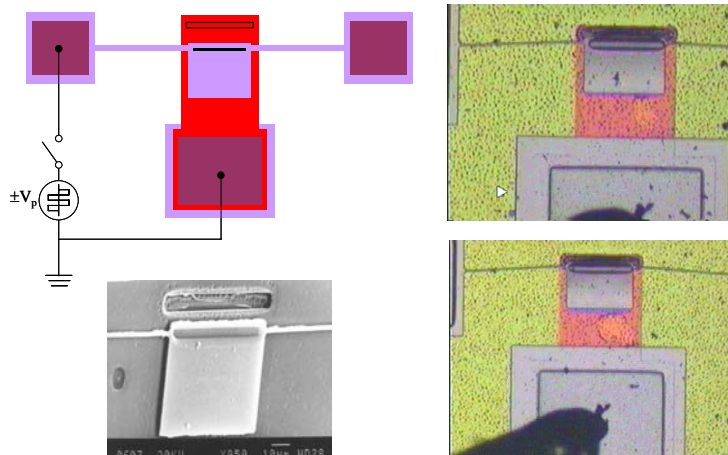
組裝 - 精密機械式



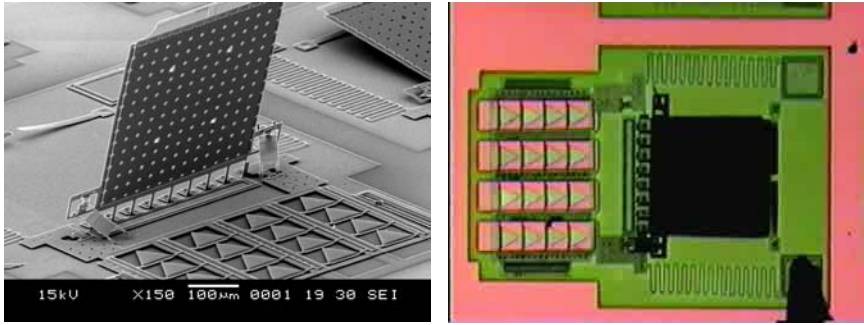
Zyvex Inc.



組裝 - 微致動器輔助式



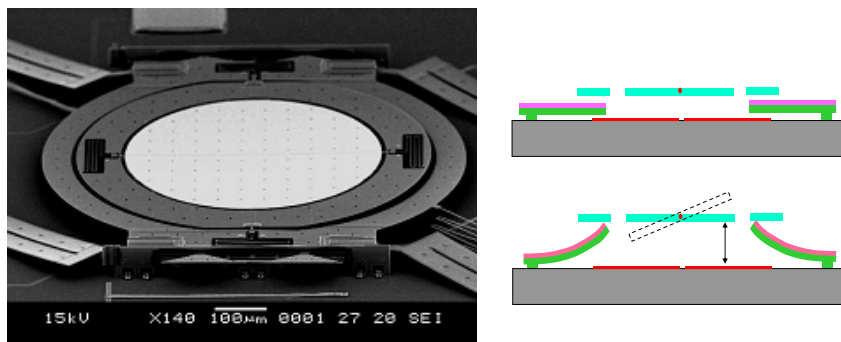
組裝 – 微致動器輔助式



C.-Y. Wu, and W. Fang, 2002

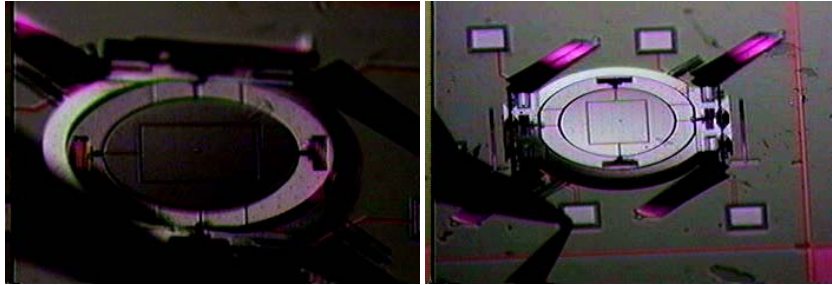


應力自組裝成形



Y.-P. Ho, M. Wu, H.-Y. Lin and W. Fang, *IEEE Optical MEMS '02*, 2002



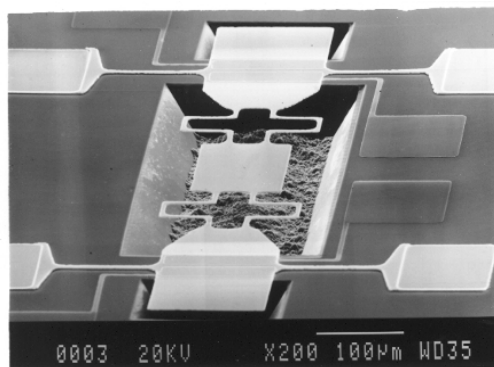


Y.-P. Ho, M. Wu, H.-Y. Lin and W. Fang, *IEEE Optical MEMS '02*, 2002



製程整合 – 一體成形

- 微定位平台

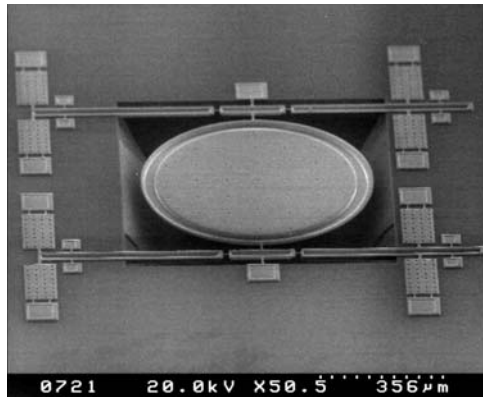


J. Hsieh and W. Fang, *Transducer'99*, Japan, 1999



製程整合 – 一體成形

- 微一維掃瞄器

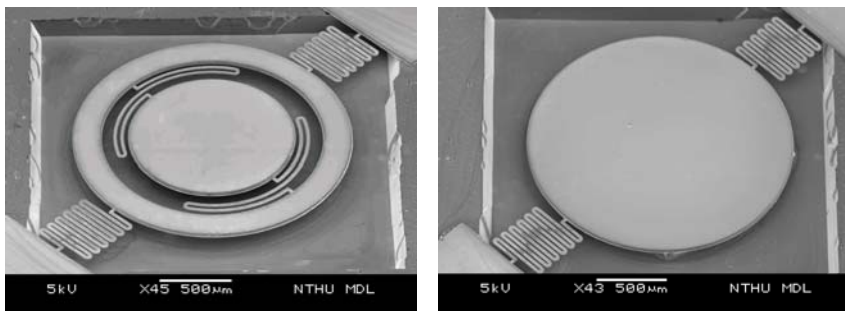


H.-Y. Lin and W. Fang, *IEEE Optical MEMS*, USA, 2000



製程整合 – 一體成形

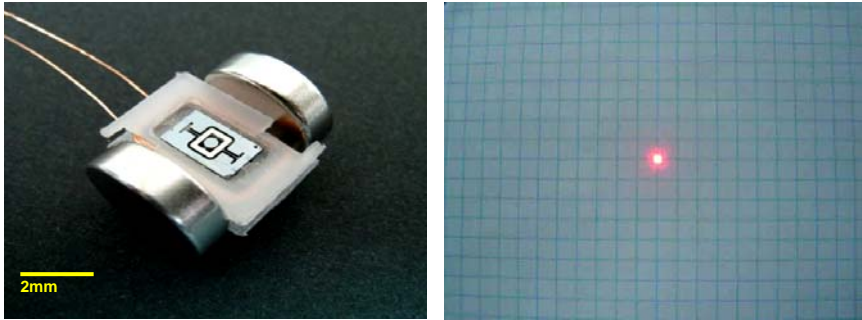
- 微掃瞄器



H. Yang, and W. Fang, *IEEE MEMS'06*, Istanbul, Turkey, 2006



• Scanning images



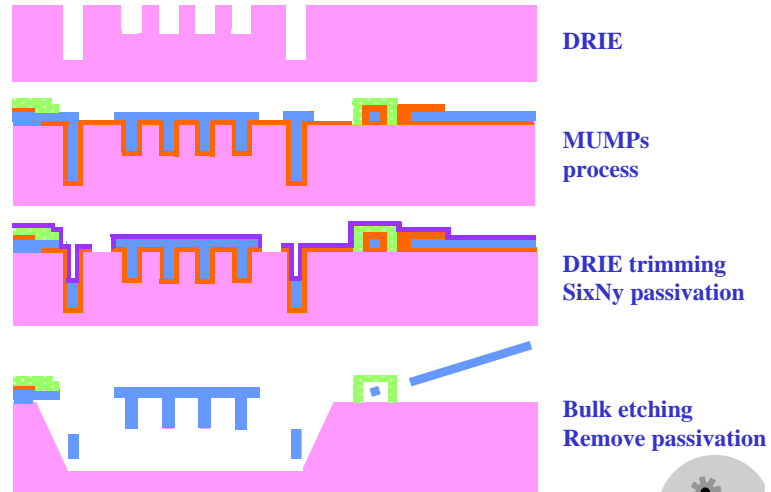
Yang, and Fang, *JMEMS*, 2007



製程平台 - 標準製程



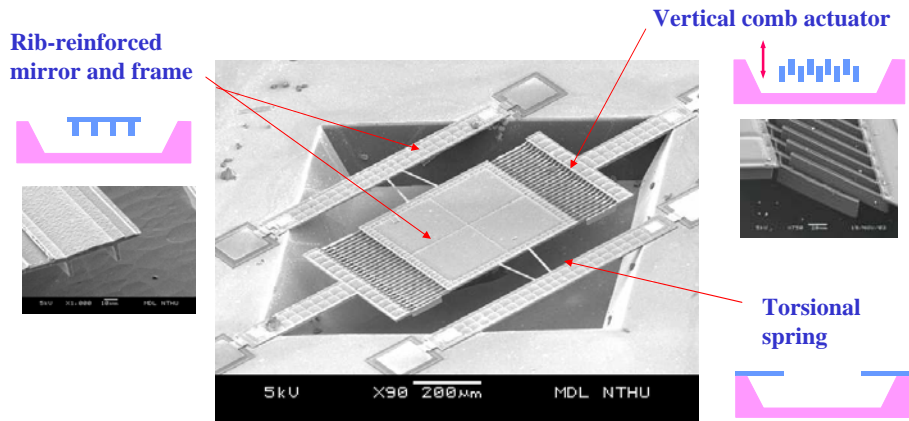
製程平台



M. Wu, C. Lai, and W. Fang, *IEEE MEMS'04*, the Netherlands, 2004



單軸式微光掃瞄器



M. Wu, and W. Fang, *IEEE MEMS*, Maastricht, the Netherlands, 2004



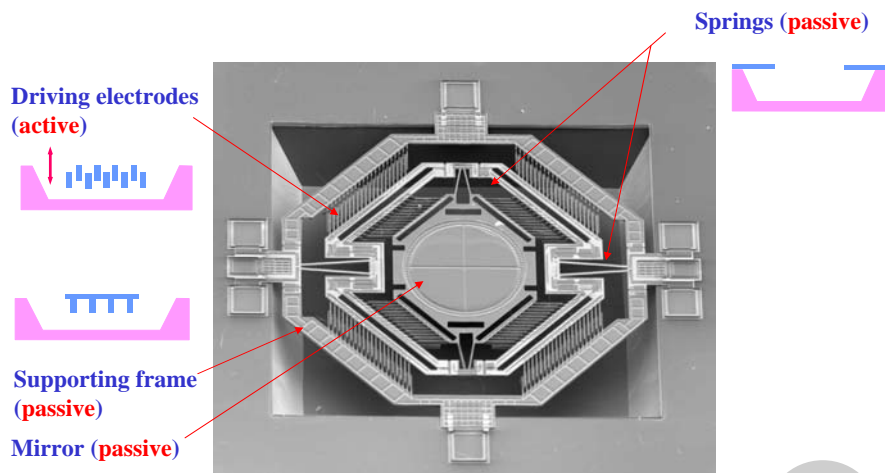
條碼器



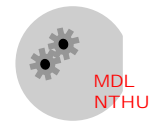
Flic



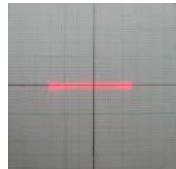
雙軸式微光掃描器



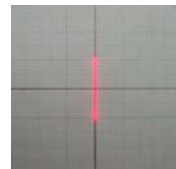
M. Wu, C. Lai, and W. Fang, *IEEE MEMS'04*, the Netherlands, 2004



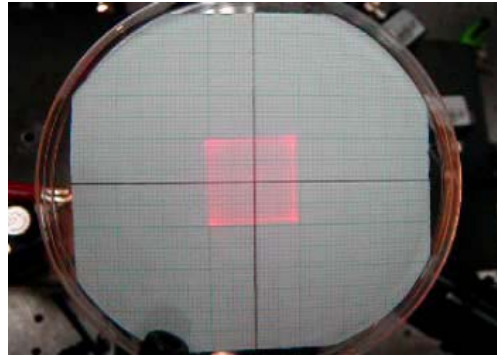
- Scanning images



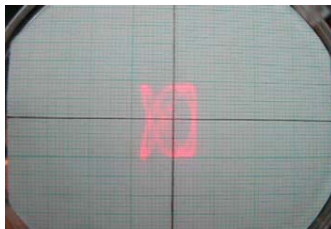
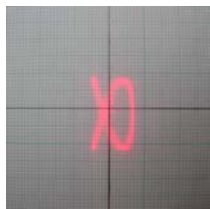
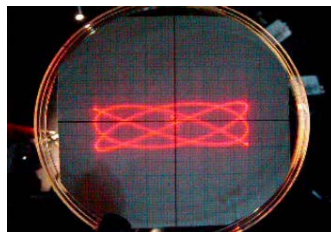
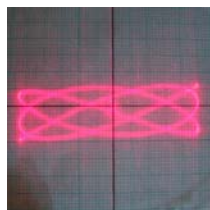
Inner axis: 4.1kHz



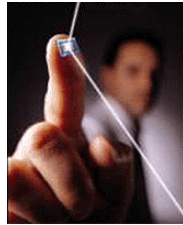
Outer axis: 7.1kHz



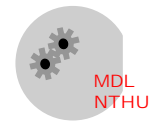
- Scanning images



掃描式投影機



Microvision Inc. 2000

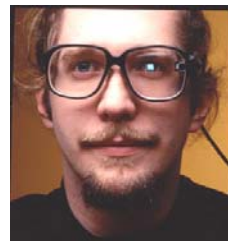


頭戴式顯示器

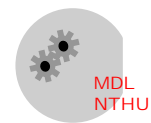
Olympus



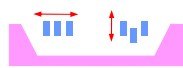
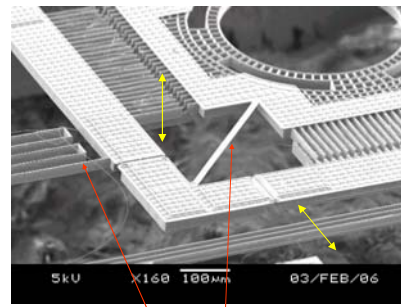
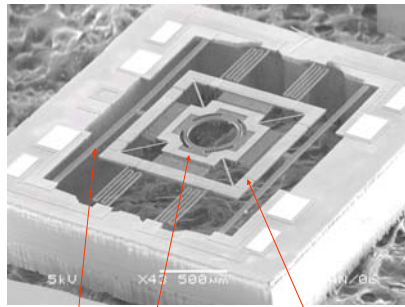
Micro
Optical



HP



微光聚焦定位器



In-plane and out-of-plane actuators

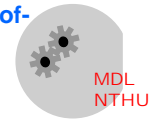


Stiff supporting frame

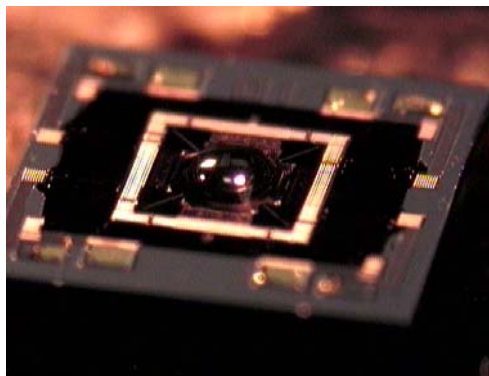


In-plane and out-of-plane springs

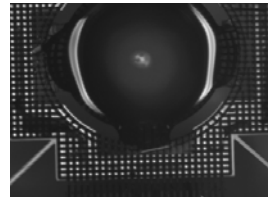
M. Wu, and W. Fang, *JMM*, 2006



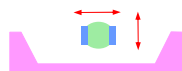
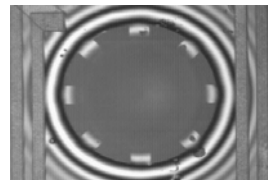
• Polymer lens and Driving test



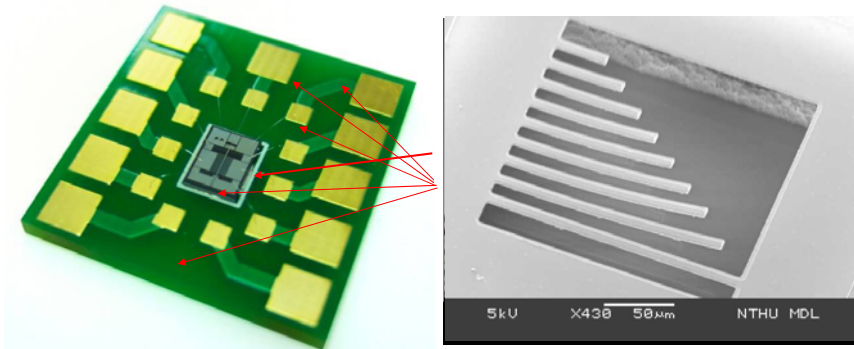
Tracking



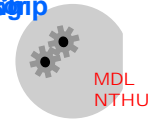
Focusing



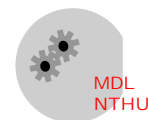
-
- Process integration - Micro test chip (SOI process)



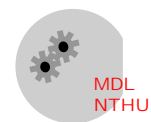
Chip Packaging Strip



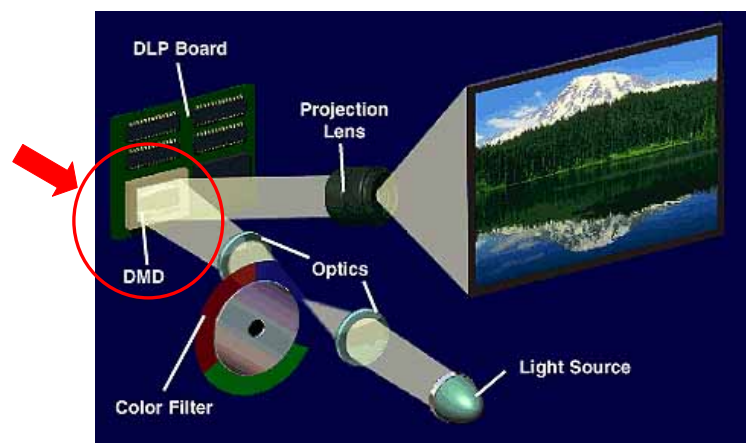
奈微系統的特色與應用



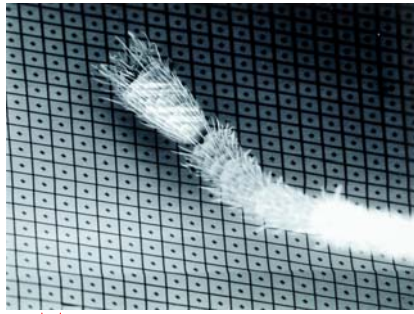
-
- **Miniaturization (縮小)** - length scale
 - **Distribution (分布)** - array, multi function
 - **Integration (整合)** - mechanical and electrical
 - **Motion (運動)** - moving parts and media
-



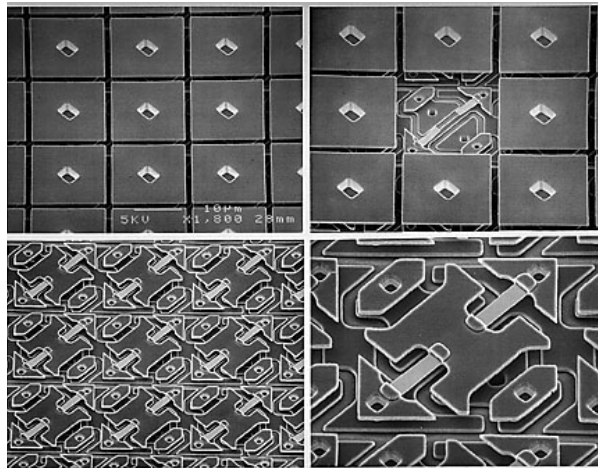
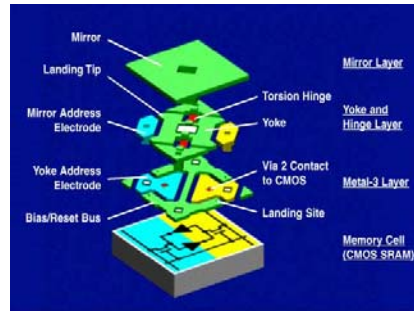
實例 - DLP Projector, TI

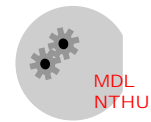
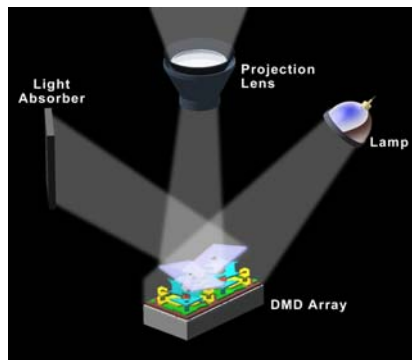
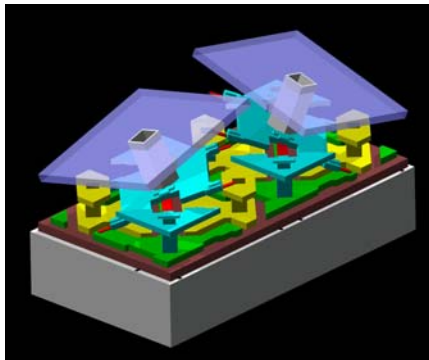


-
- 縮小/分布/整合/運動



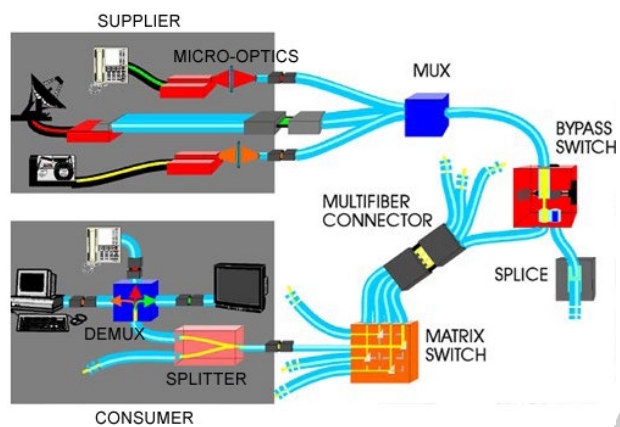
~15 μm





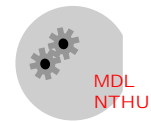
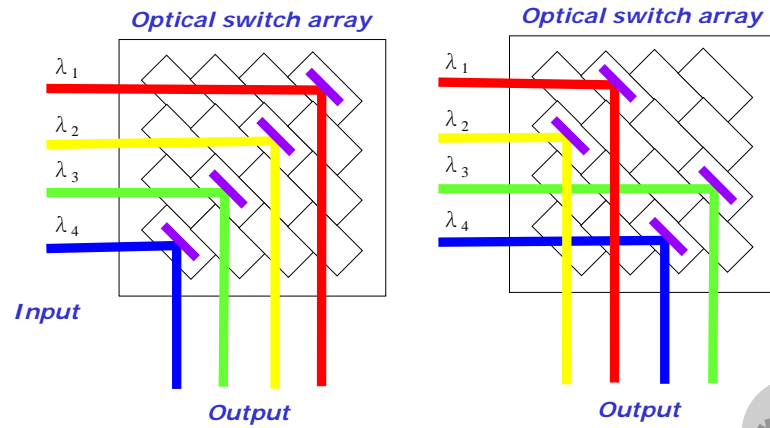
光纖通訊

Optical fiber communication



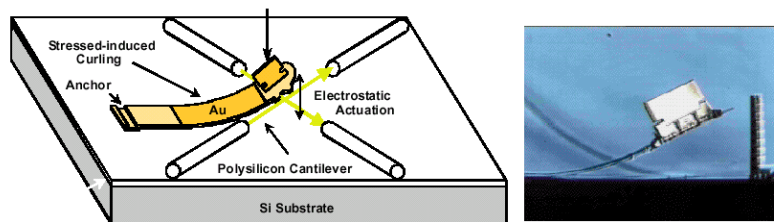
光纖通訊

- 微光開關原理



光纖通訊

- 微光開關原理

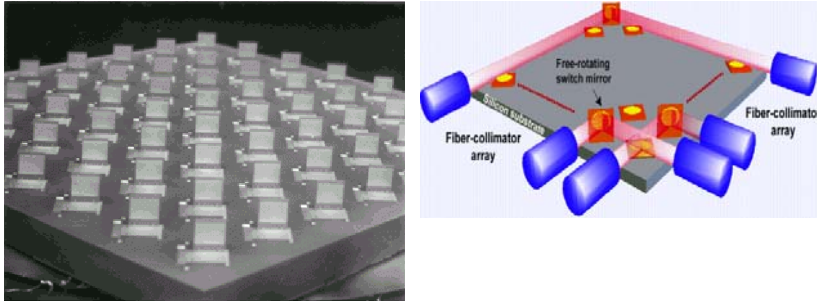


R. Chen, H. Nguyen, M.C. Wu, *IEEE MEMS Conference*, 1999



光纖通訊

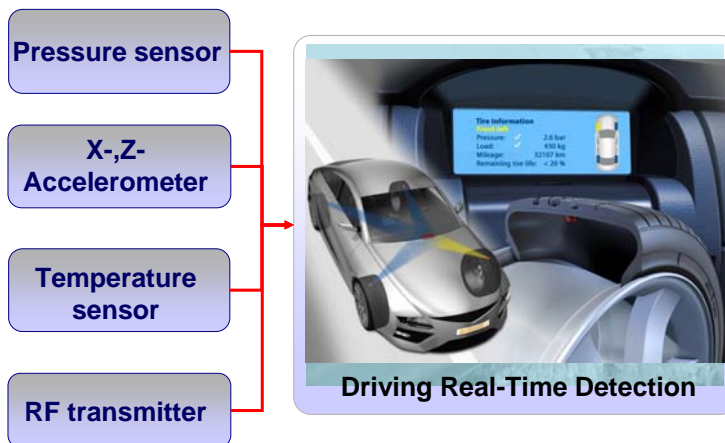
- 微光開關陣列



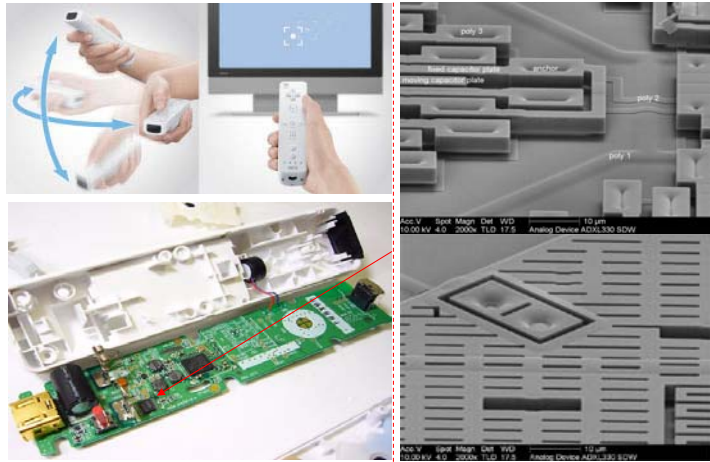
OMM



車用電子 - (TPMS)

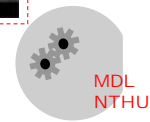


消費性電子 - Wii



Wii-Remote

MEMS accelerometer



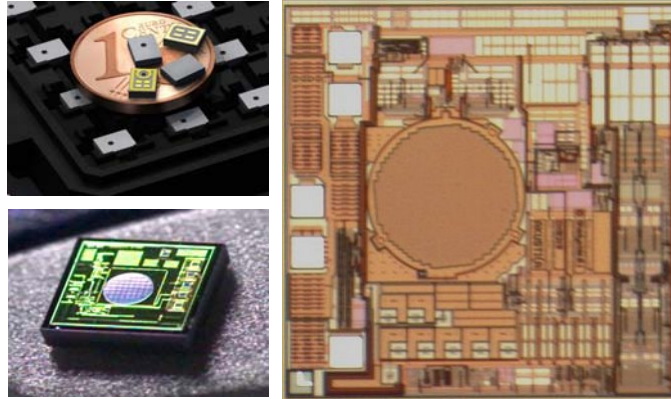
消費性電子 - iPod Touch



Movements control the action using MEMS accelerometer



消費性電子 - Microphone



“Small”, “Easy integration”, MEMS Microphone



生醫電子 - Fitbit tracker



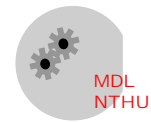
A 3-axis accelerometer to sense user movement for Health Care application



生醫電子 - Blood pressure sensor

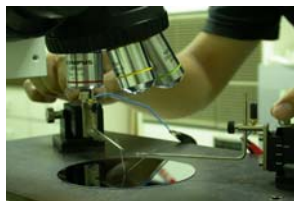


Pressure sensor for Health Care



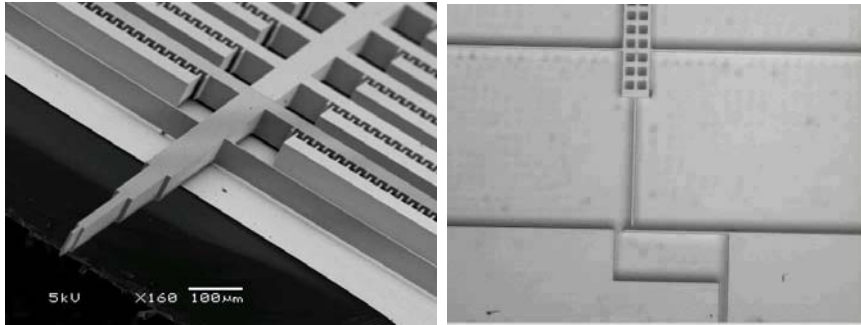
巨觀與奈米世界的介面

- Macro world (m/cm) → MEMS (mm/μm)
→ Micro/Nano world (μm/nm)



巨觀與奈米世界的介面

- 微奈米結構測試

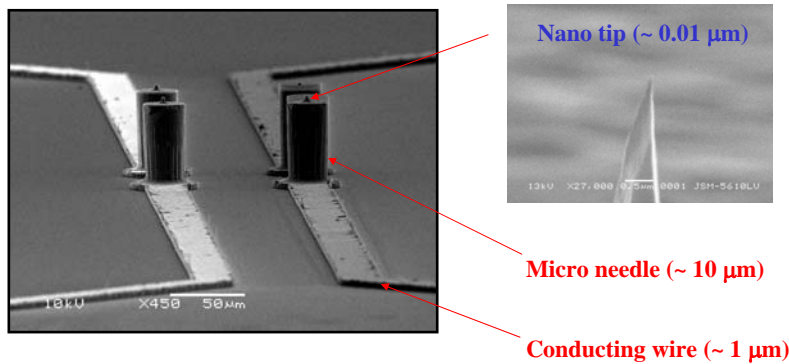


C. Chang, H.-Y. Chu, and W. Fang, 2004



巨觀與奈米世界的介面

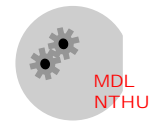
- 腦神經探針



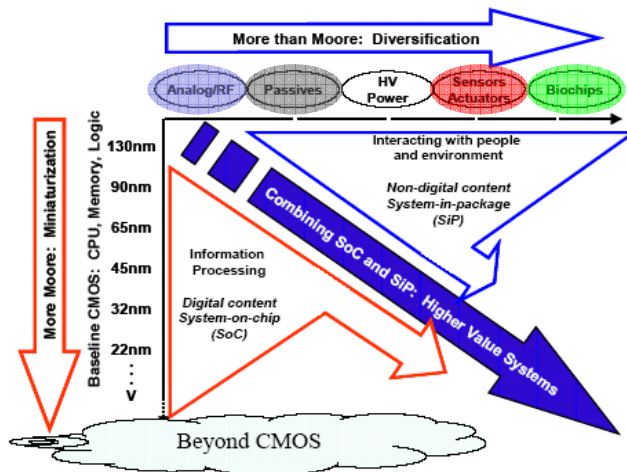
T.-Y. Kuo, H.-Y. Chu, B. Chang, and W. Fang, APCOT'04, Japan, 2004



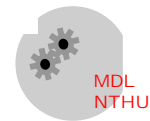
結論



Moore's Law and More than Moore

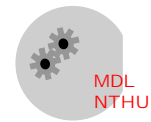
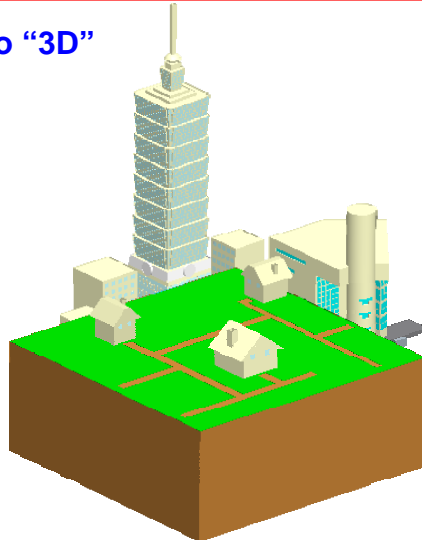


ITRS Roadmap 2005, www.itrs.net



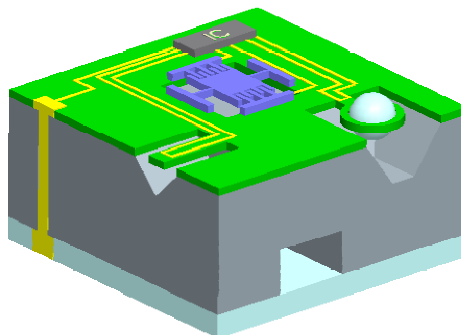
Architectures in the city

- From “2D” to “3D”

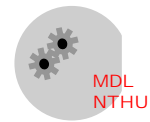


Architectures on the chip

- From “2D” to “3D”

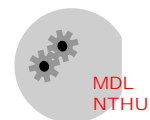


What's the primary applications for IC at 1960'



Hearing aid !!

- **1956 Nobel prize : Shockley, Brandon, and Bardin**



-
- 2000 Nobel prize : Kilby

透過 **IC** 的發明為 **Information technology** 奠立基礎

- Vacuum tube to Transistor to IC ...to N/MEMS...

這不只是一種**技術演進**的過程，更重要的是，
它，改變了一個**文明**

