



微機電系統導論

Introduction to Micro-Electromechanical System

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Micro-Electro-Mechanical System Lab.



What's MEMS

- Micro-Electro-Mechanical Systems (MEMS)
 - ▶ Integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through microfabrication 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

MEMS Lab.





Sense of Size

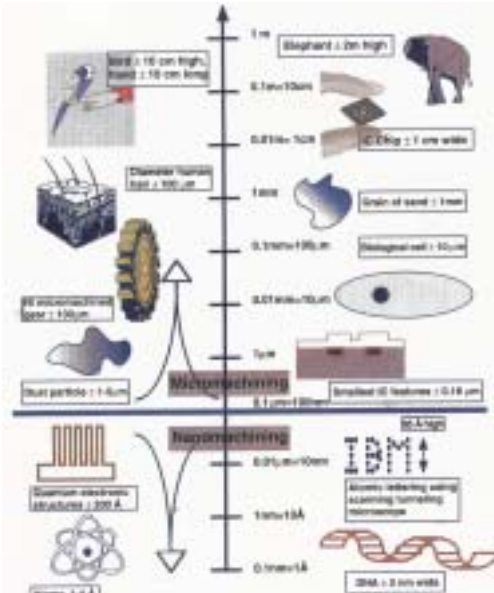


FIGURE 1.5 Various objects and their linear size.



Size of MEMS

- Spider Mite on Mirror Assembly



Source: <http://mems.sandia.gov/scripts/images.asp>



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Micro-System Technology

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graph TD
    MST[MST 技術] --> System[系統技術]
    MST --> Fabric[製技術]
    MST --> Mat[材料及設備]
    
    System --- S1[系統整合]
    System --- S2[包裝及資訊應用]
    System --- S3[系統設計及模擬]
    System --- S4[系統測試及診斷]
    System --- S5[系統集成及組裝]
    System --- S6[封裝技術]
    System --- S7[標準化]
    
    Fabric --- F1[鍍膜製]
    Fabric --- F2[微機械 (MEMS) 製]
    Fabric --- F3[微電子製]
    Fabric --- F4[微系統整合製]
    Fabric --- F5[光 製]
    Fabric --- F6[微組裝]
    Fabric --- F7[微系統 (MEMS) 製]
    
    Mat --- M1[金屬、陶瓷、矽、玻璃、有機材料]
    Mat --- M2[封裝材料]
    Mat --- M3[微加工材料]
    Mat --- M4[黏合劑]
    Mat --- M5[黏-阻層特性]
    Mat --- M6[材料相容性]
    Mat --- M7[生物相容性]
    
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圖 1-6 基本之 MST 技術

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Course Outline

- 微系統技術(MicroSystem Technology)之應用
- 微機電系統相關材料與製作
- MICROMACHINING
 - ▶ 表面微細加工 (etching, Lift-off)
 - ▶ 體型微細加工 (物理蝕刻、化學濕蝕刻)
- LIGA與LIGA-like製程
- 微感測器
- 微致動器
- 封裝技術
- 系統實例 壓電微加速度計的設計與製程規劃

MEMS Lab.

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Applications of MEMS

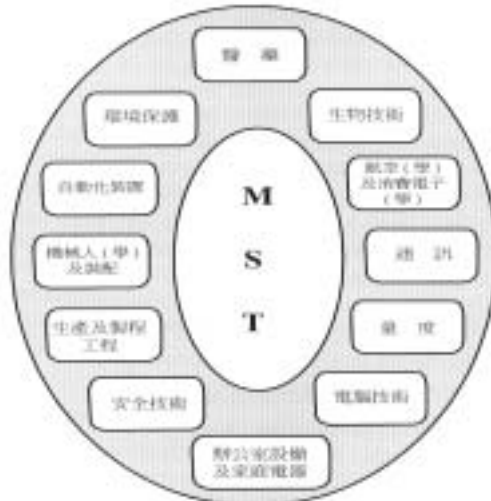
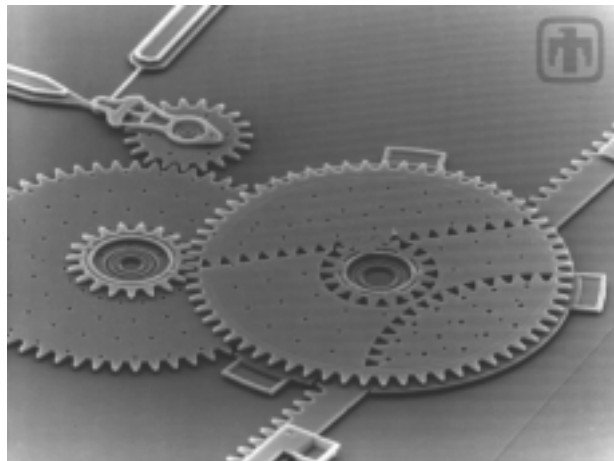


圖 2.2 MST 的應用

EMS Lab.



Linear Rack Gear Reduction Drive



Micro Engine

Source: <http://mems.sandia.gov/scripts/images.asp>

MEMS Lab.





Materials for MEMS

■ Ranges of materials

- ▶ Single crystal silicon, Polysilicon, Silicon Dioxide, Silicon Nitride, Metal, Silicon Carbide, Germanium-based materials, Piezoelectric materials, Diamond, III-V Materials.

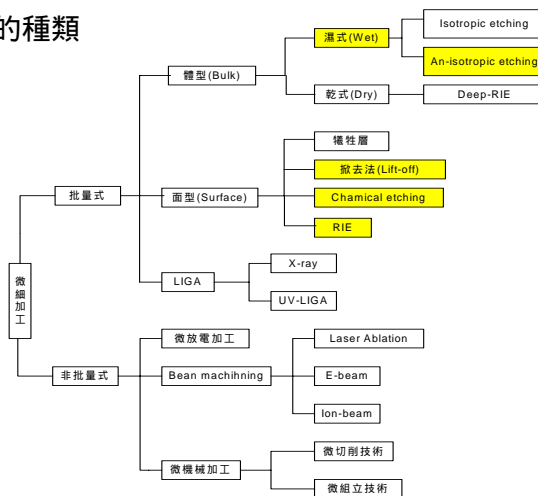
■ Fabrication Methods

- ▶ Crystallization
- ▶ Oxidation
- ▶ Film Deposition
 - Chemical Vapor Deposition (CVD)
 - Physical Vapor Deposition (PVD)



微細加工

■ 微細加工の種類





MEMS Fabrication

■ Surface Micromachining

- ▶ Lithography
- ▶ Lift-Off
- ▶ Sacrifice Layer

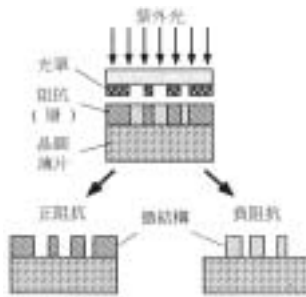


圖 4.3 不同的蝕除步驟。

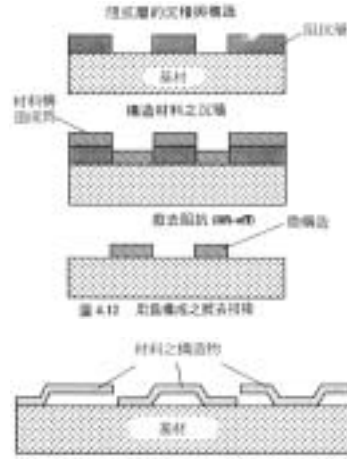


圖 4.17 典型的表面機械加工構造。



MEMS Fabrication

■ Bulk Micromachining

- ▶ Chemical wet etching
- ▶ Deep RIE, ICP

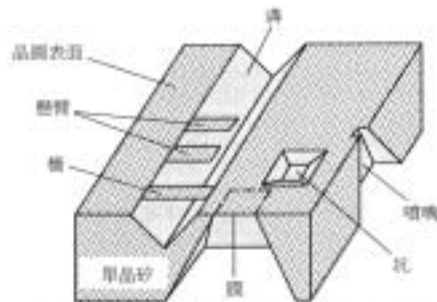
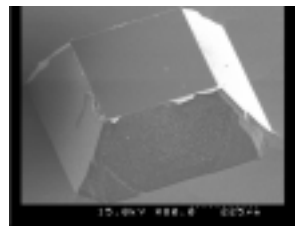


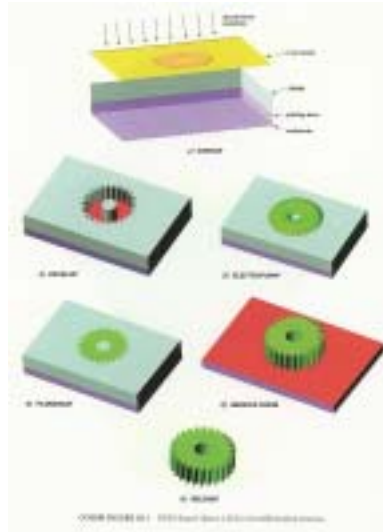
圖 4.14 各種立體機械加工構造。根據 [Hove 90]。





MEMS Fabrication

- LIGA
- LIGA-like Processes

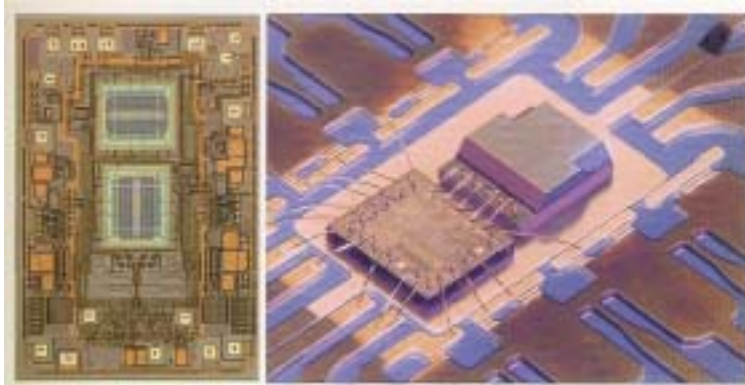


Sensors: Principles and Examples

- Microsensors
 - ▶ Force and Pressure Microsensors
 - ▶ Position and Speed Microsensor
 - ▶ Micro-accelerometer
 - ▶ Chemical Sensors
 - ▶ Biosensors
 - ▶ Temperature Sensors
 - ▶ Flow Sensors



Microaccelerometers



COLOR FIGURE 24.1 Examples of two high-volume accelerometer products. On the left is Analog Devices, Inc. ADXL280 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.)



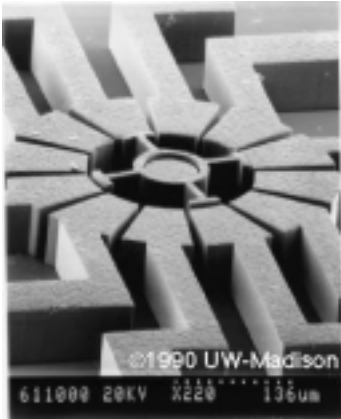
Actuators: Principles and Examples

- Microactuators
 - ▶ Electrostatic Microactuators
 - ▶ Piezoelectric Microactuators
 - ▶ Magnetostrictive Microactuators
 - ▶ Electromagnetic Microactuators
 - ▶ Thermalmechanical Microactuators
 - ▶ Hydraulic Microactuators
 - ▶ Chemical Microactuators





Micro-Motors



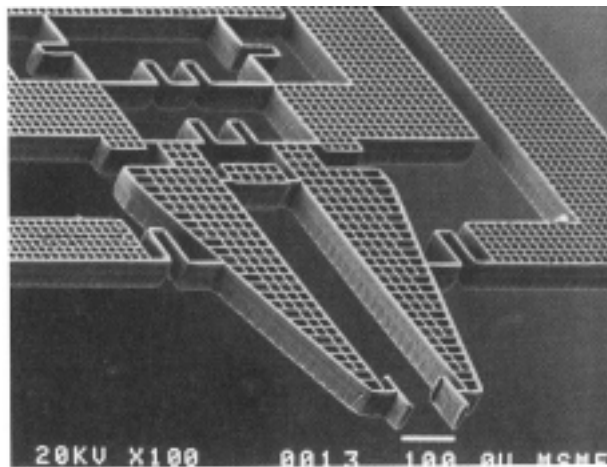
Source: MIT Motor (Dr. Guckel, Professor, U. of Wisconsin, Madison)



Source: <http://www.memsnets.org/mems/>



Tweezer



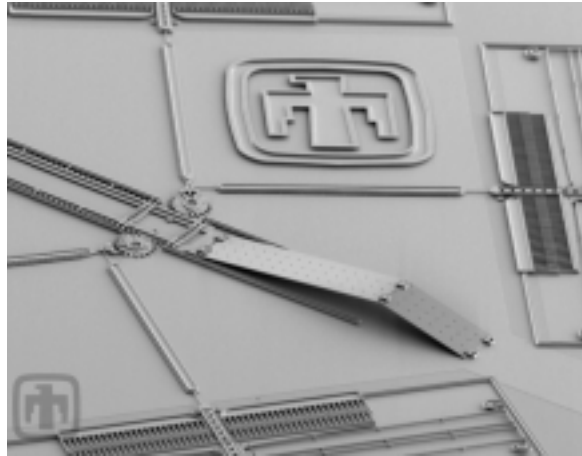
Source: <http://www.memspi.com/>

Pick Fiber





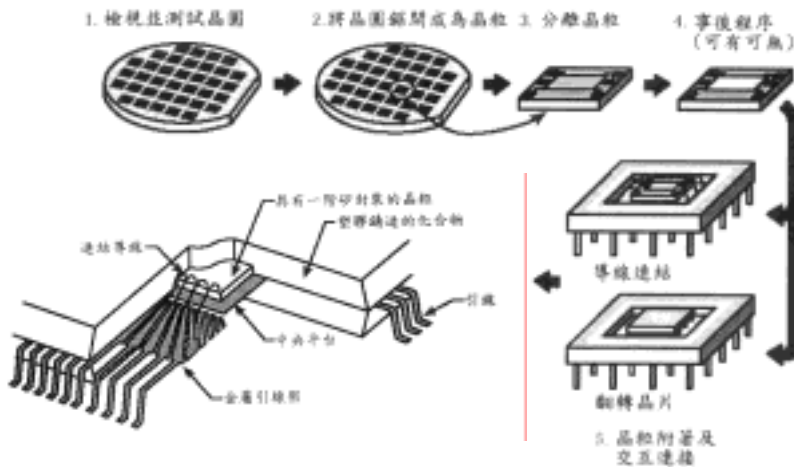
Hinged Polysilicon Mirror and Drive Motors



Source: <http://mems.sandia.gov/scripts/images.asp>



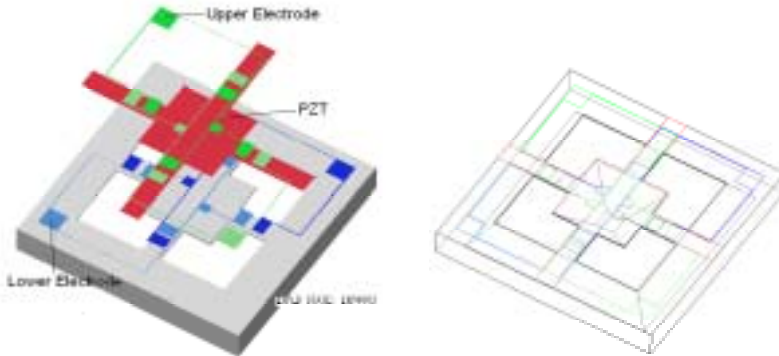
MEMS Packaging





Design of Piezoelectric Microaccelerometer

- Deposition Of Electrode And PZT Thin Films
- Surface Micromachining of Front Pattern
- Bulk Micromachining of Si Microstructure



微加速度計之結構製作流程

- 上、下電極
 - ▶ Sputtering金屬薄膜 (Pt/TiN/Ti)
 - ▶ Lift-off方式製作金屬電極圖形
 - ▶ Sol-Gel金屬氧化物薄膜 (LSMO)
 - ▶ 硝酸蝕刻LSMO製作氧化物電極
- PZT薄膜
 - ▶ Sol-Gel
 - ▶ BOE蝕刻PZT圖形
- 背面振動質塊結構
 - ▶ 光罩角落補償、KOH蝕刻
- 正面懸樑結構
 - ▶ RIE蝕刻 Si_3N_4 及Si結構

