Outline

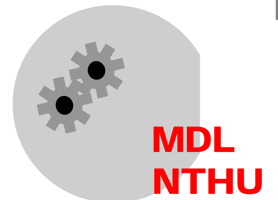
1 Introduction

2 Basic IC fabrication processes

3 Fabrication techniques for MEMS

4 Applications

5 Mechanics issues on MEMS



3. Fabrication Techniques for MEMS

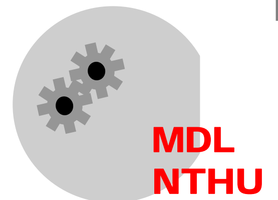
3.1 Bulk micromachining

3.2 Surface micromachining

3.3 LIGA process

3.4 Hybrid micromachining

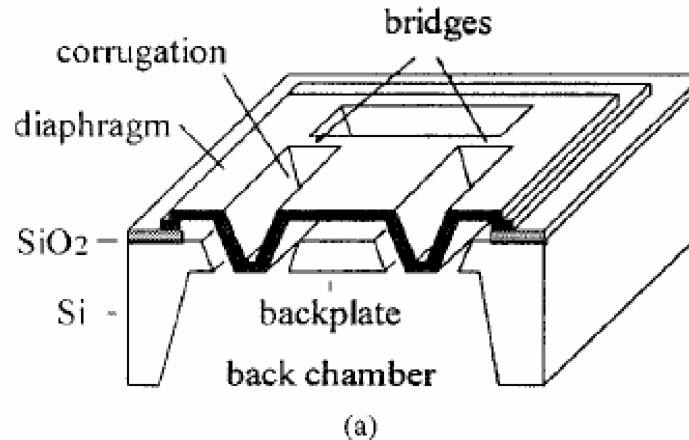
3.5 Thick micromachined structures



3.4 Hybrid micromachining

- **Hybrid micromachining – the fabrication processes containing both surface and bulk micromachining technique**

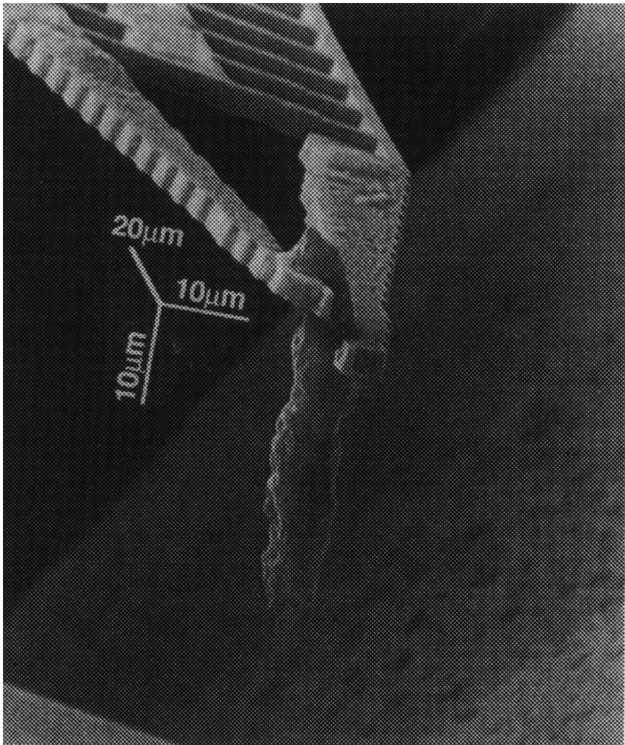
- **Presently, more and more MEMS devices are fabricated through hybrid micromachining technique**

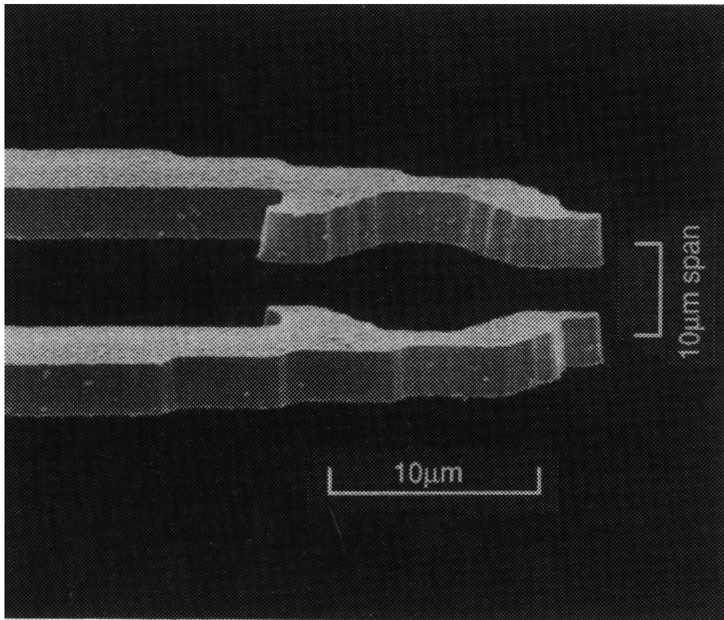


(a)

Q. Zou, Z. Li, and L. Liu, J. of MEMS, 1996

Micro Gripper





C.-J. Kim, A.P. Pisano, and R.S. Muller, J. of MEMS, 1992

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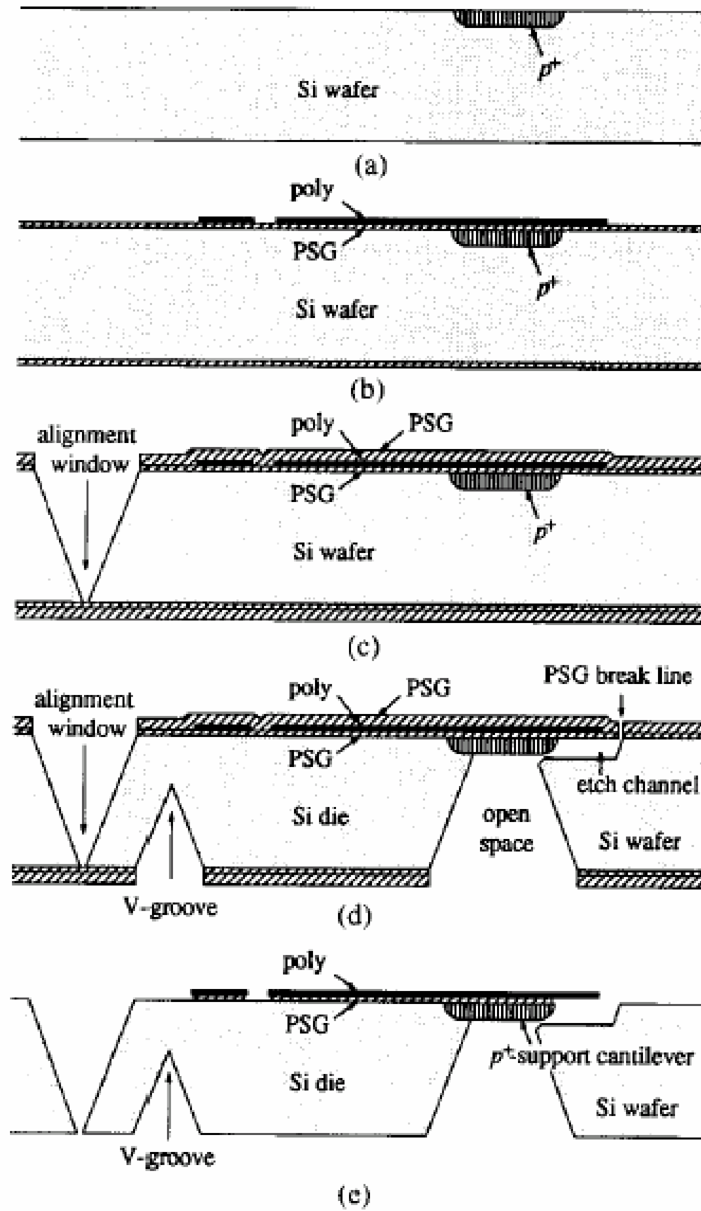
+ Fabrication processes



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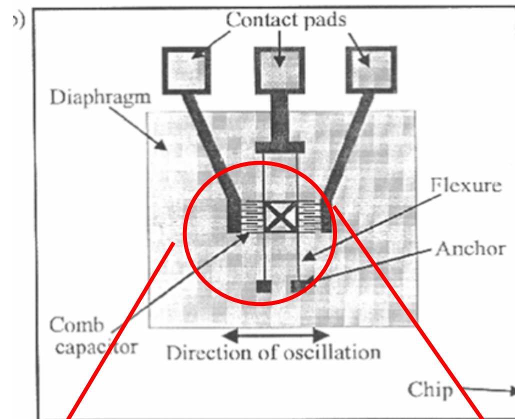
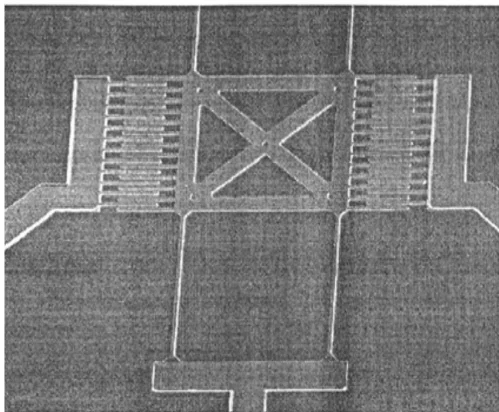
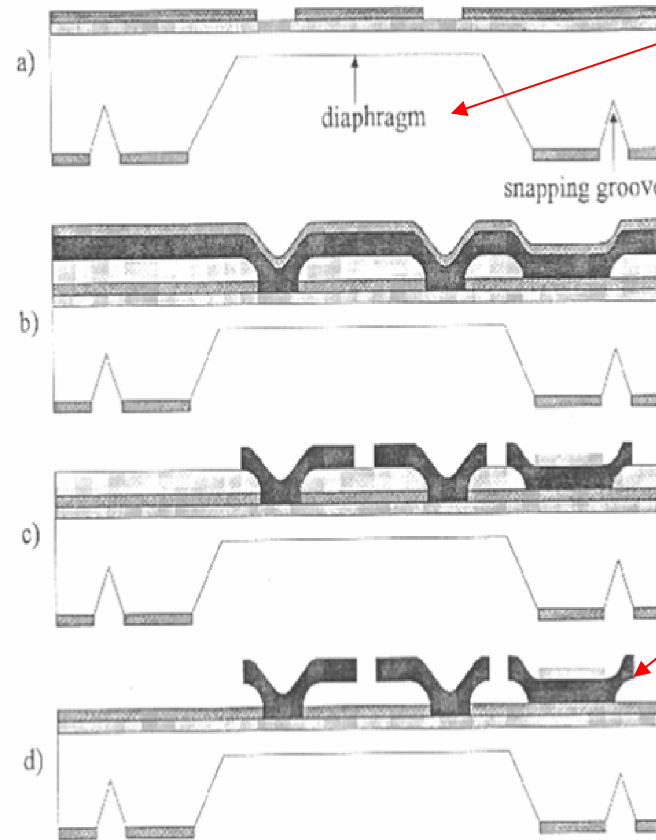
Resonant pressure transducer





surface micromachined resonator



Bulk silicon etching

Surface micromachined resonator

C.J. Welham, J.W. Gardner, and J. Greenwood, Transducer '95, 1995.

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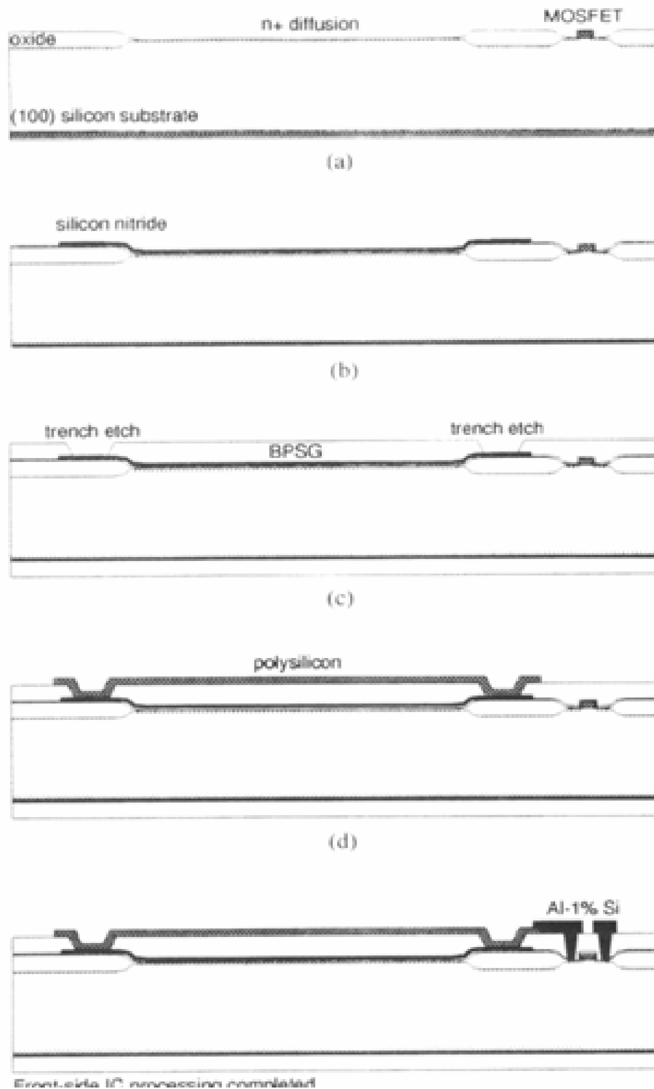
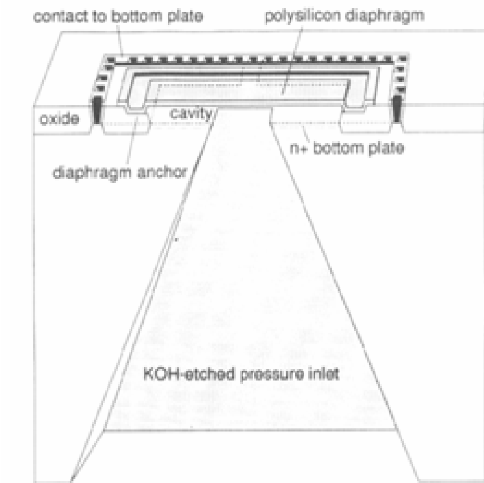
Capacitive type pressure transducer





J.T. Kung and H.-S. Lee, J. of MEMS, 1992.

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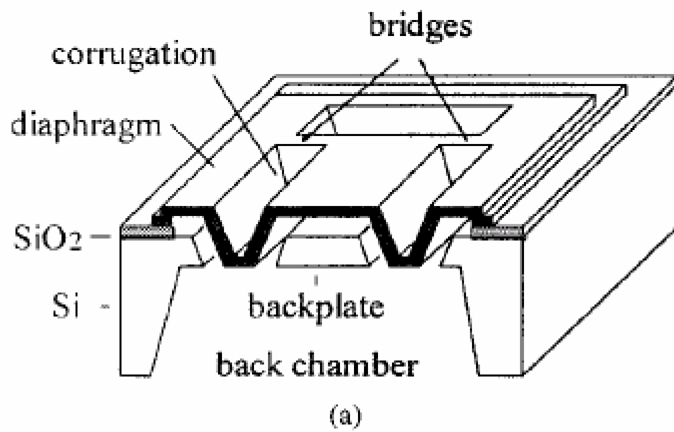
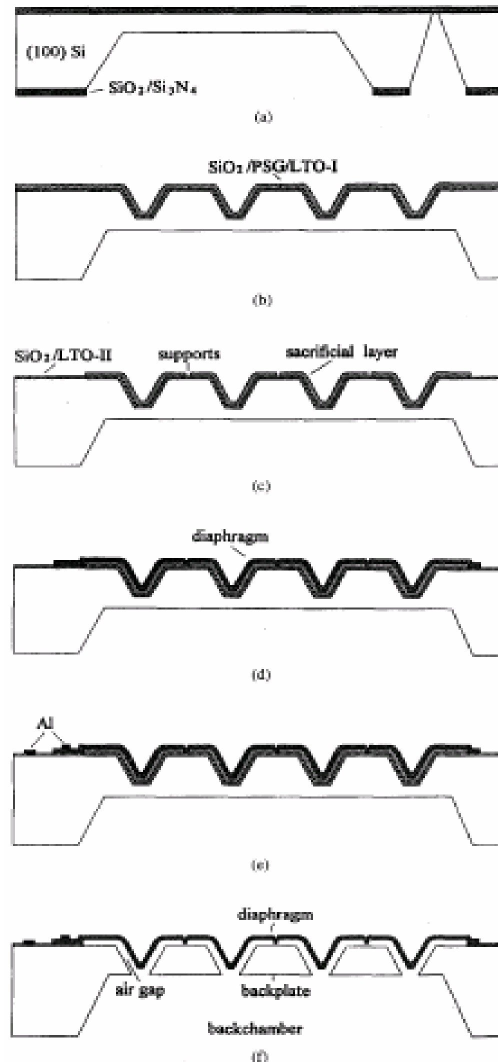
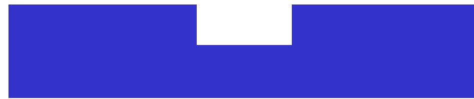
Microphone



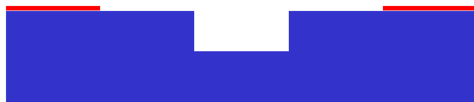


Q. Zou, Z. Li, and L. Liu,
J. of MEMS, 1996

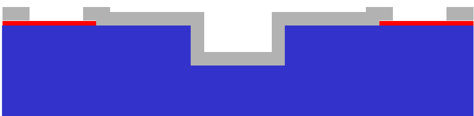
Electorstatic lever actuator



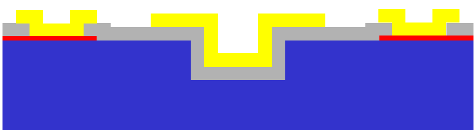
DRIE trench



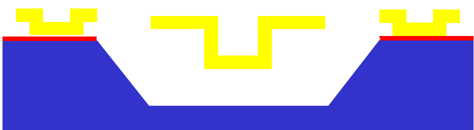
define wet anisotropic etch mask



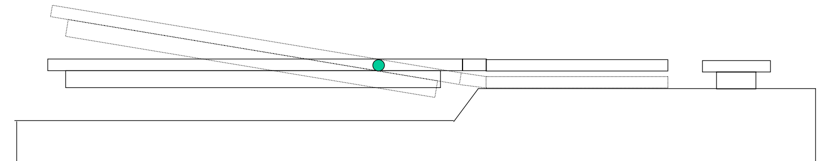
define sacrificial layer

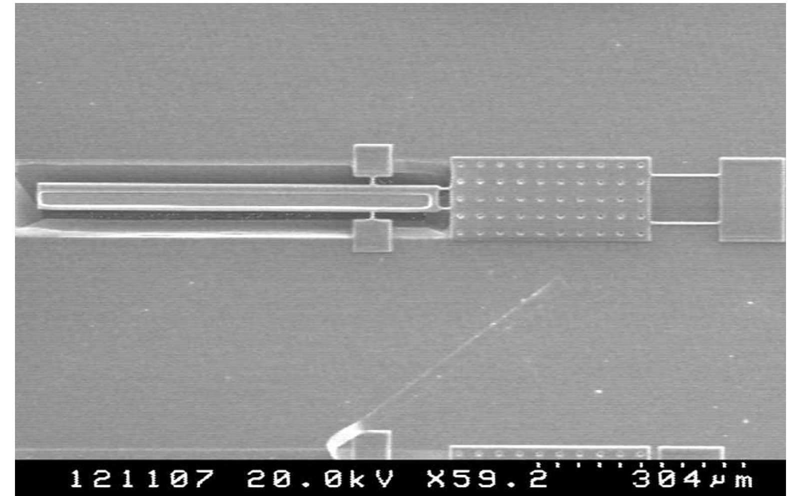


define structure layer



Wet anisotropic under etching





H.-Y. Lin and W. Fang, *ASME IMECE 2000.*

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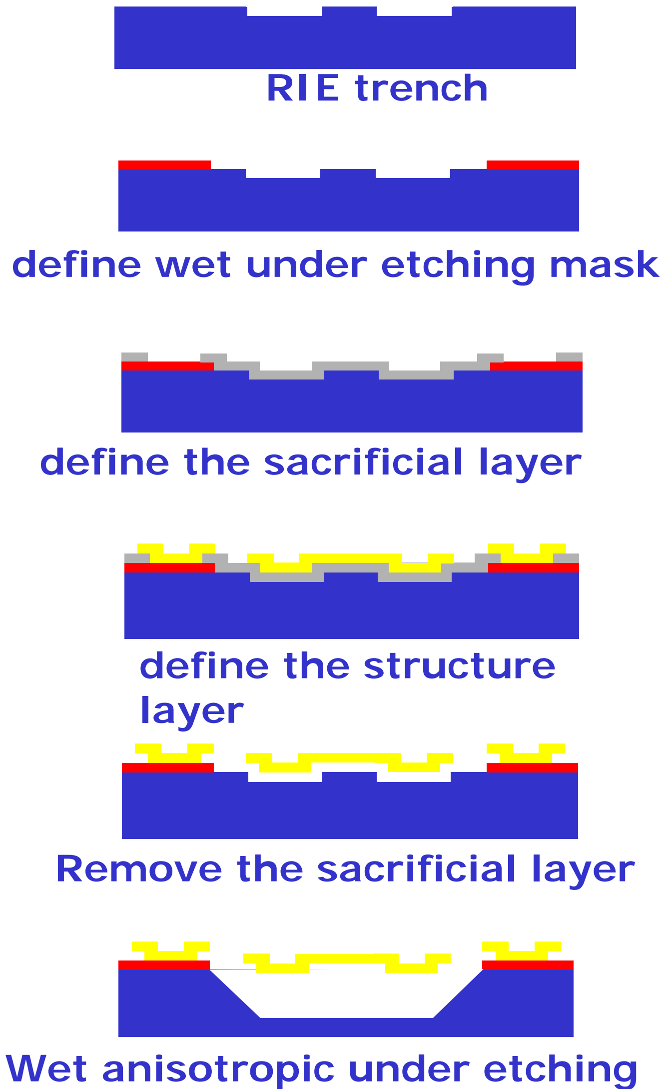
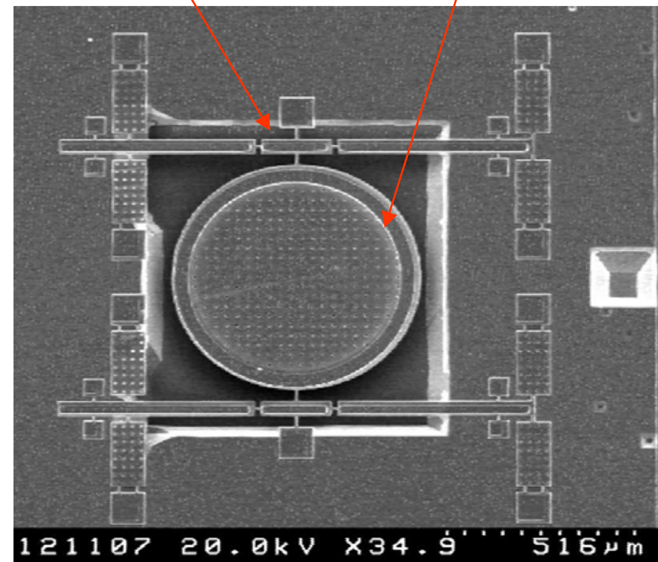
Micro scanner



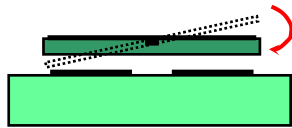
Torque generator

Folded frame

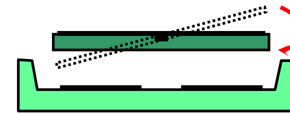


H.-Y. Lin and W. Fang, *Transducer01, 2001*

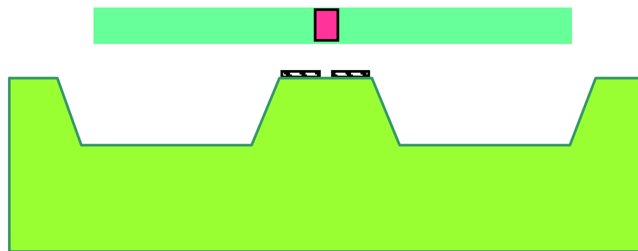
Micro scanner



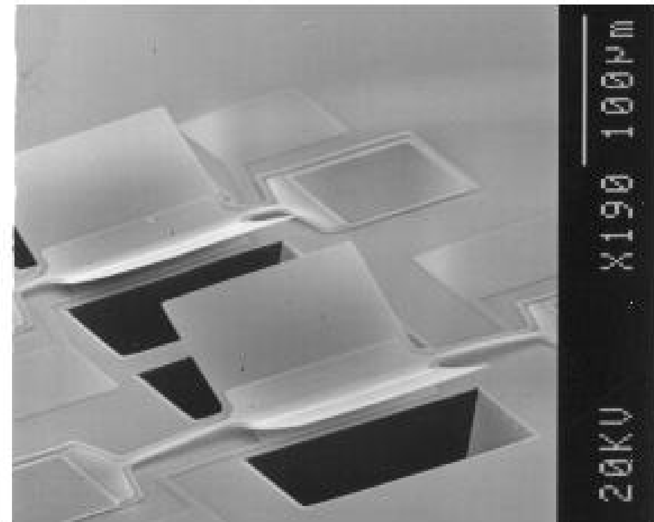
Surface device



Bulk device



Surface+ Bulk device



J. Hsieh and W. Fang, *Transducer99, 1999*

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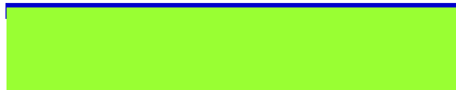
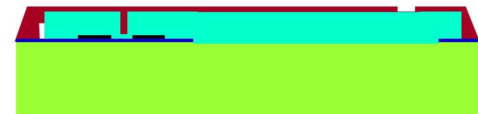
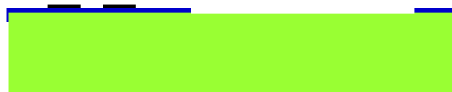
+ **Fabrication processes**



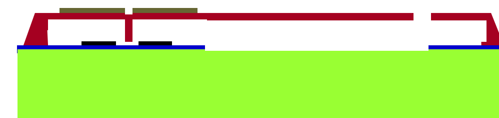
Deposit protection/isolation layer



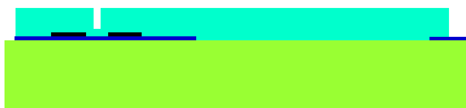
Pattern structural layer



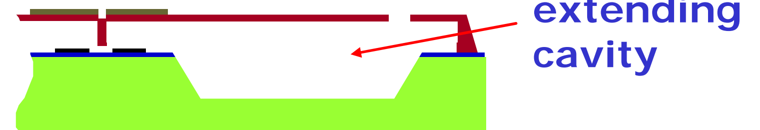
Define cavity and lower electrode



Pattern top electrode (option)
and then remove sacrificial layer



Pattern sacrificial layer



Releasing structure and etching Si

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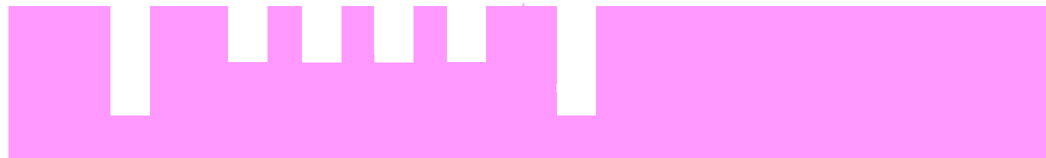
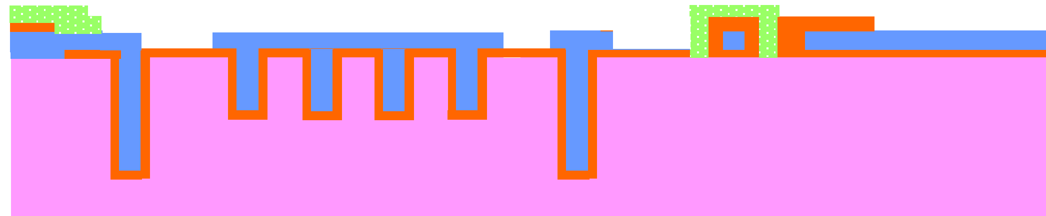
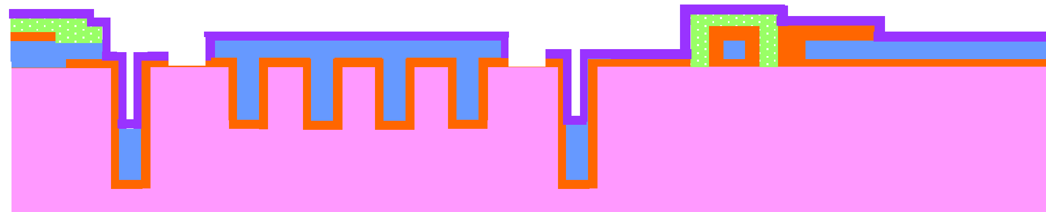
MOSBE Fabrication Platform



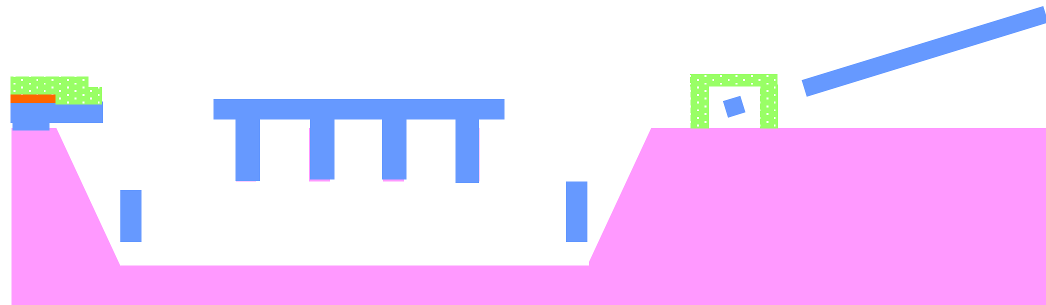
DRIE ***(~10 μm)***



MUMPs process ***(~1 μm)***

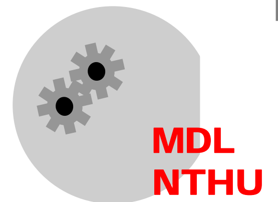


DRIE trimming
SixNy passivation

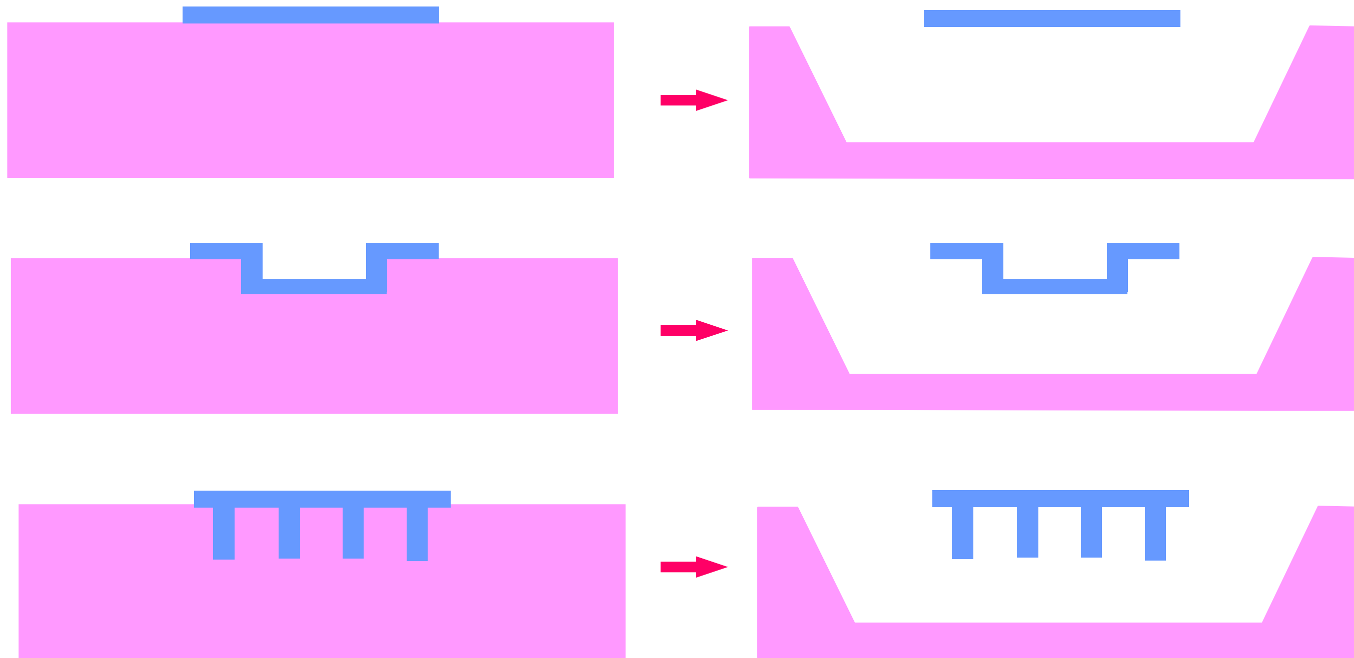


Bulk etching ***(~100 μm)***

M. Wu, C. Lai, and W. Fang, *IEEE MEMS'04*, the Netherlands, 2004
M. Wu, C. Lai, and W. Fang, *JMM*, 2005



- **Increasing the stiffness of the thin poly-Si structures** **w/o changing the film thickness**



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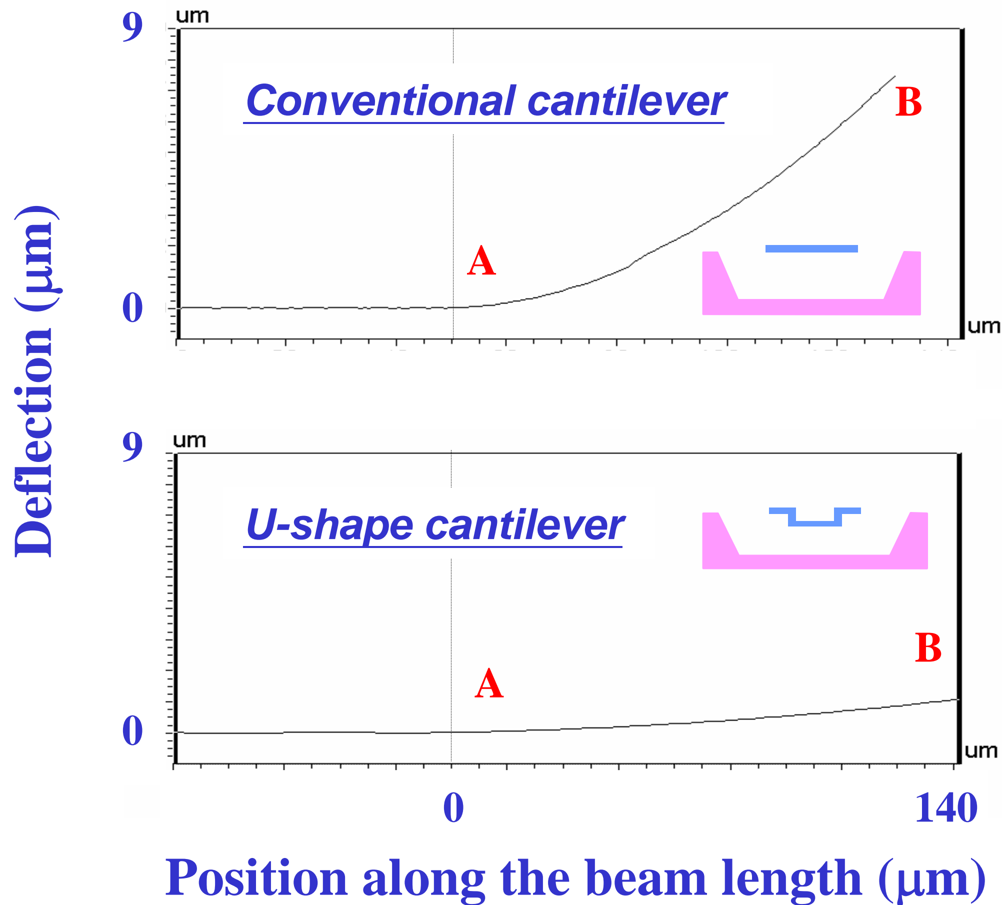
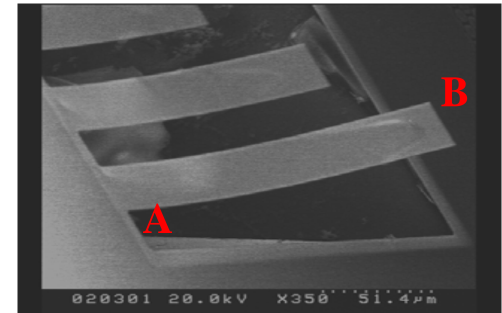
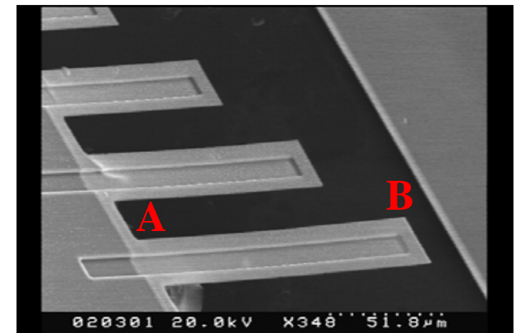
Passive component - Stiff beam







H.-Y. Lin and W. Fang, *JMM.*, 2000

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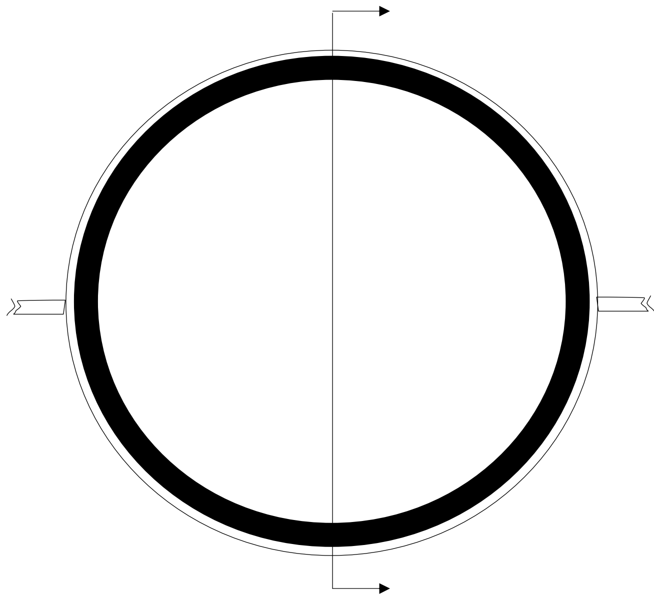
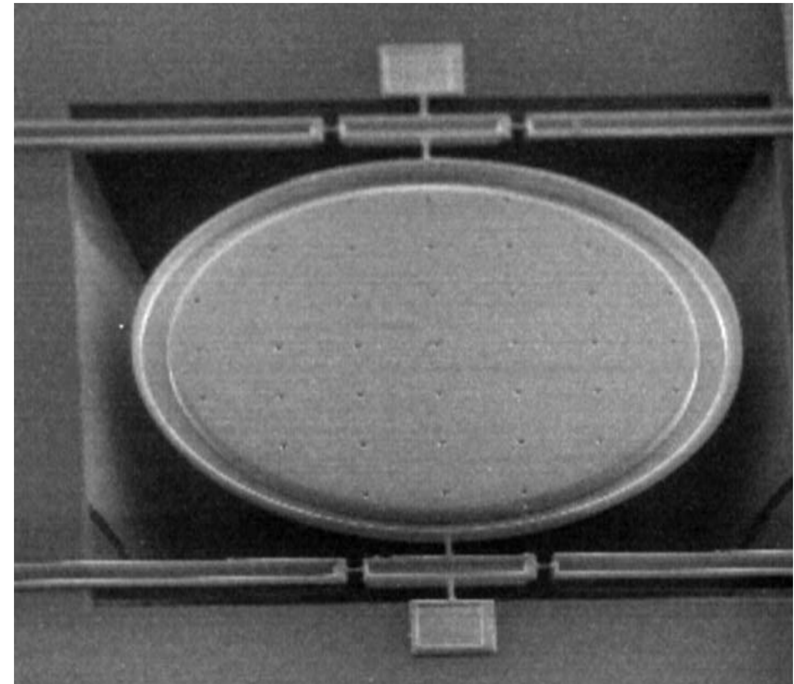
Passive component - Flat mirror



Reinforced folded frame



H.-Y. Lin and W. Fang, the *ASME IMECE,* Orlando, FL, 2000
H.-Y. Lin and W. Fang, *Sensors and Actuators A*, 2004

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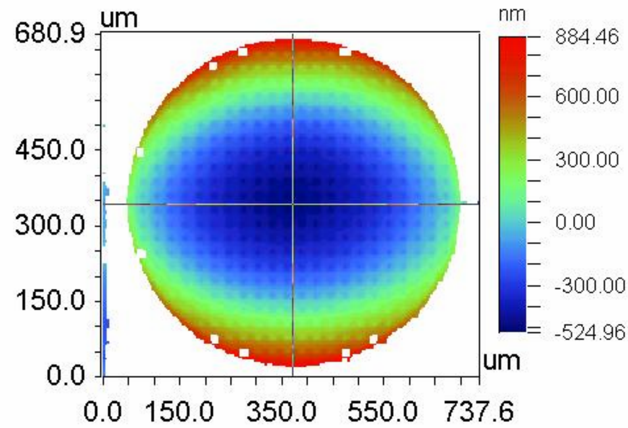
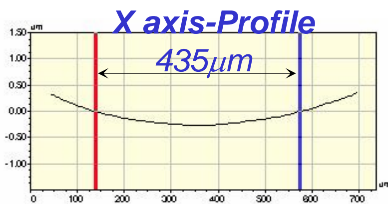
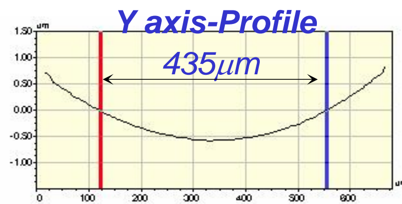
Conventional mirror



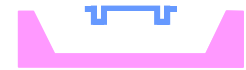


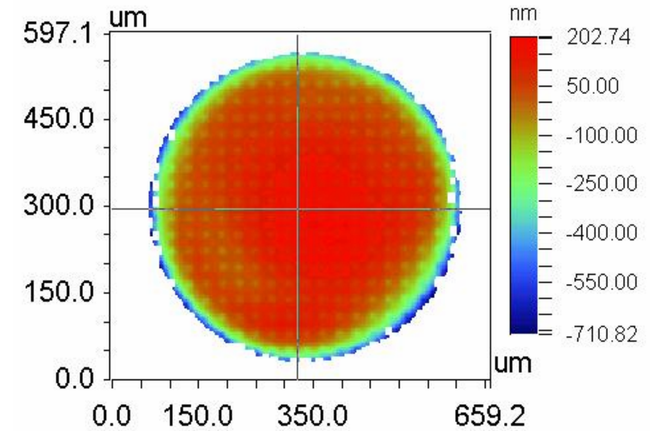
ρ : 93mm

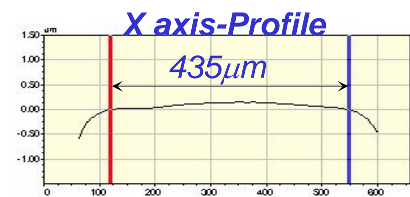


ρ : 41mm

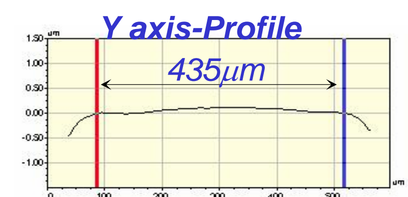
MOSBE mirror







ρ : 153mm

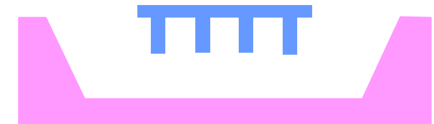


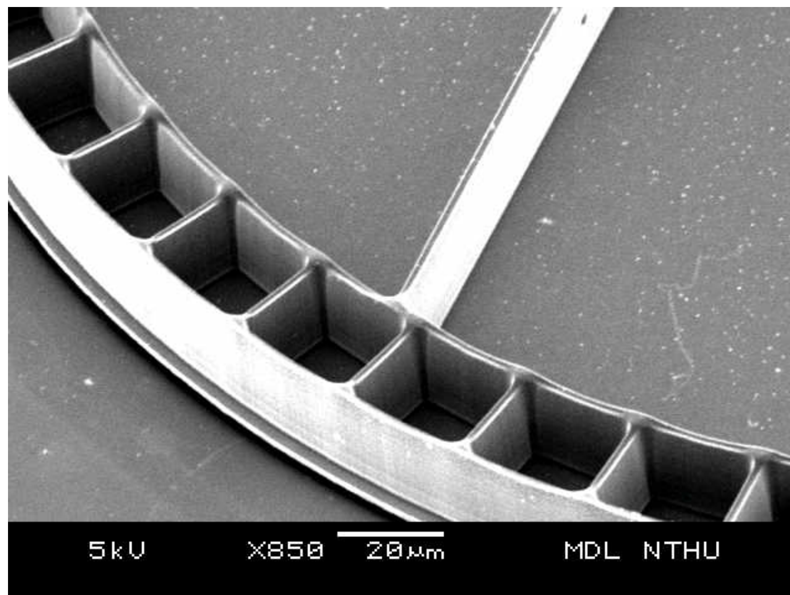
ρ : 179mm

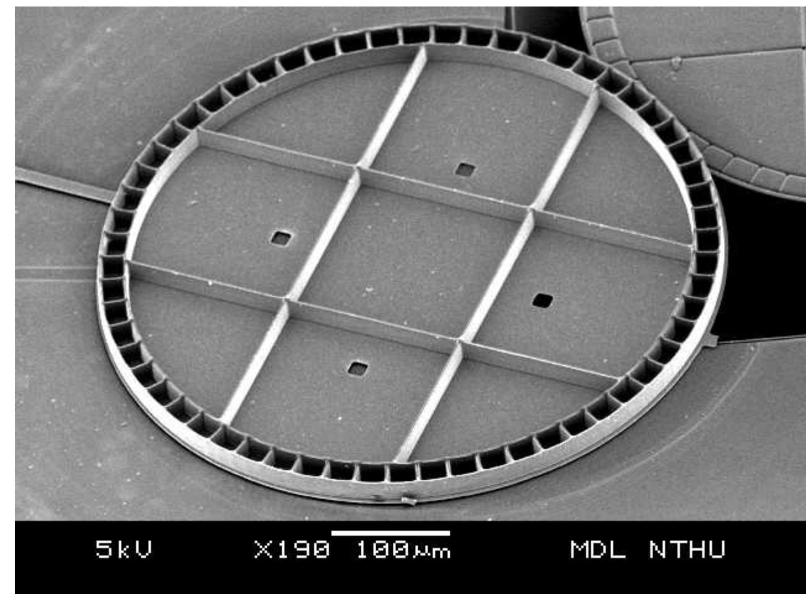
H.-Y. Lin and W. Fang, the *ASME IMECE,* Orlando, FL, 2000

Passive component – Flat mirror

- **Narrow trench-refilled poly-Si (depth ~ 20 μm)**
  - + **Double-ring reinforced rib on its boundary**
  - + **Grid reinforced rib on its domain**





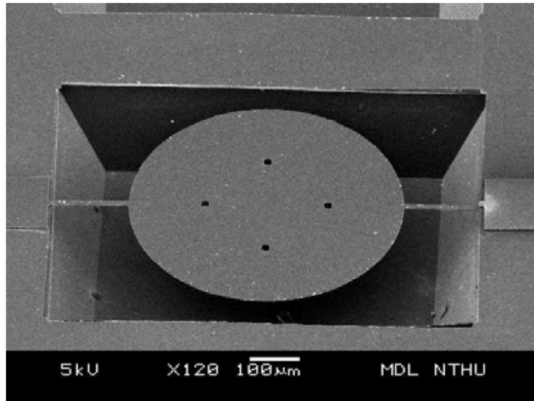


M. Wu, C. Lai, and W. Fang, *IEEE MEMS'04*, the Netherlands, 2004
M. Wu, and W. Fang, *JMM*, 2005

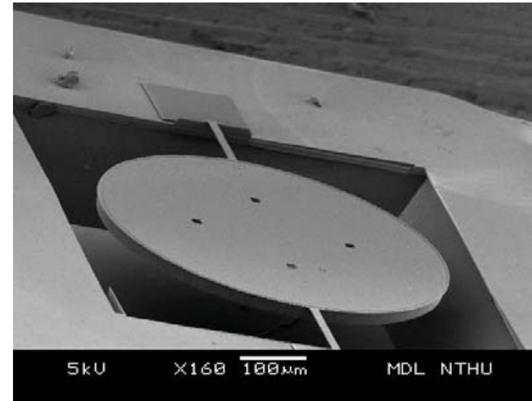
MDL
NTHU

Rib-reinforced structure

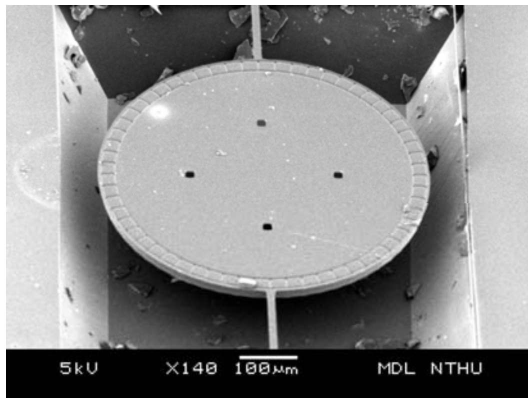
- Four different type mirror
  - + Thin film mirror (ROC: 19 mm)



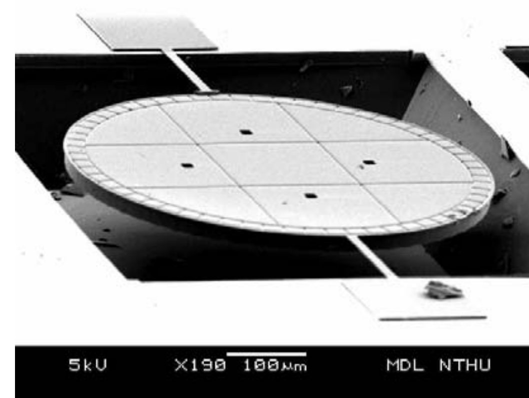
  - + Single ring mirror (ROC: 64 mm)



  - + Double ring mirror (ROC: 92 mm)



  - + Double ring with grid (ROC: 150 mm)



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Active component - Electrostatic actuator I

- **META Engine : (Micro Electrostatic Torsional Actuator)**

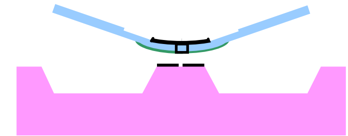
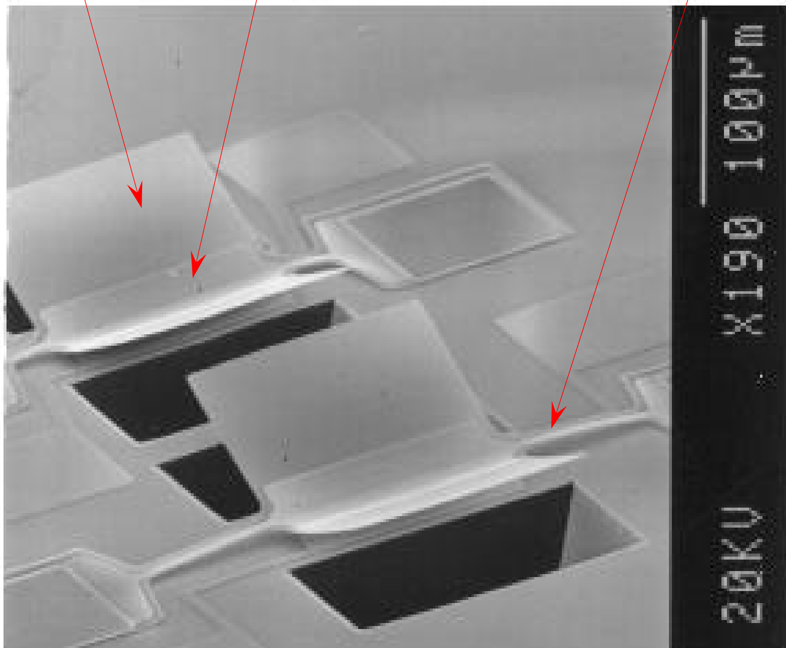
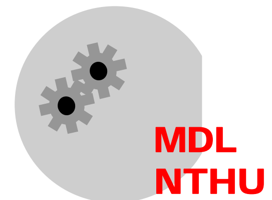


Plate **Driving electrode** **Torsional spring**



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

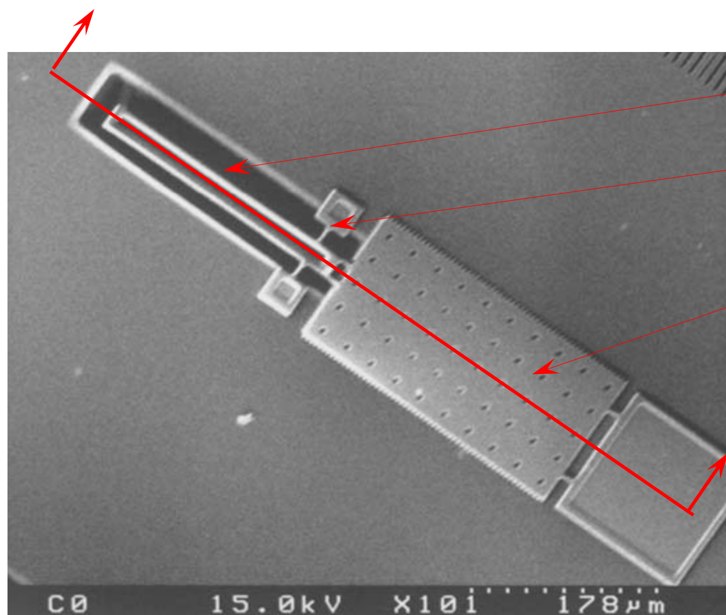
J. Hsieh and W. Fang, *Sensors and Actuators A*, 2000

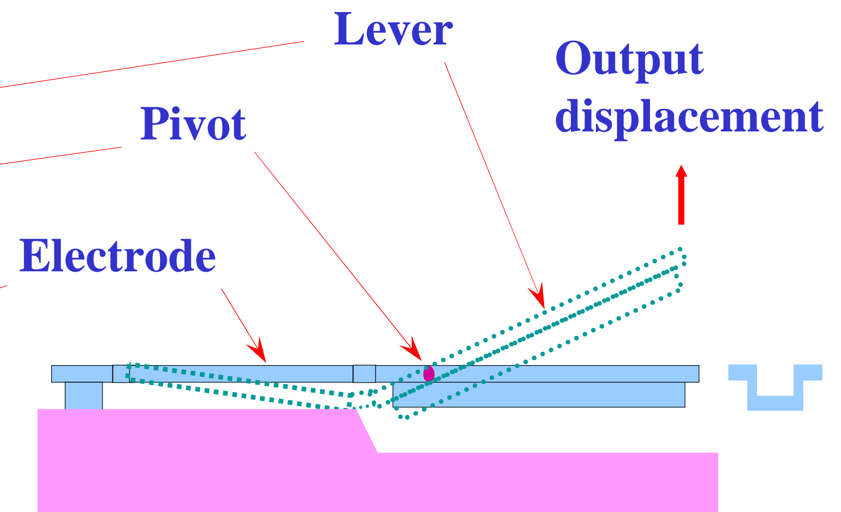


Active component - Electrostatic actuator II

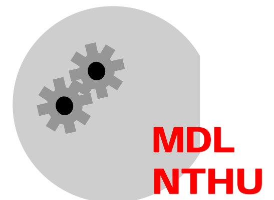
- **EDLA Engine : (Electrostatically-Driven-Leverage Actuator)**

Max disp. > 15μm **Driving voltage < 25 volt**



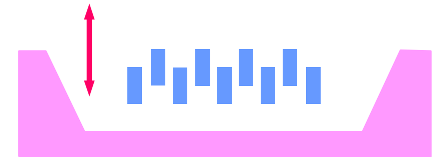


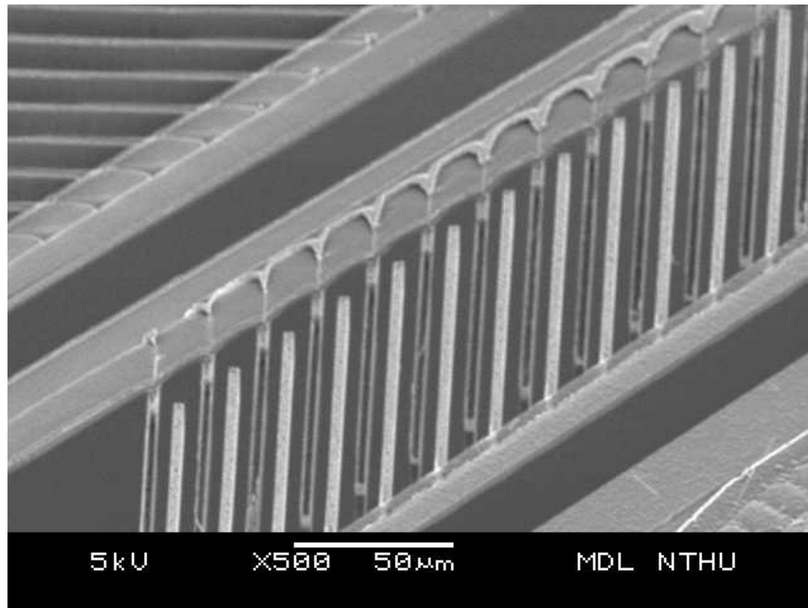
H.-Y. Lin, H. Hu, and W. Fang, *Transducers'01*, Munich Germany, 2001

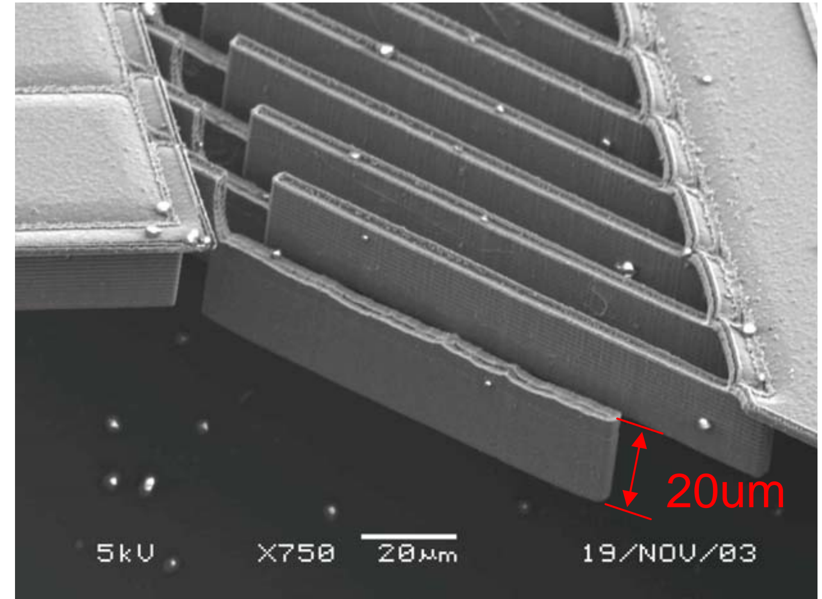


Active component - Vertical comb actuator

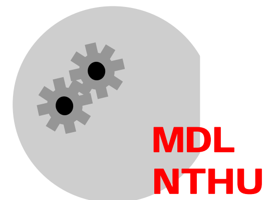
- **Vertical comb electrodes**
  - + Comb thickness ~20um
  - + Travel stoke ~20um



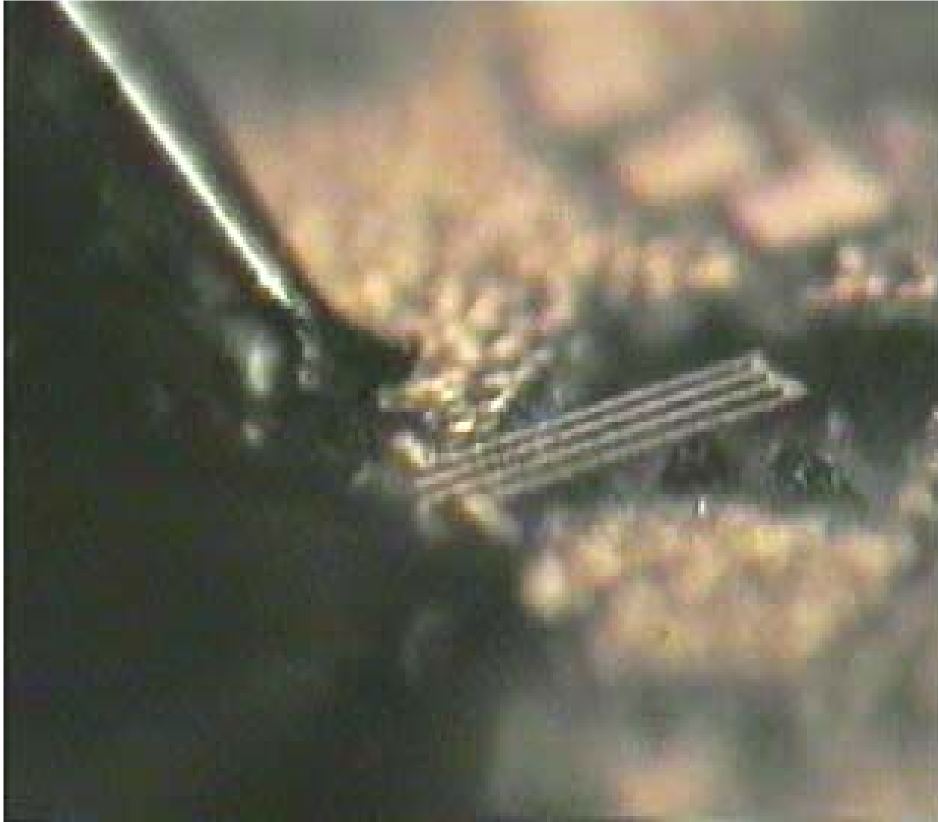


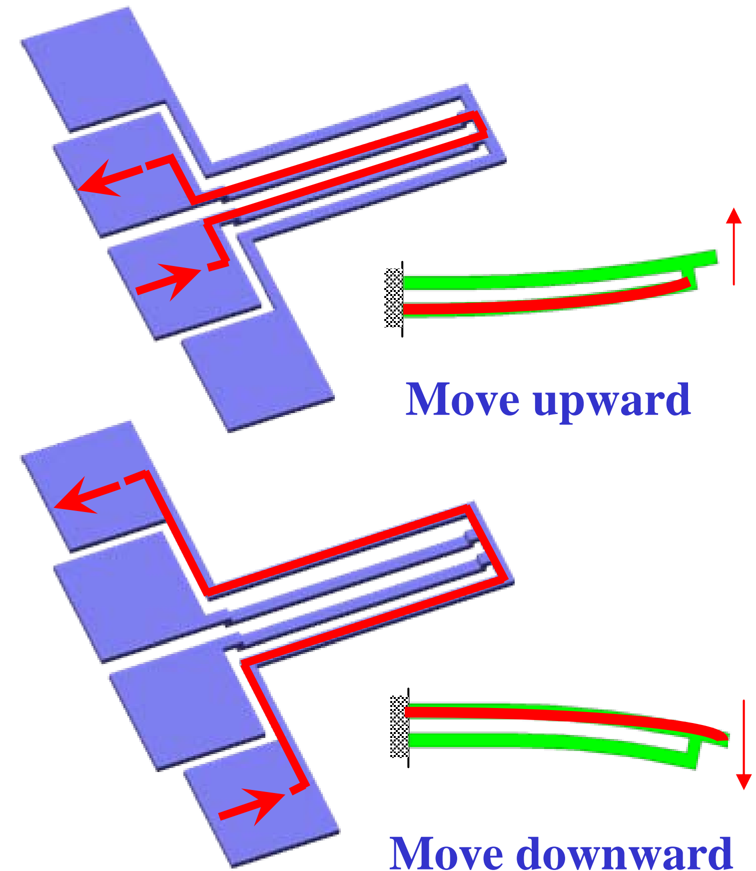


M. Wu, and W. Fang, *JMM*, 2005

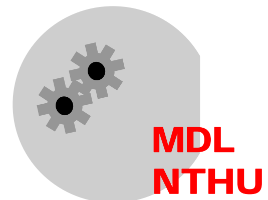


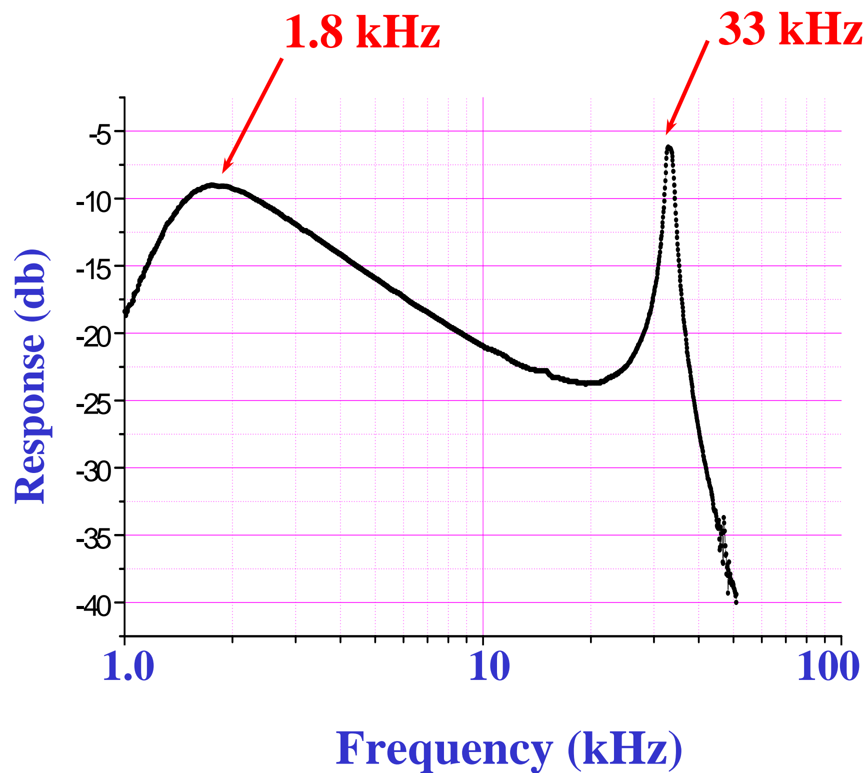
Active component - electrothermal actuator

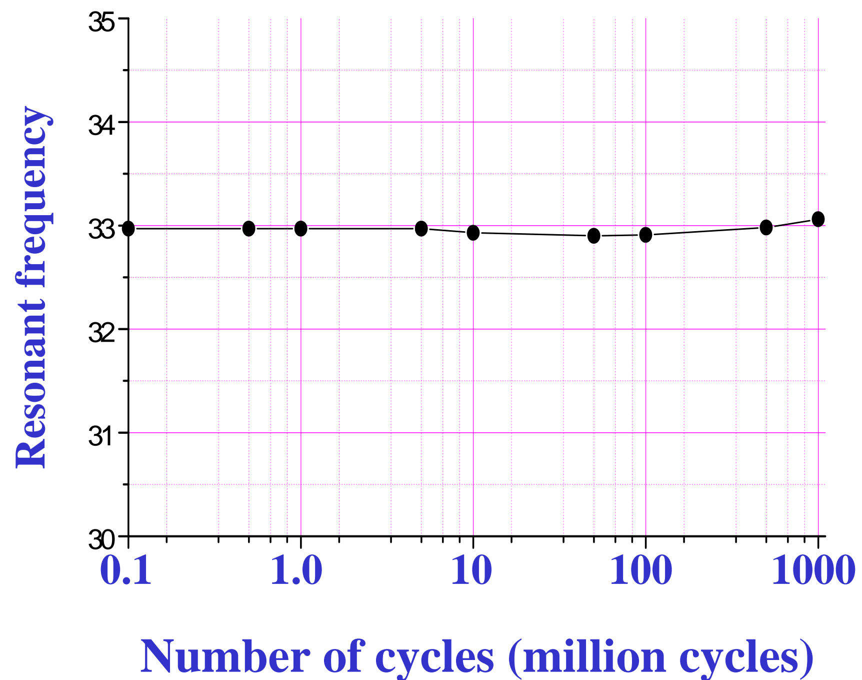




W.-C. Chen, J. Hsieh, and W. Fang, *IEEE MEMS'02*, Las Vegas, NV, 2002
W.-C. Chen, J. Hsieh, and W. Fang, *Sensors and Actuators A*, 2003







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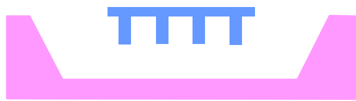
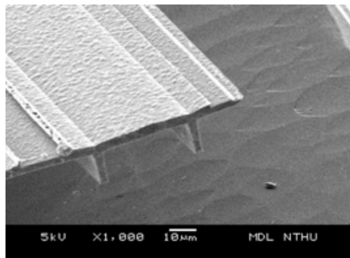
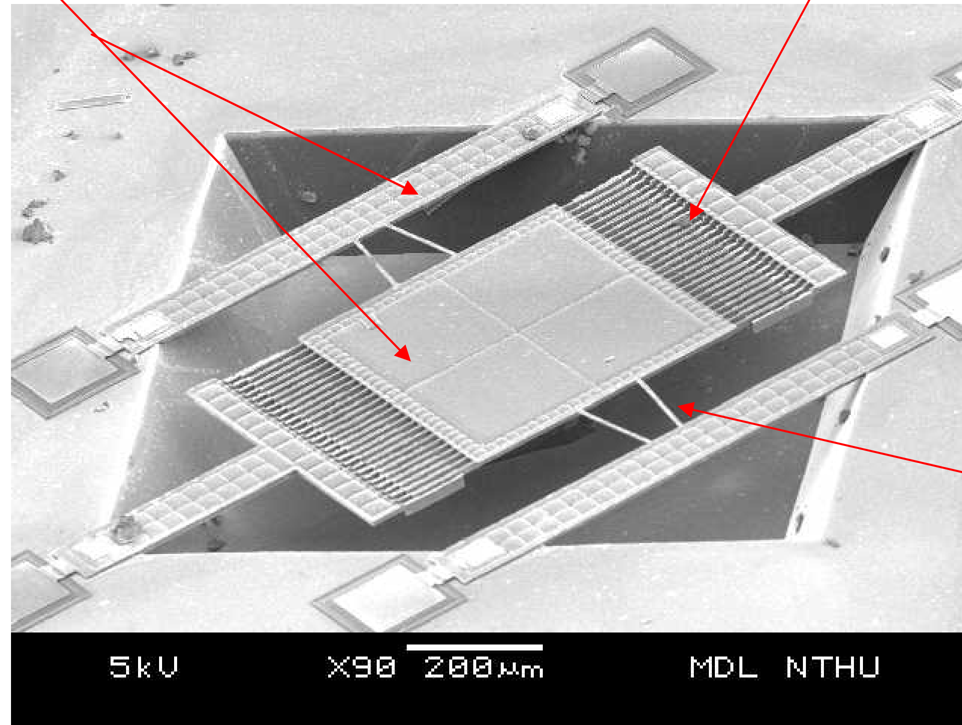
Applications – 1 axis optical scanner

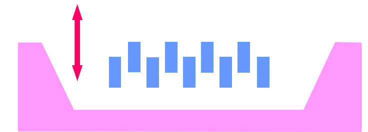
Rib-reinforced mirror and frame

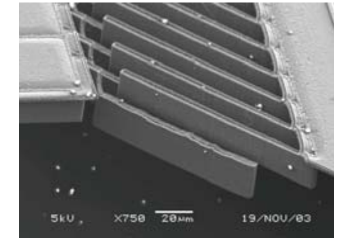






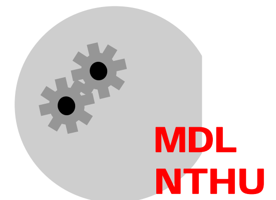
Vertical comb actuator



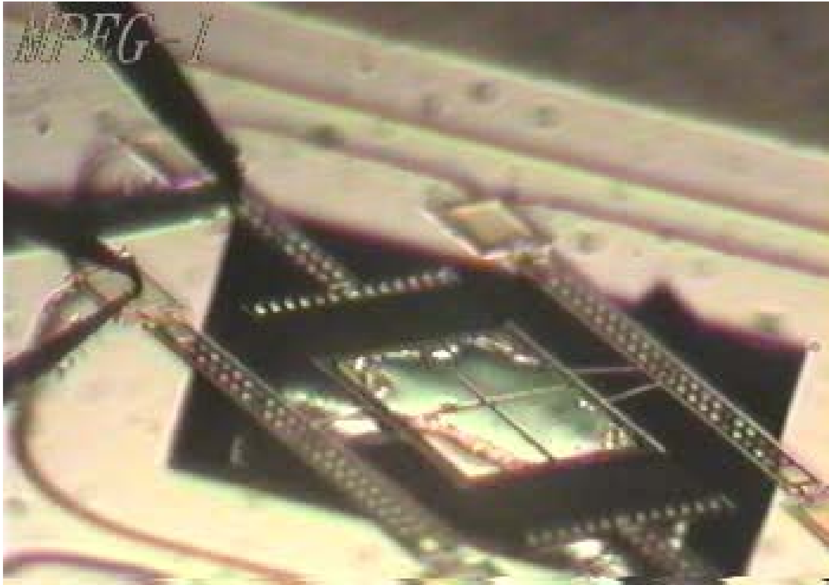


Torsional spring

M. Wu, and W. Fang, *IEEE MEMS*, Masstricht, the Netherlands, 2004
M. Wu, and W. Fang, *JMM*, 2005



Scanning test

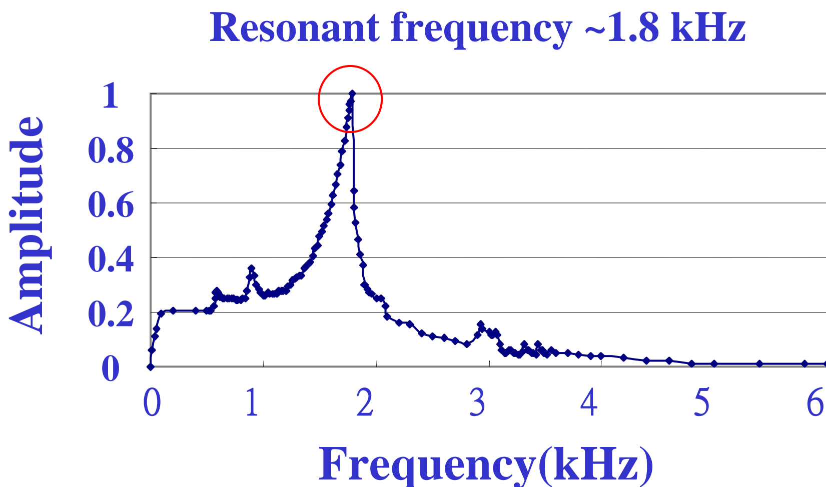


M. Wu, and W. Fang, *IEEE MEMS*, Masstricht, the Netherlands, 2004

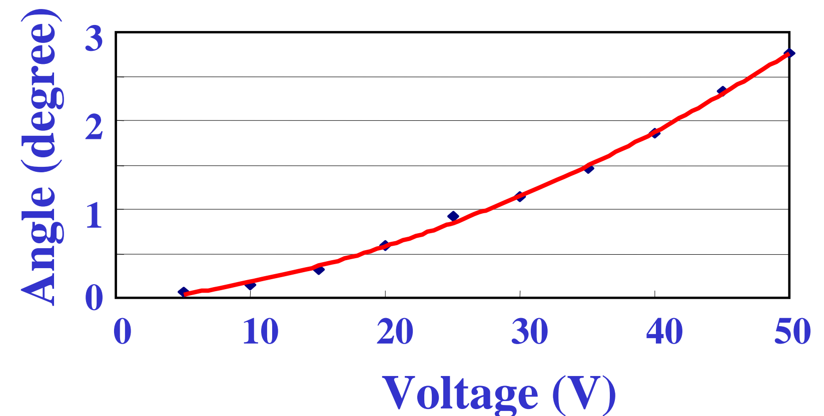
Dynamic measurement

- **Dynamic test driven by AC**

Resonant frequency ~1.8 kHz



- **Static load-deflection test**
  - + out-of plane displacement **~12.03 μm at 50V**
  - + scanning angle **~ 2.8 degree**



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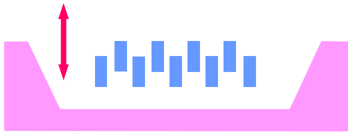
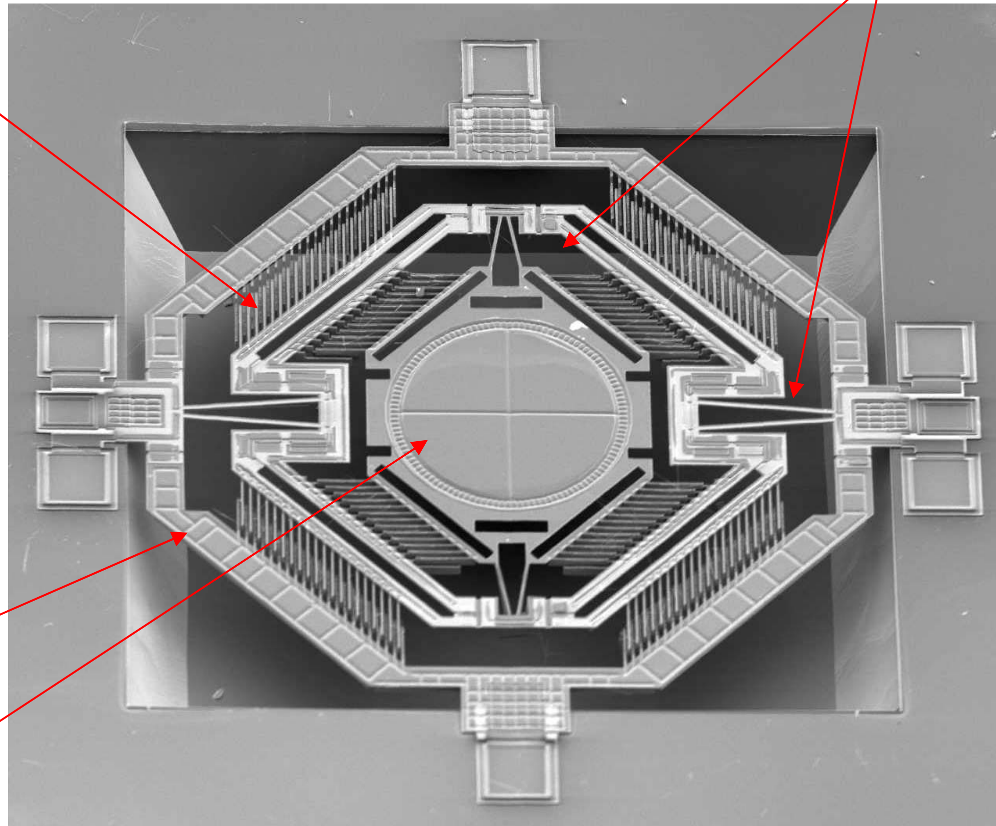
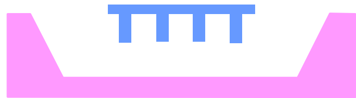
Applications - 2D Gimbal mirror

Springs (passive)

Driving electrodes (active)



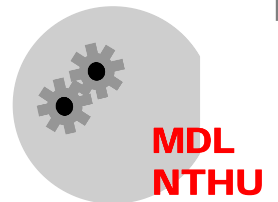




Supporting frame (passive)

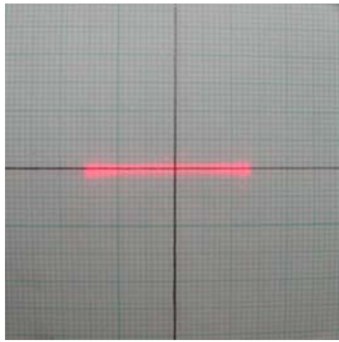
Mirror (passive)

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

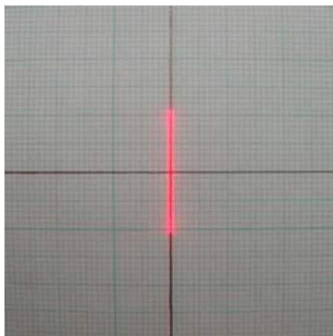


Scanning test

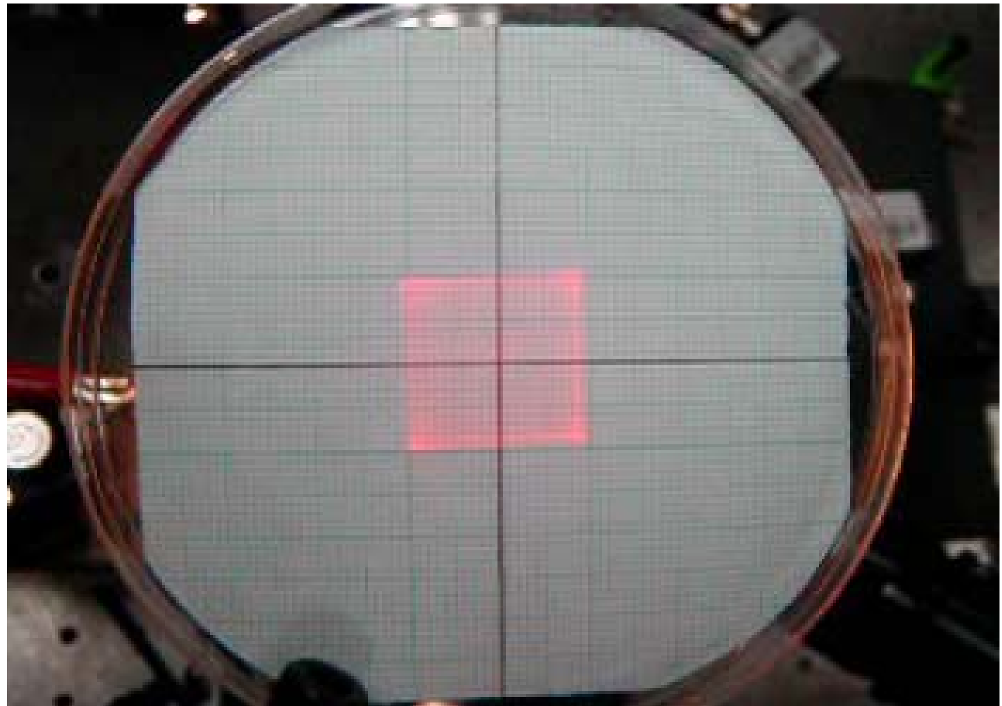
- **Scanning images**



Inner axis: 4.1kHz



Outer axis: 7.1kHz



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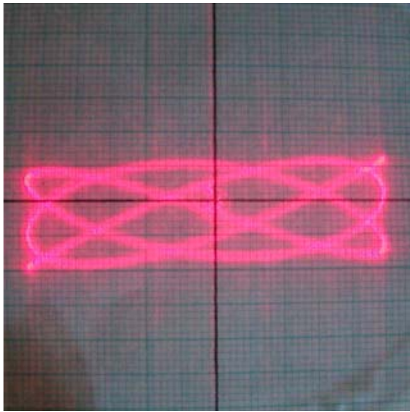
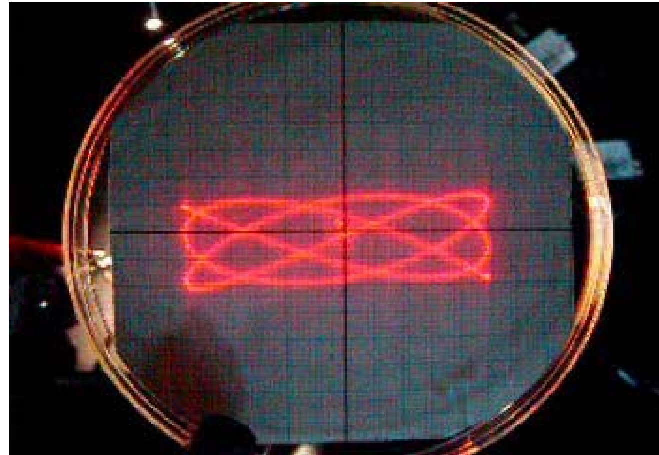
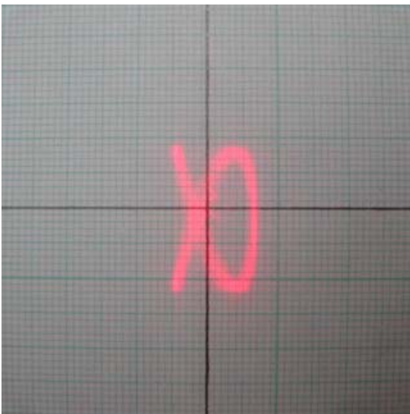
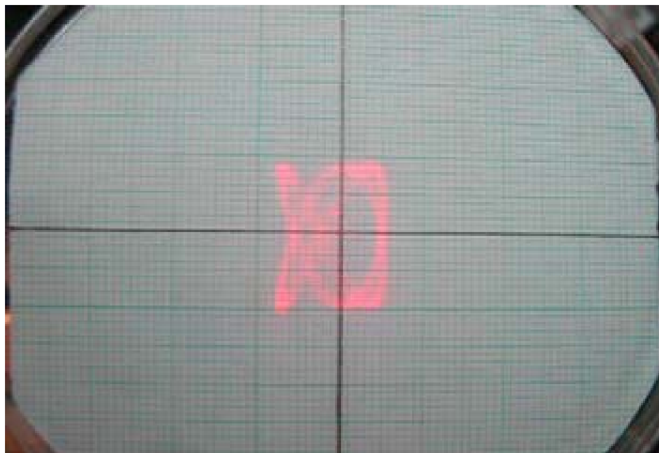
- **Scanning images**

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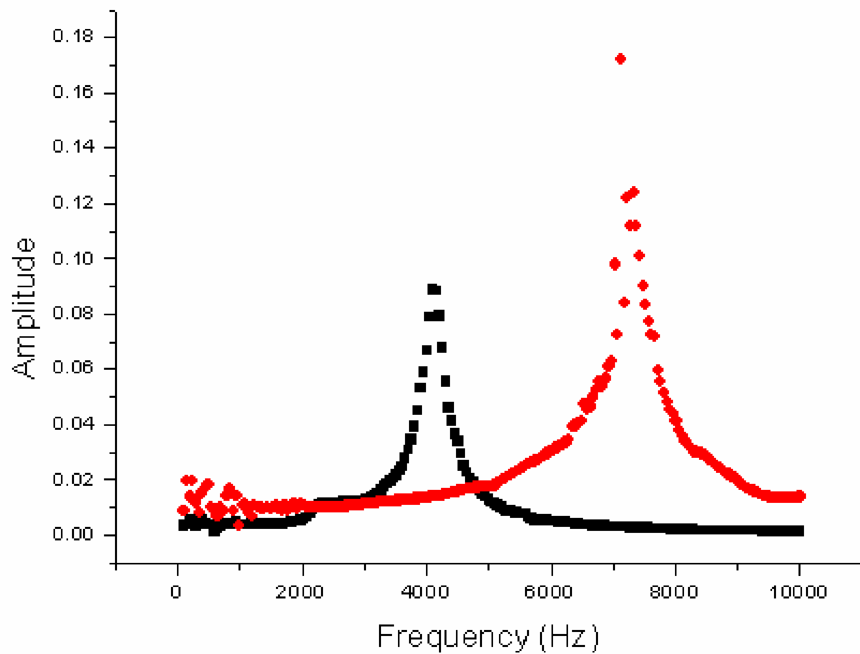
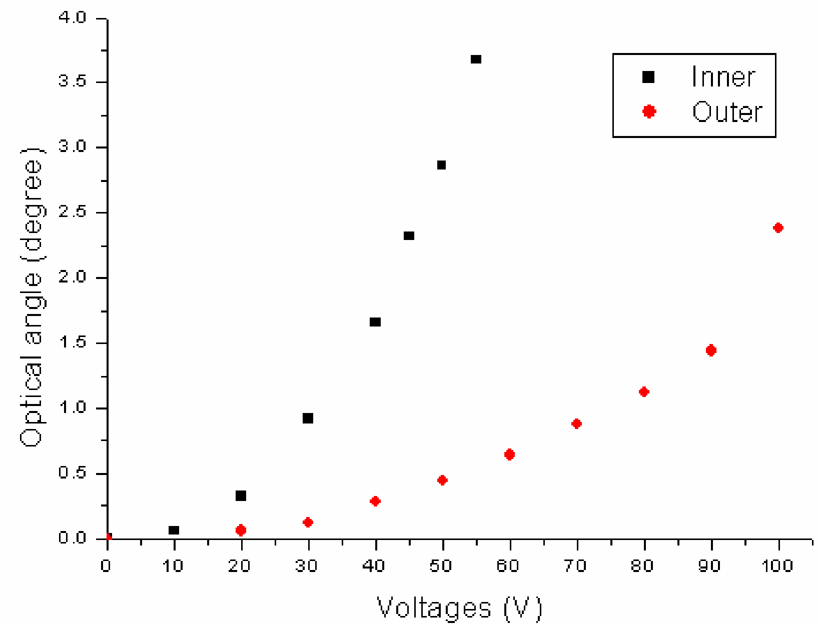
Dynamic measurement

- **Dynamic test driven by AC**
- **Static load-deflection test**





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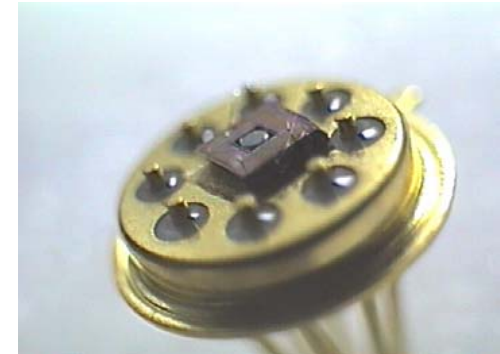
Applications: optical scanner

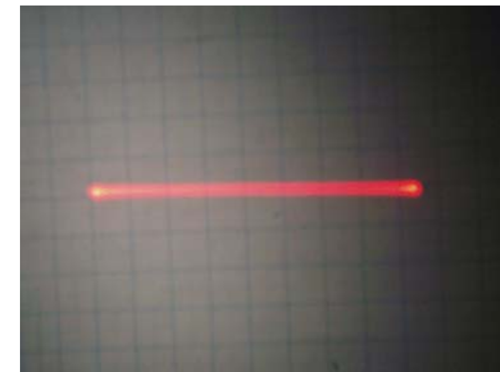
Torsional spring

Mirror

0721 20.0kV X50.5 356µm

EDLA engine



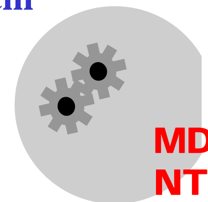


1 cm

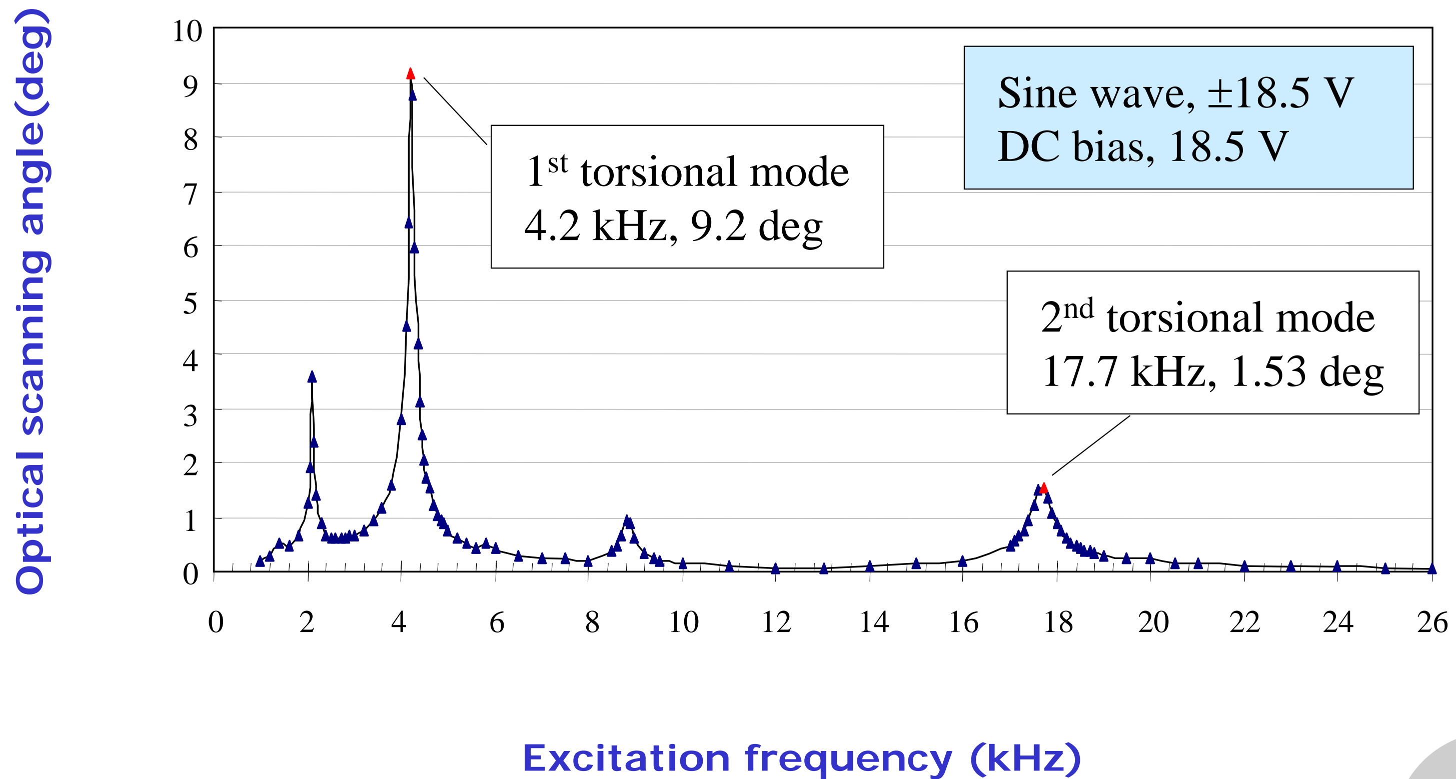
H.-Y. Lin and W. Fang, *IEEE Optical MEMS*, Kauai, Hawaii, 2000

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

H.-Y. Lin and W. Fang, *Sensors and Actuators A*, 2004



- **Measured frequency response**



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