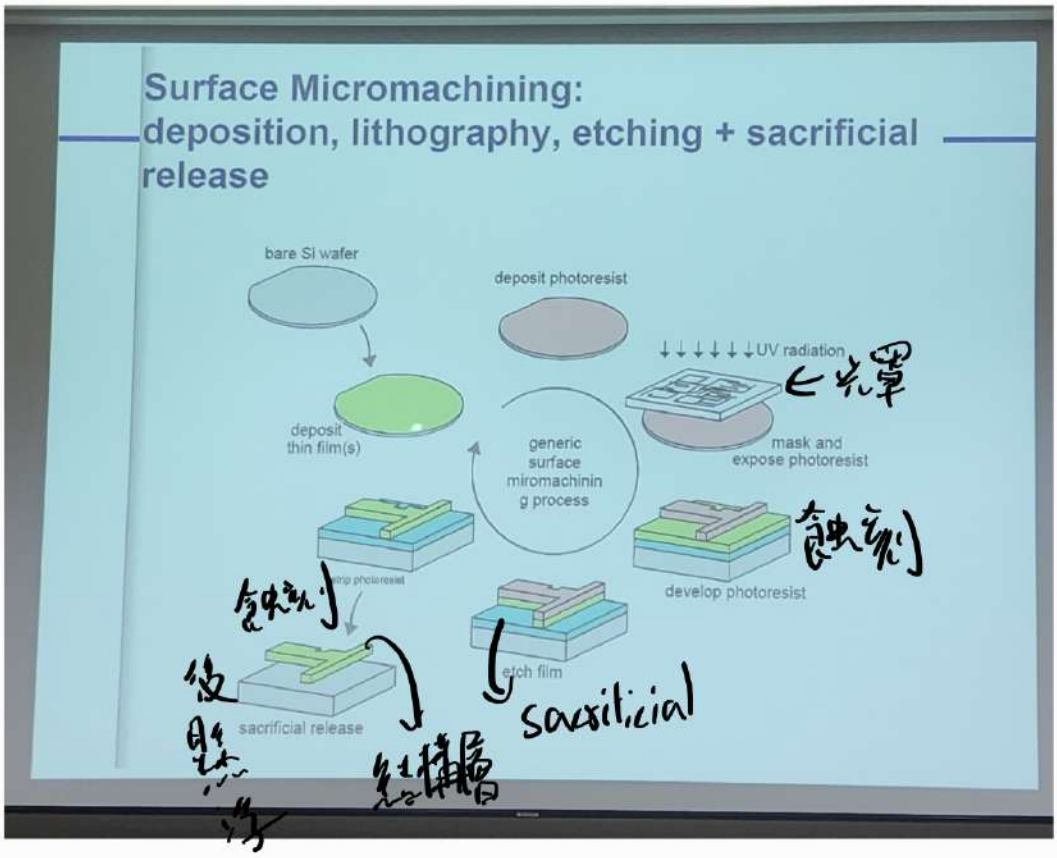
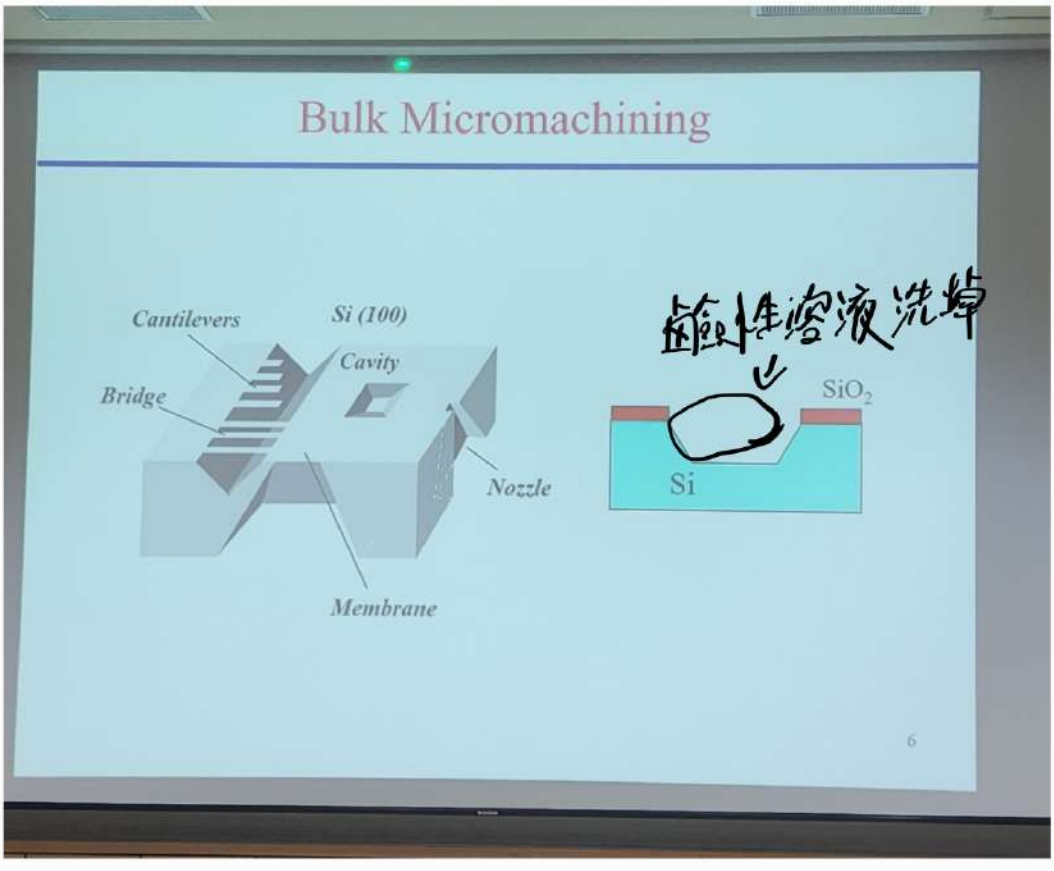
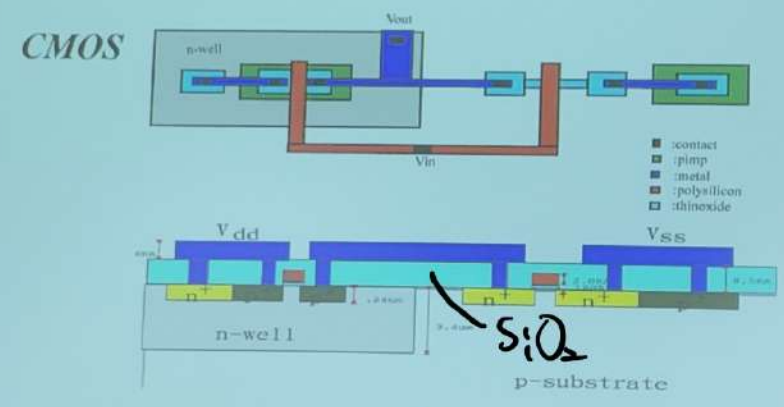
日期:2025/9/30　　講者:戴慶良

題目:奈微機電系統技術及應用

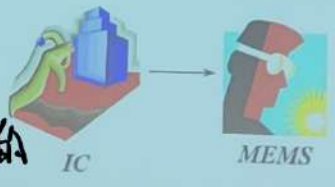




CMOS MEMS



Post-IC Process



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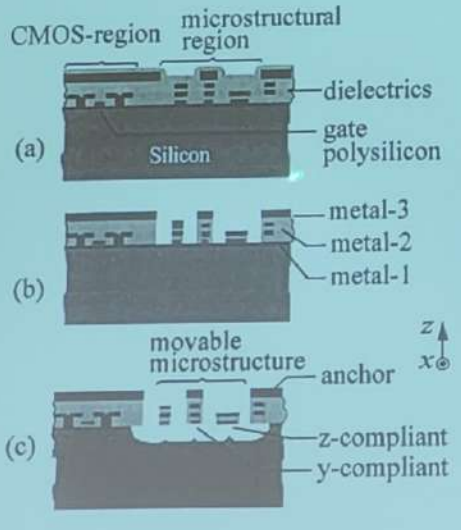
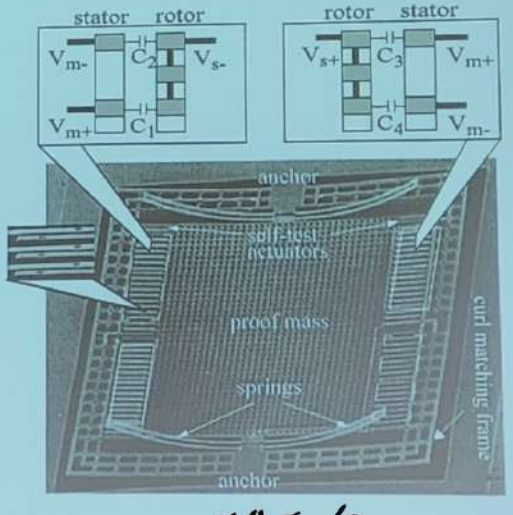
整合的概念
節省成本
降低干擾

Accelerometer





電容

Sensors and Actuators A 95 (2002) 212–221

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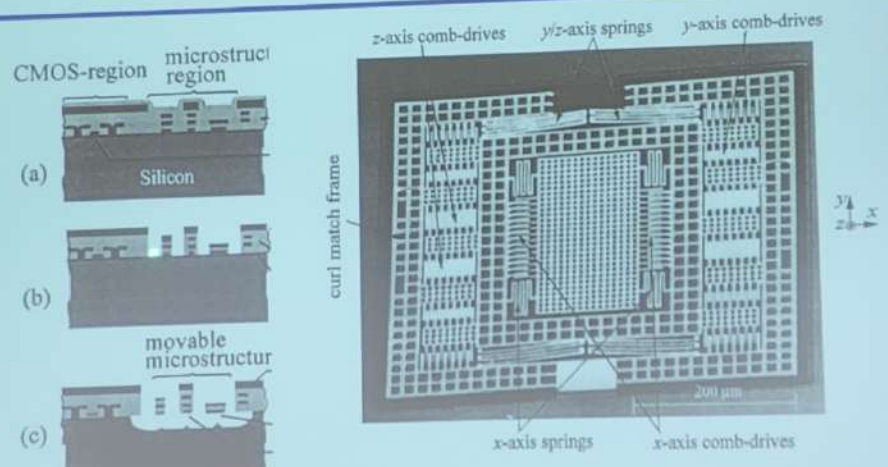
Microstage



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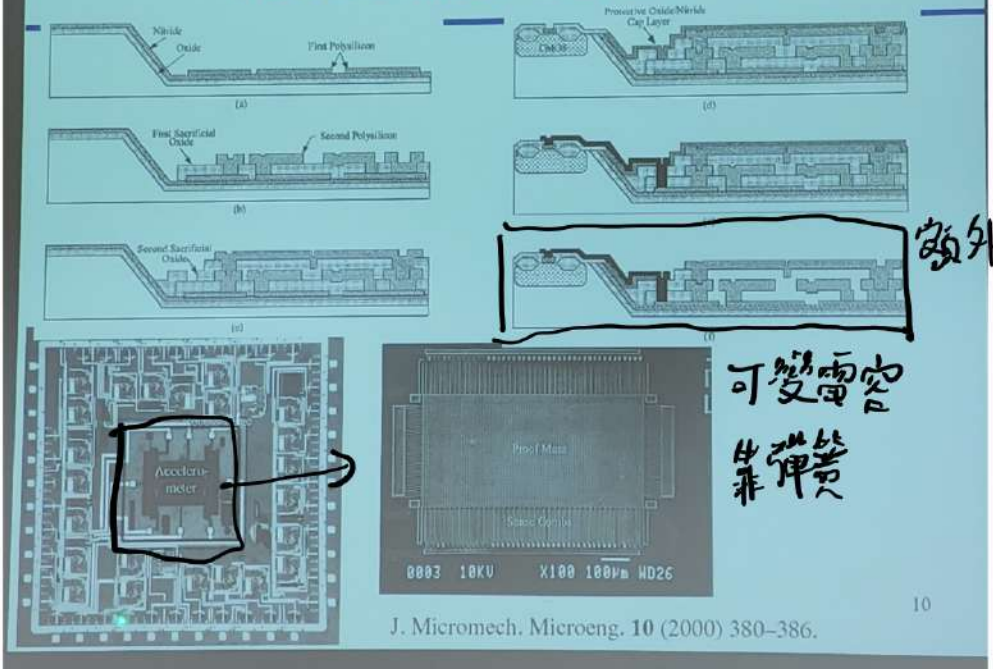
Accelerometer with circuits



額外處理

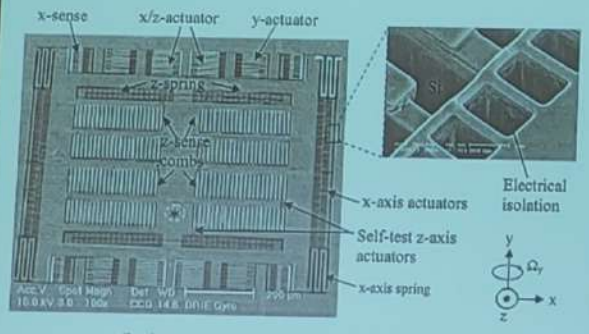
可變電容

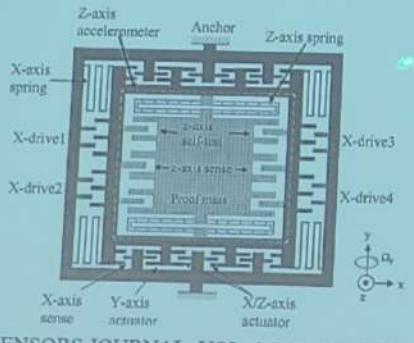
靠彈簧

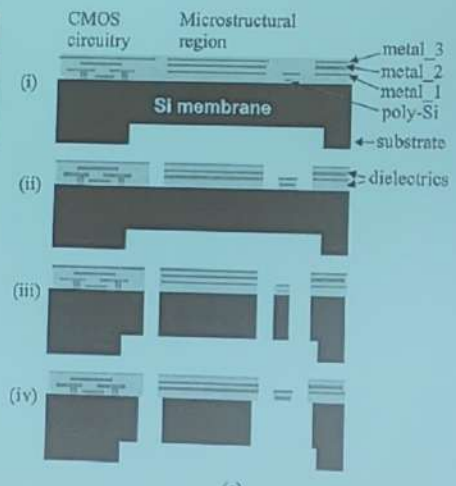
J. Micromech. Microeng. **10** (2000) 380–386.

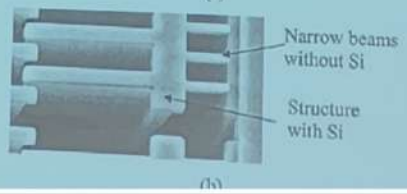
10

Gyroscope



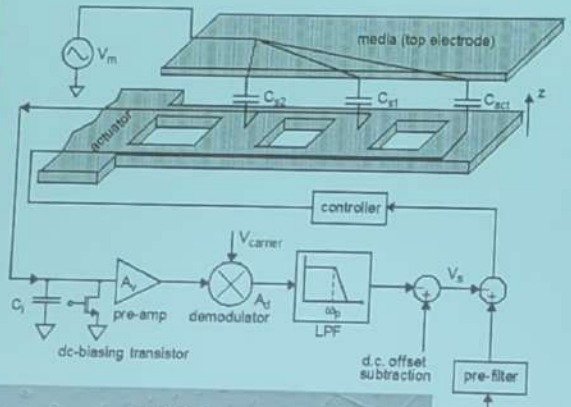


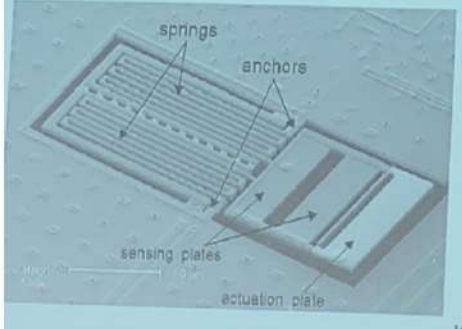


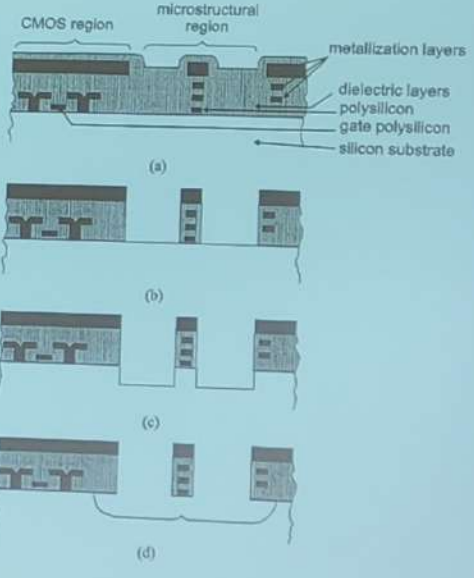


IEEE SENSORS JOURNAL, VOL. 3, NO. 5, OCTOBER 2003

Probe-based data storage

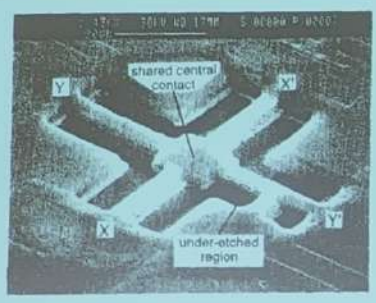


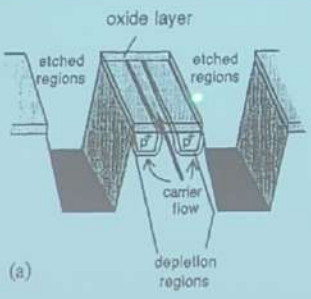


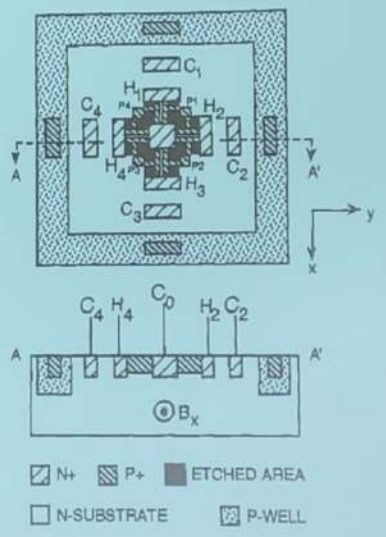


JOURNAL OF MICROELECTROMECHANICAL SYSTEMS, VOL. 13, NO. 5, OCTOBER 2004

Hall magnetic field sensor







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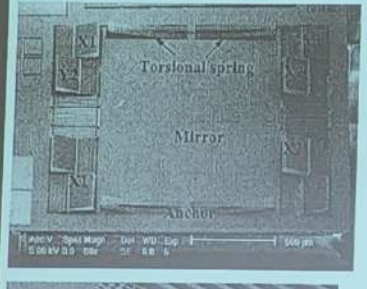
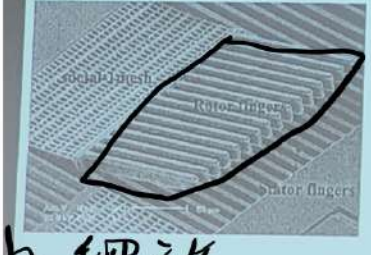
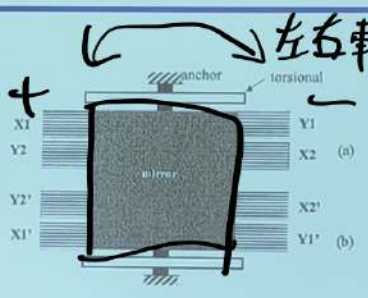
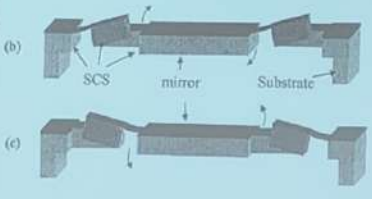
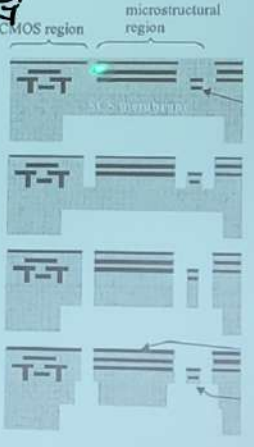
Mirror with comb drives







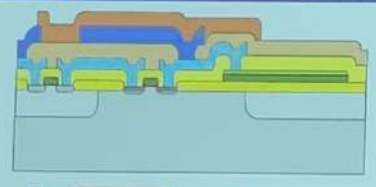


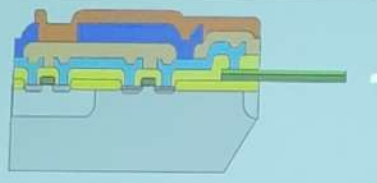


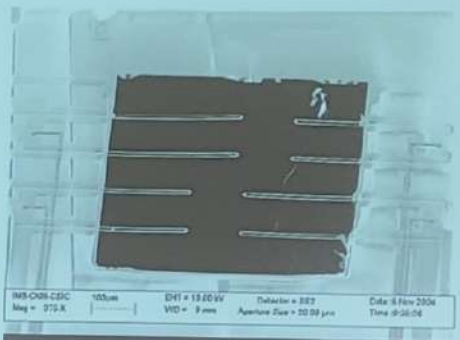
應力釋放

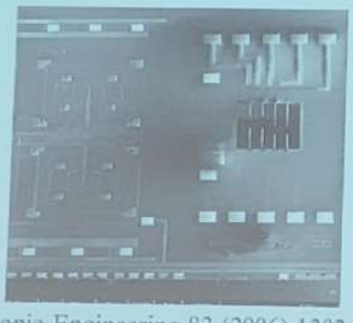
JOURNAL OF MICROELECTROMECHANICAL SYSTEMS, VOL. 12, NO. 4, AUGUST 2003 14

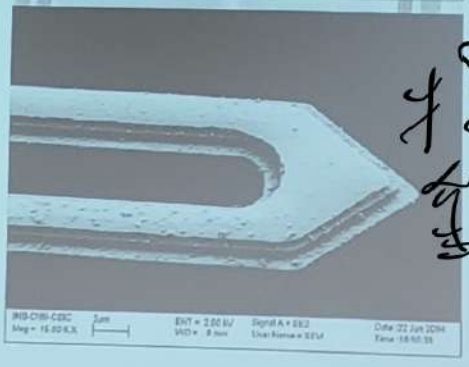
Intermolecular force detection











探針

Microelectronic Engineering 83 (2006) 1302–1305

研究腦波

Topics

- Micro mechanical RF switch
- Micro tunable resonator 可調式共振器

Introduction

- Why RF MEMS Switches ?

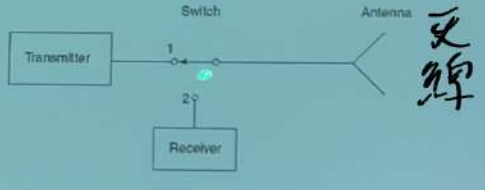
Switch Type	Insertion loss	Isolation	Power handling	Power consumption	Switching speed	Cost
PIN diodes	Good	Good	Good	Poor	Good	Good
GaAs FETs	Good	Good	Poor	Good	Excellent	Poor
MEMS switches	Excellent (0.1~0.6dB)	Excellent (-40~-50dB)	Excellent	Excellent	Poor	Good

速度慢

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

I. Introduction

- Applications of RF MEMS Switch



交換

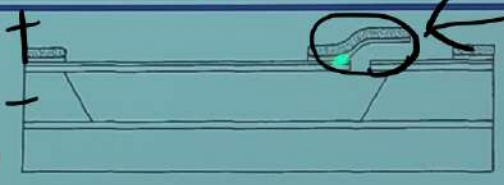
the switch can be used to share an antenna between a transmitter and a receiver

- Electrostatic-type MEMS switches
  - Metal contacting
  - Capacitive coupling

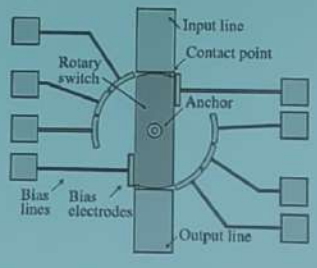
手機通訊用

Introduction

- 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



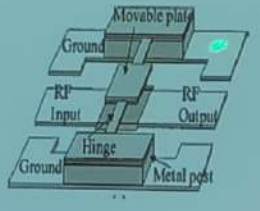
K. E. Petersen, "Micromechanical membrane switches on silicon," IBM J. Res. Develop., vol. 23, no. 4, pp. 376–385, July 1979.



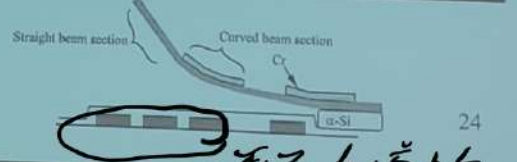
L. E. Larson et al., "Micromachined microwave actuator (MIMAC) technology—a new tuning approach for microwave integrated circuits," in IEEE Microwave and Millimeter-Wave Monolithic Circuits Symposium Digest, Boston, MA, June 1991, pp. 27–30.

Introduction

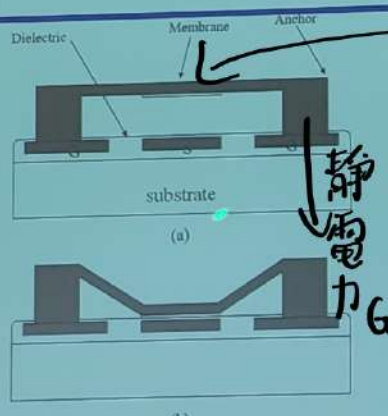
- 2000, J. Y. Park (LG-Korea)
  - strontium titanate oxide ($SrTiO_3$) with high dielectric constant
  - insertion loss of 0.08 dB at 10 GHz
  - isolation of 42 dB at 5 GHz
  - On GaAs substrate
- 2000, C. Chang et al. (NTU)
  - 0.5 μm thick evaporated aluminum cantilever which is covered in part by a 0.1 μm 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



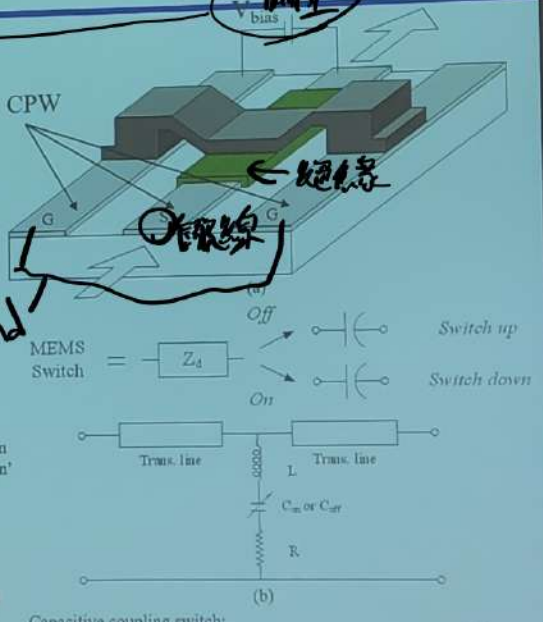
Structure Design and Simulation



Schematic of cross-section view of the RF MEMS switch: (a) in the unactuated state or 'off' state; (b) in the actuated state or 'on' state.

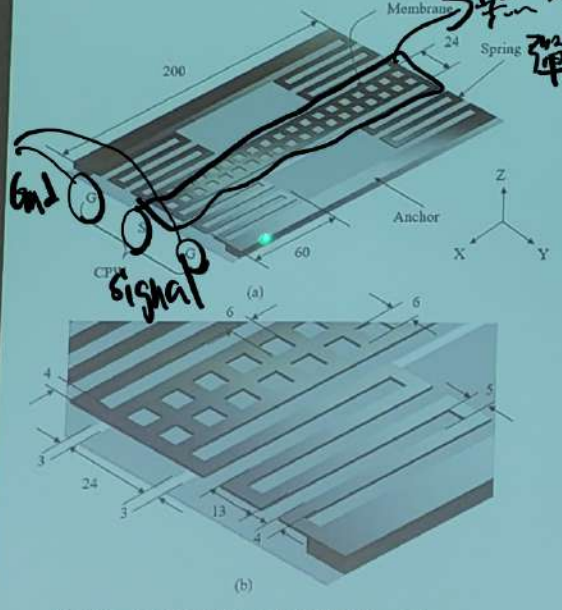
$$Z_c(j\omega) = \frac{V_c(j\omega)}{I(j\omega)} = \frac{1}{j\omega C}$$

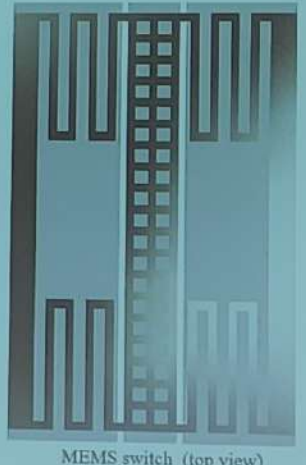
Impedance of a capacitor, a capacitor acts like a short circuit at high frequencies, whereas it behaves more like an open circuit at low frequencies.



Capacitive coupling switch:
(a) Schematic of the capacitive MEMS switch over CPW line
(b) Equivalent circuit model of the capacitive MEMS switch

Structure Design and Simulation

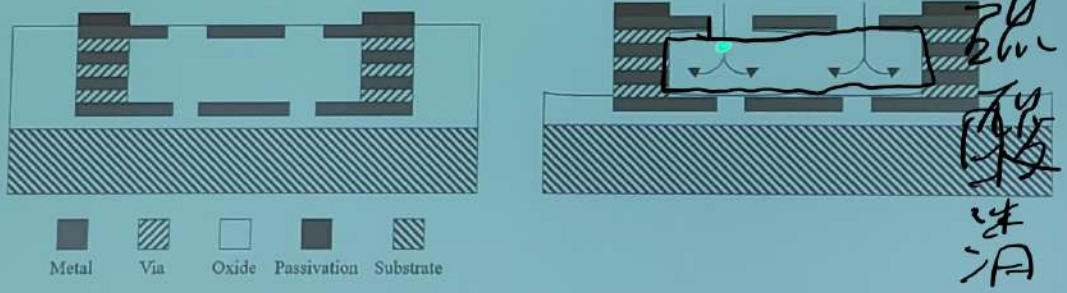




MEMS switch (top view)

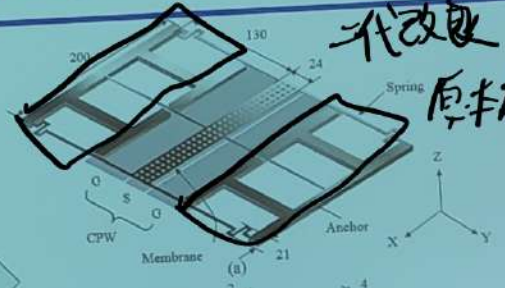
Structure and dimensions of the RF MEMS switch:
(a) CPW transmission lines and suspended membrane,
(b) flexural supported springs.

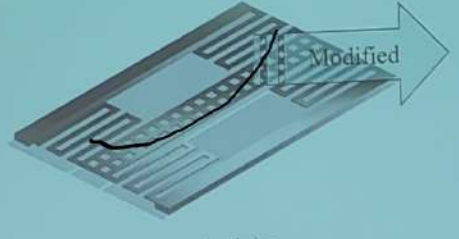
Fabrication & Post-CMOS Process



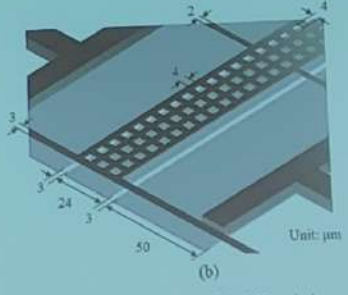
(b)

Improved Design (2nd generation design)



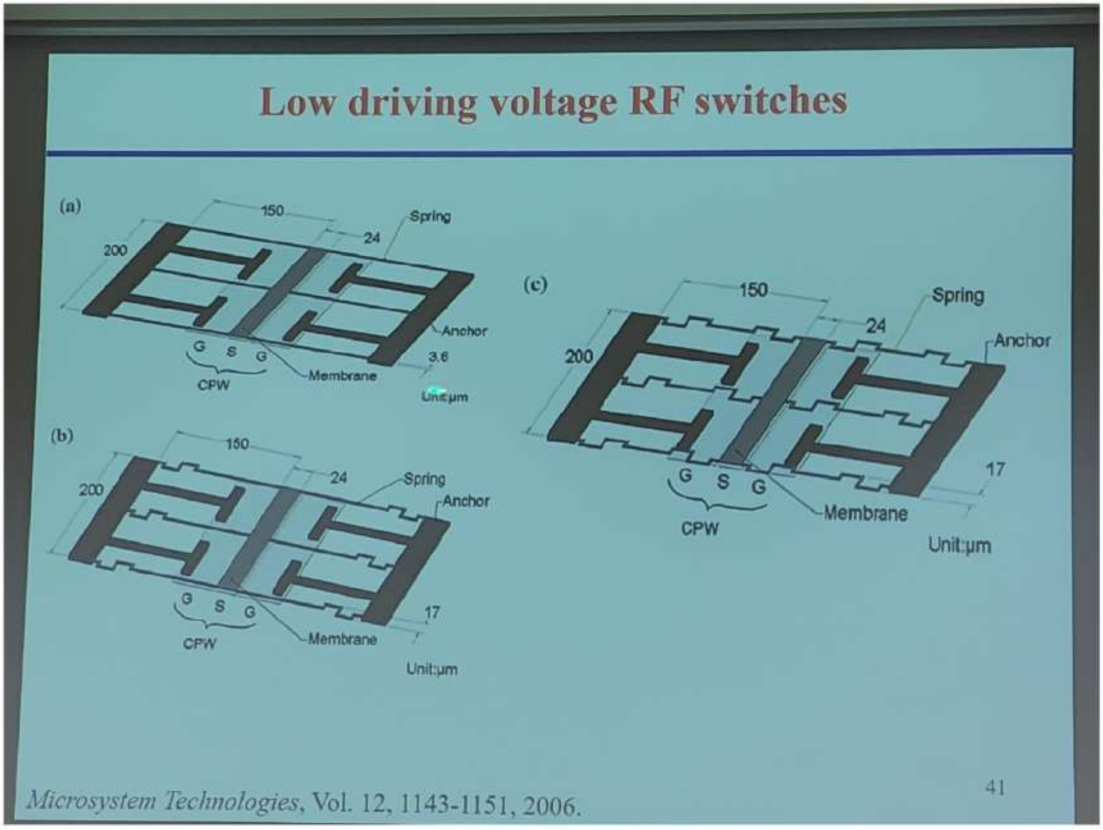


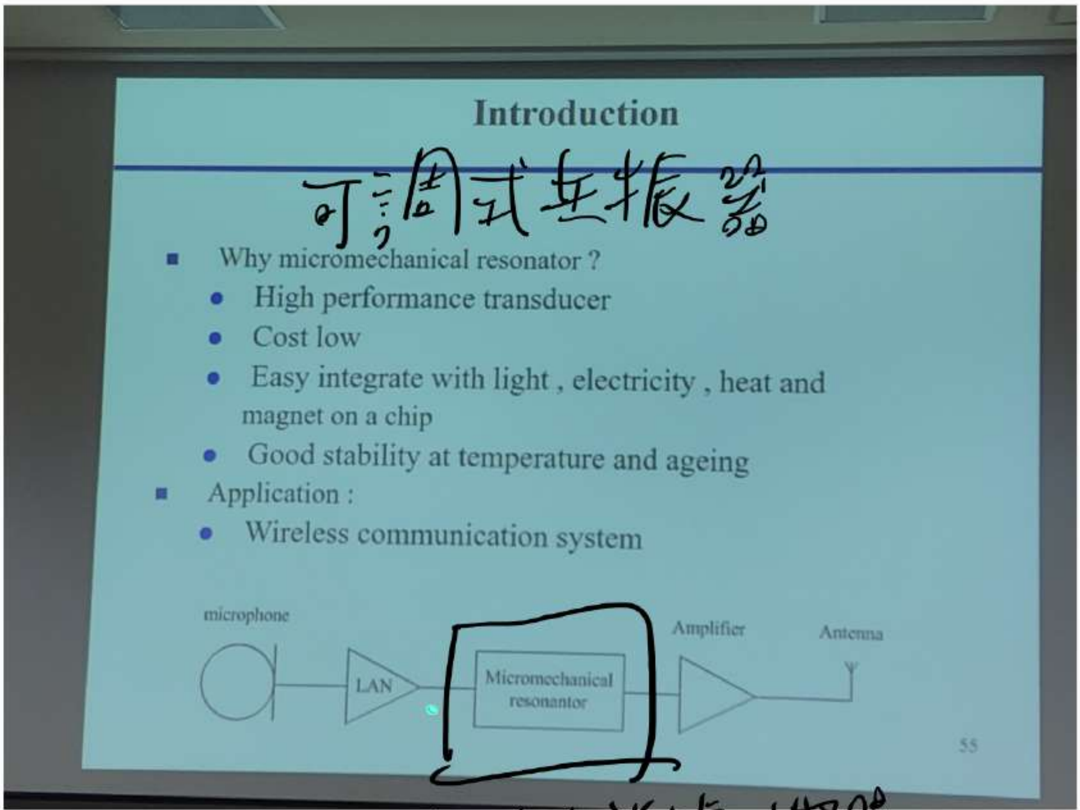
1st generation design



Structure and dimensions of the RF switch:
(a) CPW transmission lines and suspended membrane,
(b) flexural supported springs.

目標把
18V↓
5V~6V





可以當濾波器