

Sensori meccanici

2.3 sensore di accelerazione per applicazioni biomediche (Roylance&Angell, 1978)

2.4 sensore di accelerazione a 3 assi (FUJIKURA)

3. Sensori capacitivi:

3.1 sensore di accelerazione verticale (Petersen et al., 1982)

3.2 sensore di accelerazione laterale ADXL (ANALOG DEVICES)

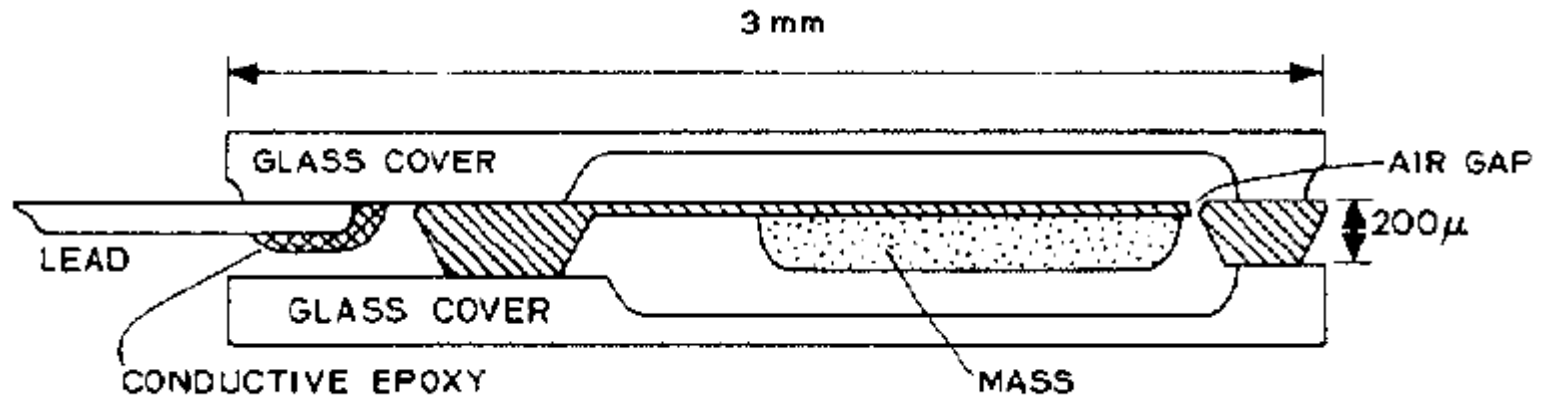
Sensore di accelerazione piezoresistivo

(L.M. Roylance and J.B. Angell, "A Batch-Fabricated Silicon Accelerometer", IEEE Tr. ED 26, 1979)

uno dei primi esempi di accelerometro integrato con tecniche MEMS per applicazioni biomediche. Dimensioni totali (con package): $2 \times 3 \times 0.6 \text{ mm}^3$. Peso totale (con package): 20 mg.

Accelerazione minima: 0.01g

Accelerazione massima: 50g



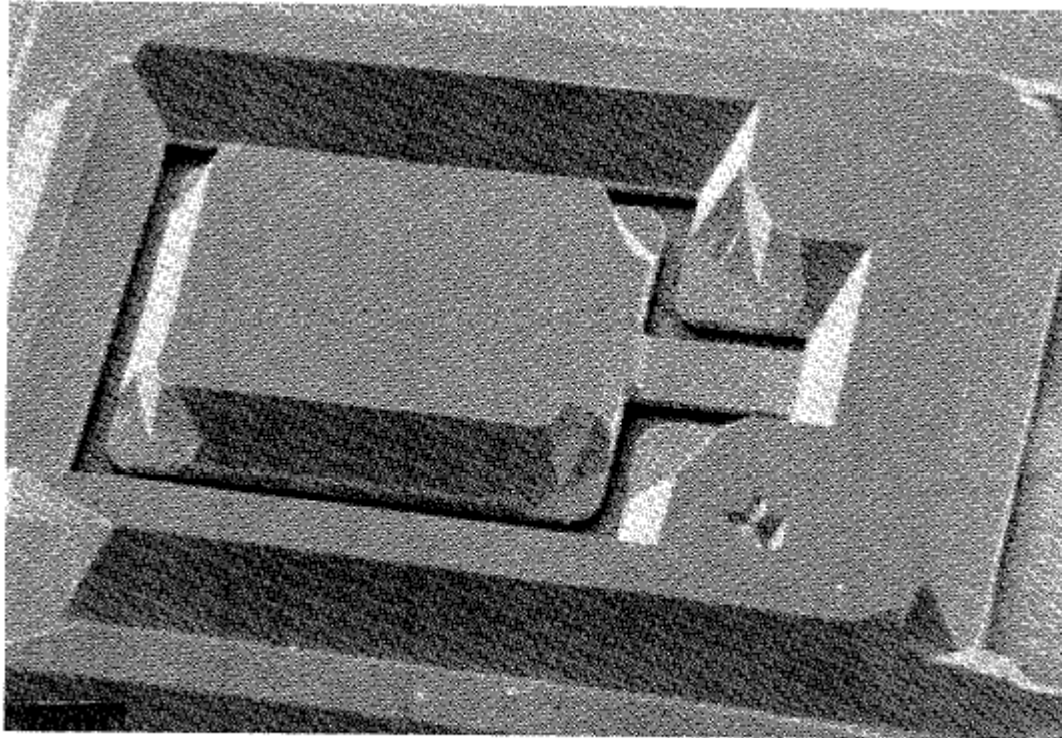
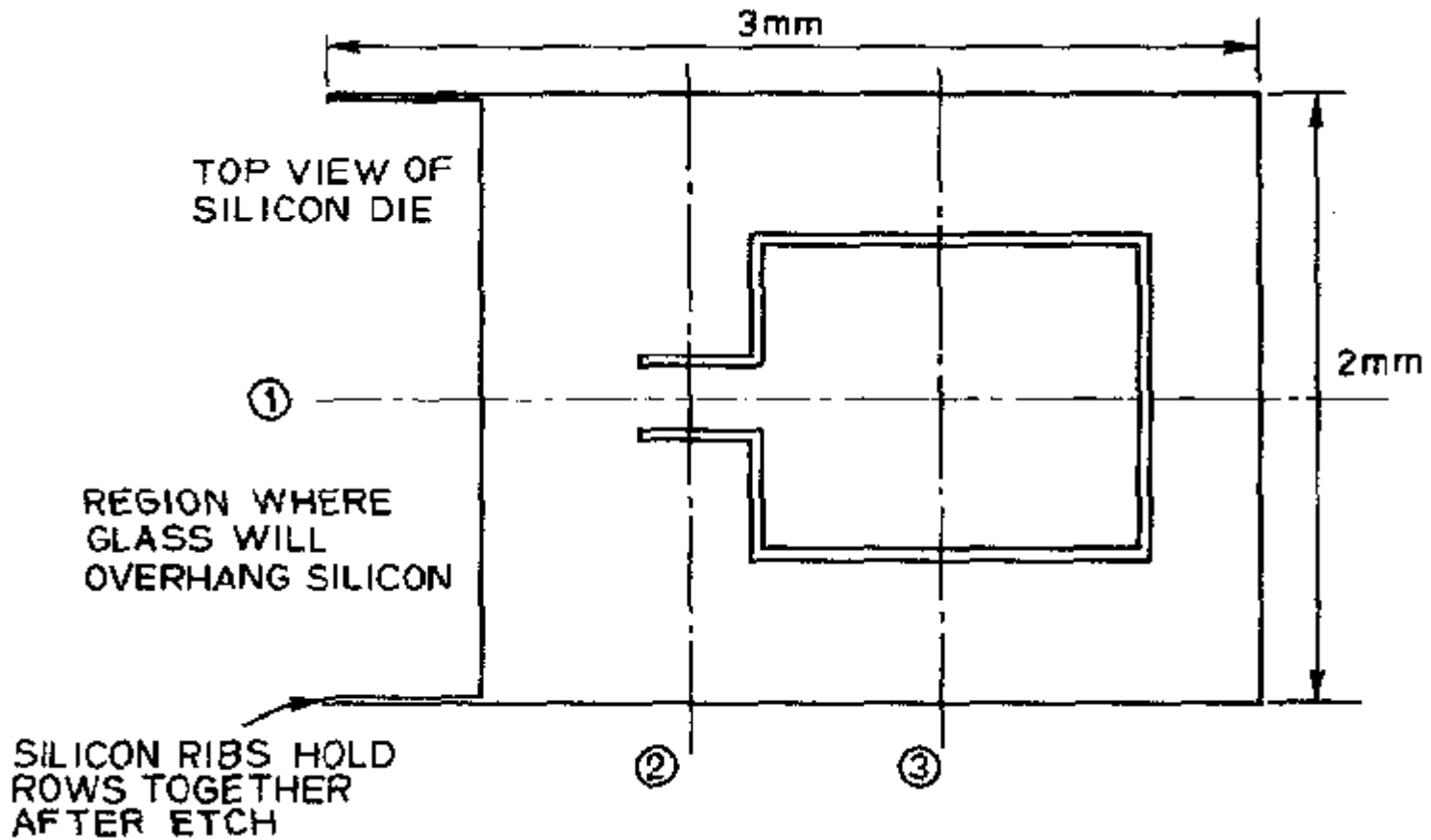


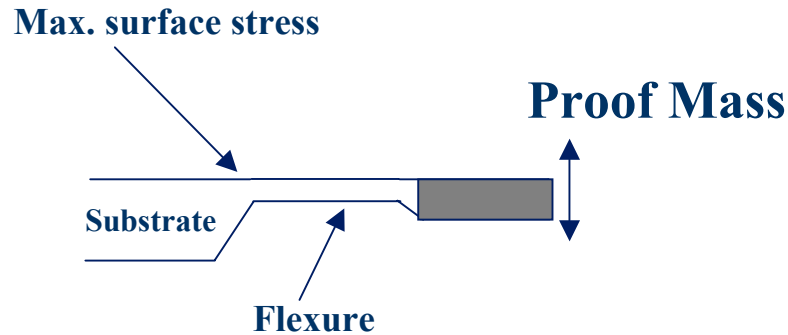
FIGURE 2—SEM of backside of the silicon element of the accelerometer, showing silicon mass loading beam.



$$L_p = 1,5 \text{ mm}; W_p = 1 \text{ mm}; H_p = 200 \text{ um} \rightarrow m = 0.7 \text{ mg}$$

$$L_b = 400 \text{ um}; W_b = 200 \text{ um}, H_b = 10 \text{ um}$$

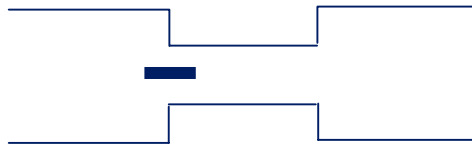
Concept of a piezoresistive sensing scheme



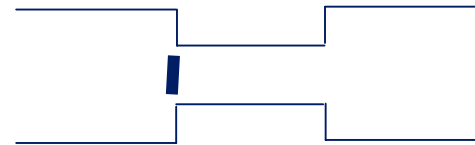
If piezo-resistor is along [110]:

n-type: $\pi_l: -31.2 \cdot 10^{-11} \text{ Pa}^{-1}$, $\pi_t: -17.6 \cdot 10^{-11} \text{ Pa}^{-1}$

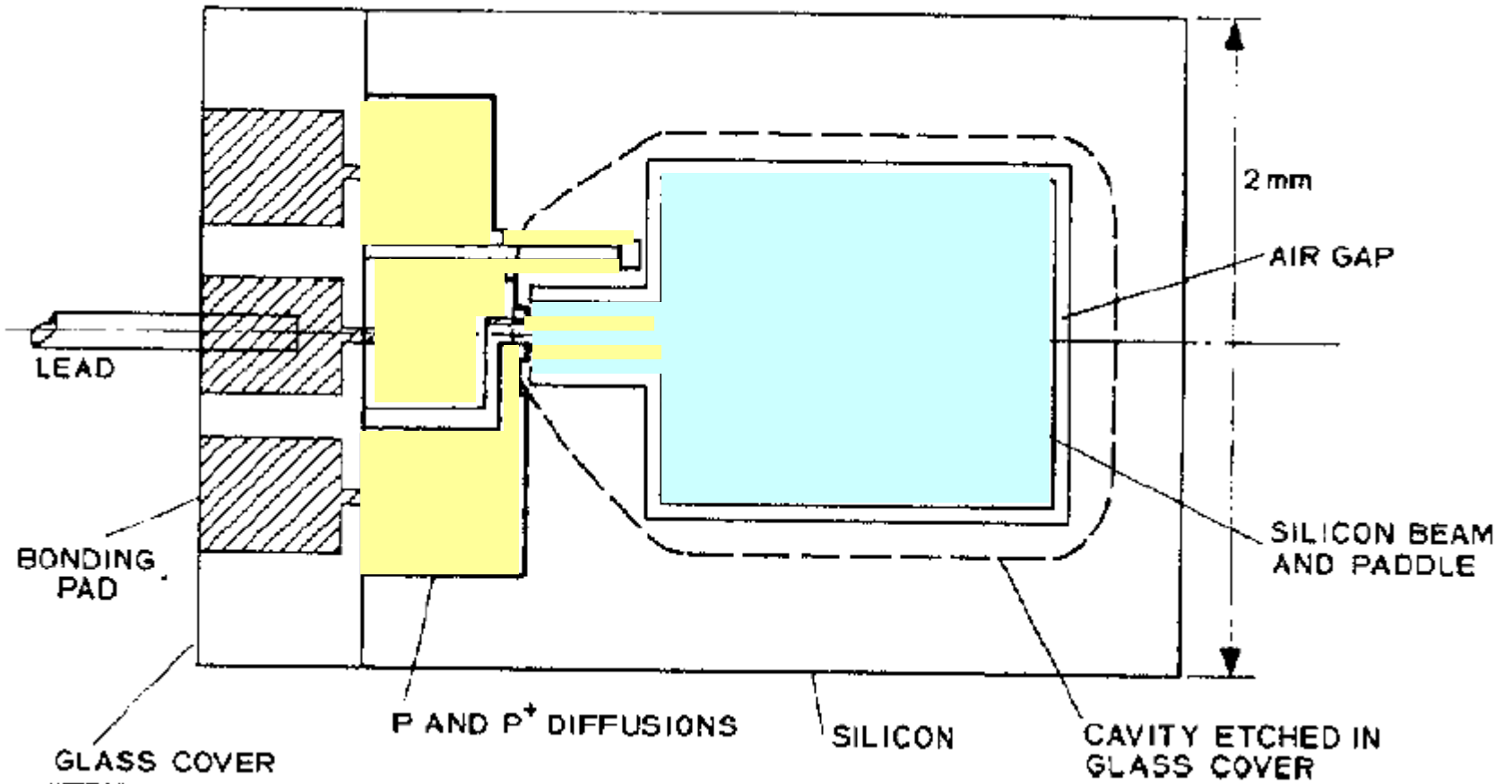
p-type: $\pi_l: 71.8 \cdot 10^{-11} \text{ Pa}^{-1}$, $\pi_t: -66.3 \cdot 10^{-11} \text{ Pa}^{-1}$



Longitudinal



Transverse



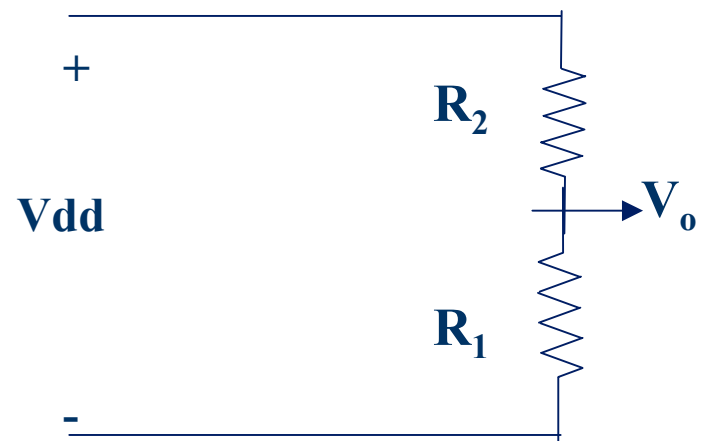
$$\frac{\Delta R}{R} = \pi_1 \sigma_1$$

$$m = 0.7mg \rightarrow \sigma_1 = ma \frac{3L_b}{(W_b H_b^3)}$$

$$L_b = 400 \text{ um}; W_b = 200 \text{ um}, H_b = 10 \text{ um}$$

$$\rightarrow \frac{\Delta R}{R} = 3 \times 10^{-4} \text{ /g of acceleration}$$

$$\rightarrow S = -0.075 \text{ mV/gV}$$



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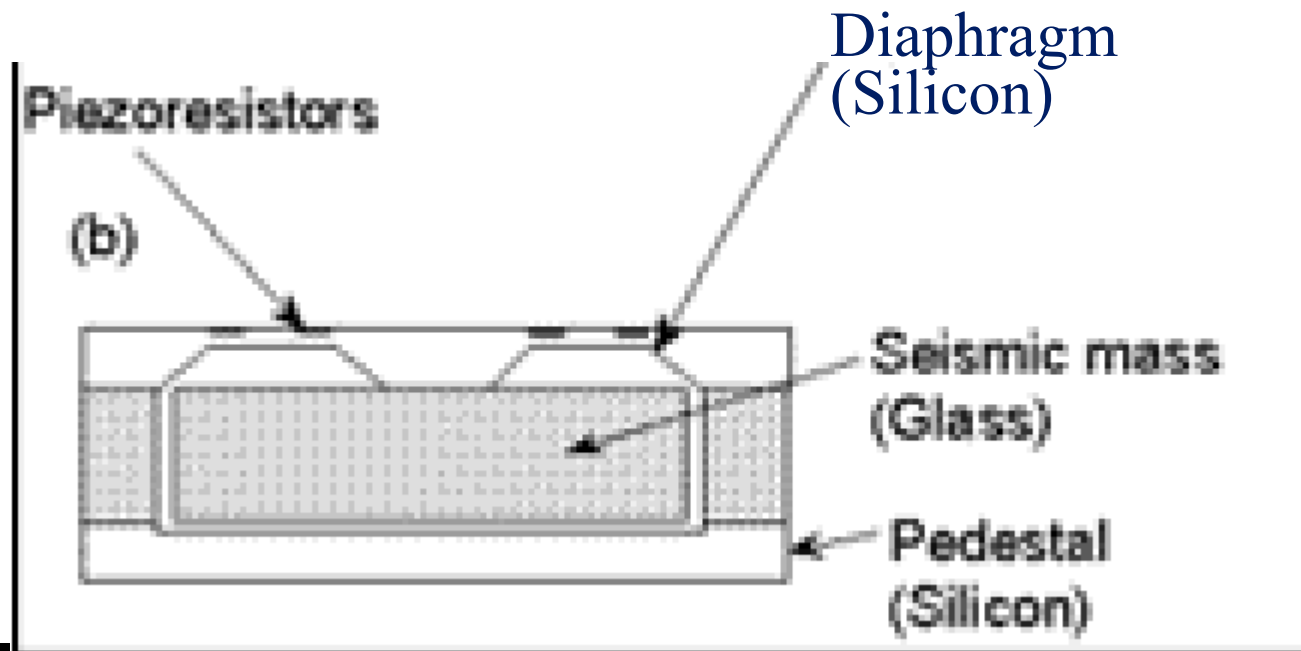
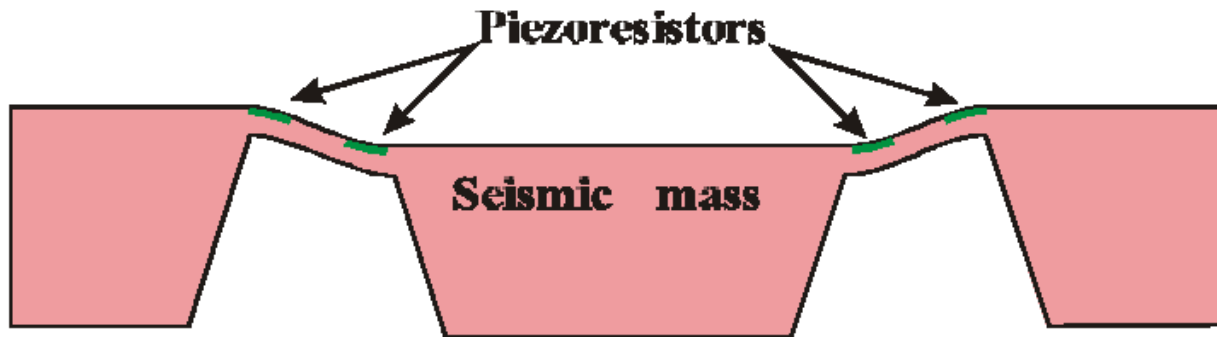
2.4 sensore di accelerazione a 3 assi (FUJIKURA)

3. Sensori capacitivi:

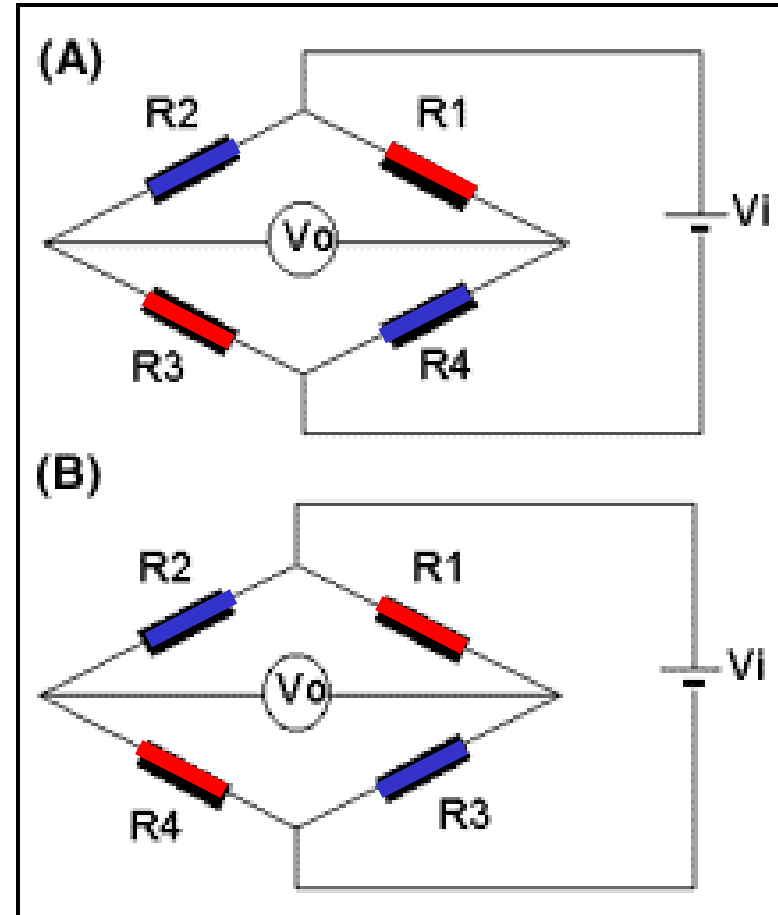
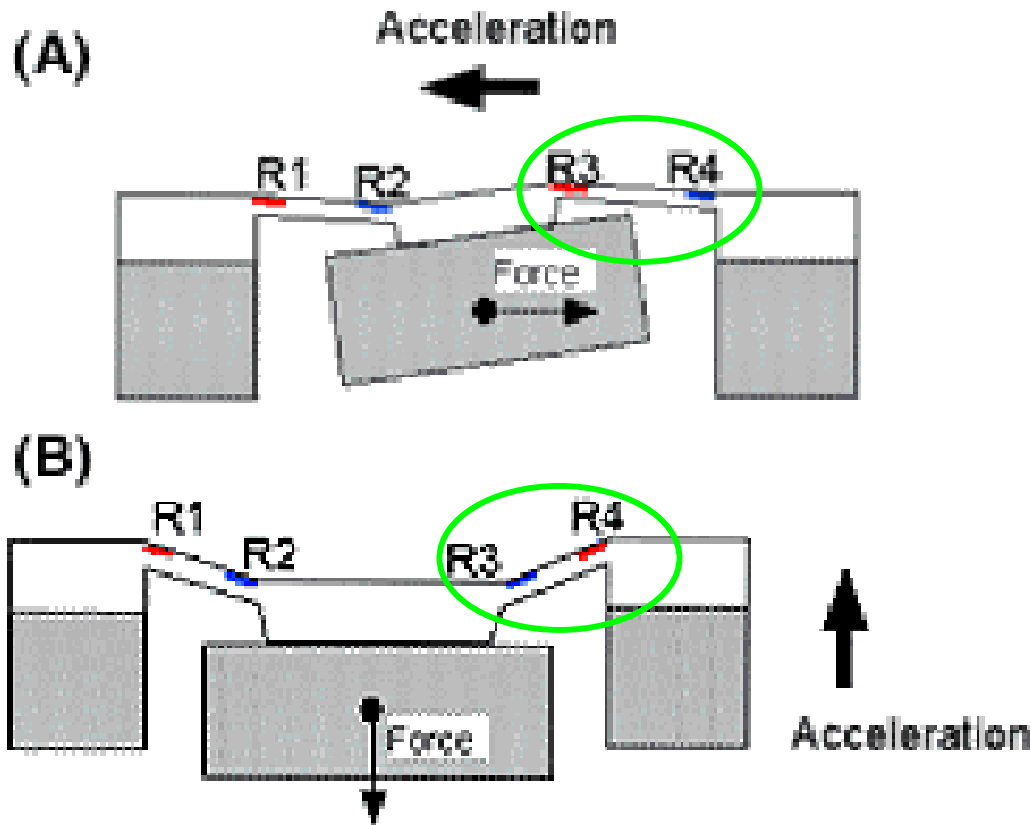
3.1 sensore di accelerazione verticale (Petersen et al., 1982)

3.2 sensore di accelerazione laterale ADXL (ANALOG DEVICES)

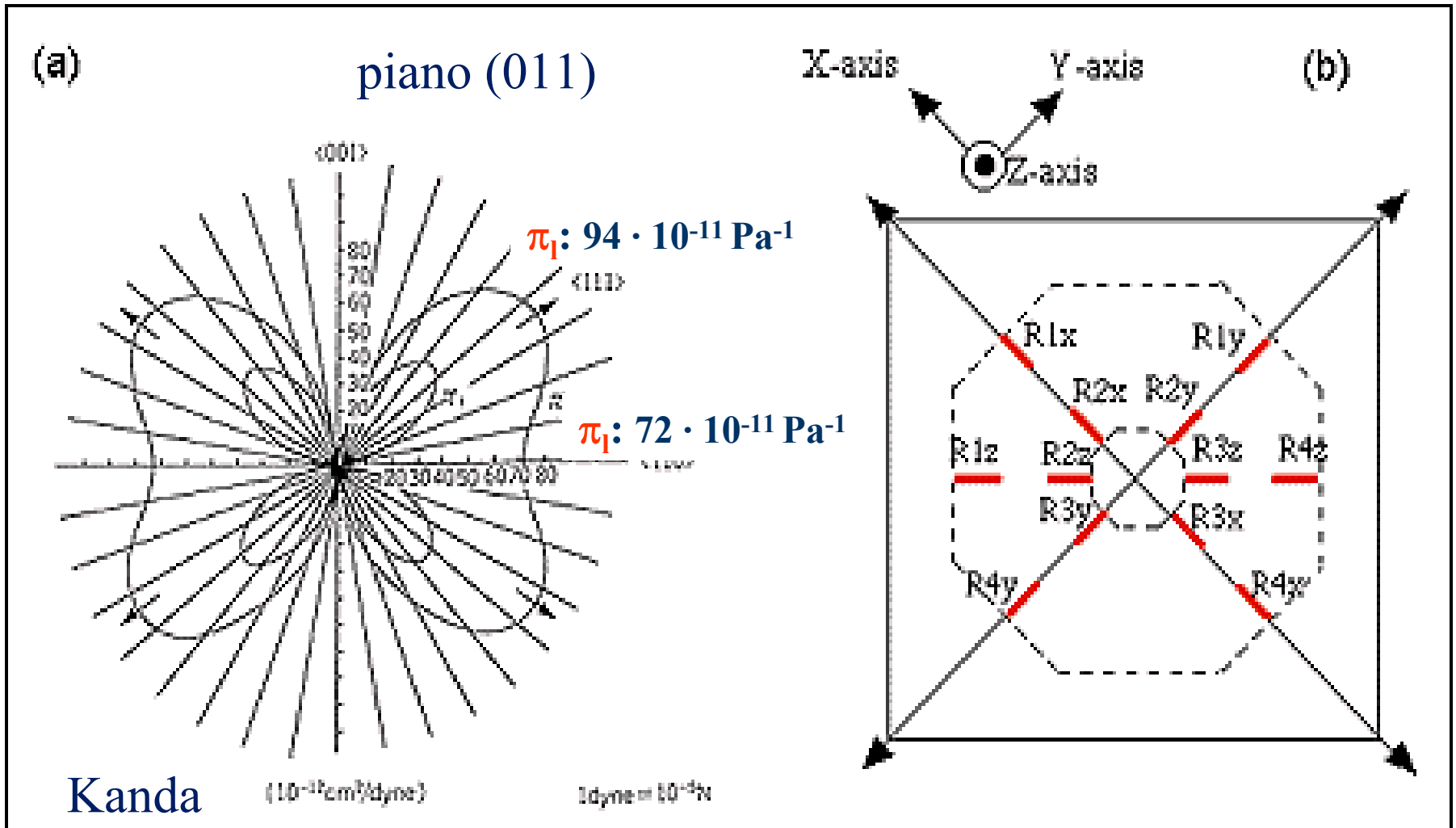
Sensore di accelerazione piezoresistivo a 3 assi (FUJIKURA)



Sensore di accelerazione piezoresistivo a 3 assi (FUJIKURA)



Sensore di accelerazione piezoresistivo a 3 assi (FUJIKURA)



Sensore di accelerazione piezoresistivo a 3 assi (FUJIKURA)

TABLE 1

Change of each piezoresistance value in response to acceleration input along three axes

Detection axis	X-axis				Y-axis				Z-axis			
	R1x	R2x	R3x	R4x	R1y	R2y	R3y	R4y	R1z	R2z	R3z	R4z
X-axis (horizontal)	+	-	+	-	0	0	0	0	+	-	+	-
Y-axis (horizontal)	0	0	0	0	+	-	+	-	+	-	+	-
Z-axis (vertical)	+	-	-	+	+	-	-	+	+	-	-	+

Note: + = increase; - = decrease; 0 = no change

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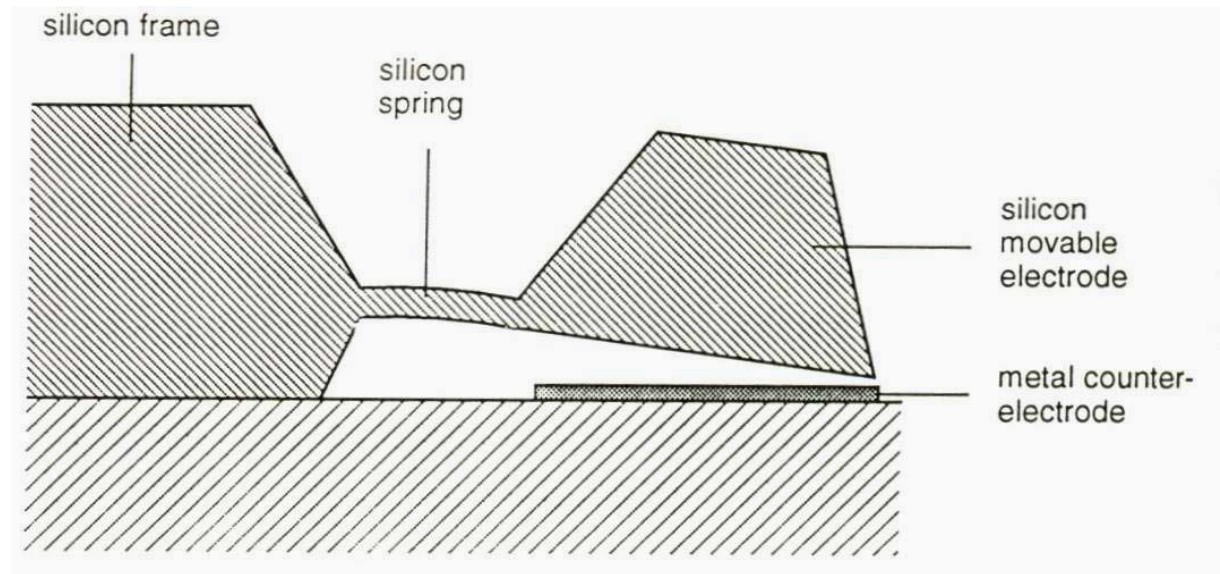
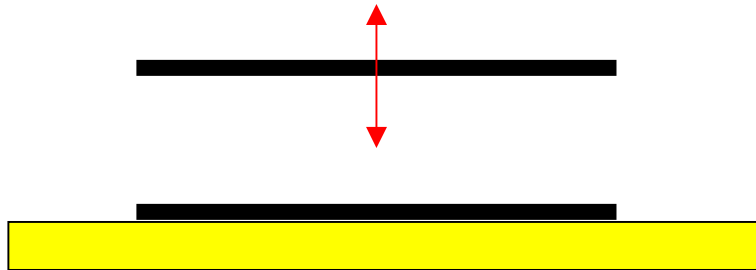
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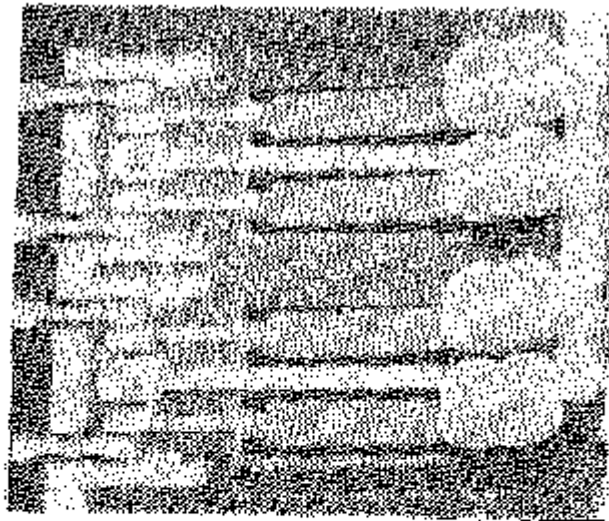
SENSORE VERTICALE DI ACCELERAZIONE

Variazioni verticali di capacità



SENSORE VERTICALE DI ACCELERAZIONE

(K.E: Petersen et al., "Micromechanical Accelerometer Integrated with MOS Detection Circuitry", IEEE Tr. ED 29, 1982)

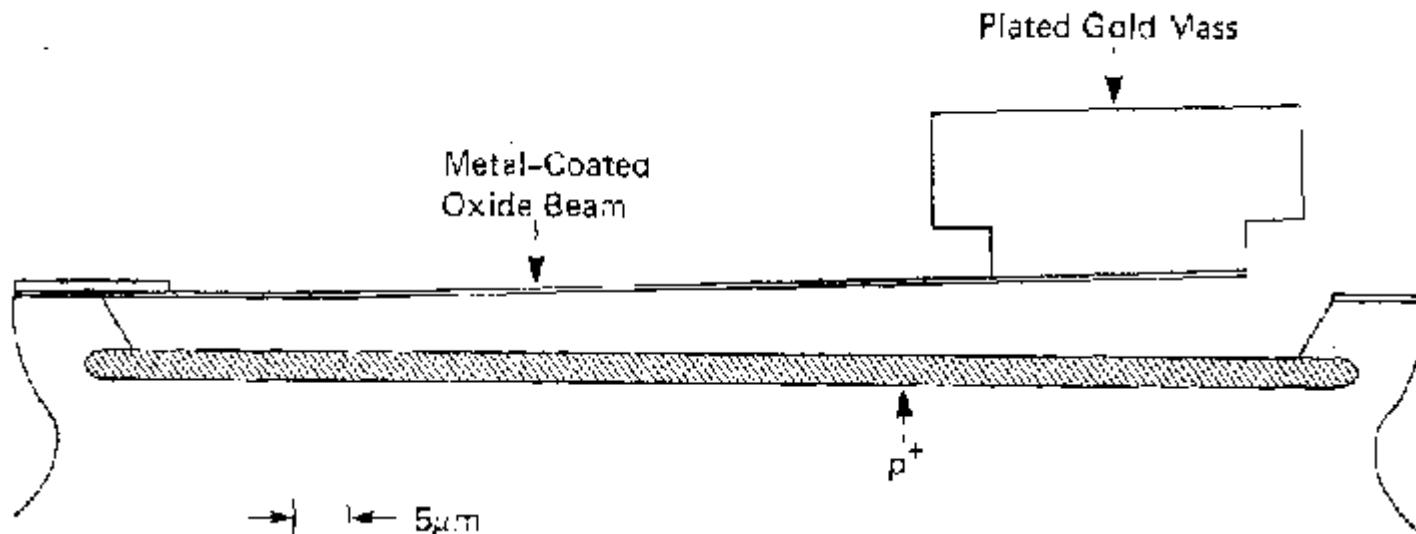


100 μm

Fig. 3. Scanning electron micrograph of an array of four free-standing cantilever beams loaded on the end with plated gold masses (0.35 μg) to increase sensitivity. The MOS circuitry is on the left with two anisotropically etched ground via holes.

SENSORE VERTICALE DI ACCELERAZIONE

(K.E: Petersen et al., "Micromechanical Accelerometer Integrated with MOS Detection Circuitry", IEEE Tr. ED 29, 1982)



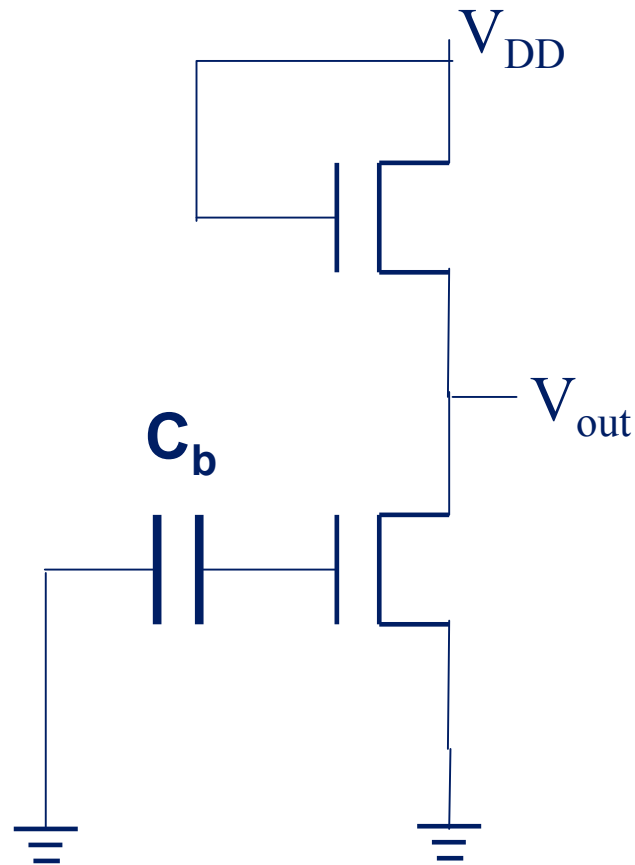
$$L_b = 108 \text{ } \mu\text{m}; W_b = 25 \text{ } \mu\text{m}; H_b = 0.46 \text{ } \mu\text{m}; m_{\text{Au}} = 0.35 \text{ } \mu\text{g}$$

$$d = 7 \text{ } \mu\text{m} \rightarrow C_b = \epsilon_0 L_b W_b / d$$

$$E_{\text{SiO}_2} = 60 \text{ GPa} \rightarrow \Delta C_b / C_b \approx 5 \times 10^{-3} / g$$

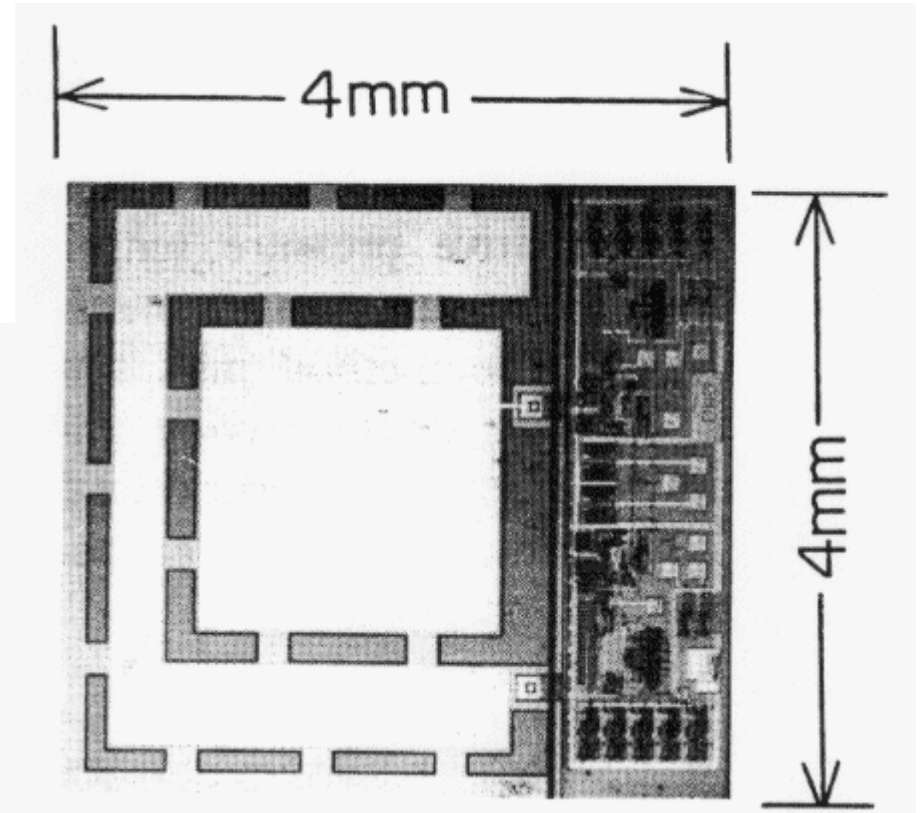
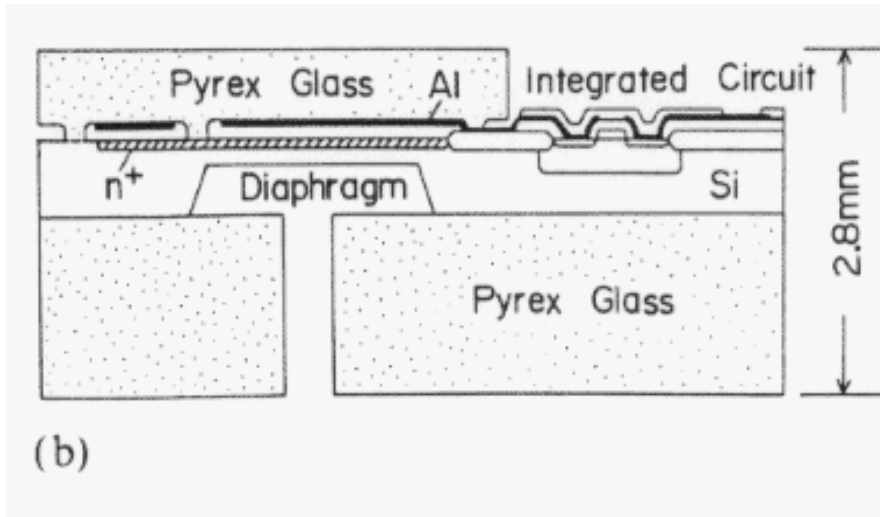
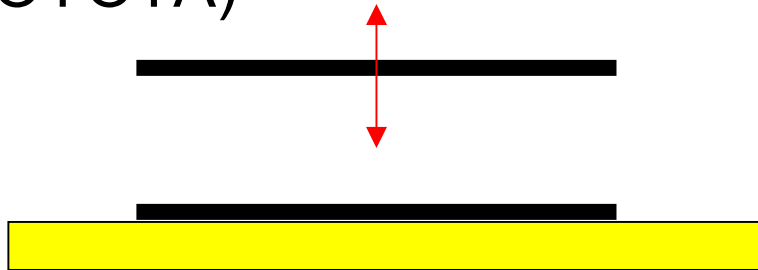
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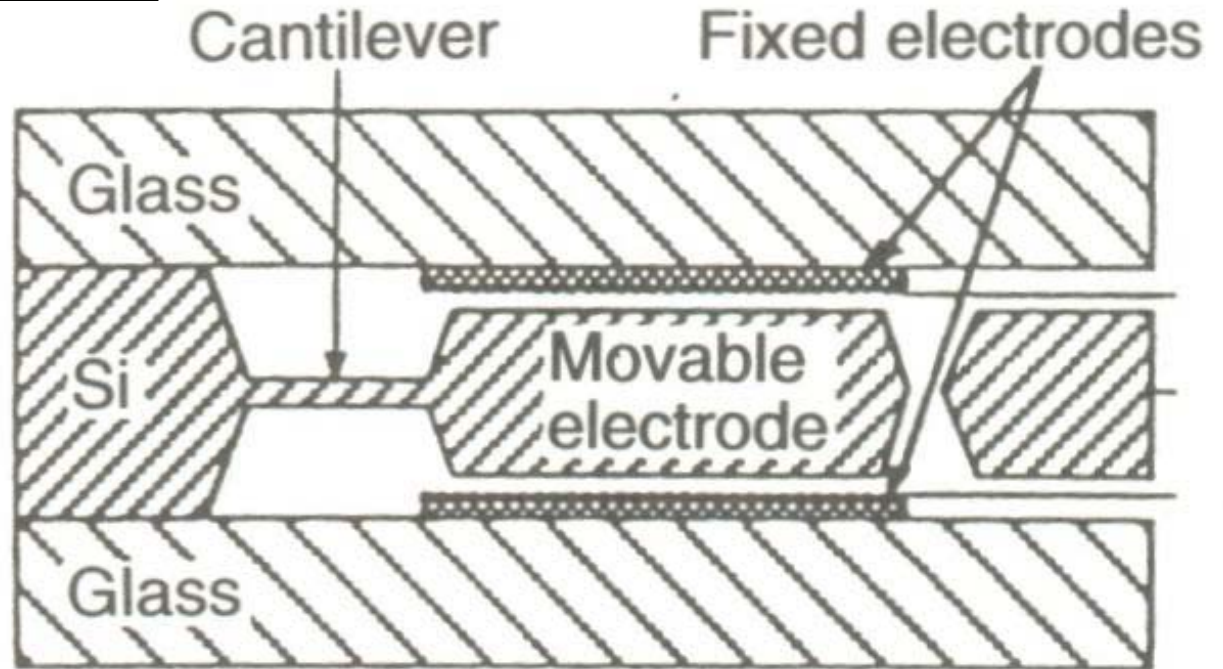
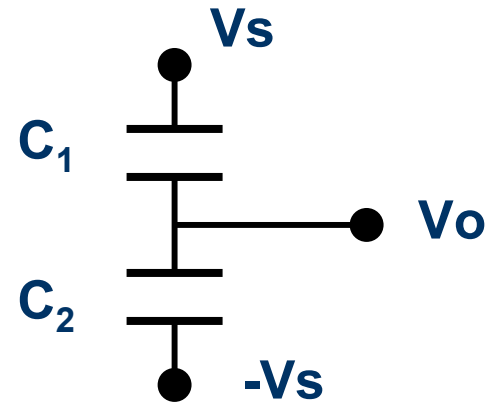
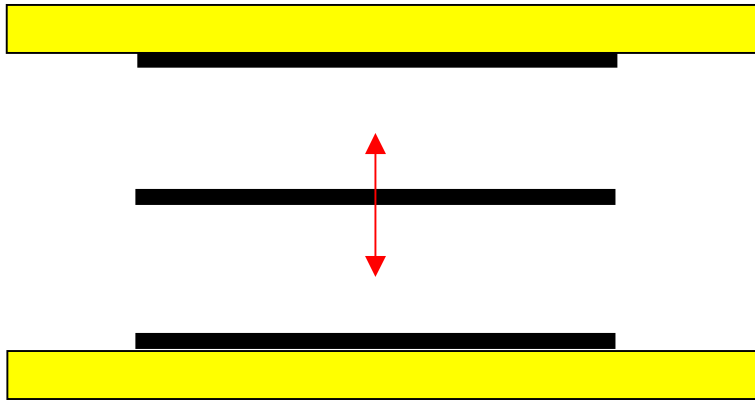


SENSORE VERTICALE DI ACCELERAZIONE

Variazioni verticali di capacità
(TOYOTA)

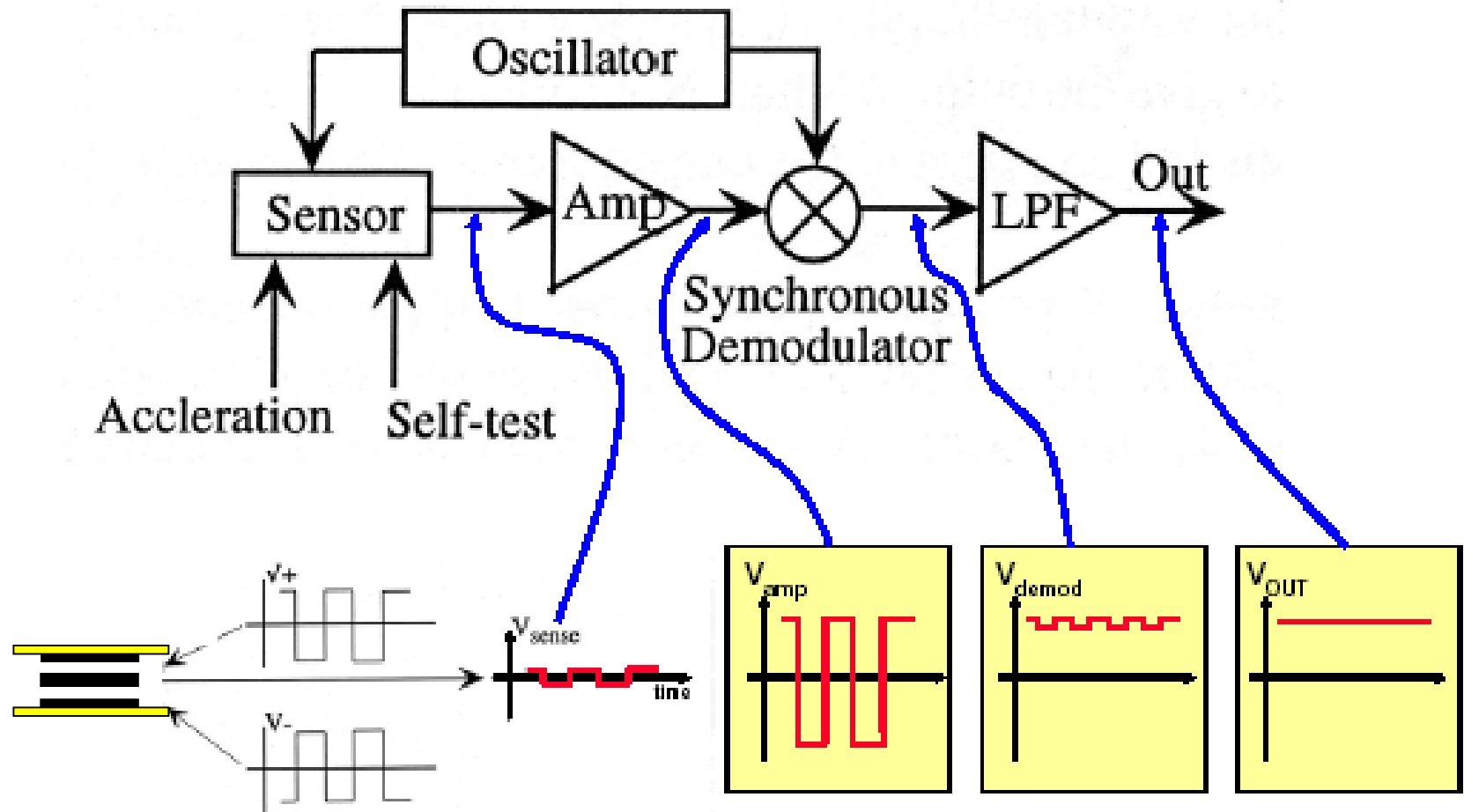


Variazioni differenziali di capacità

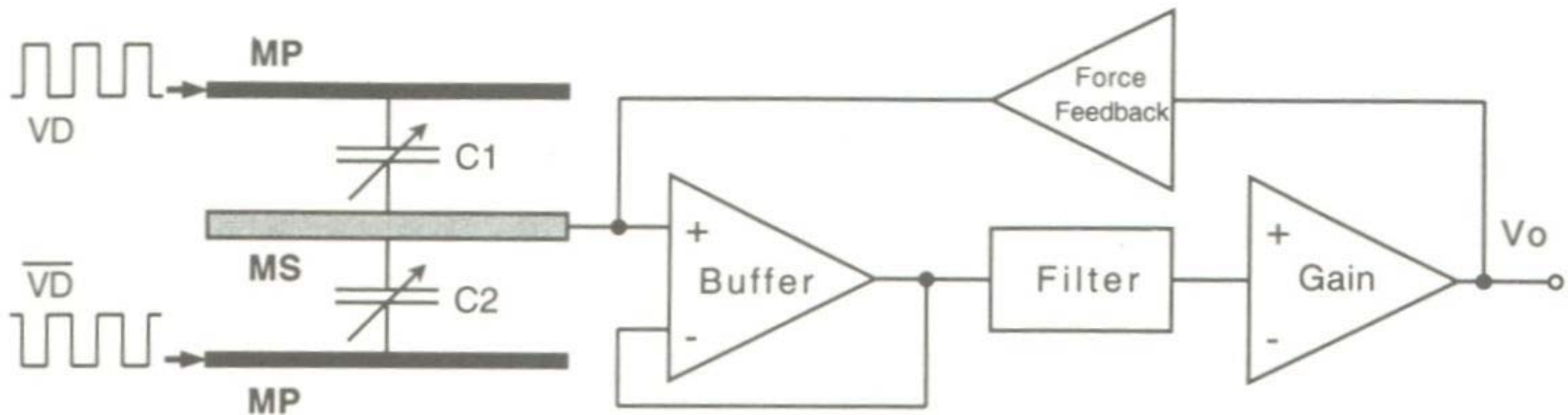


(HITACHI)

Tecnica di lettura della variazione differenziale di capacità senza retroazione



Tecnica di lettura della variazione differenziale di capacità a bilanciamento di forza



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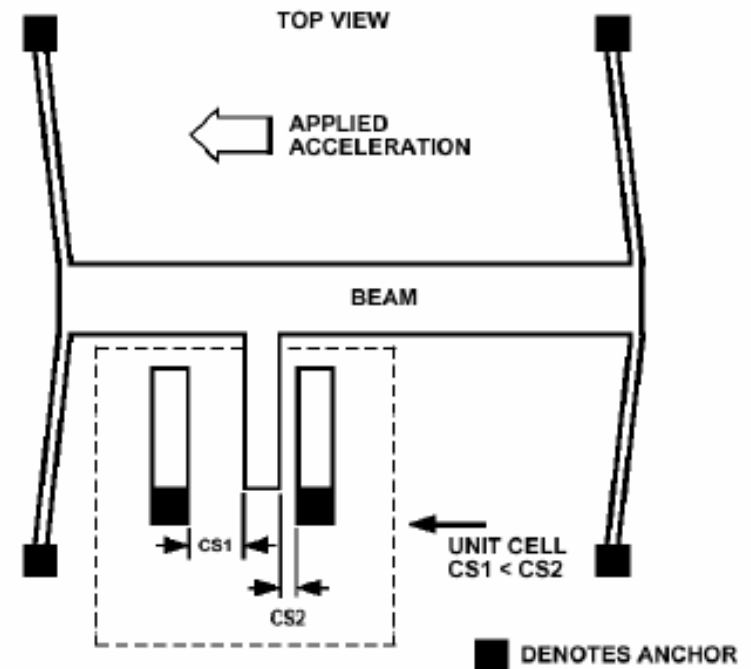
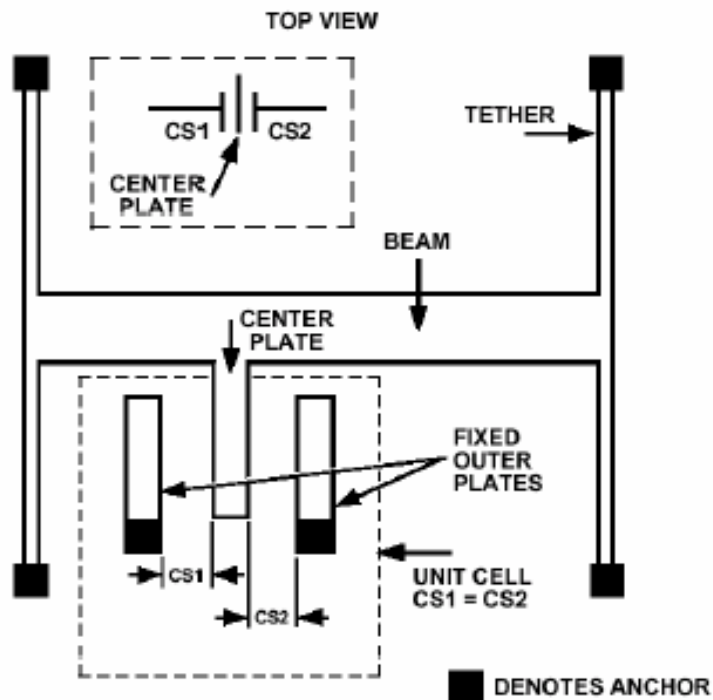
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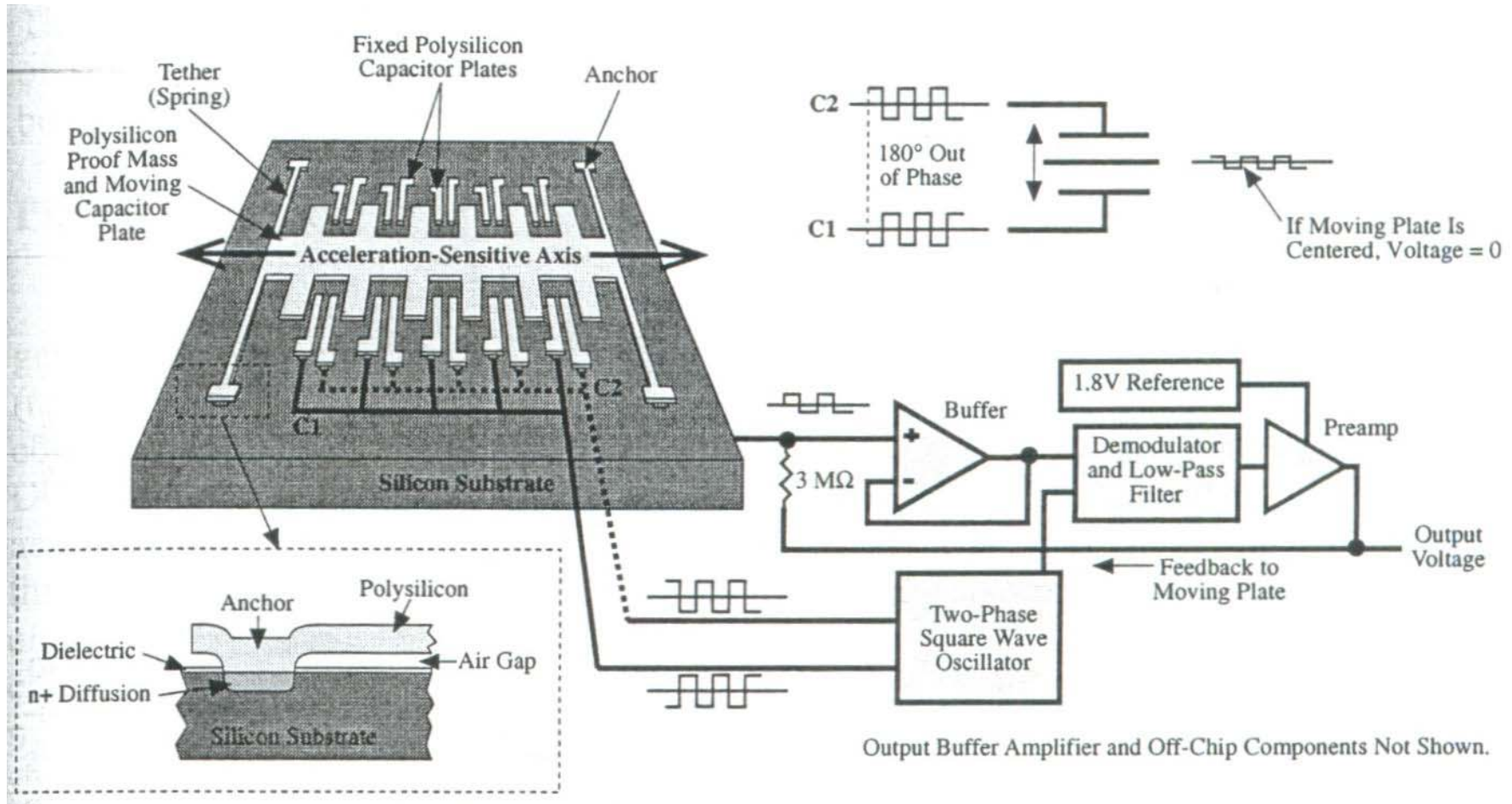
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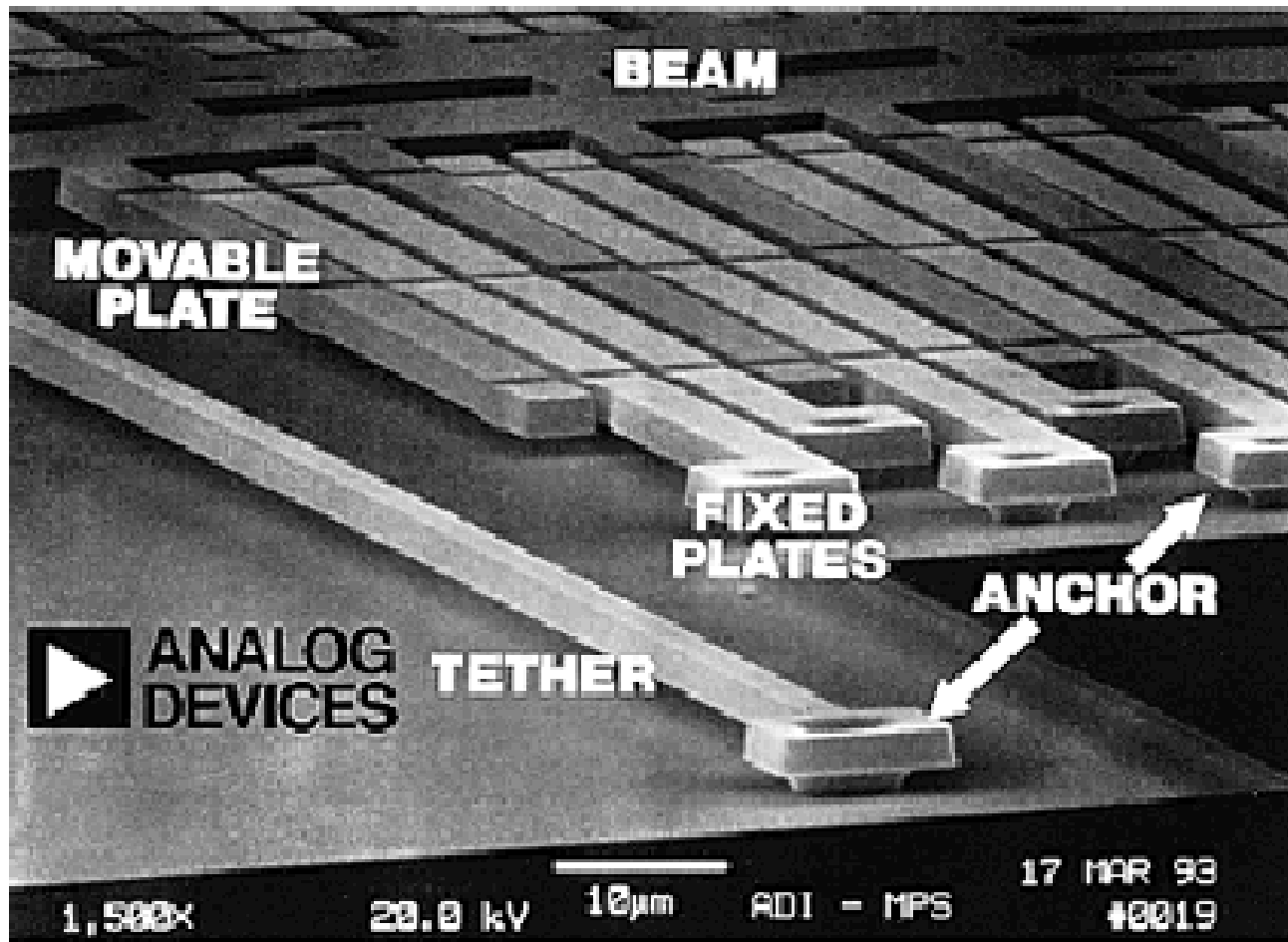
**3.2 sensore di accelerazione laterale
ADXL (ANALOG DEVICES)**

SENSORE LATERALE DI ACCELERAZIONE

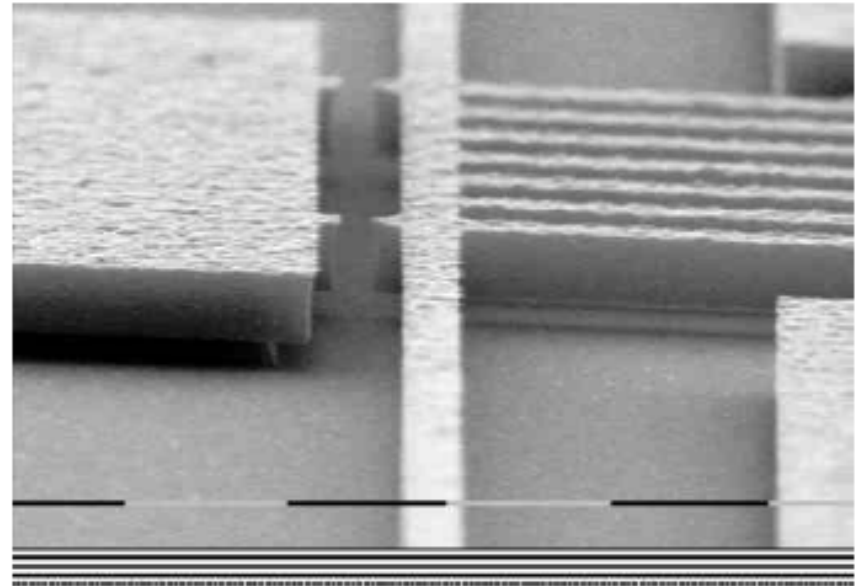
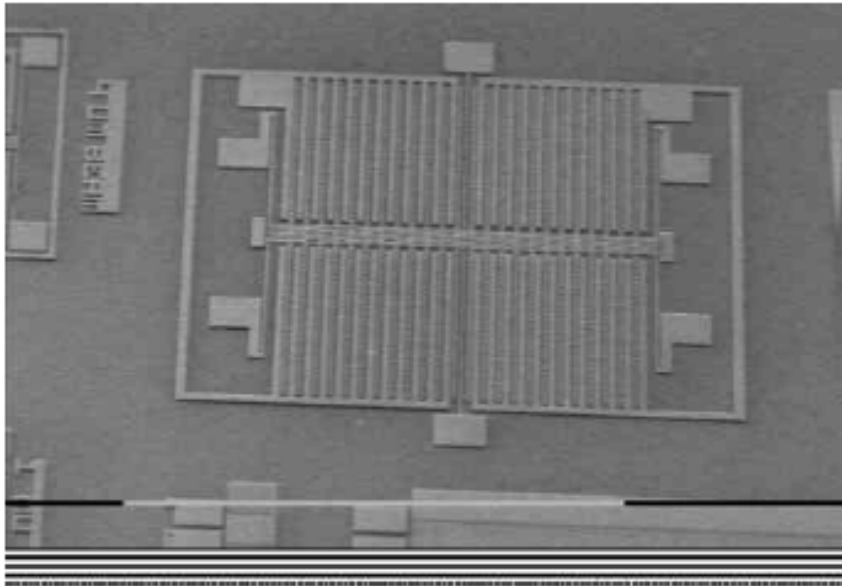
ADXL Differential Capacitive Sensor





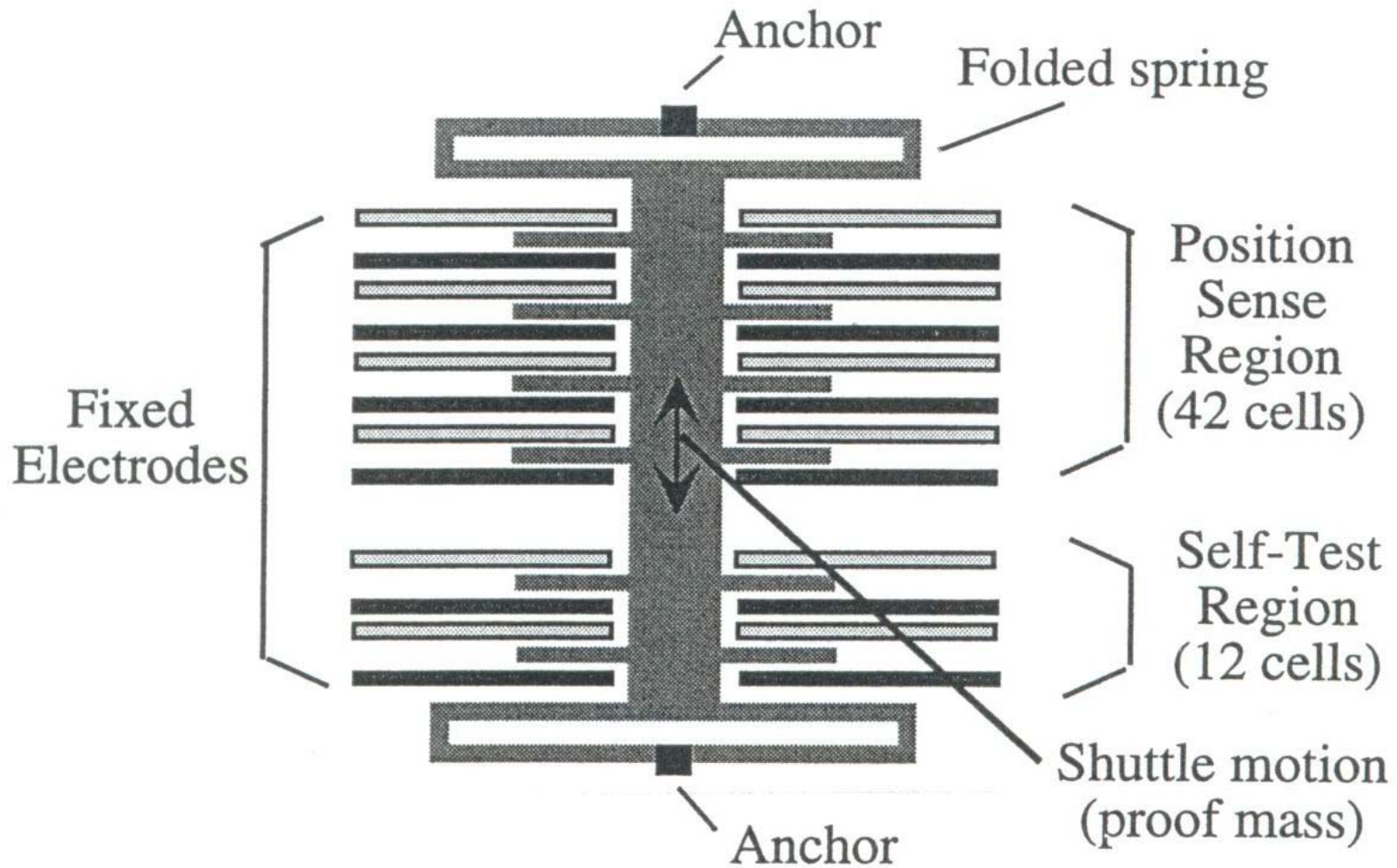


Lateral accelerometer



Accelerometer manufactured in Delft using epi-micromachining

ANALOG DEVICES ADXL



ANALOG DEVICES ADXL

