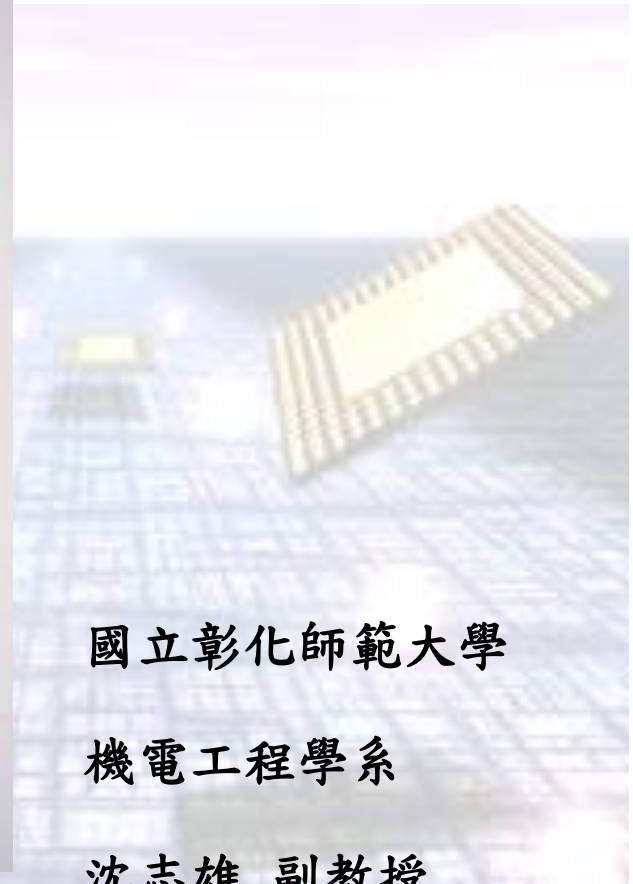
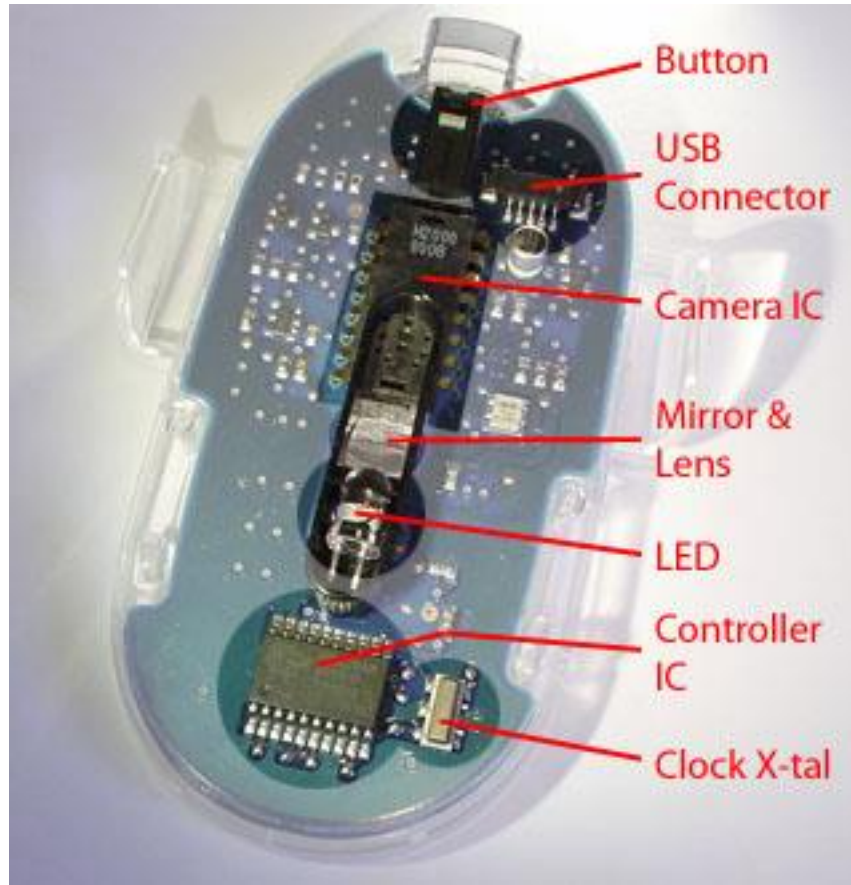
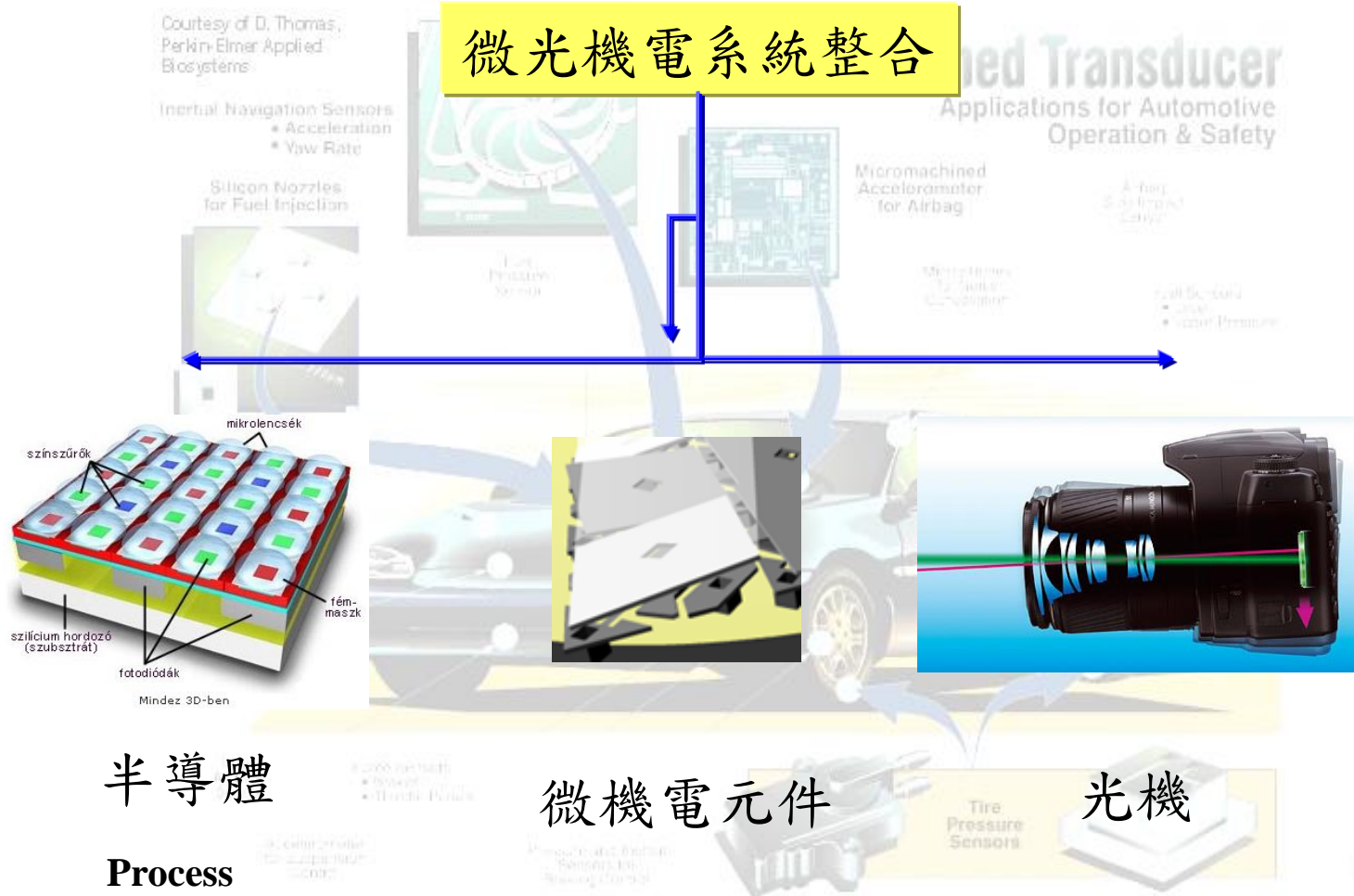


CMOS微機電於生活中的應用



科學家在做些什麼

微光機電系統整合



半導體

Process

微機電元件

光機



MOEMS

微機電產業與應用

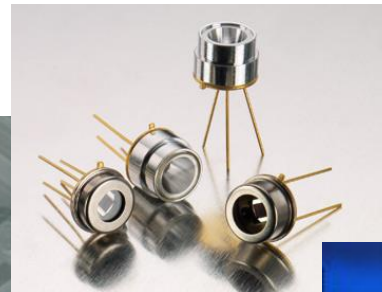
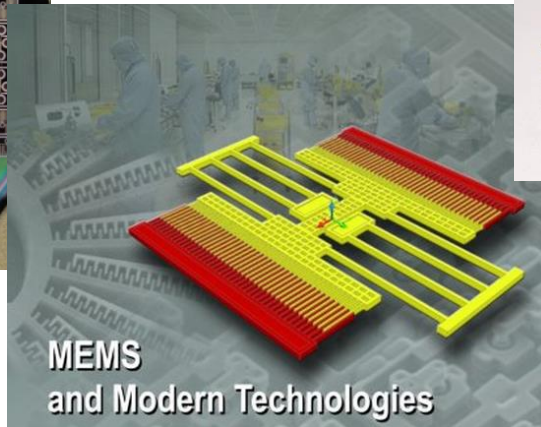
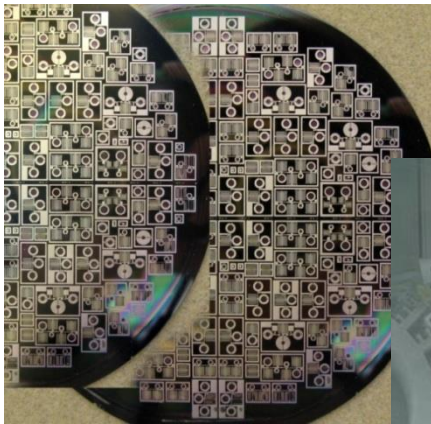
CMOS MEMS 應用

加速計

生物感測

感測電路架構

紅外線感測電路



全球微機電產業發展

2011年全球微機電(Micro Electro Mechanical System；MEMS)前4大廠依序為德州儀器(Texas Instruments)、意法半導體(STMicroelectronics)、惠普(Hewlett Packard；HP)、博世(Robert Bosch)，除惠普為系統業者外，其他3家廠商均為整合元件廠(Integrated Device Manufacturer；IDM)。

2011年**德州儀器**MEMS事業營收較2010年成長51.2%，為9.1億美元，其現為數位光學處理(Digital Light Processing；DLP)晶片獨家供應商，營收主要來自以MEMS元件為基礎的DLP投影相關產品。

2011年**意法半導體**MEMS事業營收較2010年成長6.7%，接近9.1億美元，其現於消費性MEMS市場居龍頭地位，不僅可將加速度計、陀螺儀、地磁感測器、壓力感測器等MEMS元件整合於單一模組，亦可供應技術難度較高的3軸加速度計與3軸陀螺儀。

2011年**惠普**MEMS事業營收較2010年衰退5.6%，為7.6億美元，受制於整體印表機需求漸難成長，惠普於全球MEMS廠商營收排名有下滑現象。

2011年**博世** MEMS事業營收較2010年成長15.9%，為7.4億美元，其MEMS產品原先以供應汽車應用為主，然已跨入消費性電子應用，由於車用電子市場所需認證時間長，博世 MEMS事業在站穩汽車應用後再跨入消費性電子應用，相對其他廠商自消費性電子跨入汽車應用具一定優勢。

2010年**樓氏電子**(Knowles Electronics)於全球MEMS廠商營收排名第18，其以供應MEMS麥克風為主，在行動裝置擴大採用MEMS麥克風情形下，營收具成長潛力。

台積電 2011年營收145.33億美元。

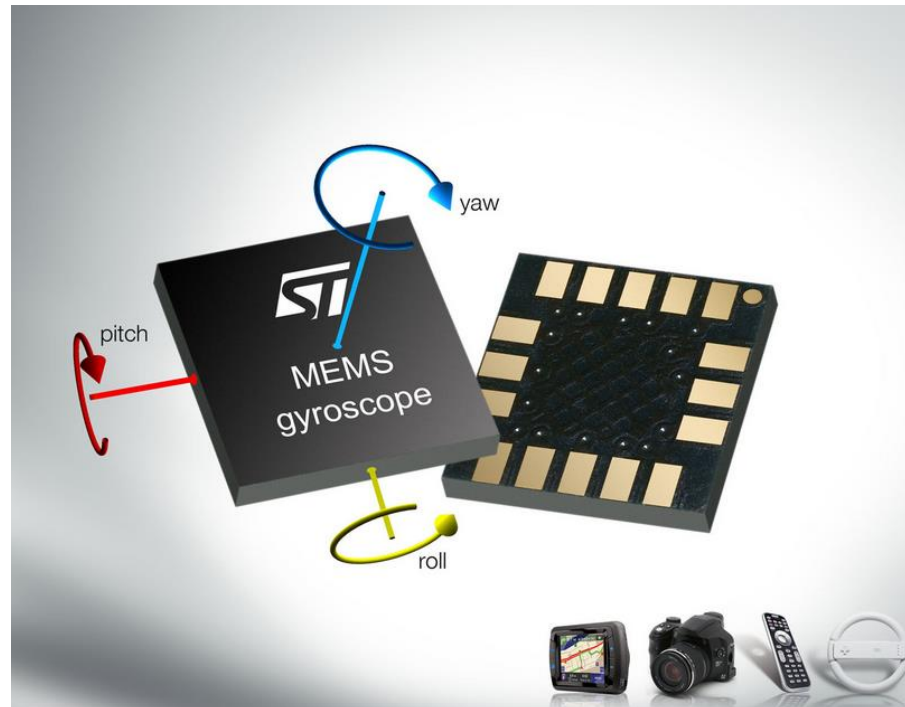
全球消費性電子與行動裝置用**MEMS**營收**2011年將達22.5億美元，年成長37%**，MEMS市場在2012-2014年間，預計將有10位數的成長率，2014年營收可達**108.1億美元**。

研調機構Yole Dveloppement則預估，2016年MEMS市場將達196億美元規模，
取自: DIGITIMES 》 Research 》 IC製造



動作感測無所不在 微機電系統開展全新應用

在一般的動作感測中，可分為加速度、震動、衝擊、傾斜及旋轉。而除了旋轉之外，其餘動作實際上都是在不同時間區間中加速度的不同表現型式。然而，由於不能直接將這些動作感測就當成是加速度/減速度的變化，因此分別考慮每一種模式，將有助於更多可能性的開展。



紅外線熱影像



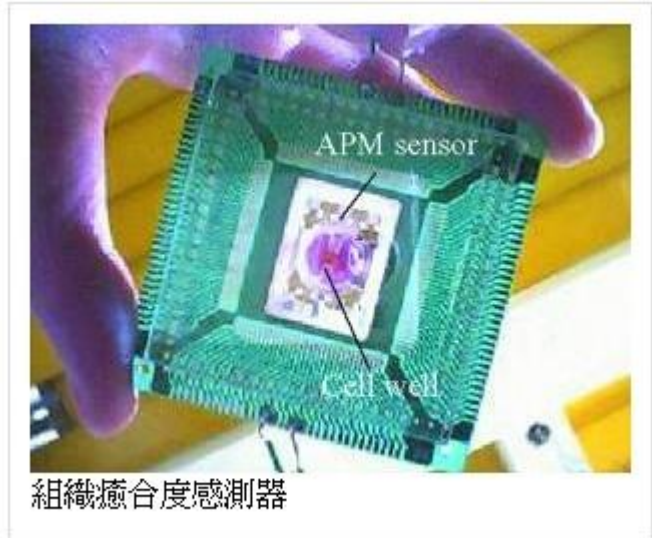
攜帶式紅外線熱影像攝影機可讓機場、運輸系統、公共衛生官員及其他人迅速篩檢並測量大量人群的皮膚溫度。體溫顯示高於正常範圍的人，可將其隔離並安排進一步的評估，以幫助預防疾病擴散。



生醫晶片及微流體系統

近年來生醫檢測晶片為眾所矚目的熱門研發題材，主要原因為其具有成本低、可攜帶與快速檢驗的特性，因此被寄予厚望，期能帶動新一波生化科技革命。以 SARS 病毒檢驗為例，未來若解開 SARS 病毒之謎，人手一具生物晶片，可即時檢驗感染與否，相信定可避免其擴大傳染。

生醫微機電系統為整合生醫感測及奈微流體系統於單一晶片上的微小系統，用以達成自動化生醫檢測、藥物釋放或藥物篩檢等功能。目前常見的產品有全血檢測、基因晶片、微藥物釋放系統等，最終的目標將是整合所有功能於一的實驗室晶片 (lab on a chip, LOC) 或微全分析系統 (micro total analysis system, μ TAS)。



慣性感測器發展

微機電(Micro Electro Mechanical Systems ; MEMS)慣性感測元件(Inertial Sensors)是採MEMS技術製造，用於量測運動(Motion)狀態變化的感測元件(Sensors)，其中，估算線性(Linear)速率變化的MEMS加速度計(Accelerometer)，以及角度(Angle)速率變化的MEMS陀螺儀(Gyroscope)，則為MEMS慣性感測元件的2大主要產品類別。

MEMS慣性感測元件早期應用集中於汽車市場，包括提供撞擊緩衝防護的安全氣囊(Air-Bag)與防止車輛側滑的電子車身穩定系統(Electronic Stability Control ; ESC)等。

隨任天堂(Nintendo)在2006年11月推出的遊戲機Wii，與蘋果(Apple) 2007年6月推出的iPhone雙雙創下銷售佳績，MEMS慣性感測元件市場自此正式起飛。

MEMS慣性感測元件不僅能獨立應用在硬碟保護(HDD Protection)、光學防手震(Optical Image Stabilization ; OIS)裝置，透過動作感知(Motion Sensing)功能，得以透過手勢識別(Gesture Recognition)介面控制行動裝置，並為遊戲控制器(Game Controller)、智慧遙控器(Remote Control)、3D滑鼠等，提供更直觀的操控介面。

手機平板裝置應用結合利用地球磁場(Magnetic Field)原理量測地磁方位的MEMS磁力計(Magnetometer)，與利用大氣壓力(Atmospheric Pressure)量測的MEMS壓力計(Barometer)，則能將相關應用延展至電子羅盤(Electronic Compass ; E-Compass)與慣性導航系統(Inertial Navigation System ; INS)。

機會: MEMS技術向來掌握在歐美廠商手中，值此技術已臻成熟之際，再加上亞洲地區MEMS晶圓製程日漸成形，為求降低製造成本，歐美MEMS大廠商已逐漸向國內台積電、聯電等晶圓廠釋出代工機會與技術，促成中國大陸與台灣MEMS廠商勢力崛起，未來，國外MEMS大廠對於亞洲市場的布局，以及MEMS製造重鎮是否向亞太地區位將備受矚目。



台灣微機電產業

元件廠商	晶圓代工	封裝測試
<p>慣性感測器: 利順、矽創、矽立 (mCube)、合發微、原相..</p> <p>微反射鏡: 華新麗華(探微科)、先進微系統(OPUS)</p> <p>噴墨: 研能、國際聯合</p> <p>壓力計: 聯興微、全磊</p> <p>紅外線: 眾智</p>	<p>台積電 亞太優勢 探微科 聯電 旺宏</p>	<p>菱生 矽品 日月光 同欣 精材 微邦</p>

台積電之微機電發展

台積電在微機電系統(MEMS)晶圓代工市場發展有成。IHS iSuppli最新研究指出，台積電2011年MEMS晶圓代工營收達5,300萬美元，較2010年的1,760萬美元大增200%；不僅一躍成為全球專業MEMS晶圓代工市場龍頭，更是前五大業者中，唯一由半導體晶圓代工領域跨足投入的業者。

2011年全球專業MEMS晶圓代工廠營收排名 (單位：百萬美元)

公司	2011年	2010年	年增率(%)
台積電	53.0	17.6	201%
Silex	45.9	36.0	28%
Teledyne Dalsa	37.0	30.9	20%
亞太優勢	26.2	31.2	-16%
IMT	22.0	19.9	11%
Micralyne	16.8	31.3	-46%
X-Fab	16.1	12.0	34%
Tronics	14.9	10.2	46%
探微科技	11.5	12.6	-9%
Jazz	7.5	4.0	88%
Semefab	6.0	4.4	36%
GlobalFoundries	5.0	1.8	178%
其他	24.1	19.9	
總計	286.0	231.8	

資料來源：IHS iSuppli(07/2012)



微機電機電整合趨勢



微機械設計

半導體製程技術

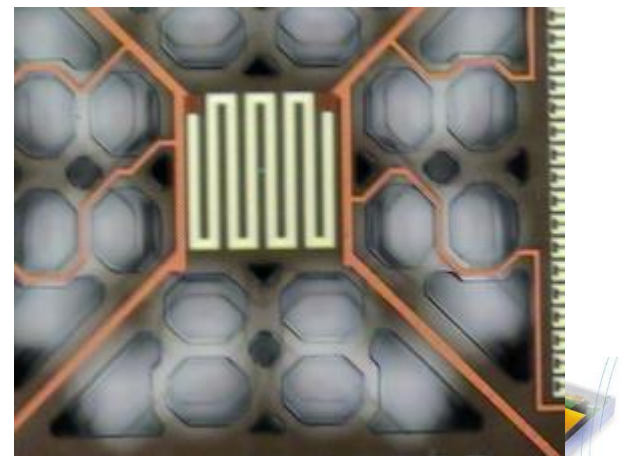
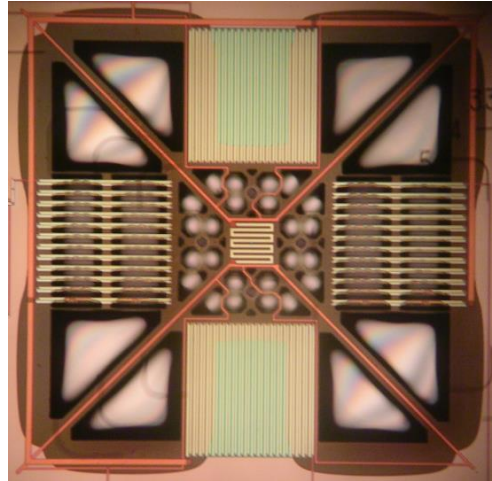
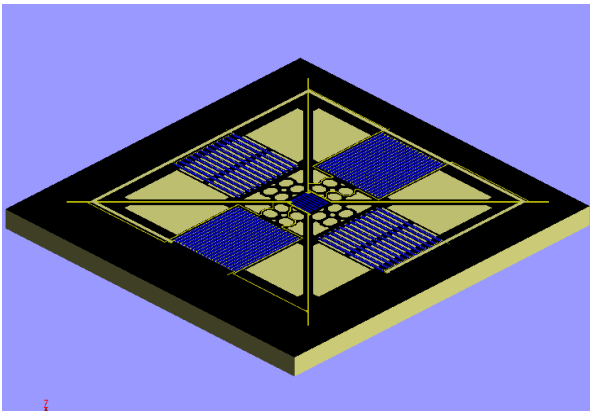
數位類比積體電路設計

整合性方案

產品應用開發



加速計/傾斜計



加速計感測電路-電容感測



open loop:



$$V_{out} = a_{in} \times \underbrace{\frac{m}{k}}_{\text{spring-mass response}} \times \underbrace{\frac{\partial C}{\partial x}}_{\text{cap. interface}} \times \underbrace{\frac{V_0}{C_{int}}}_{\text{position sense}}$$

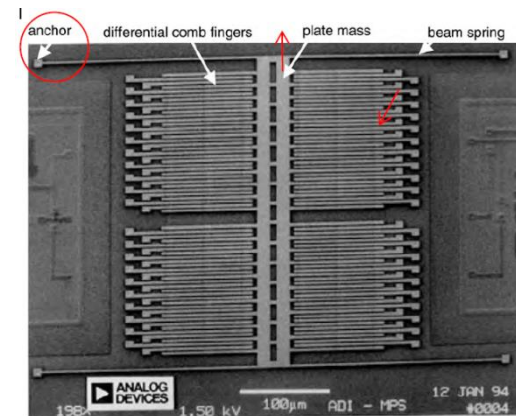
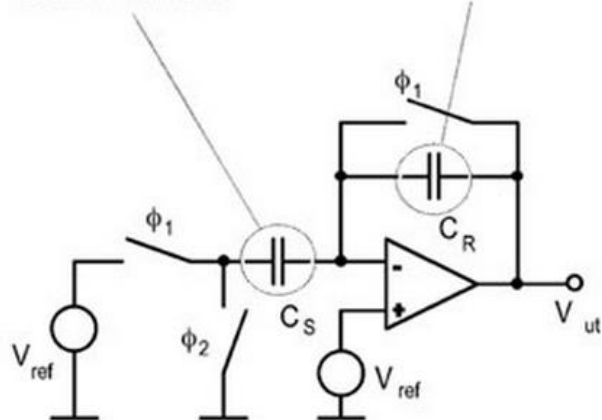
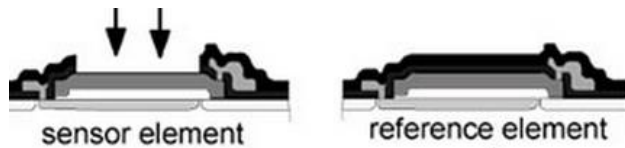
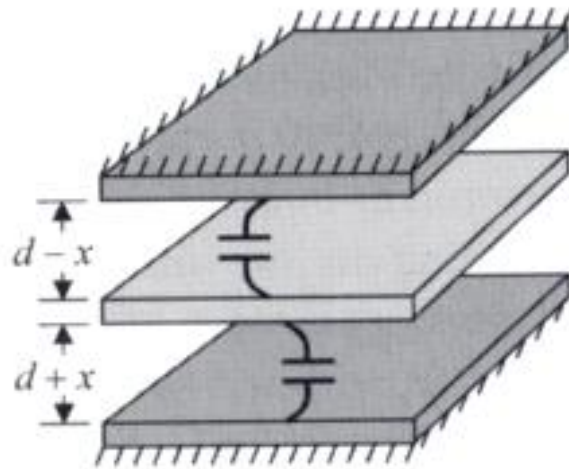


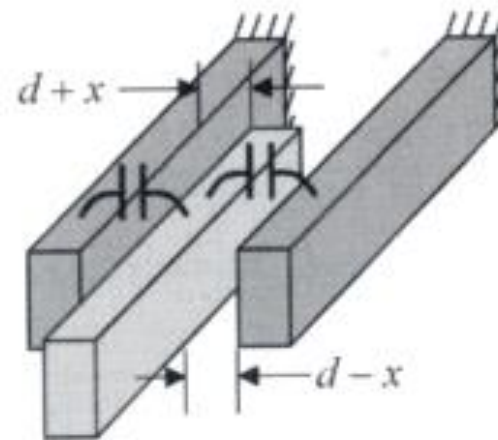
Fig. 3.5a ADXL50 - transducer



Vertical Plate Electrodes and Sidewall Electrodes



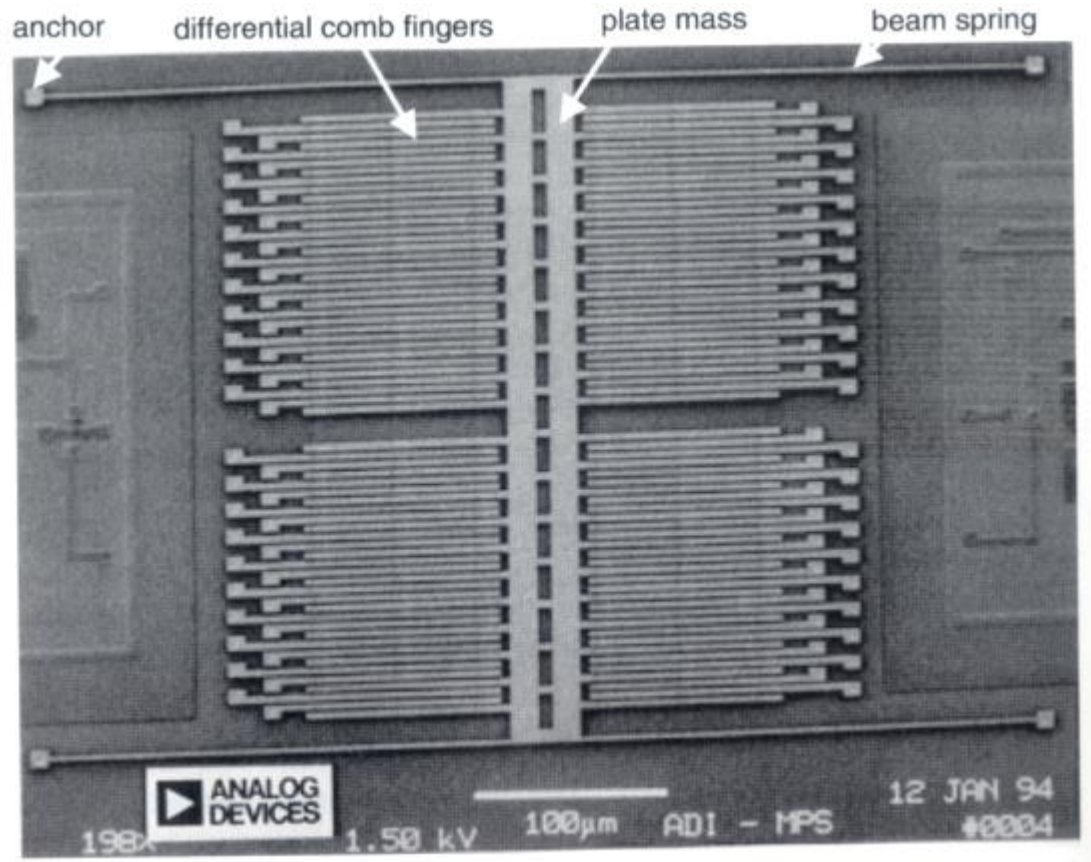
(a)



(b)

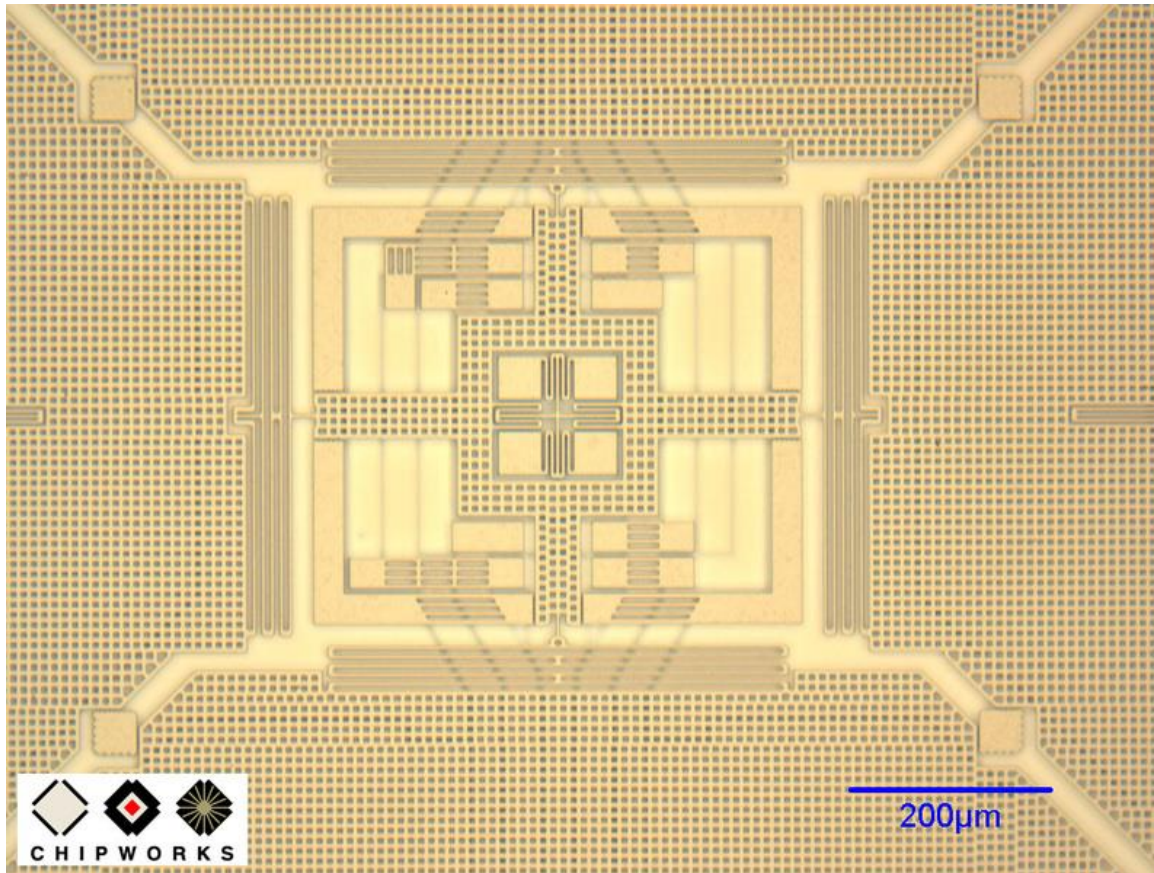
電極設計

AD XL50 - Transducer

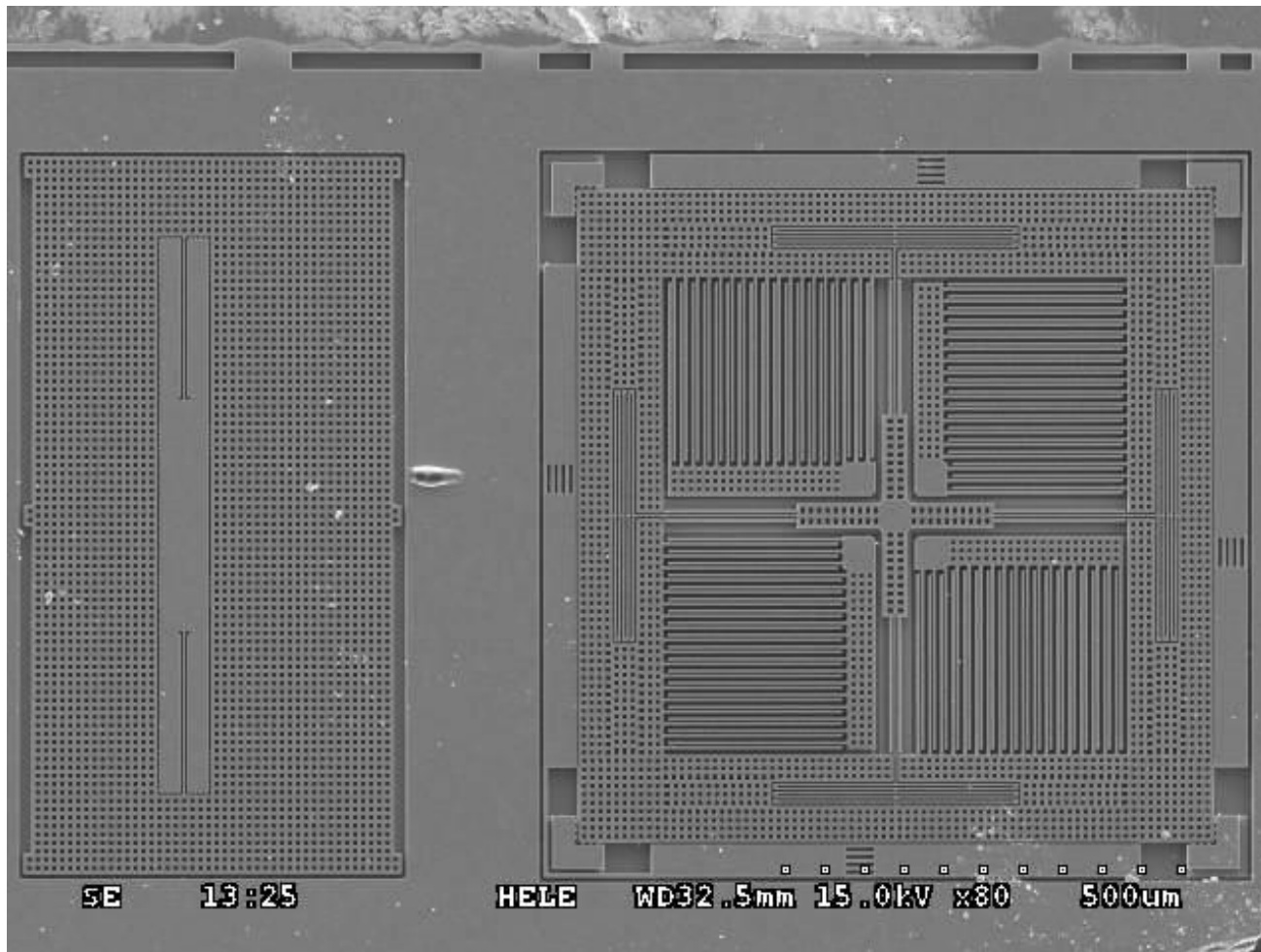


STMicroelectronics L3G4200D gyroscope

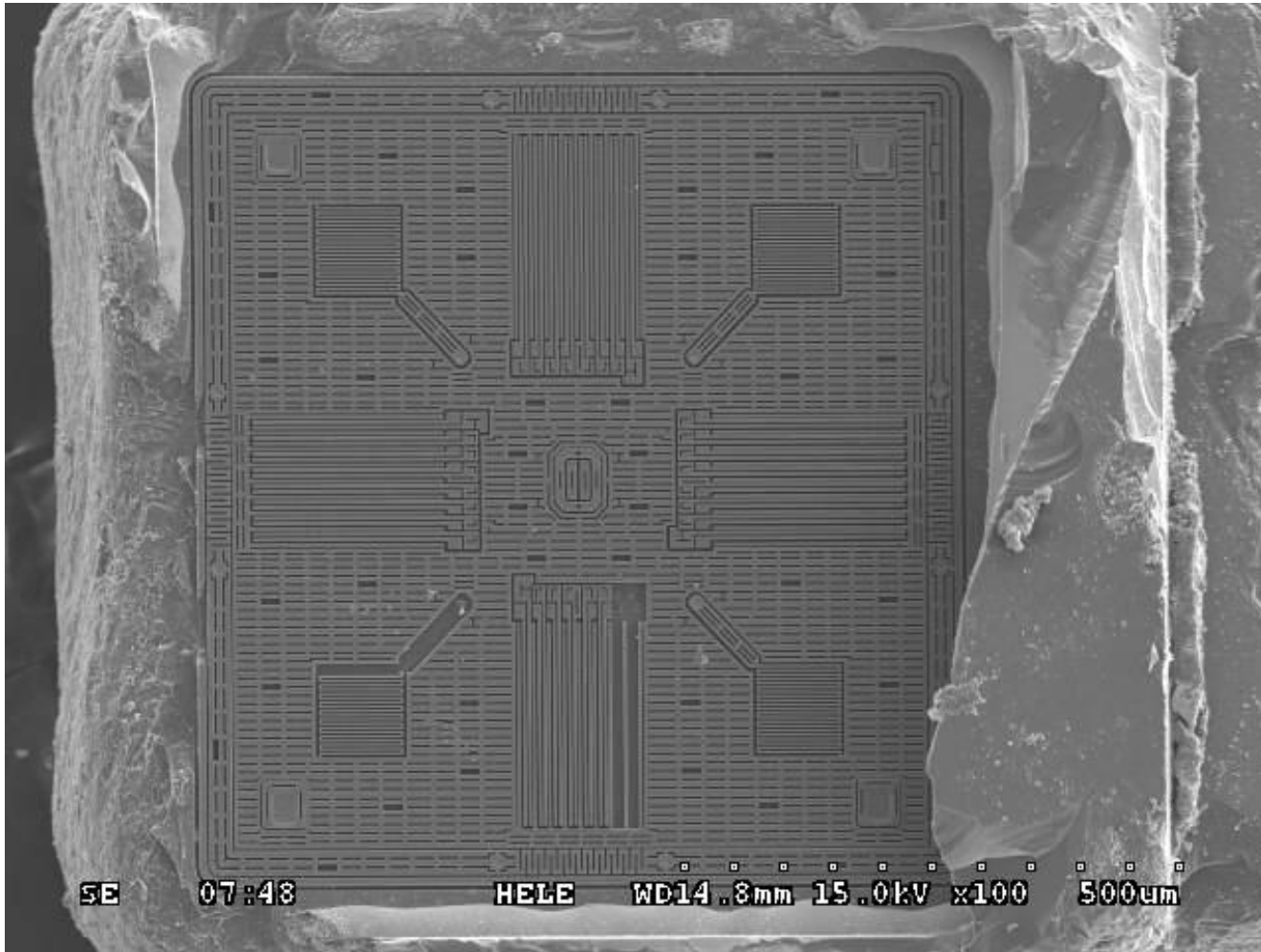
It's confirmed that the MEMS gyroscope found inside the iPhone 4 is nearly identical to an off-the-shelf STMicroelectronics L3G4200D gyroscope.



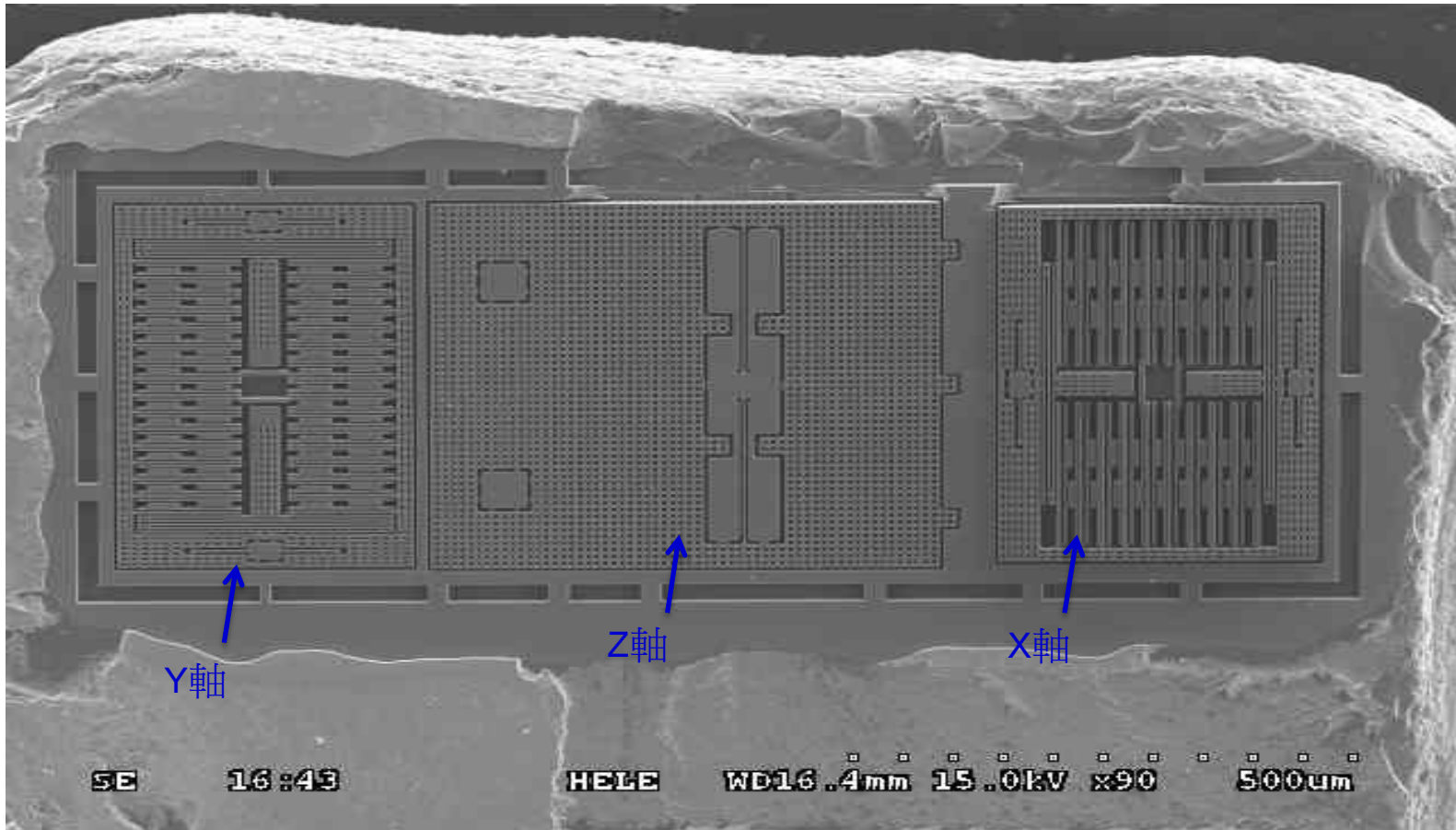
ST-LIS331HH(SEM)



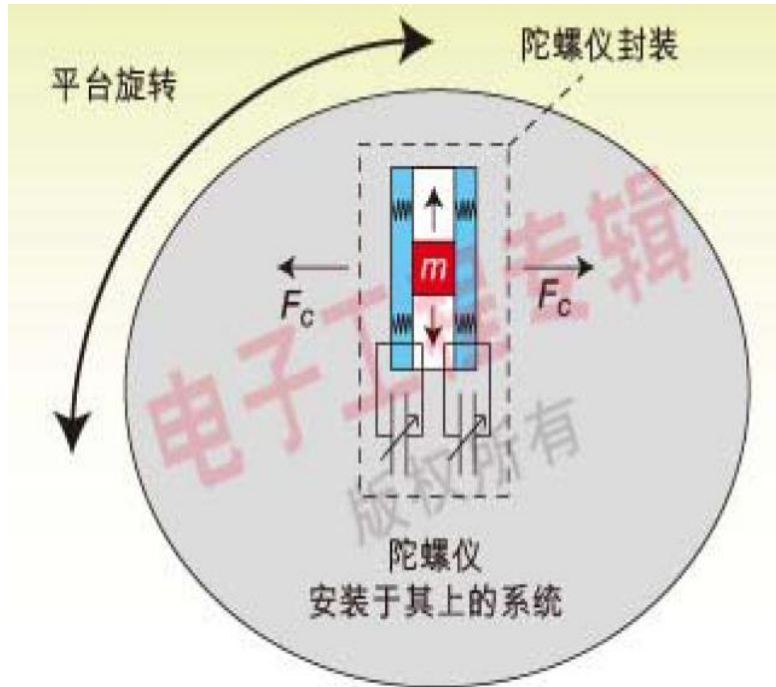
ADI-ADXL346 (SEM)



BOSCH-BMA250



加速計感測電路-陀螺儀應用



$$\vec{a}_c = 2\vec{\Omega} \times \vec{U}$$

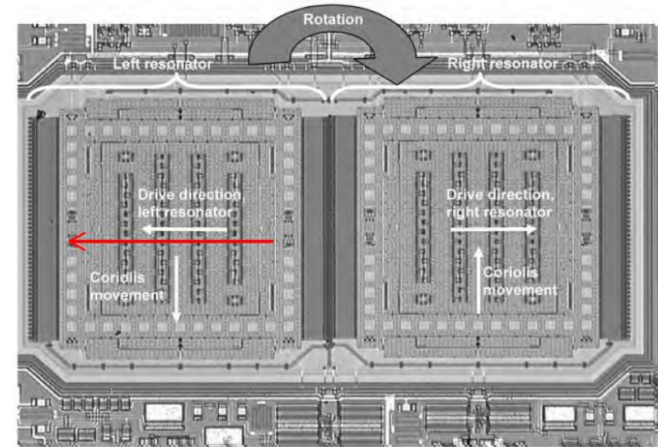
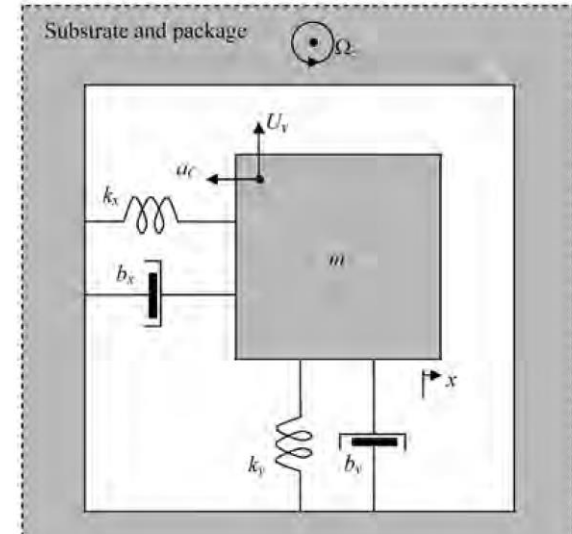
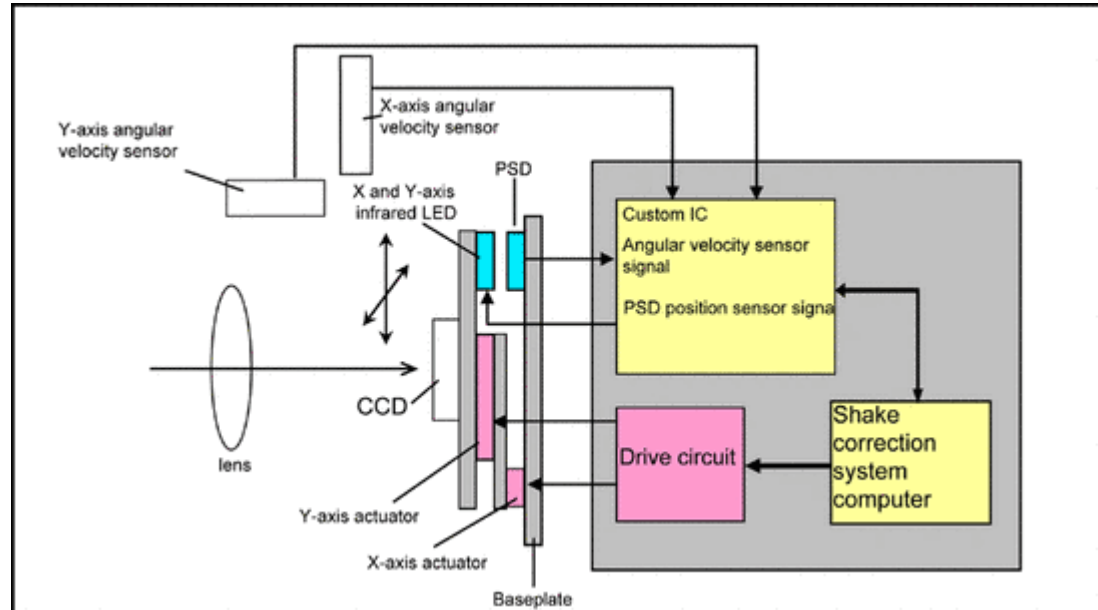
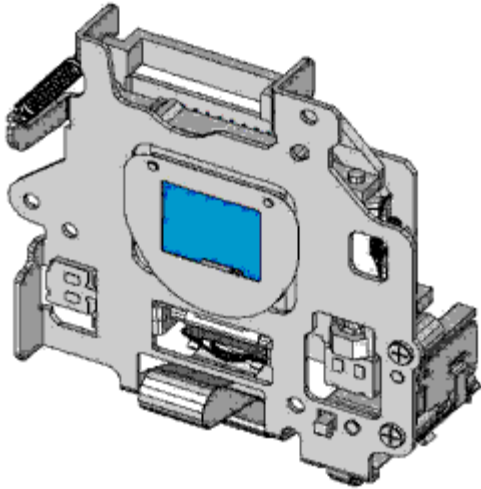


Fig. 3.11 XRS150 gyroscope transducer, showing differential lateral resonator structure

加速計感測電路-防手震應用



The movement of the camera is acquired with the help of **two gyroscope-sensors**. It is not only necessary to detect the angle of movement, but also the speed of it. The signal generated by the sensors measuring the angle of the camera is passed on to a microprocessor. The microprocessor is getting additional data about the position of the CCD-mount from a position-sensor. The data is passed on to the Anti-Shake processor, that calculates the exact movement that is necessary to compensate for the camera shake.

加速計感測電路-陀螺儀應用

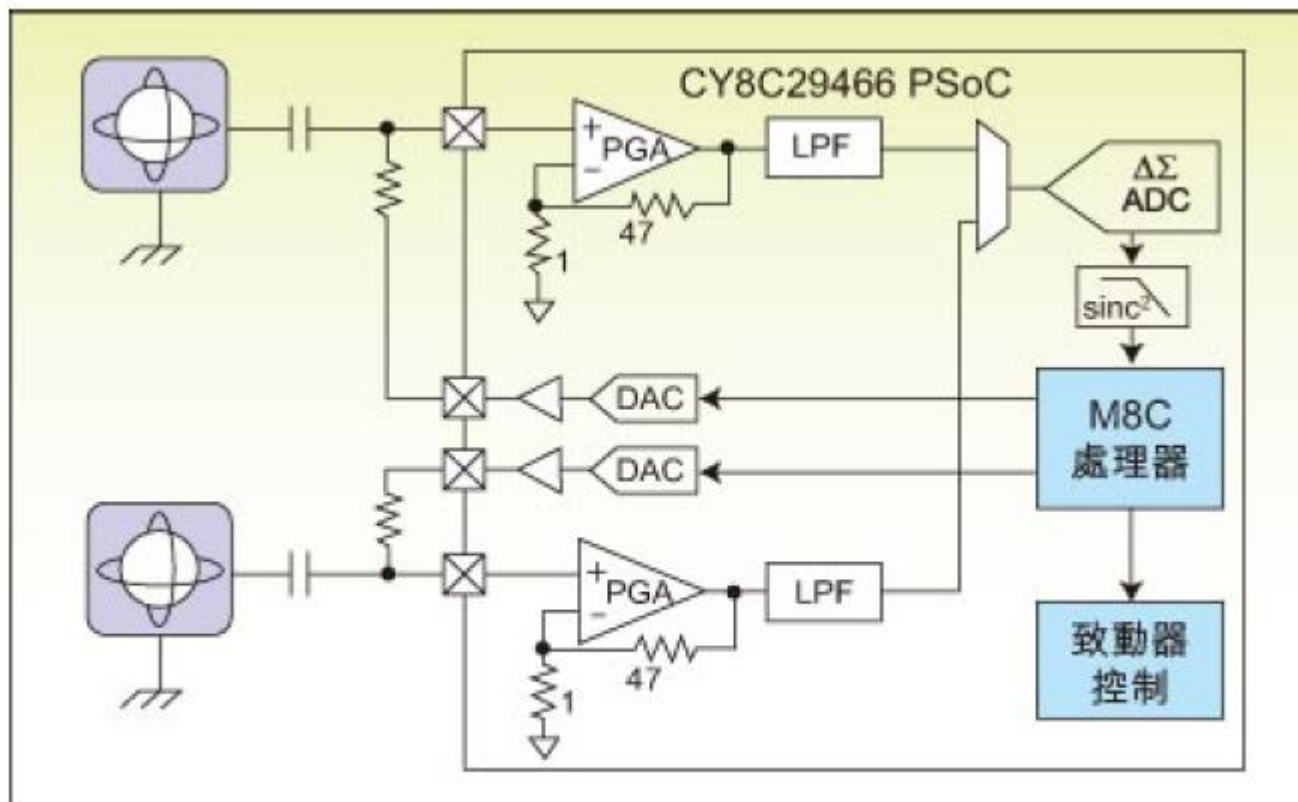
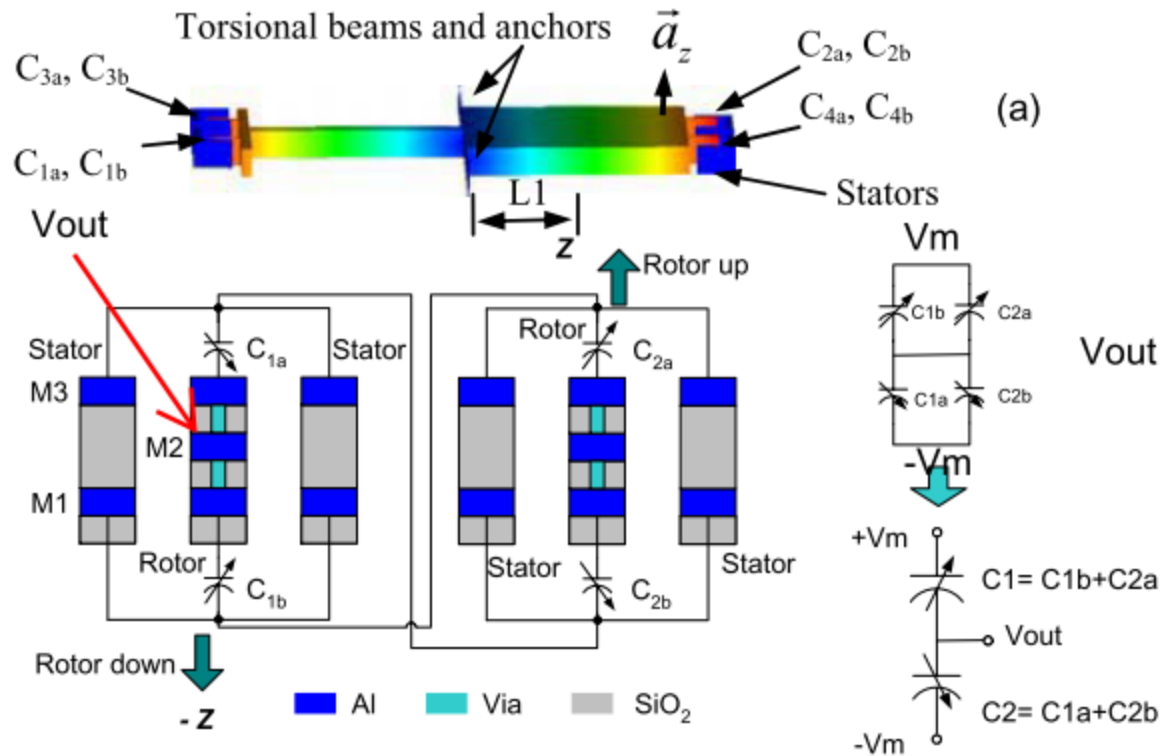
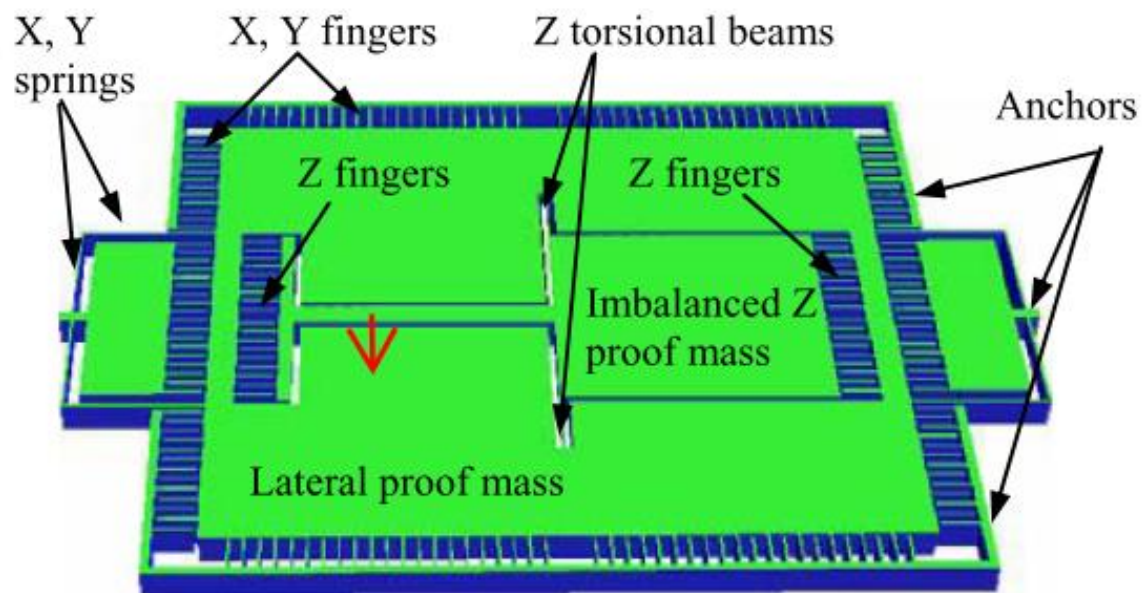


圖7. 完整的影像防震電路。

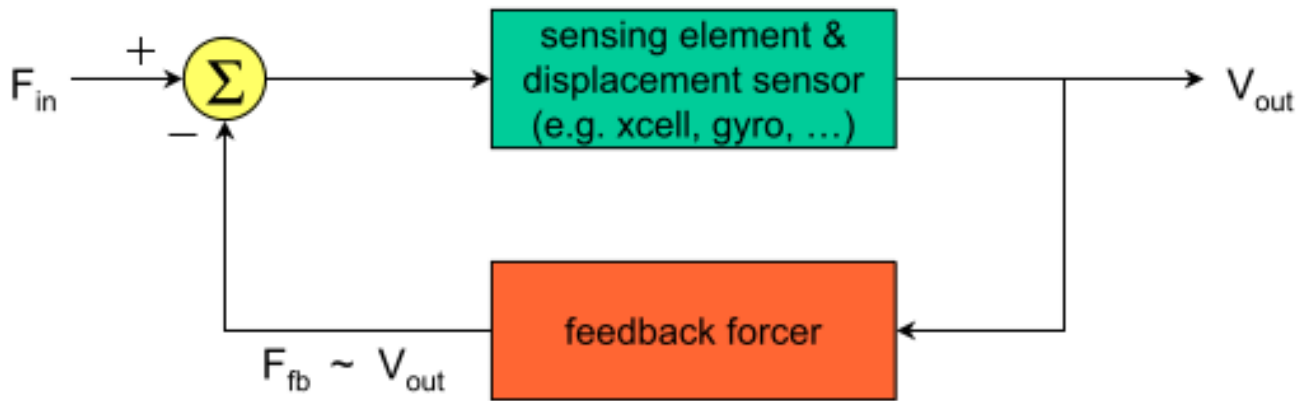
三軸電極設計



三軸結構設計



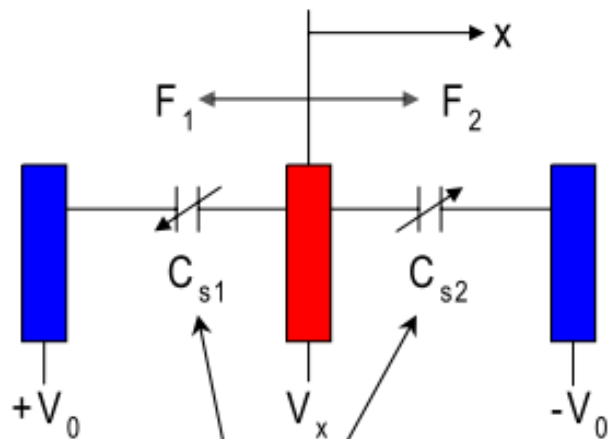
回授原理



Overall system linearity depends on linearity of electrostatic forcer.

→ Need linear feedback forcer.

差動回授作用力



Matched parallel capacitors
(e.g. transverse comb).

$$\begin{aligned}\Delta F &= F_1 - F_2 \\ &\approx -\frac{1}{2} \frac{C_0}{x_0} \left[(V_0 - V_x)^2 - (V_0 + V_x)^2 \right] \\ &\approx \frac{2C_0 V_0 V_x}{x_0} \quad x \ll x_0\end{aligned}$$

Microphone



Figure 2. EmKay Sisonic Microphone. This microphone is made from Silicon and is only millimeters large.

(Photo Courtesy of EmKay)

Microphone



Necessity of Communication

from
Hand
to Mouth



the Origins
of Language



Human Communication (Humanities)



MOEMS

Sound

Sound is adiabatic pressure variation of the air in the audio band. The sound intensity is often given in

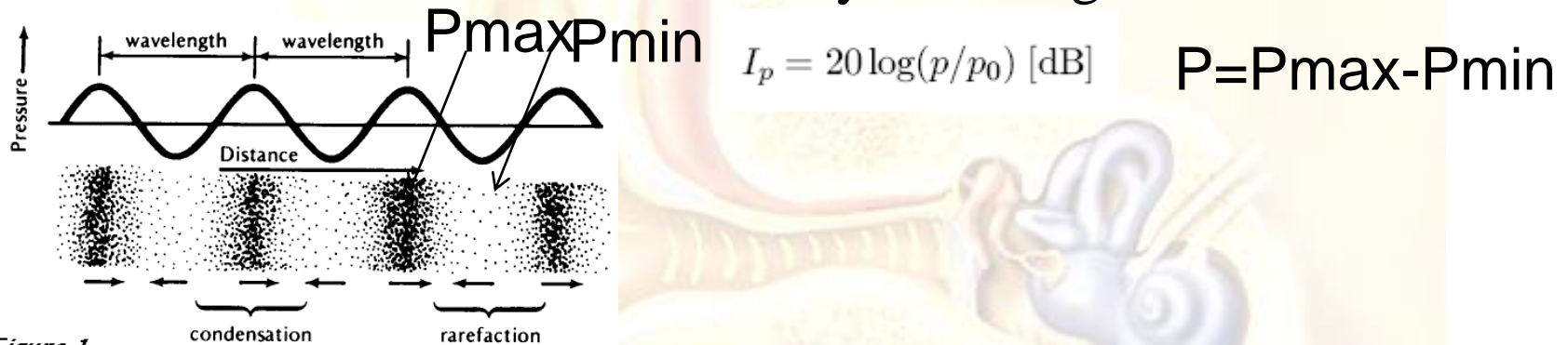
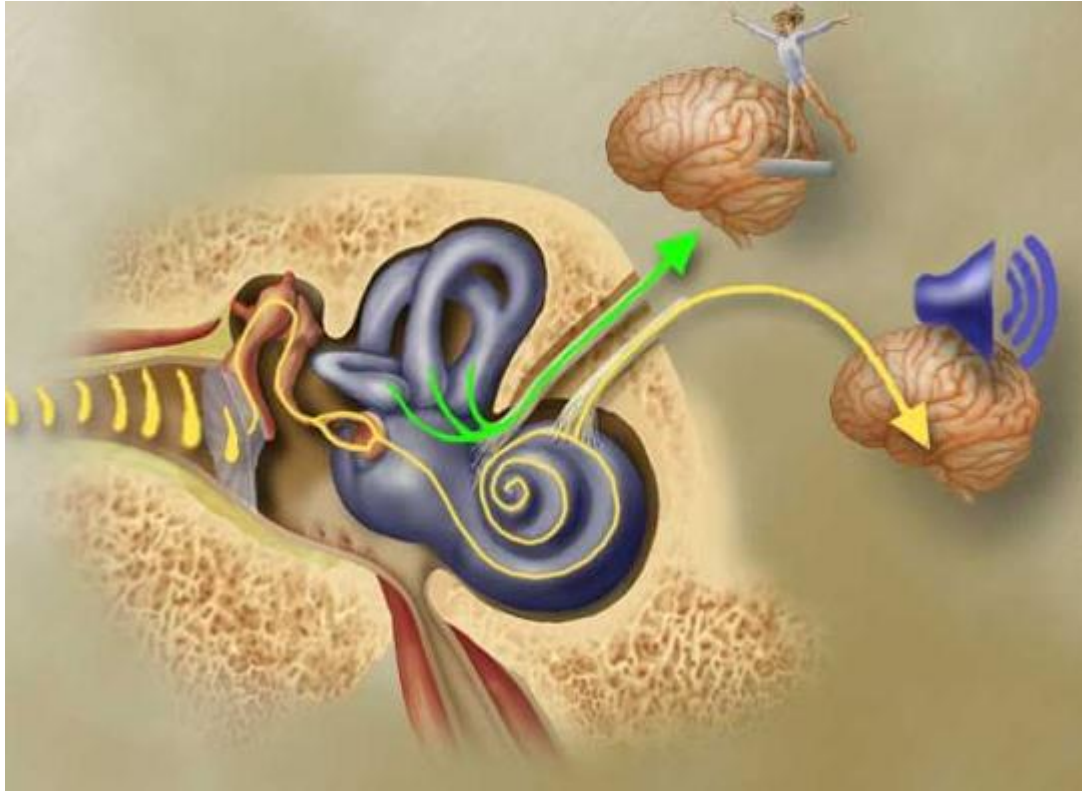


Figure 1

where 0 dB corresponds to $p_0 = 20 \mu\text{P}$. Human ear is not a very hifi sound sensor, since its sensitivity is highly peaked at 1 – 10 kHz. The A-weighted curve mimics the ear resolution and is often used to characterize the resolution of microphones (Fig. 1). A good microphone has a resolution, integrated over all frequencies, ≤ 34 dB(A)



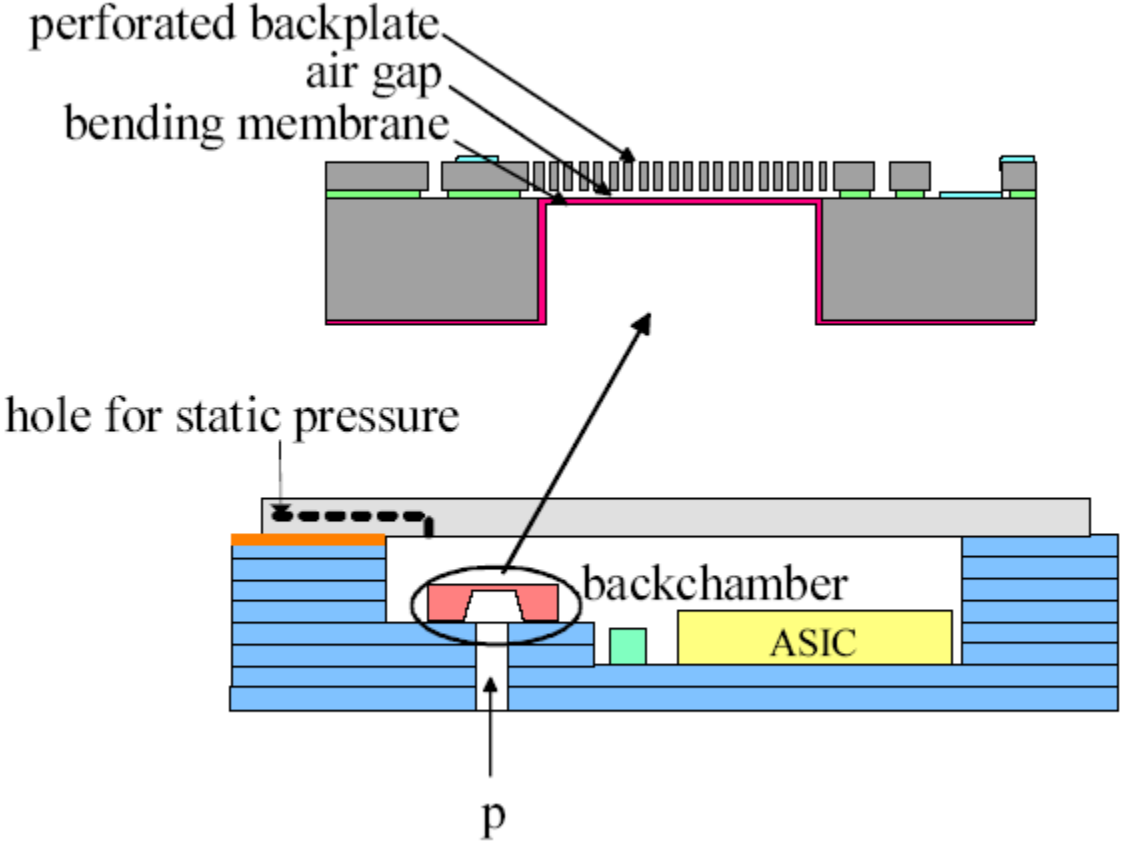
Sensing Sound



Sound passes through the tympanic membrane, vibrates the tiny bones of the ear, and is translated to a nerve impulse through the cochlea. The cochlea, in turn, sends sound impulses to the temporal lobe of the brain. The ear is also responsible for the sense of balance, which occurs within the vestibular apparatus. The vestibular apparatus translates information about the body's position to the brainstem.



1. MEMS Microphone



Process Flow

nitride



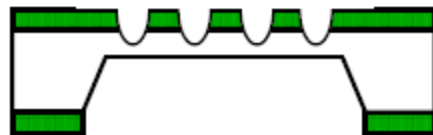
Parylene coating

KOH etch



PR spacer & electrode

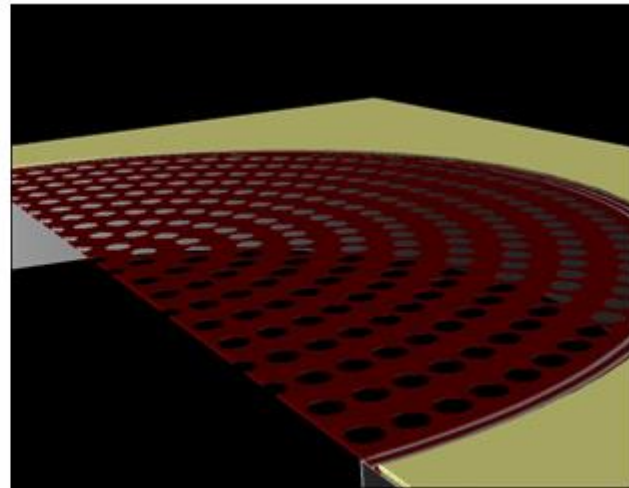
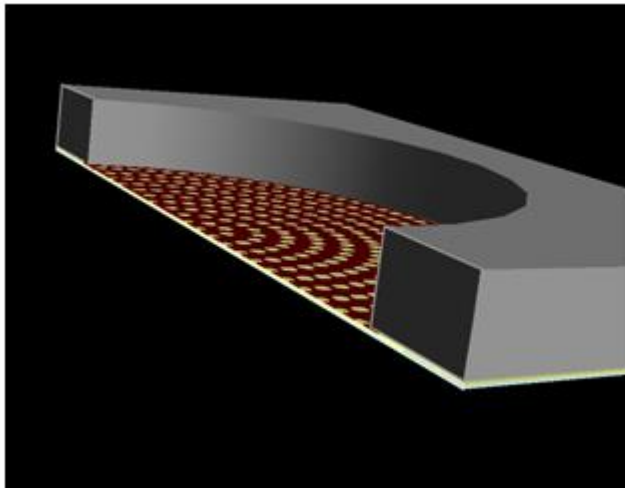
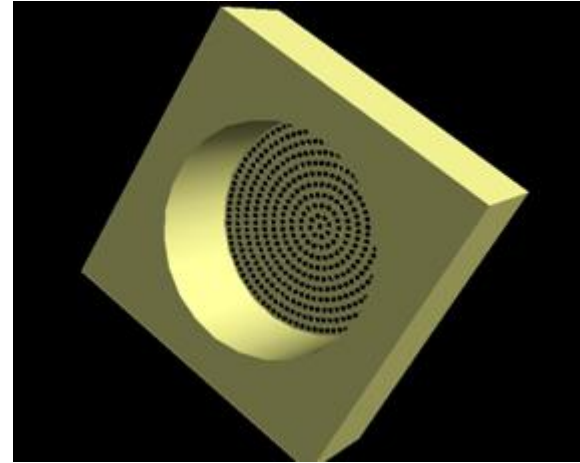
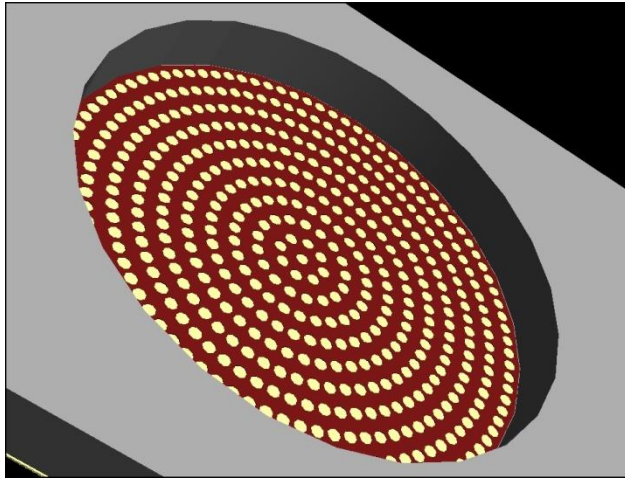
cavity etch



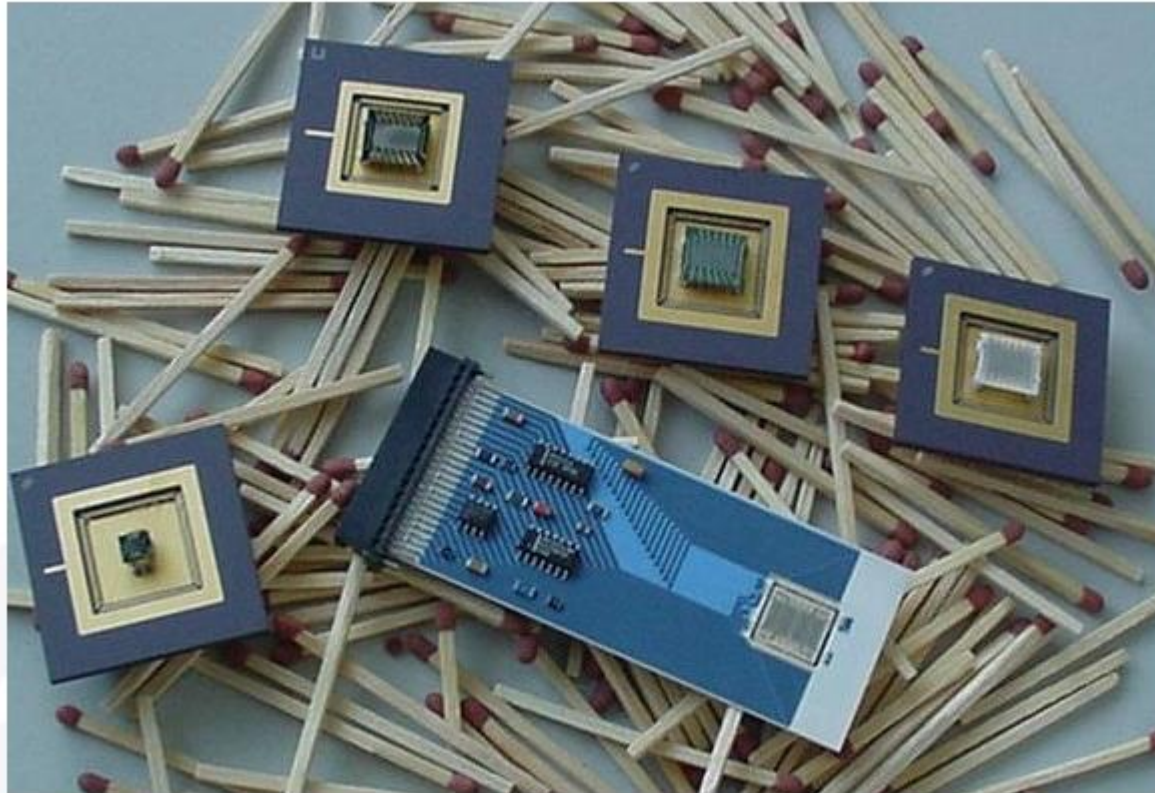
Etch Parylene & BrF_3 etch



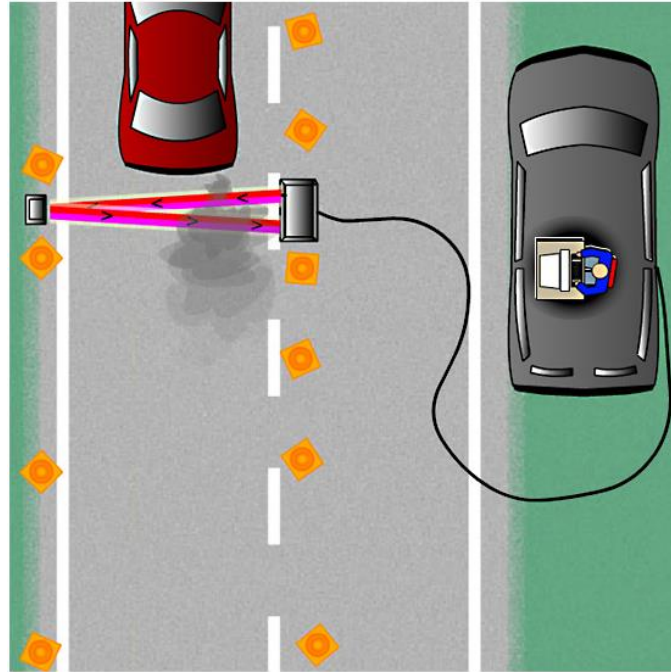
CMOS Microphone



Gas Sensor



Applications



Cities and states may soon have a new high-tech tool in the battle against automotive air pollution, thanks to NASA satellite technology originally developed to track global greenhouse gases and the Earth's protective ozone layer.

As envisioned, NASA's atmospheric remote sensing technology will be adapted to an autonomous roadside system to monitor motor vehicle emissions. Cars and trucks will pass through a low-power light beam, without stopping or slowing down. Space-age sensor technology will instantly analyze vehicle exhaust pollutants important to local and state governments working to meet federally mandated air quality standards.



Next-Generation IR Gas Measurement



Next-Generation IR Gas Measurement

More accurate, lower cost integrated sensors will soon replace discrete components in gas sensor systems. Find out how the first of this new breed works.

Chris Von Benken, Ion Optics, Inc.

<http://www.sensormag.com/articles/1098/nex1098/main.shtml>

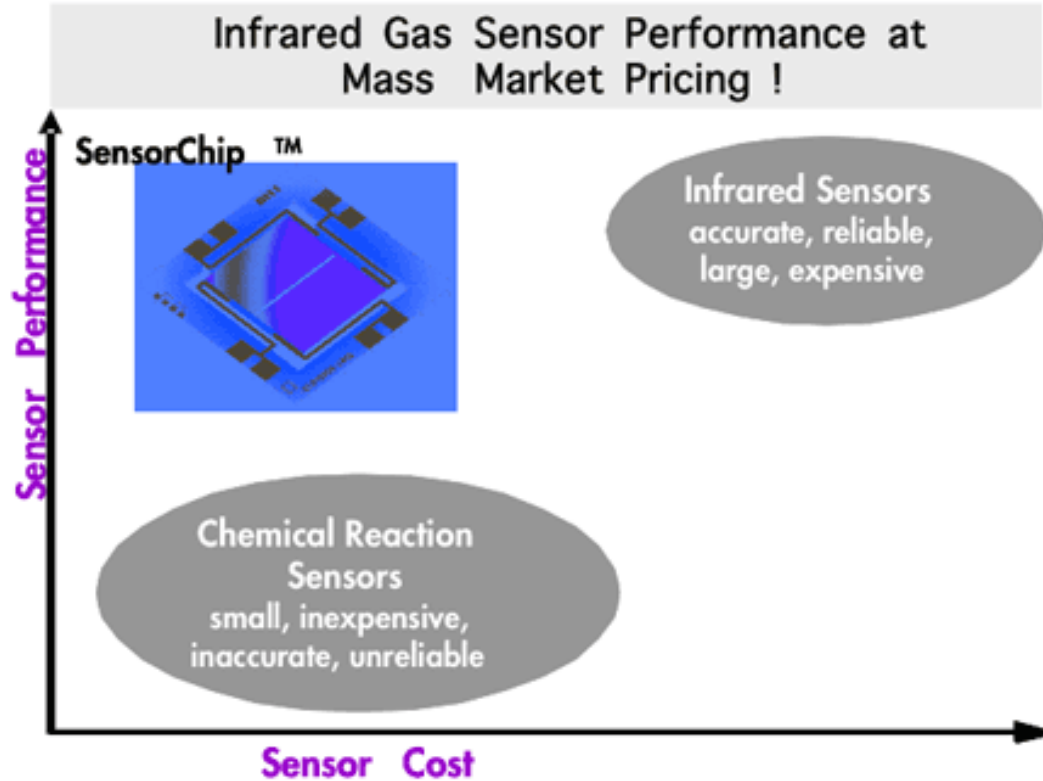


蒙特婁議定書的決議

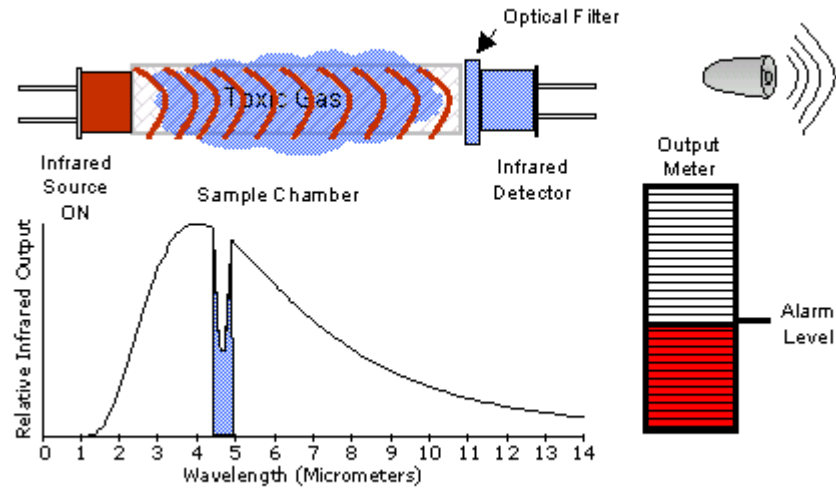
- 我國目前約有五百萬量的汽車，並且百分之九十九以上都配備有空調設備。由圖二所示，1991年約使用2000公噸的CFC-12，其中有百分之五十是做為汽車空調冷媒之用。但自1994年7月1日起，新車皆不得再使用CFC-12冷媒。
- 目前我國新車中小型汽車所使用的冷媒為HFC-134a，大客車與卡車則HFC-134a與 HCFC-22兩者皆有，火車車廂則主要使用HCFC-22系統。
- 儘管如此，舊車維修保養充填時所使用的冷媒仍以CFC-12為主，完成換裝冷媒的舊車，據調查低於5%。由於仍有大量的汽車空調使用CFC-12冷媒，



Infrared Gas Sensor Market



Infrared Gas Detection Principle



4) The detector measures this decreased transmission to determine the gas concentration. Too much of the gas might trigger an audible alarm for example.



NDIR System

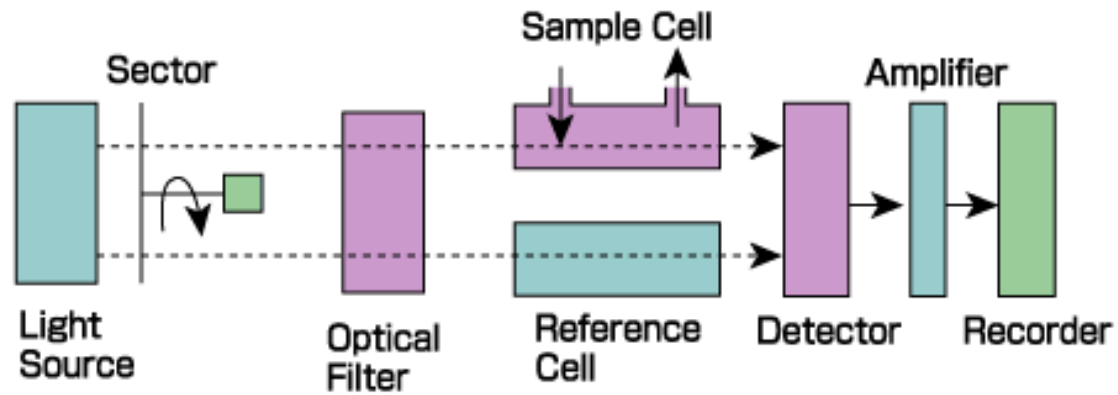


Figure 10. Non-dispersive Infrared Gas Analyzer

光源(Light Source -Broad Band)

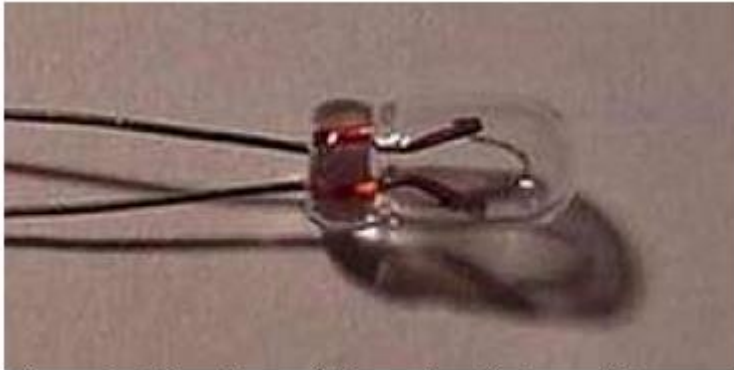
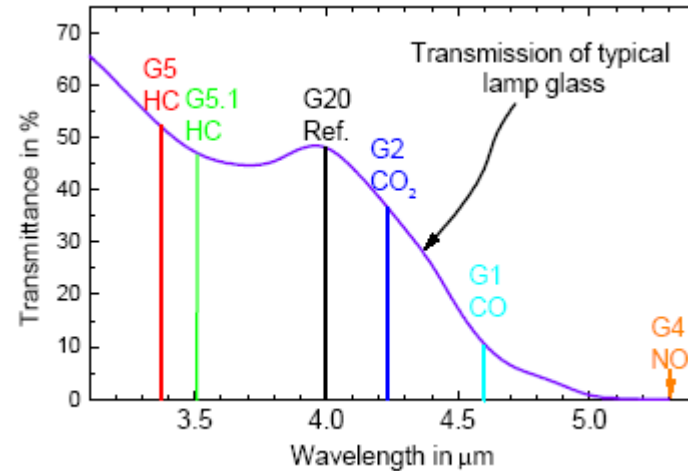


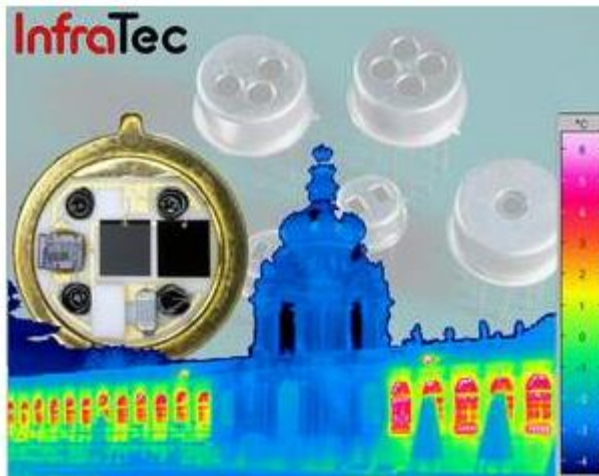
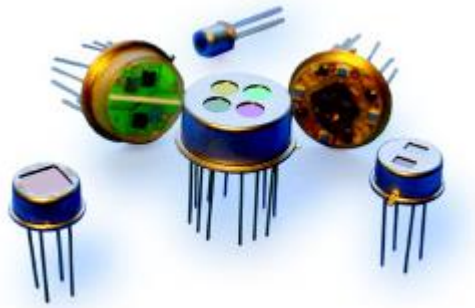
Figure 9: Glass housed thermal radiator as IR source for the range 2 to 4.6 μm (PerkinElmer IRL 715).



The curve shows the transmission characteristics of a typical lamp glass together with the center position of some gas absorption bands. The intensity of the IR light decreases above 4 μm with a cutoff wavelength, which is located at 5 μm . The CO₂ absorption is still well within a high intensity region, whereas the detection of CO is already extremely difficult due to the limited IR output.



感測器(Sensor)



<http://www.infratec.de/>

NEW - PMY 151 Smart Natural Gas Sensor



Natural gas has become one of the most widely used sources of energy today. Natural gas is used for heating and cooking, generating electrical energy and driving engines. Due to the increased use of natural gas in everyday life, natural gas concentrations have risen sharply. When natural gas levels exist in the 4.4% to 15% range, explosions can occur. PerkinElmer's new PYM 151 is designed for use in detecting/monitoring natural gas in homes and represents a technology platform to further develop CO2 sensors for automotive applications. The system allows OEM alarm manufacturers to integrate the PYM 151's unique non-dispersive infrared absorption (NDIR) technology with a simple snap-in design and add-on alarm processing and actuations.

<http://optoelectronics.perkinelmer.com/Content/Corporate/News/PressRelease.aspx?RowId=1055>



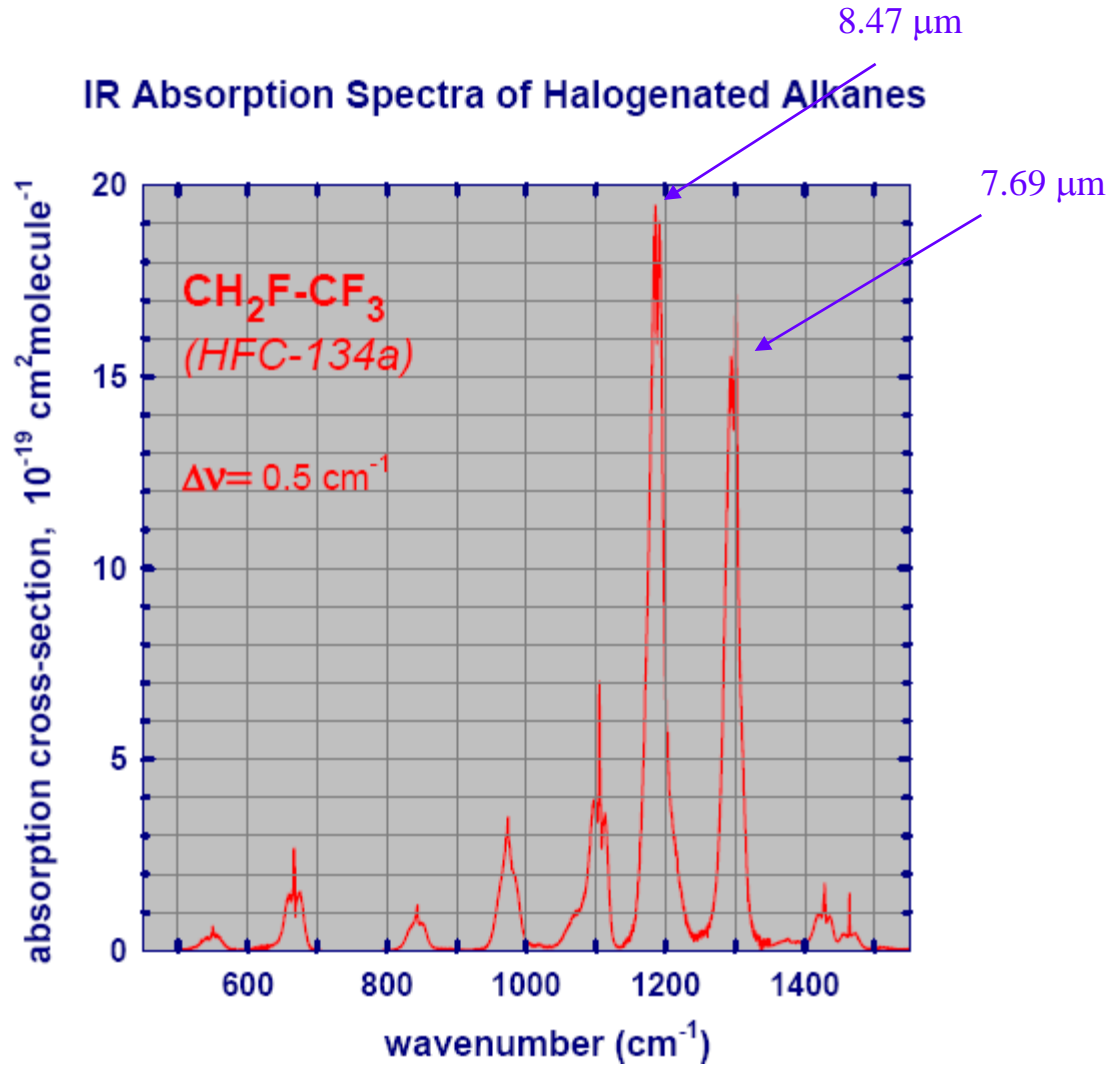
PerkinElmer

Identifier	Matching gas	HPB/CWL	center wavelength (CWL) [μm]	half power bandwidth (HPB, FWHM) [nm]
G5.3	HC	5.2%	3.09 ± 0.030	160 ± 20
G5.2	HC (CH_4)	4.8%	3.30 ± 0.033	160 ± 20
G5	HC	5.3%	3.40 ± 0.070	180 ± 20
G5.1	HC	4.7%	3.46 ± 0.050	163 ± 10
G20	Reference	2.3%	4.00 ± 0.080	90 ± 20
G2	CO_2	4.2%	4.26 ± 0.043	180 ± 20
G2.3	CO_2	2%	4.30 ± 0.033	85 ± 10
G2.2	CO_2	1.4%	4.43 ± 0.040	60 ± 5
G1	CO	3.9%	4.64 ± 0.047	180 ± 20
G4	NO	3.4%	5.30 ± 0.053	180 ± 20

Table 2: Selection of PerkinElmer standard IR band-pass filters for gas analysis. All filters are silicon based.



HFC-134a



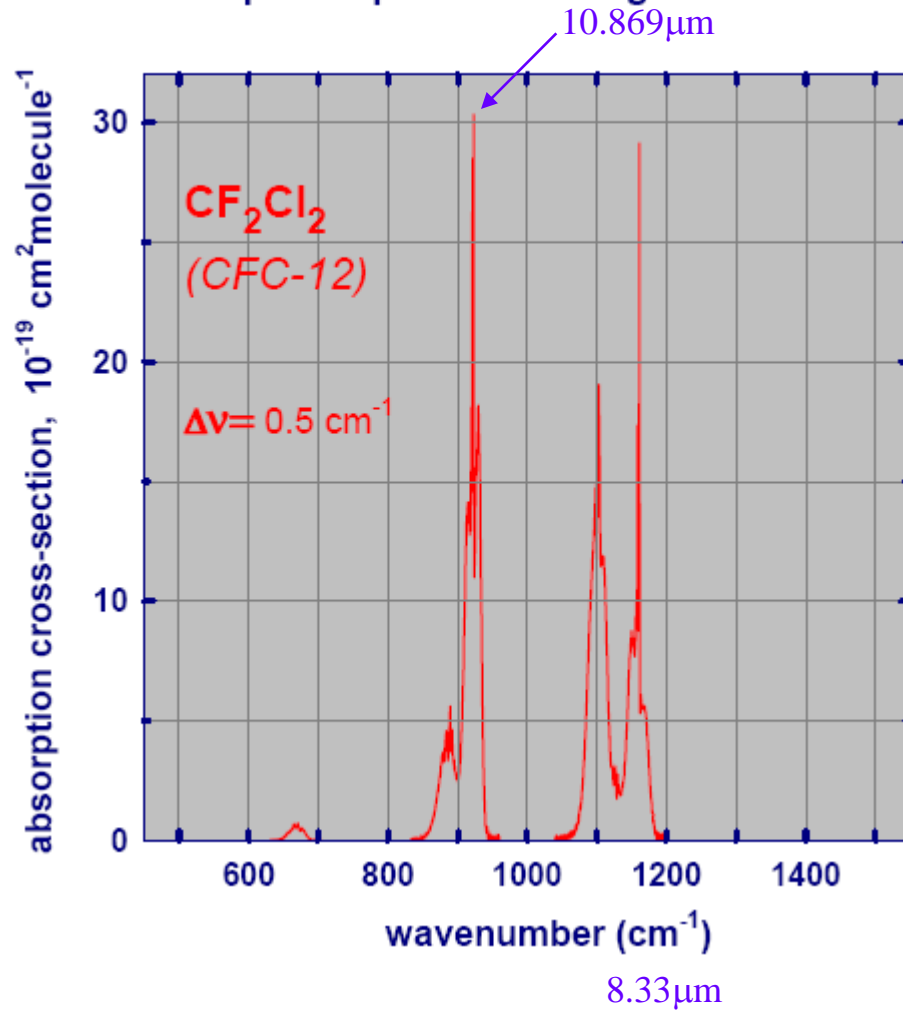
$$\lambda \text{ in } \mu\text{m} = 10^4 / (\text{wavenumber in } \text{cm}^{-1})$$

10 μm 8.33 μm 7 μm

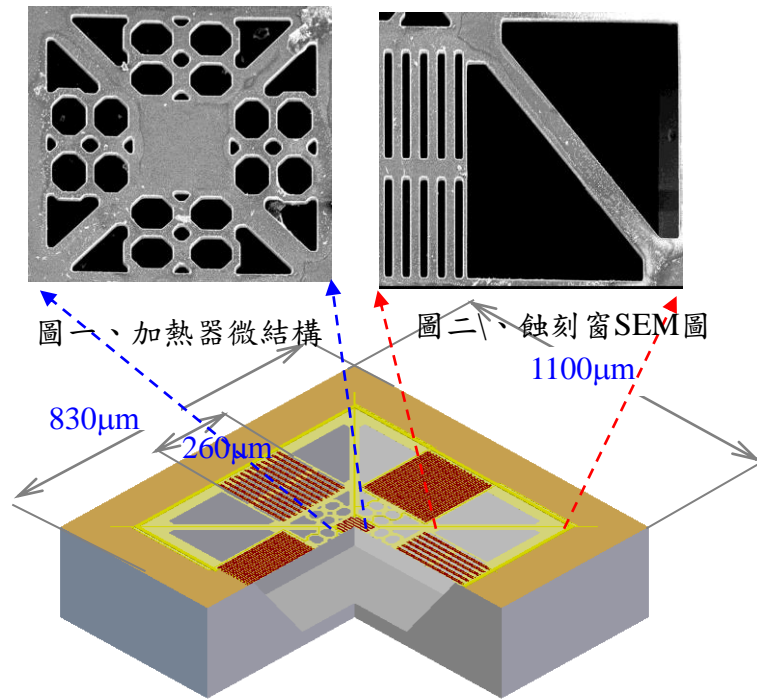


CFC-12

IR Absorption Spectra of Halogenated Alkanes



II. 熱型加速計



圖一、加熱器微結構

圖二、蝕刻窗SEM圖

830 μm

260 μm

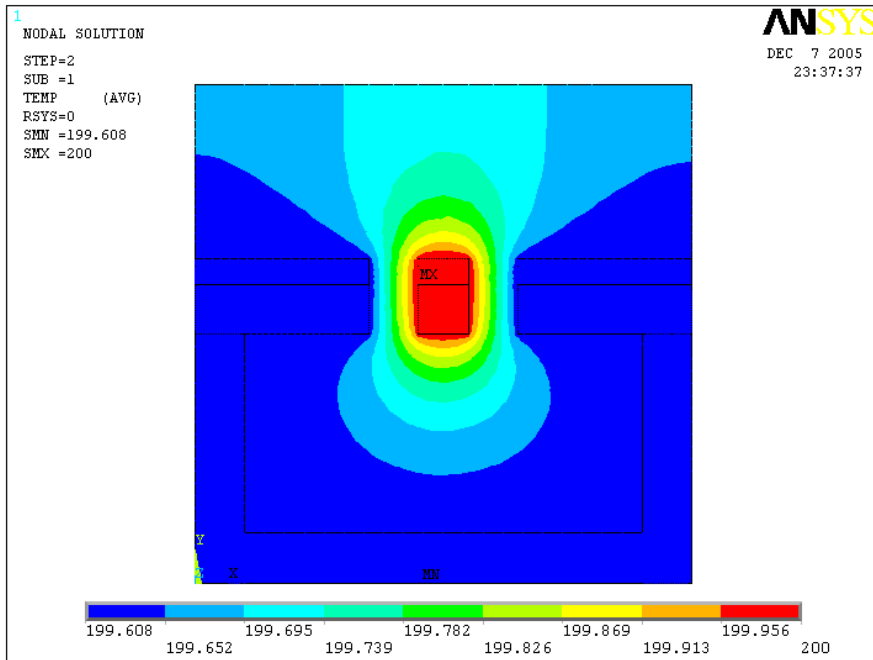
1100 μm

圖三、新穎2D的熱型加速計元件尺寸側視圖

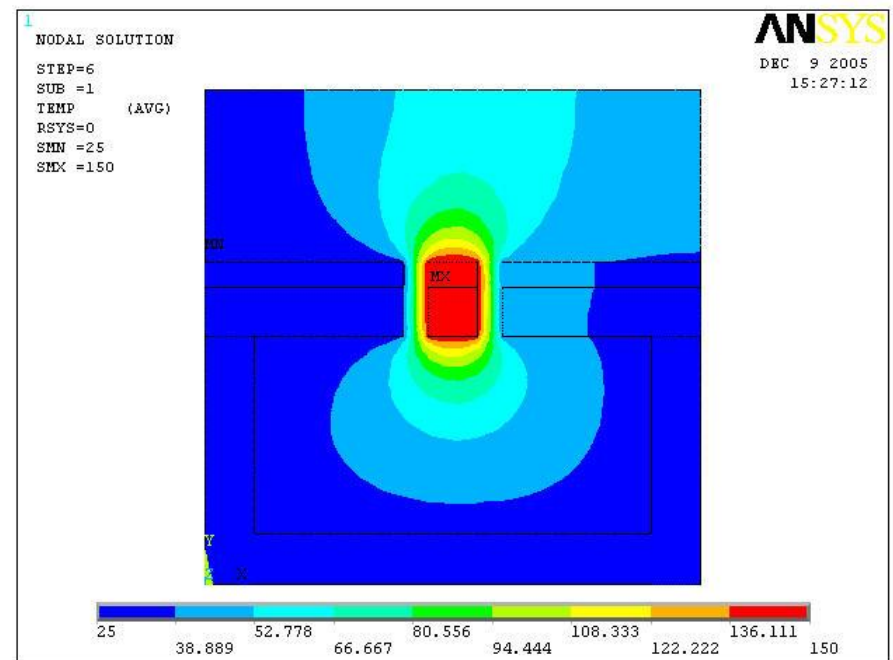
- 利用TSMC0.35um CMOS製程中的不同材料來製作出熱電堆的感測元件。
- 熱電堆元件在CMOS製程製作新式熱型加速度計的2-D層次圖。
- 首先在矽基材上長出一層Field Oxide，利用CMOS製程 2P4M的n+ Poly和Al或p+ Poly來製作成熱電偶。



感測原理



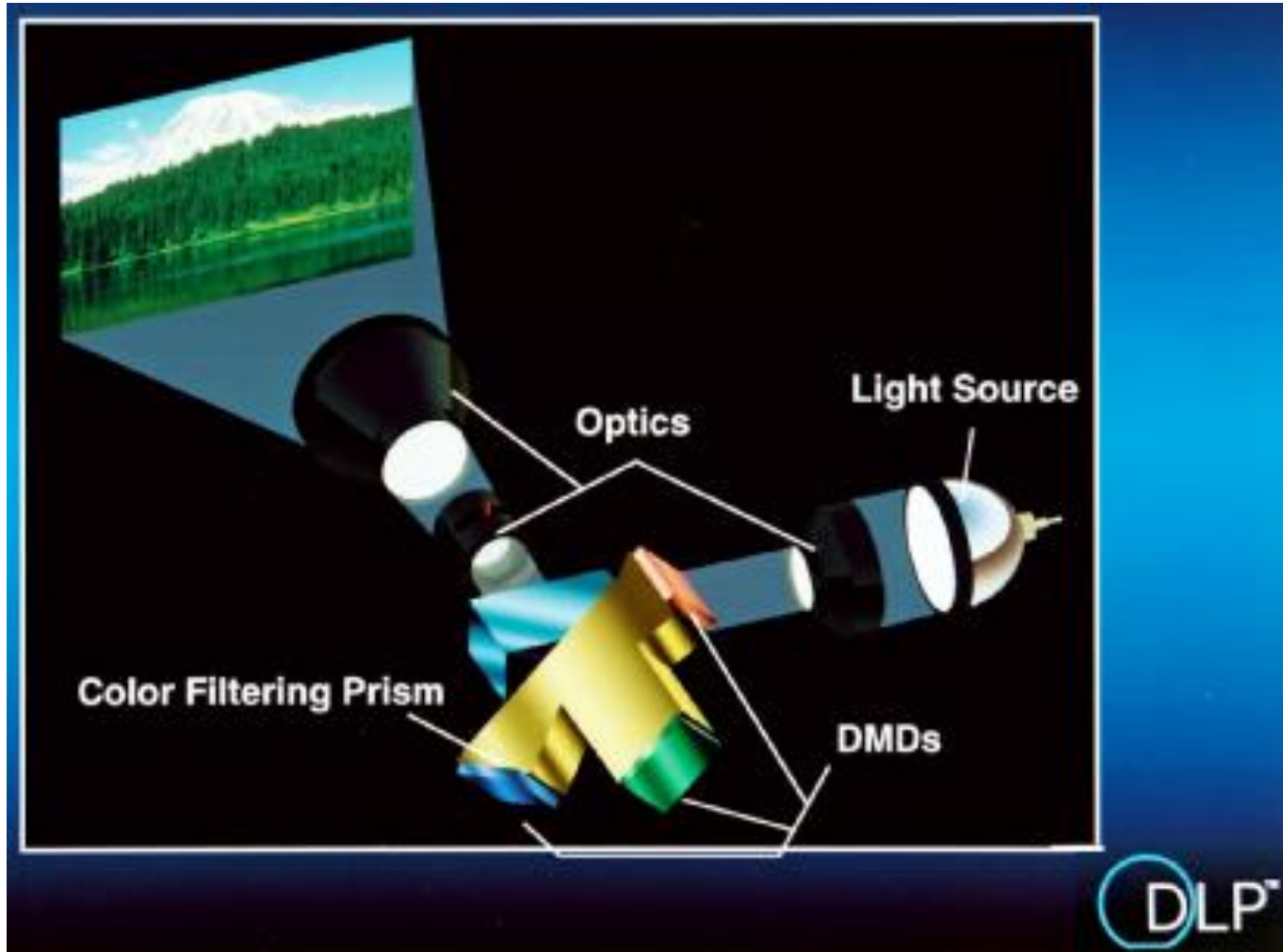
2-D元件模擬~靜止狀態



2-D元件模擬~往__運動



DLP

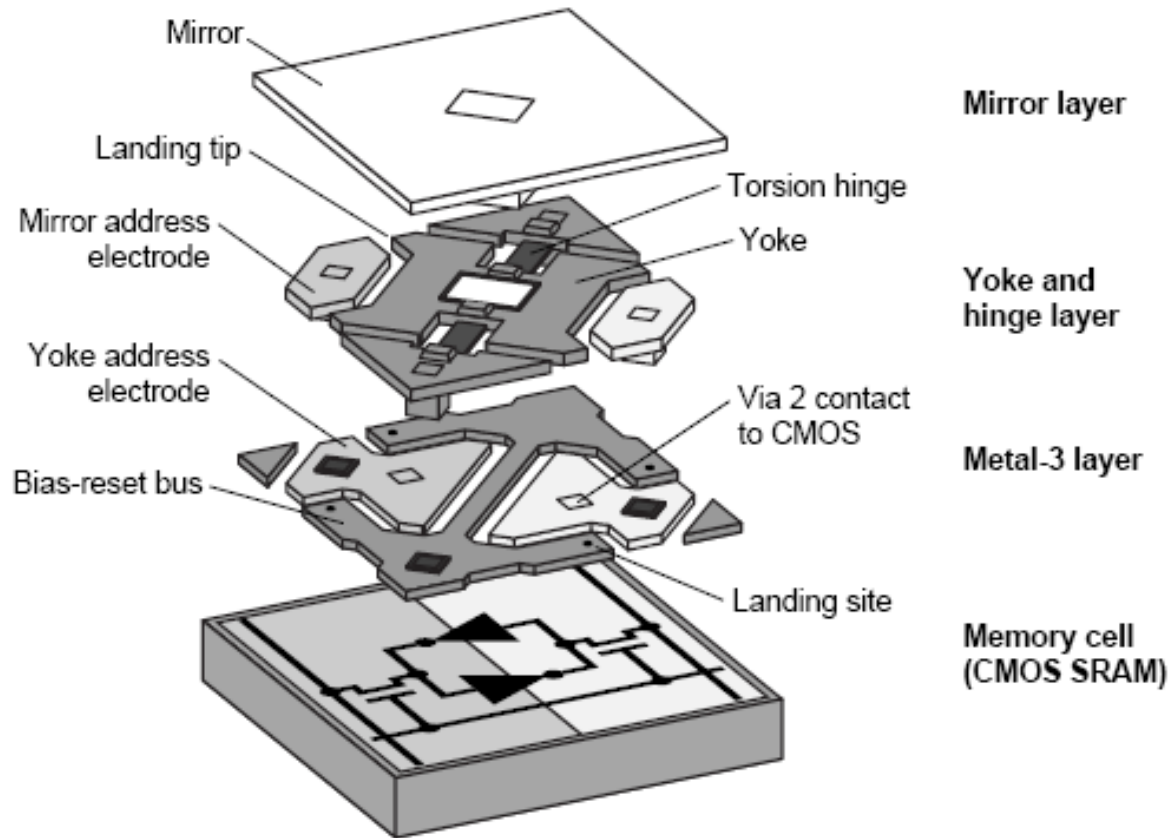


DLP[®]



MOEMS

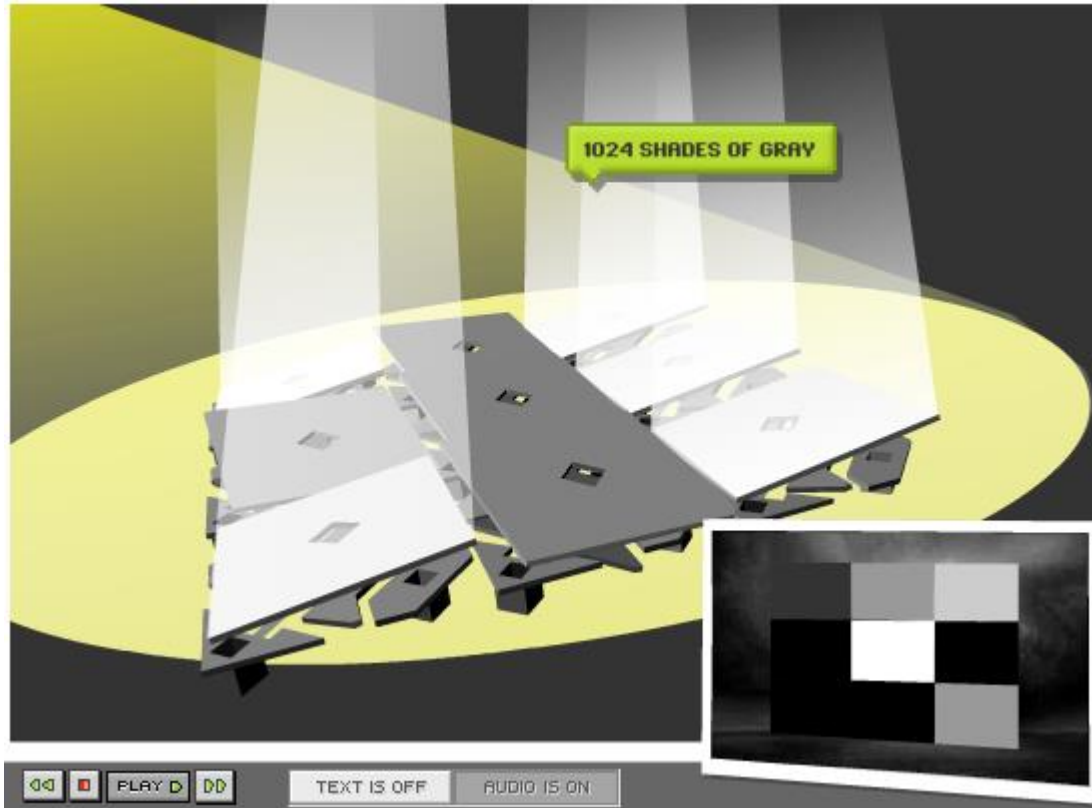
SOC of DMD



<http://www.dlp.com/>



Reflector



DMOS

MOSFET Metal Oxide Semiconductor Field Effect Transistor。金屬氧化半導體場效電晶體。

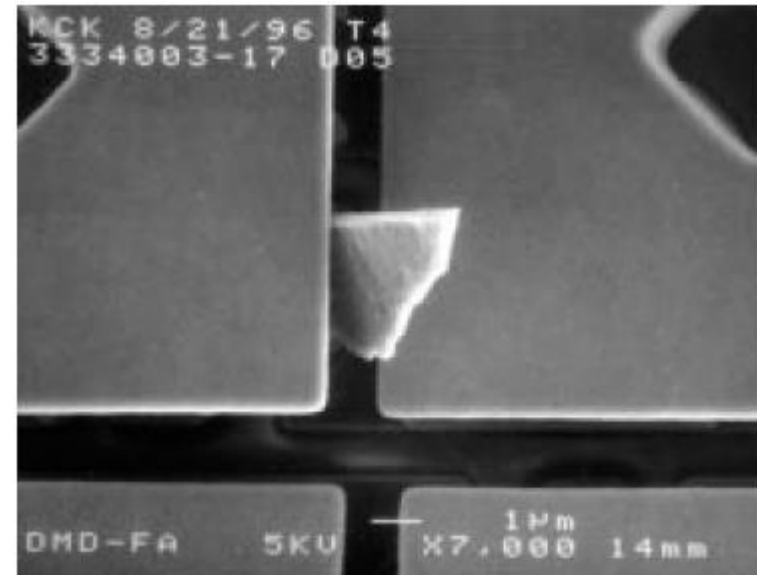
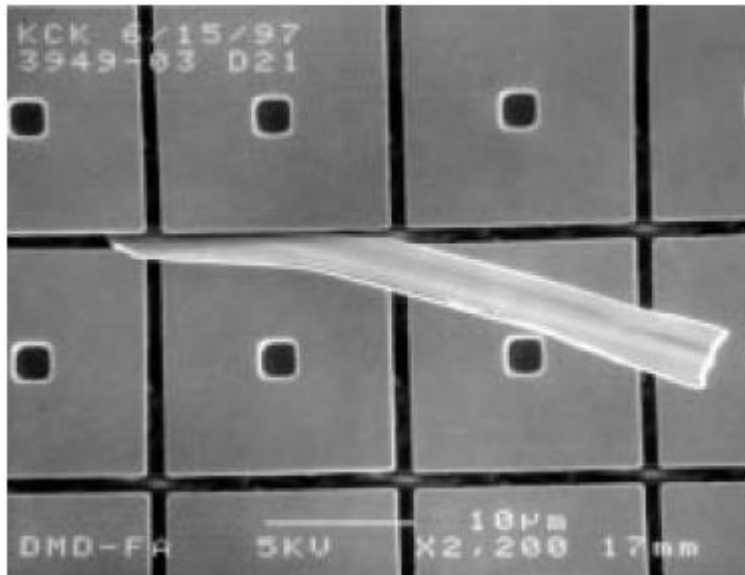
是FET兩種主要形式之一。是在源極（**Source**）區與洩極（**Drain**）區的半導體基板表面覆蓋在一層薄薄的二氧化矽（**SiO₂**）作為絕緣層，再把金屬沈積在氧化層上形成元件的閘極（**Gate**）而製成。

MOSFET又可分為兩種：增強式（**Enhancement**）與空乏式（**Depletion**）。增強型（**Enhancement**，簡稱**EMOS**），是在MOSFET元件中增加通道載子，加強通道（洩極與源極之間的導通路徑）的傳導性。

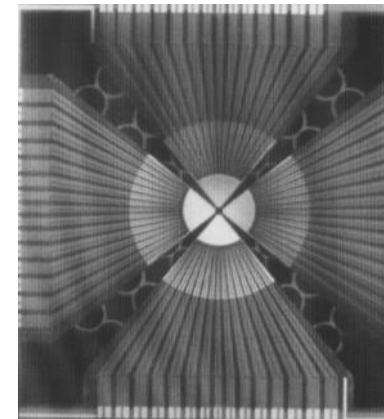
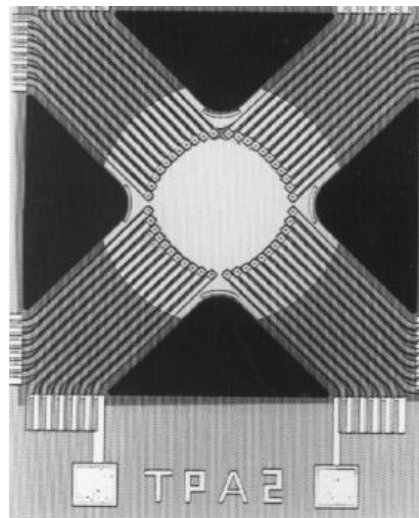
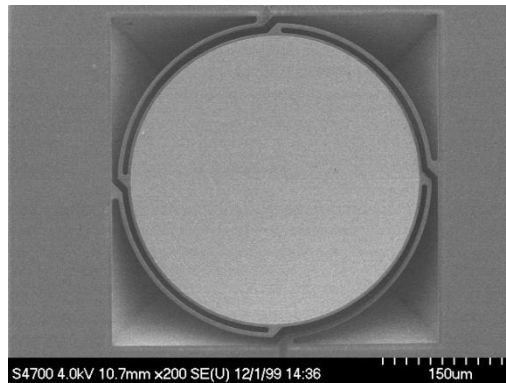
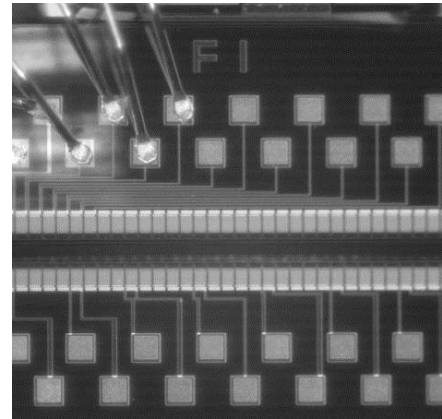
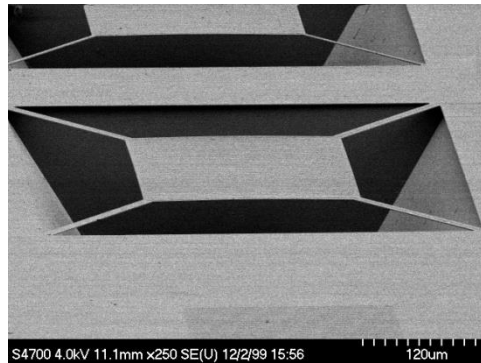
空乏型（**Depletion**，簡稱**DMOS**），則是在MOSFET元件中減少通道載子，降低通道的傳導性。



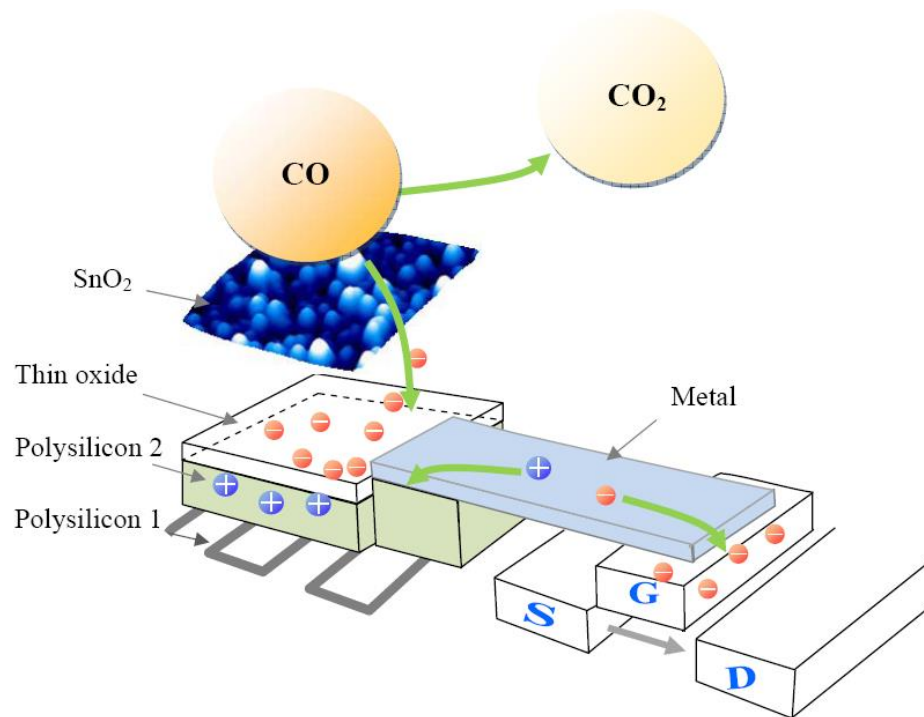
DMD pixels with particle defects



I. MEMS Infrared Sensors



III. 1 CMOS MEMS FET感測晶片



離子感測場效電晶體(ISFET): 一氧化碳氣體感測晶片

- N型多晶矽(N-poly Silicon)當微型加熱器電阻
- P型多晶矽(P-poly Silicon)在感測薄膜上再加熱成長一層薄氧化層,一氧化碳的感測薄膜,
- SnO₂溶膠-凝膠法(Sol-Gel)滴附在感測薄膜上偵測CO氣體
- 差動放大器電路介面電路技術與設計
- TSMC 0.35 μ m之CMOS 2P4M 標準製程以及後製程製作

