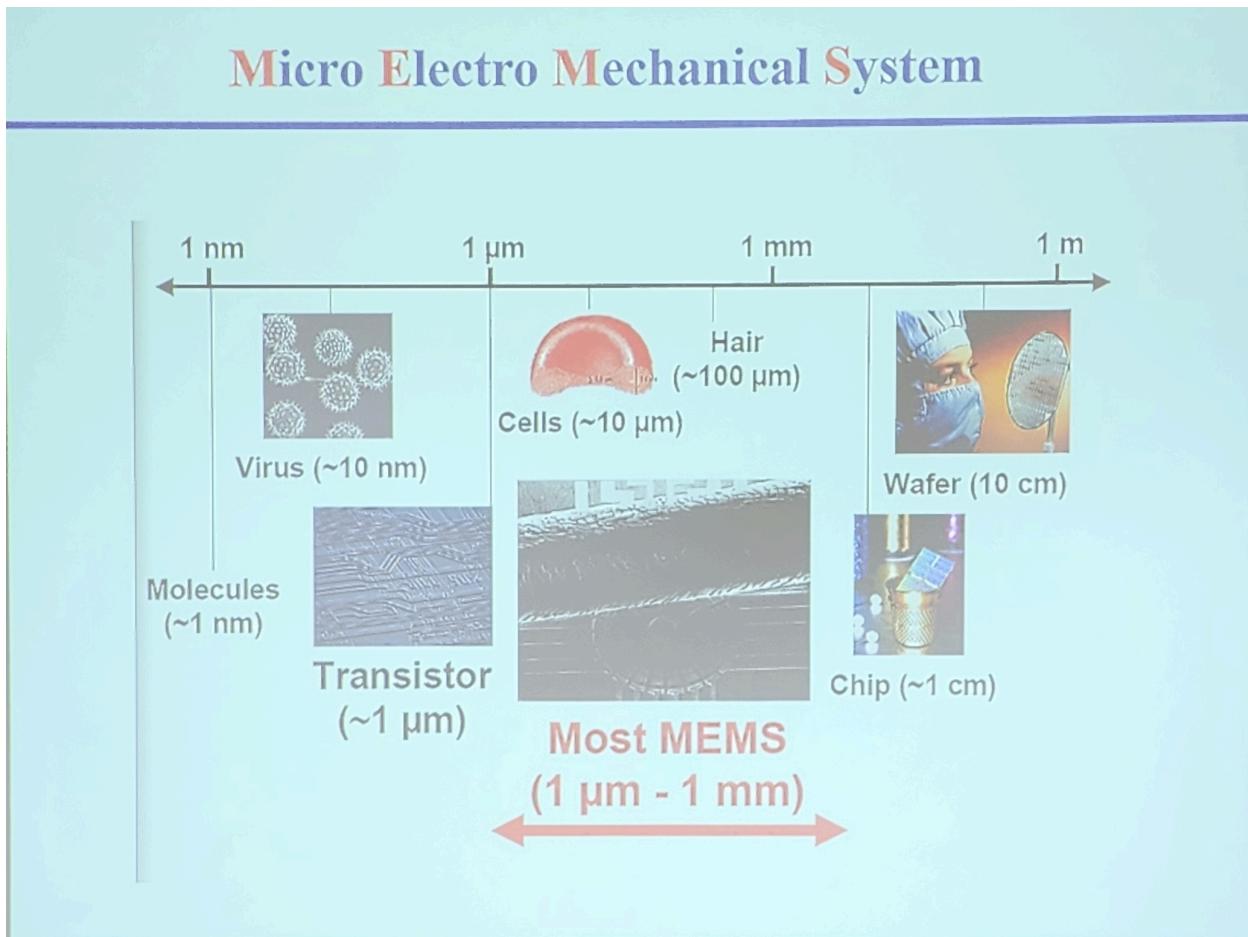


# 奈微機電系統技術及應用

日期：2025/9/30

講者：戴慶良

## Micro Electro Mechanical System



## Fabrication



跟半導體一樣

# Surface Micromachining

1. deposition

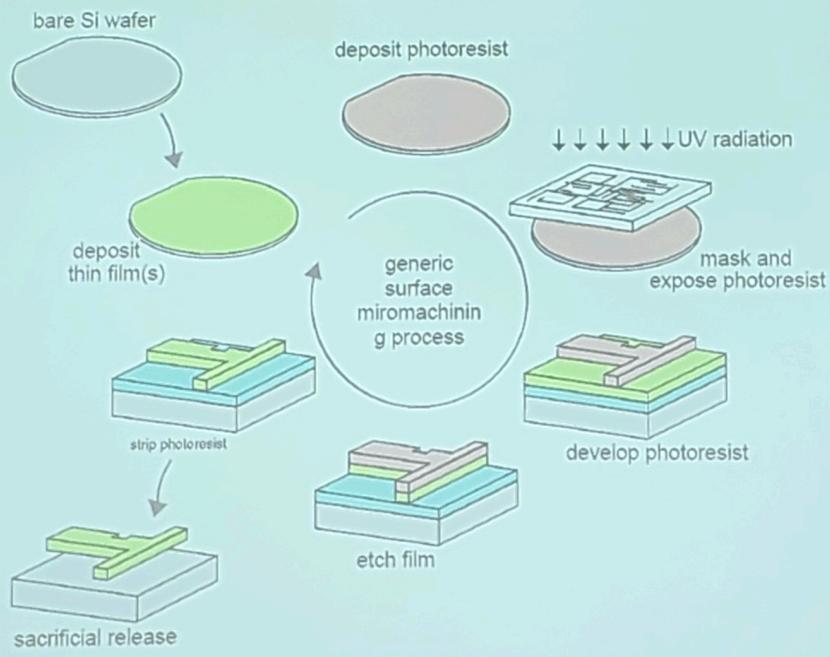
2. lithography 光刻

3. etching 蝕刻

4. sacrificial release

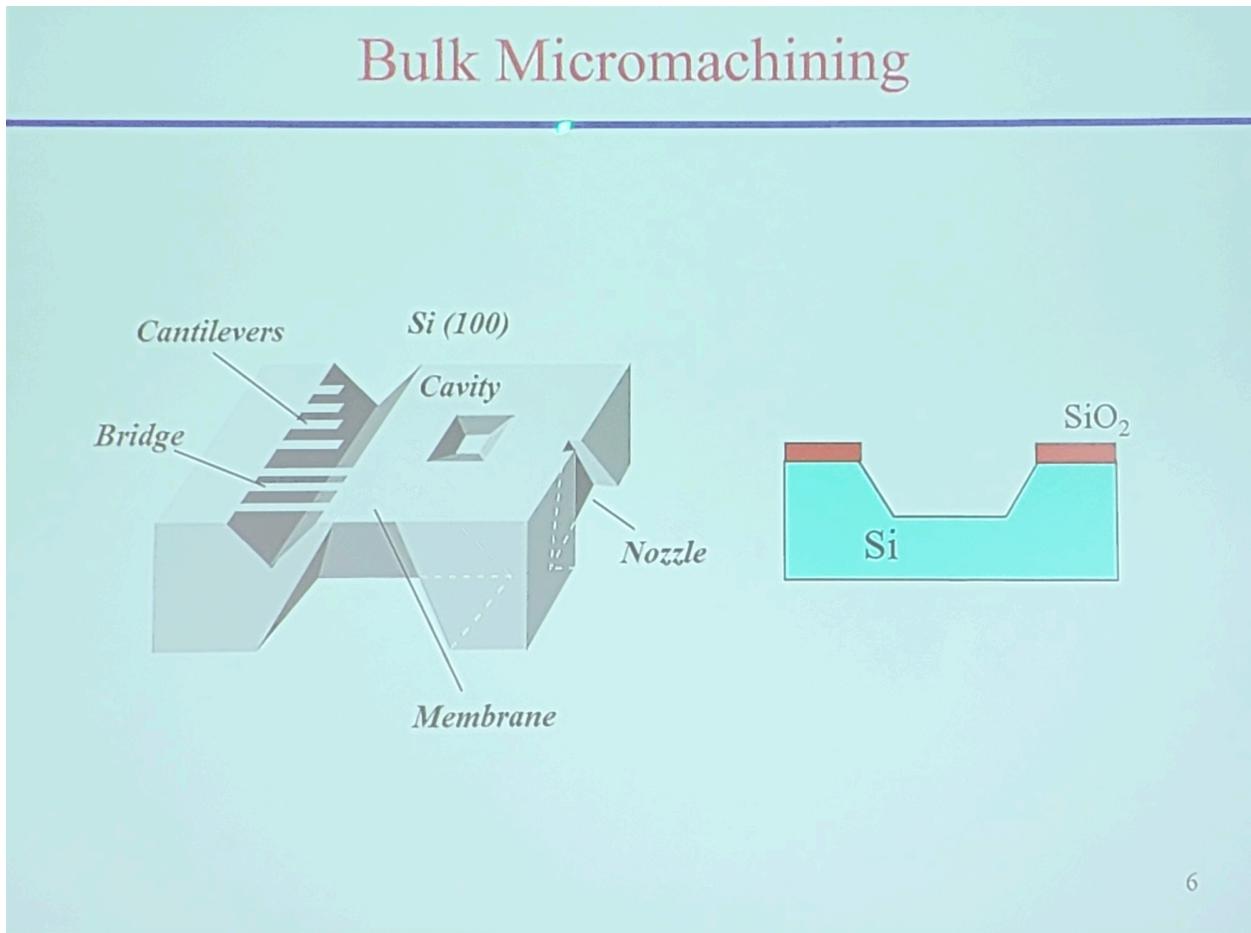
- 元件可動

## Surface Micromachining: deposition, lithography, etching + sacrificial release



# Bulk Micromachining

- 微機械結構
- 會蝕刻到矽晶材

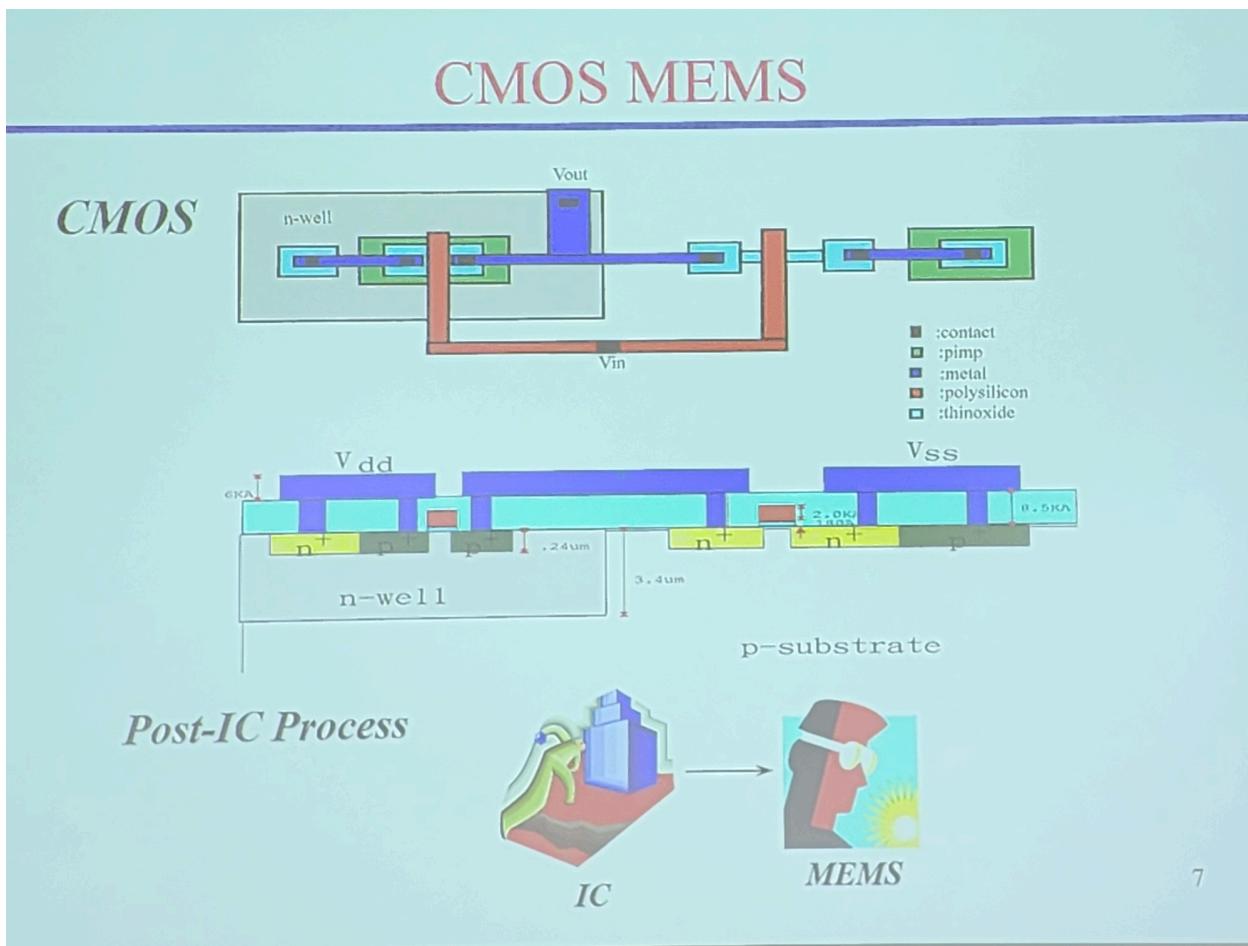


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# CMOS MEMS

- 半導體場加工 → 自行處理 p-substrate

# CMOS MEMS

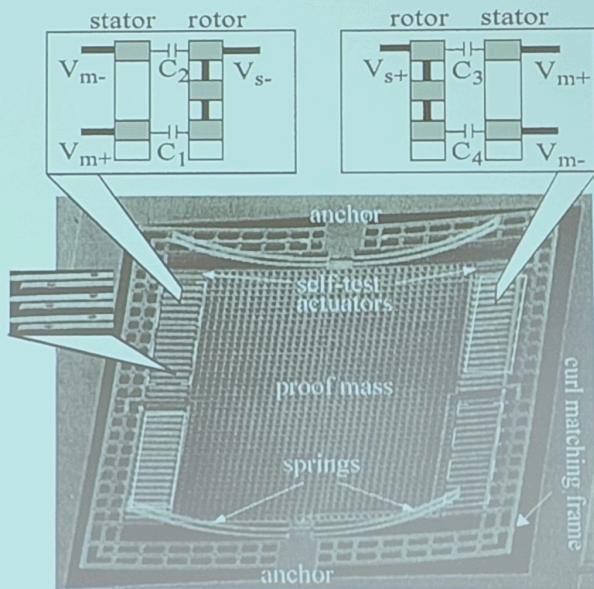
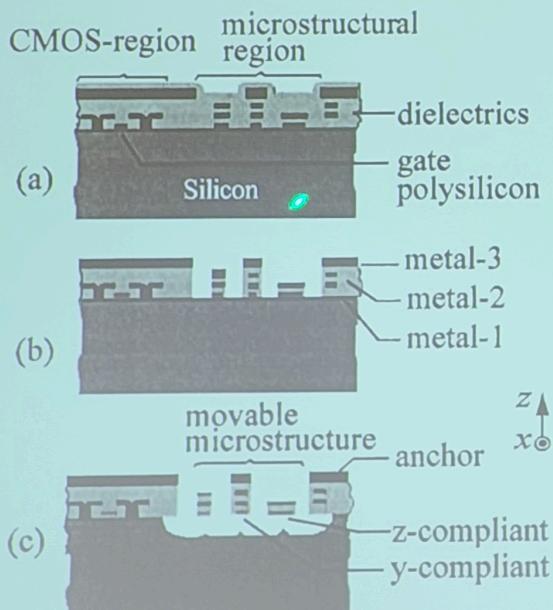


## 元件結構

### Accelerometer

- a 半導體場做
- b 反應離子蝕刻技術
- c 自己泡藥水

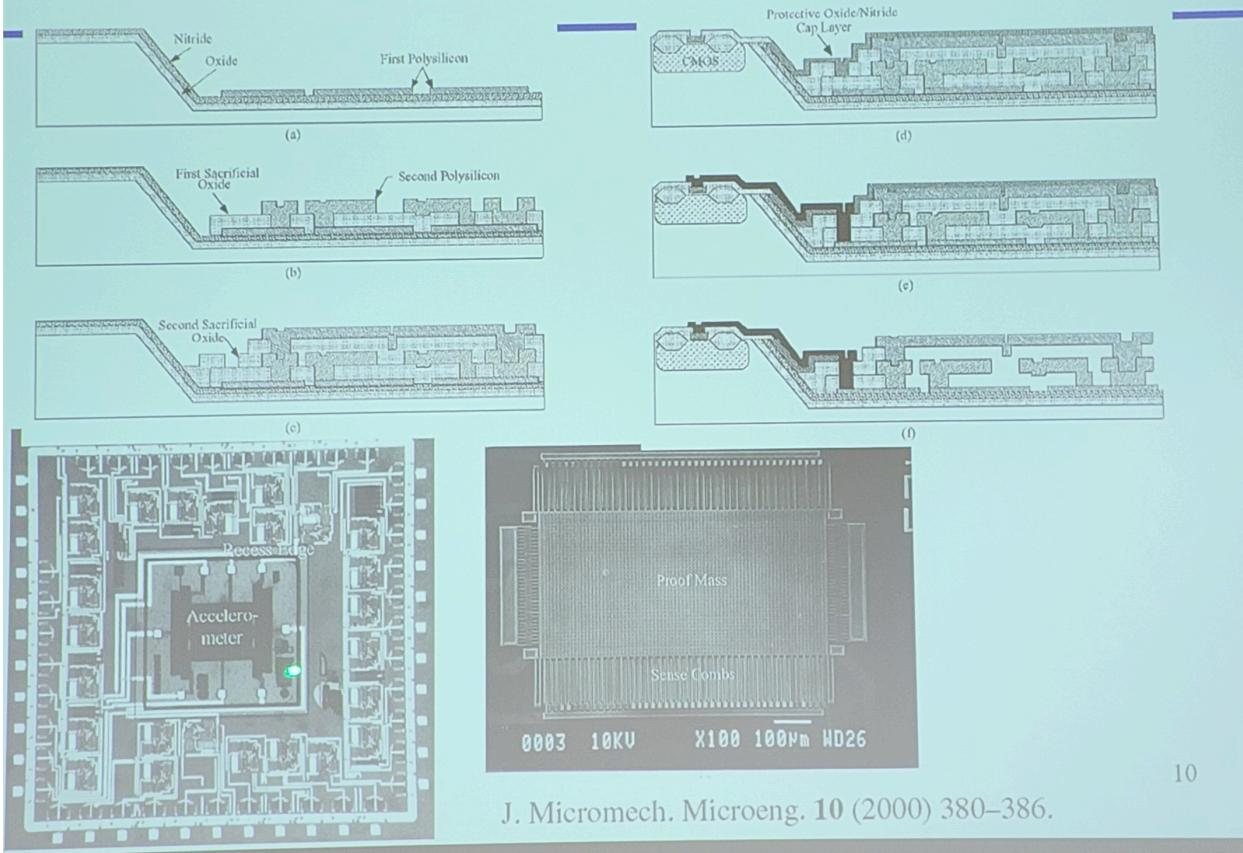
# Accelerometer



Sensors and Actuators A 95 (2002) 212–221

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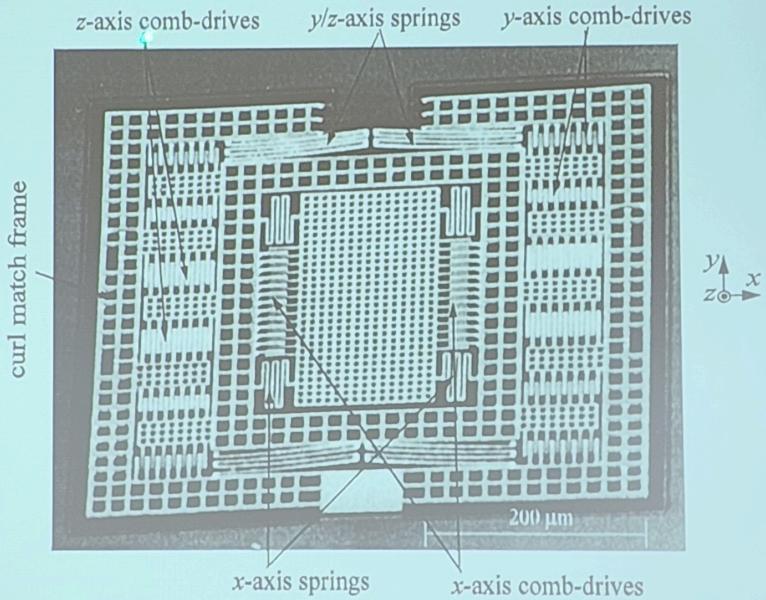
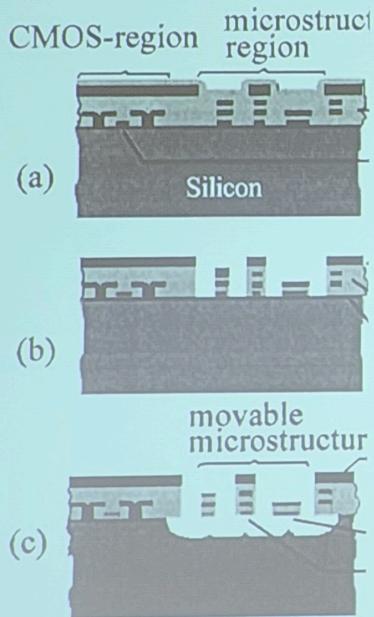
## Accelerometer with circuits



## Microstage

- 可以微移動的平台

## Microstage



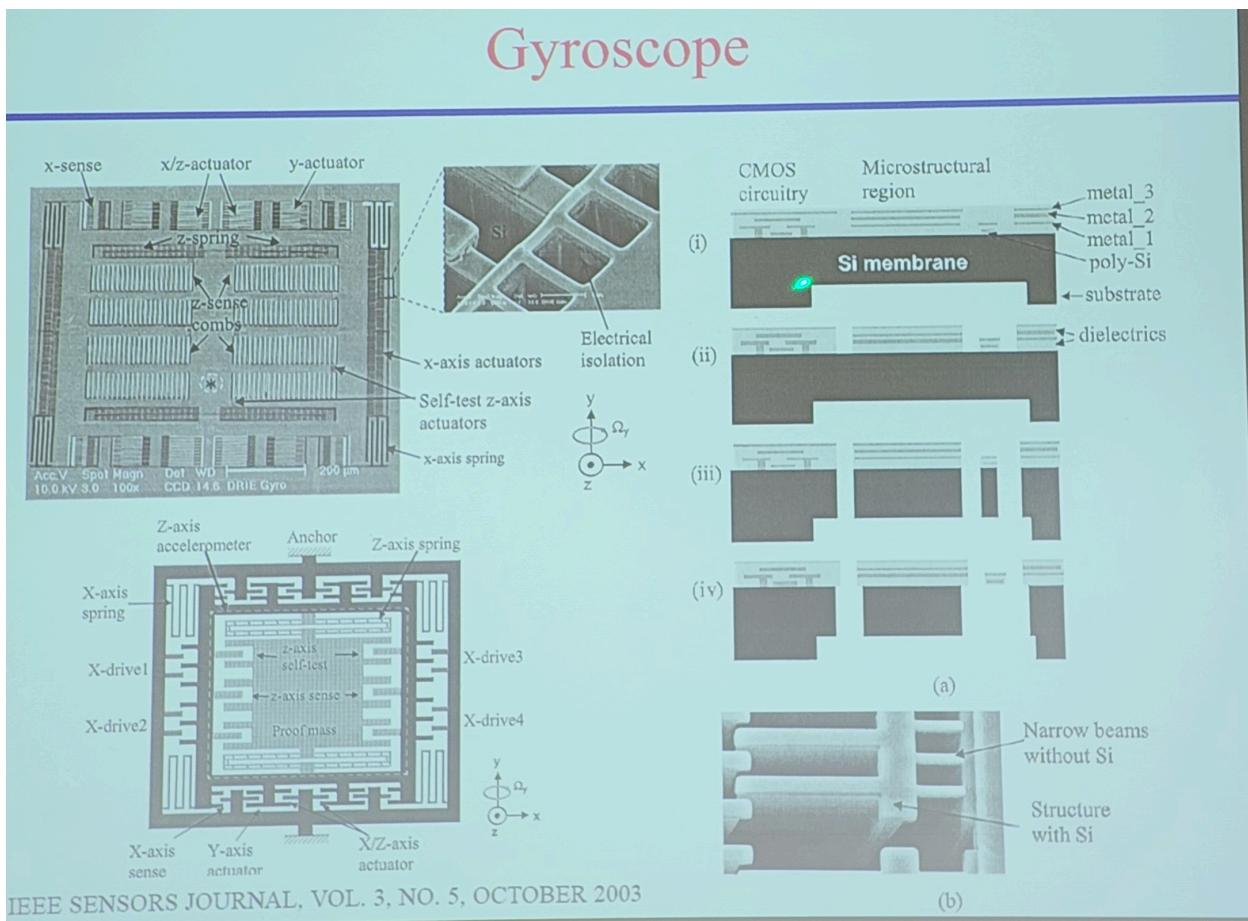
Sensors and Actuators A 95 (2002) 212–221

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## Gyroscope

- 需要一個重一點的質量塊

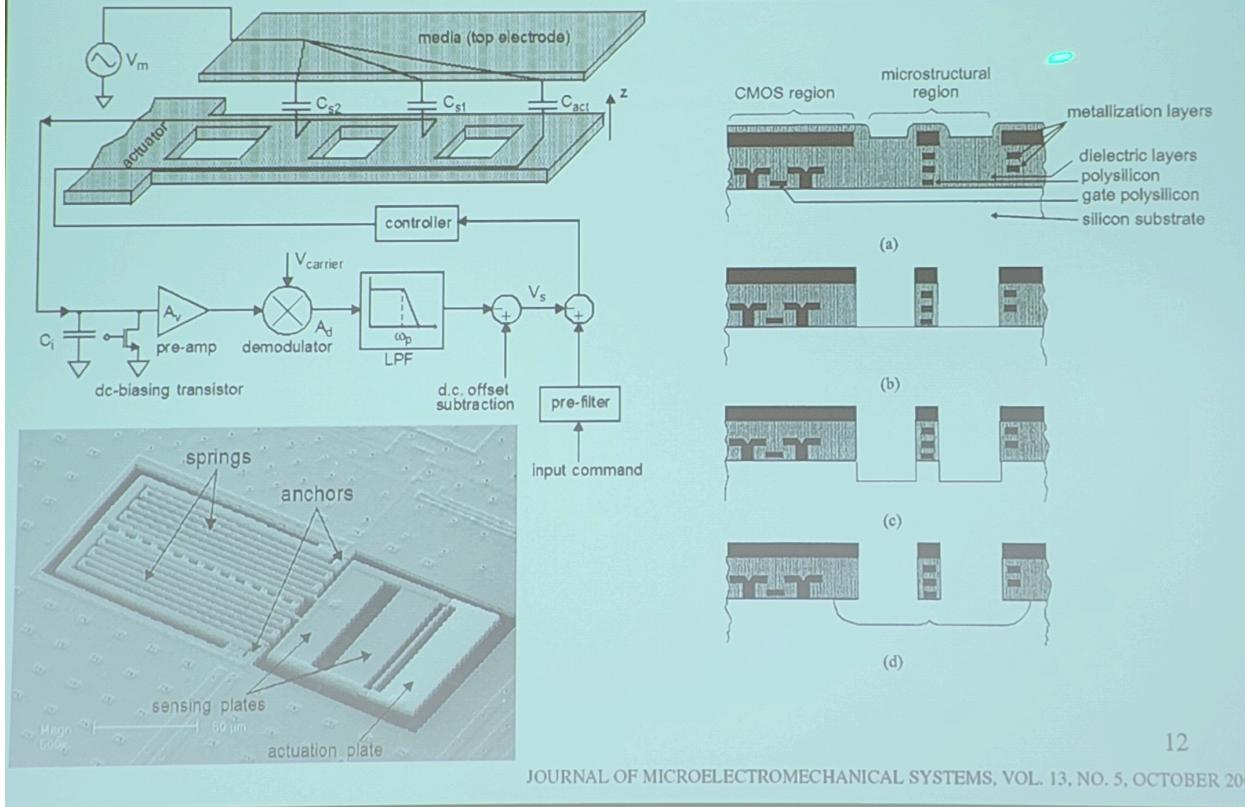
# Gyroscope



## Probe-based data storage

- 磁碟機用的

## Probe-based data storage



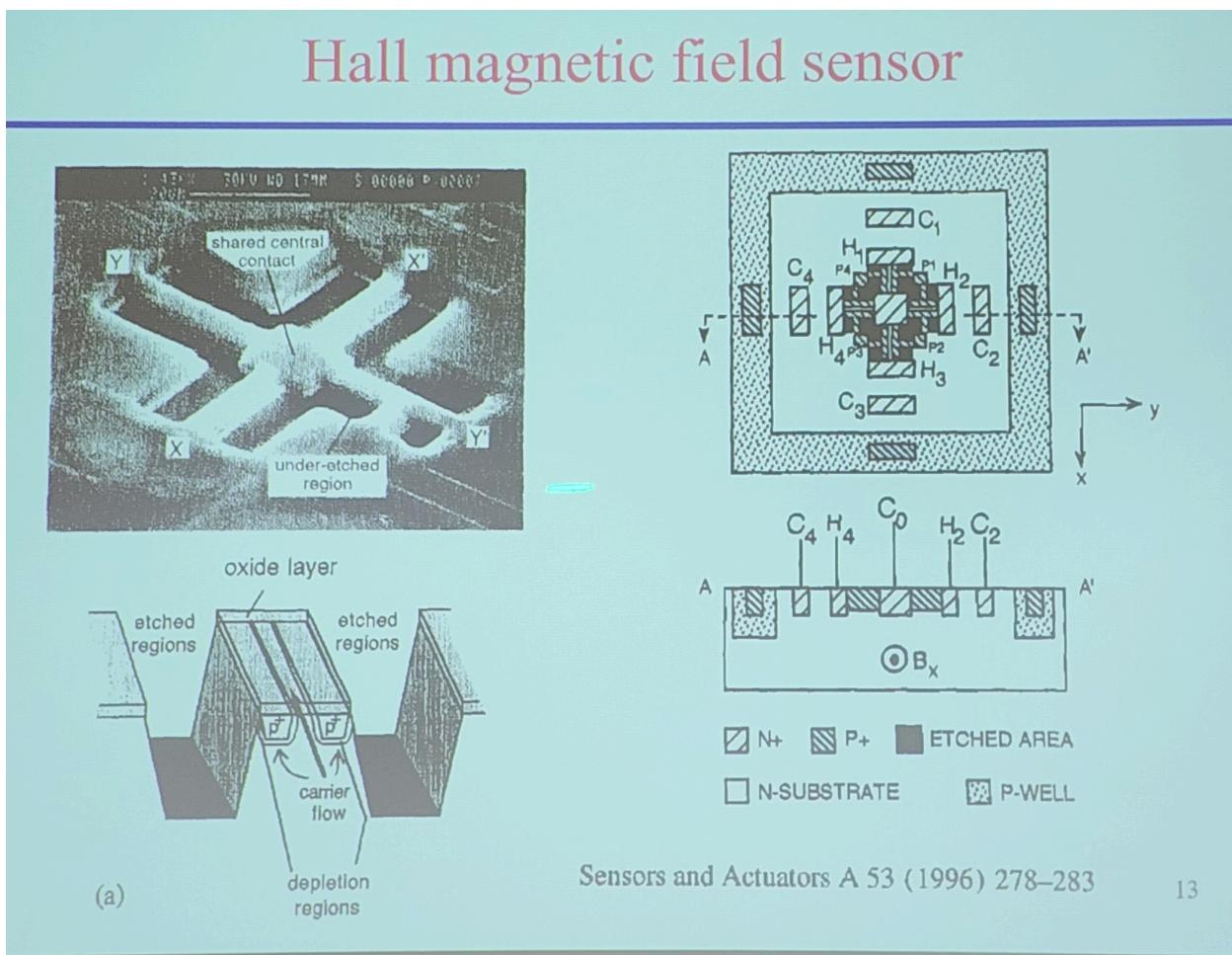
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JOURNAL OF MICROELECTROMECHANICAL SYSTEMS, VOL. 13, NO. 5, OCTOBER 2000

## Hall magnetic field sensor

- 磁場感應器

## Hall magnetic field sensor



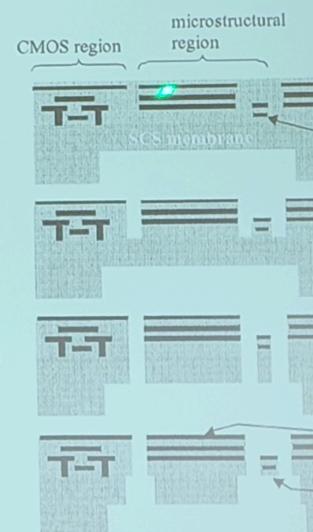
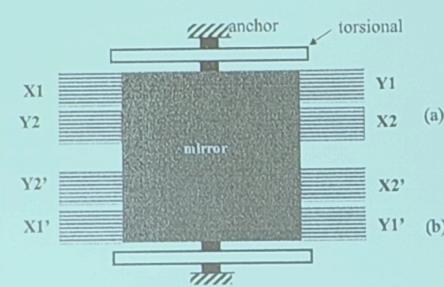
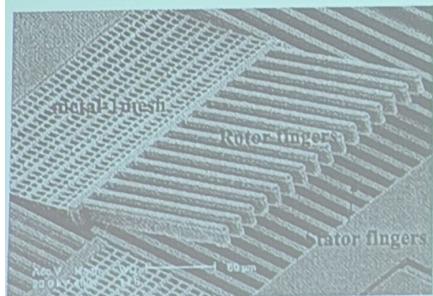
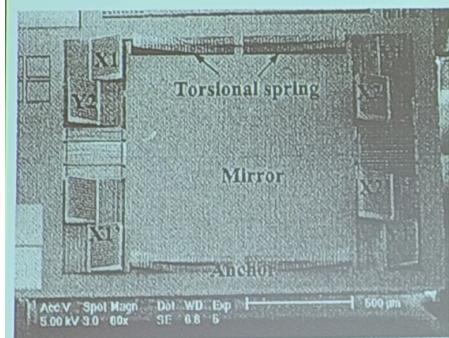
Sensors and Actuators A 53 (1996) 278–283

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## Mirror with comb drives

- 左右擺
- 可以當 scanner 用

## Mirror with comb drives



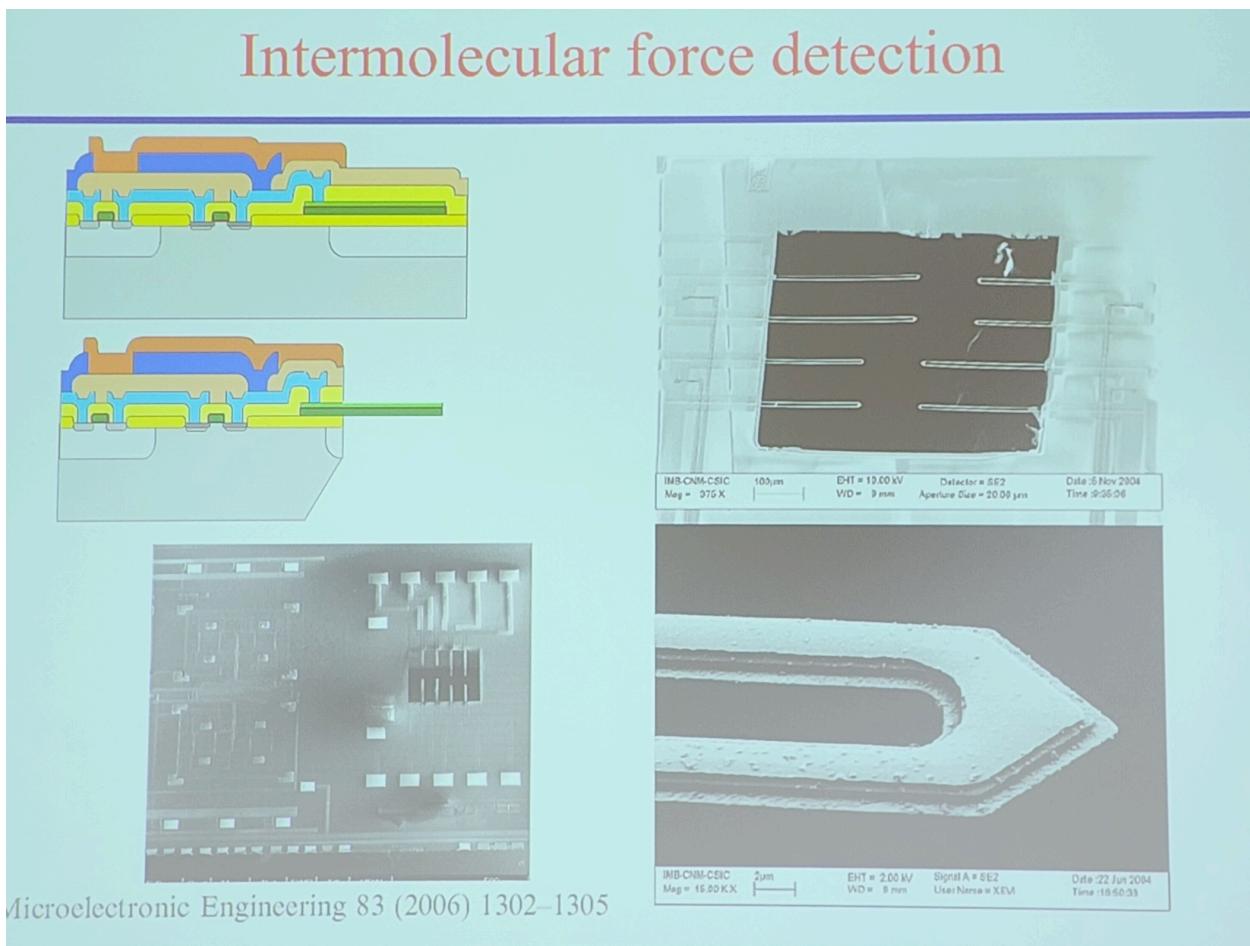
JOURNAL OF MICROELECTROMECHANICAL SYSTEMS, VOL. 12, NO. 4, AUGUST 2003

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## Intermolecular

- 研究腦波探針

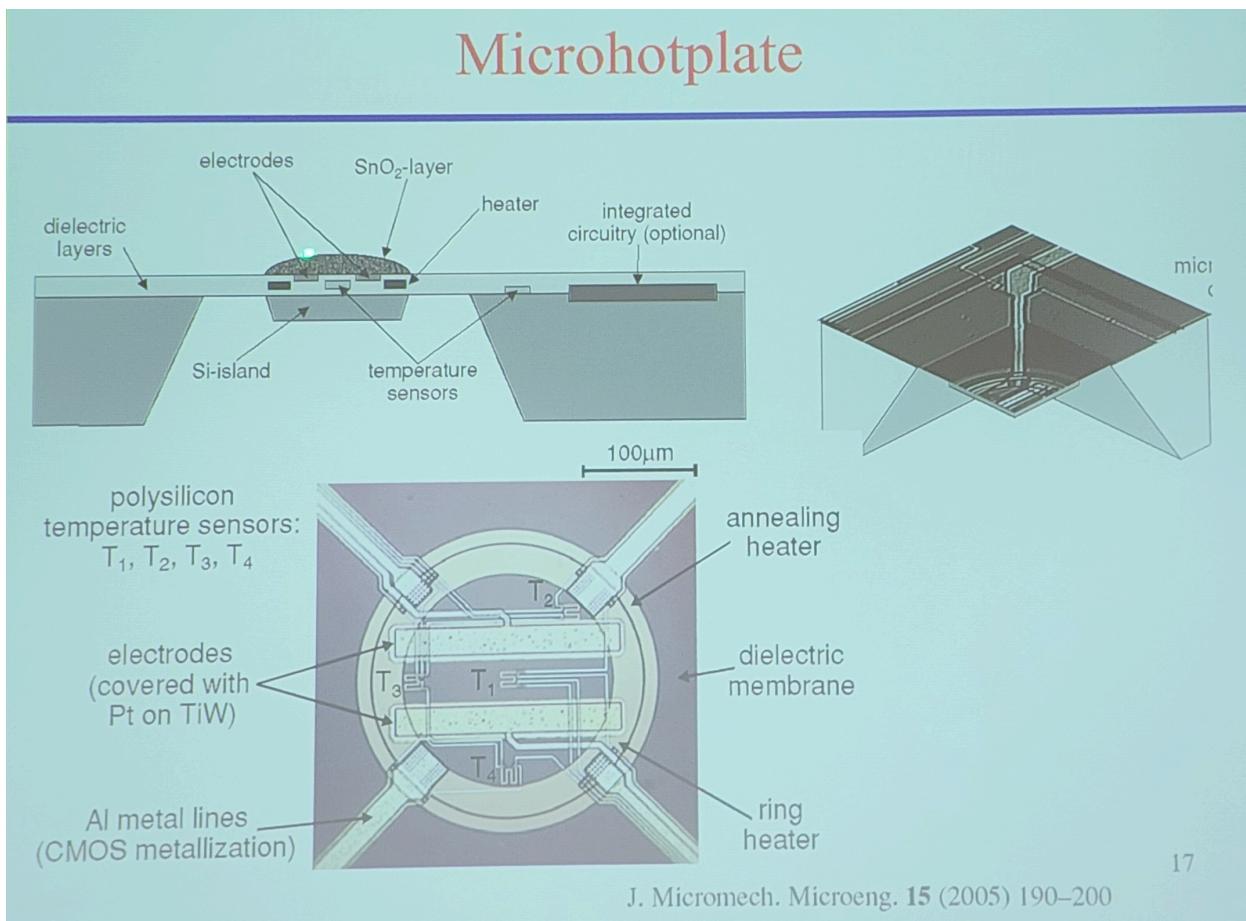
## Intermolecular force detection



## Microhotplate

- 氣體感測器
- 工作溫度300度
  - add a heater
  - 避免熱量散失 → 將矽基材蝕刻 → 元件懸浮

## Microhotplate



## Micro mechanical RF switch

## ■ Why RF MEMS Switches ?

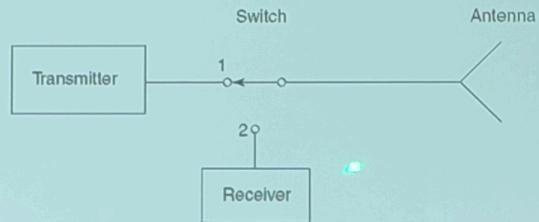
Switch Type	Insertion loss	Isolation	Power handling	Power consumption	Switching speed	Cost
PIN diodes	Good	Good	Good	Poor	Good	Good
GaAs FETs	Good	Good	Poor	Good	Excellent	Poor
MEMS switches	Excellent (0.1~0.6dB)	Excellent (-40~-50dB)	Excellent	Excellent	Poor	Good

Liu, Yu "MEMS and BST technologies for microwave applications",  
PhD UNIVERSITY OF CALIFORNIA, SANTA BARBARA, 2002

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- Insertion → 通
- Isolation → 斷

## ■ Applications of RF MEMS Switch

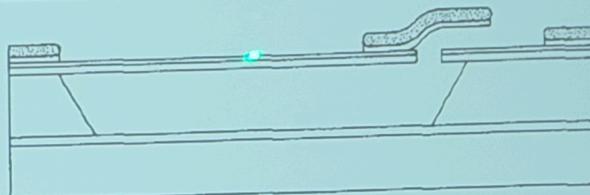


the switch can be used to share an antenna between a transmitter and a receiver

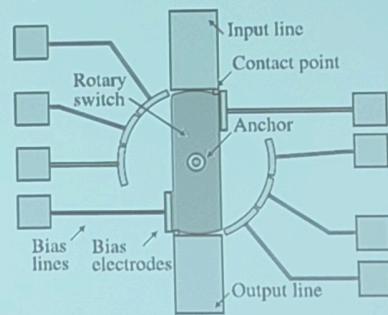
## ■ Electrostatic-type MEMS switches

- Metal contacting
- Capacitive coupling

- 1979, K. E. Petersen et al. (IBM)
  - cantilever beam
  - bulk micro machining
  - ac signal switching arrays
- 1991, L. E. Larson et al.
  - rotary switch, historical
  - In this design, a rotating t-line was fabricated and exhibited less than -0.4 dB insertion loss and an isolation better than -35 dB up to 45 GHz
  - On GaAs substrate



K. E. Petersen, "Micromechanical membrane switches on silicon," IBM J. Res. Develop., vol. 23, no. 4, pp. 376–385, July 1979.



L. E. Larson et al., "Micromachined microwave actuator (MIMAC) technology—a new tuning approach for microwave integrated circuits," in IEEE Microwave and Millimeter-Wave Monolithic Circuits Symposium Digest, Boston, MA, June 1991, pp. 27~30.

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- 通電產生靜電力 → 被吸引
- 壽命短
  - 接觸面氧化
    - 除非鍍金

→ 改為旋轉式

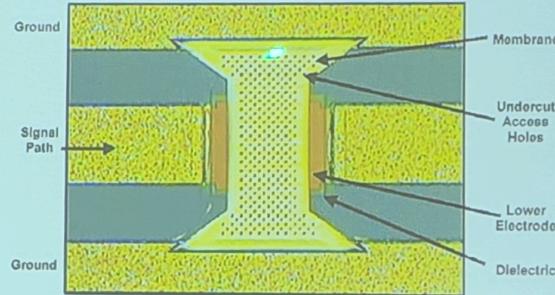


大部分 switch 為 電容式的

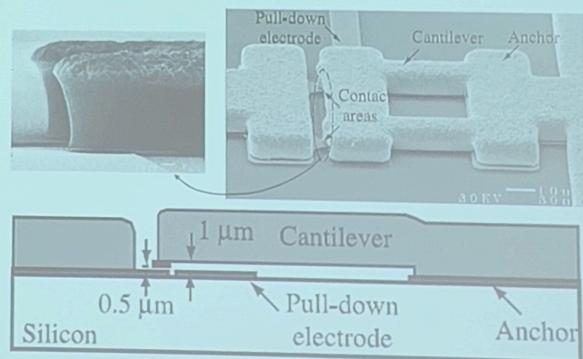
## Micro tunable resonator 可調式共振器

- 可以當濾波器使用

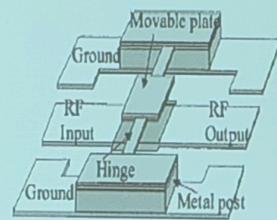
- 1996, C. Goldsmith et al.  
(Texas Instruments, Raytheon)
  - capacitive coupling
  - low loss(<0.25 dB at 35 GHz)
  - good isolation (35 dB at 35 GHz)
  - On High-resistivity silicon substrates
- 1999, P. M. Zavracky et al.  
(Analog Devices)
  - DC-contact MEMS inline series switch on silicon substrates
  - pull-down voltage of 60-80V
  - suitable for DC to 1000-MHz applications and can pass up to 1 A of current



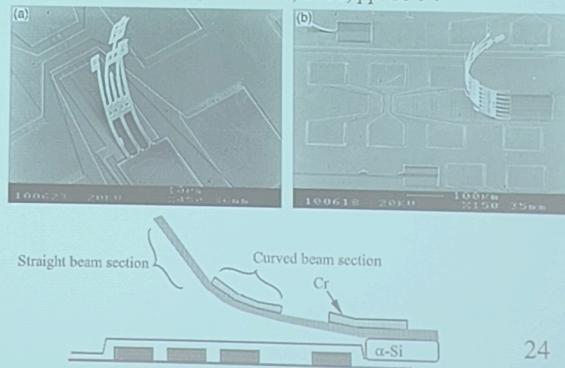
C.L. Goldsmith, et al., "Performance of Low-Loss RF MEMS Capacitive Switches" Microwave and Guided Wave Letters, IEEE, Volume: 8 , Issue: 8 , Aug. 1998 Pages:269 - 271



- 2000, J. Y. Park (LG-Korea)
  - strontium titanate oxide ( $\text{SrTiO}_3$ ) with high dielectric constant
  - insertion loss of 0.08 dB at 10 GHz
  - isolation of 42 dB at 5 GHz
  - On GaAs substrate
- 2000, C. Chang et al. (NTU)
  - $0.5 \mu\text{m}$  thick evaporated aluminum cantilever which is covered in part by a  $0.1 \mu\text{m}$  thick evaporated Cr layer
  - curls up due to the residual stress difference between the Al and the Cr layers
  - The actuation voltage is 26-30 V
  - On GaAs substrate



Park, Jae et al., "Monolithically integrated micromachined RF MEMS capacitive switches" Sensors and Actuators A: Physical Volume: 89, Issue: 1-2, March 20, 2001, pp. 88-94



- Why micromechanical resonator ?
  - High performance transducer
  - Cost low
  - Easy integrate with light , electricity , heat and magnet on a chip
  - Good stability at temperature and ageing
- Application :
  - Wireless communication system

