

Improvement of sensitivity of force sensor probe using quartz crystal resonator



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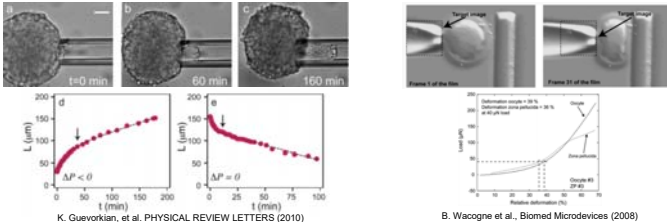
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Measurement-range: 0.73 μN – 50 mN, Waterproof

Background & Purpose

Demands on measuring the mechanical properties of living tissue increase



Features of biological samples

- Non-linearity of reaction force
- Soft & Small
- Medium environment

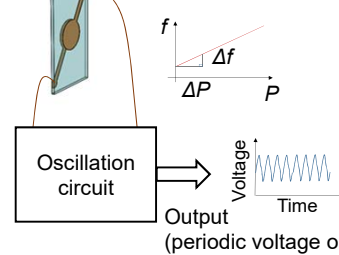
Sensor requirements

- ❑ Wide measurement-range
- ❑ High resolution
- ❑ Waterproofing

QCR sensor

Quartz Crystal Resonator (QCR)

- ❑ High stable periodic signal
- ❑ Frequency changes linearly depending on stress.
- ❑ Quartz crystal has high Young's modulus.



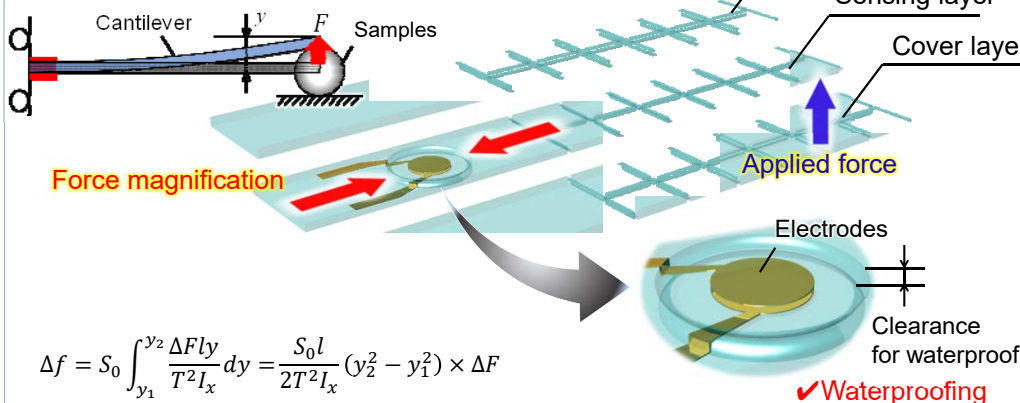
Features

- ✓ high resolution
- ✓ wide-range
- ✓ long-term stability

But not enough

Force sensor probe using QCR

Measurement method of cantilever type

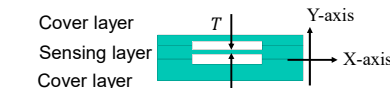


$$\Delta f = S_0 \int_{y_1}^{y_2} \frac{\Delta F l y}{T^2 I_x} dy = \frac{S_0 l}{2 T^2 I_x} (y_2^2 - y_1^2) \times \Delta F$$

I_x : Second moment of area T : Thickness of cantilever
 l : Length of cantilever S_0 : Stress sensitivity f : Frequency

$$S_s = \Delta f / \Delta F = \int (S_0 l y / T^2 I_x) dy$$

S_s : Sensor sensitivity

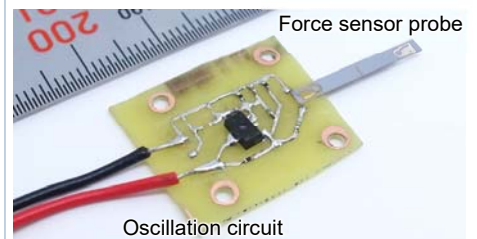


Thickness: T
 $41.7 \mu\text{m} \rightarrow 15 \mu\text{m}$

Sensitivity: S_s
 $\times 2.9$ times
 ✓ High resolution

Fabrication process

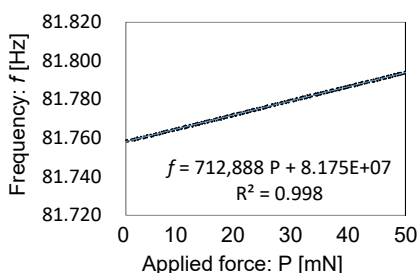
- Patterning of Cr/Au
- Patterning of resist
- Sandblasting
- Wet etching
- Sputtering of Cr/Au
- Atomic diffusion bonding
- Patterning of Cr/Au
- Patterning of resist
- Patterning of resist
- Sandblasting
- Wet etching



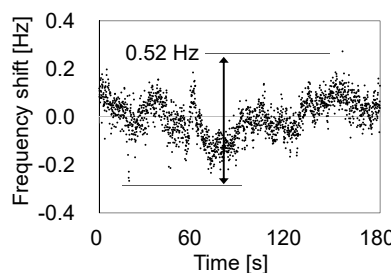
Calibration results

Loading characteristic

Time stability



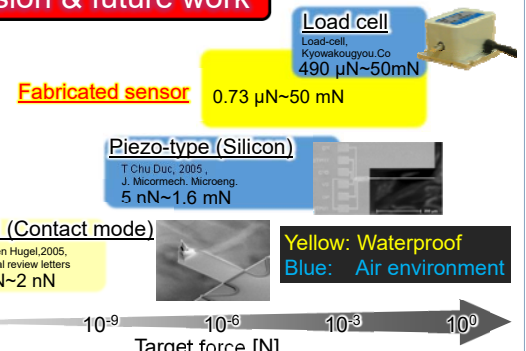
Sensitivity : 712,888 Hz/N



Resolution: 0.73 μN

Measurement range: $6.8 \times 10^4 (0.73 \mu\text{N} - 50 \text{ mN})$

Conclusion & future work



We will measure mechanical characteristics of living tissues in liquid environment by fabricated sensor.