The Novel Resonator Cell (RC) for both Portable Biosensor and High Quality Filter for Cell Phones

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Background

Biosensors are very crucial for the health and food industry. It can be used as biomarkers for evaluating diabetes, halitosis, kidney malfunction, lung cancer, HIV etc. There are many type of biosensor designs as shown below;

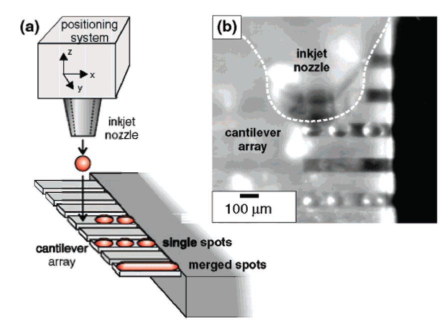
Sensing Method	Sensor Type	Sensitivity	Disadvantages
Conductance change	Electrochemical	Moderate	• It requires biomolecule labeling technique • It has much more noise compared to frequency shift method and require high tech. reading equipment • High noise may results due to electrolytes from the samples
	Nanowires, nanotubes, CNT, FET	High	• In a premature level and not ready to be a portable device. To be a portable device. It requires millions of nanowires connected to the circuit properly. Very challenging in this technology • Functionalized surface is less than %1 • It has much more noise compared to frequency shift method and require high technology reading equipment
	Magnetic	Moderate	• Nonspecific interactions can occur between magnetic nanoparticles and results in high noise. • It requires labeled analyte be present in the sample • It has much more noise compared to frequency shift method
Frequency change	Optical	High	• Most of them are very large and require laboratory usage such as tagging a molecule with a fluorescent • It is very expensive method • It requires Spectrophotometry or Fluorescence detector or microscope to sense the wavelength shift • Not portable and very hard to miniaturize. If succeeded than it would cost at least $1000 for a single device without high performance • Channel that carries liquid should be clean for accurate sensing • Alignment and stability problem unless there is an integrated optics • The lifetime of reagents can be short under incident light (Photobleaching) • Can be affected by humidity and water • Dust and drift can coat the optics and impair the response • Linearity is not good
	Mass sensitive	High	• Well known device is the cantilever and has an efficient area smaller than %20 • It uses antibody/antigen method that's why it is a one time use and disposable
	Surface Acoustic Waves	Moderate	• Frequency change can be affected from conductance of the liquid and dielectric. • Elastic constants of the absorbents results in noisy output

The Motivation

- Increasing the functionalized surface area. To our knowledge, in current technology the functionalized area to the chip area is less than %20, on the other hand in our design it is between 65%-80%. The functionalized surface is even less than 1% for high sensitive devices (attogram sensitivity).
- The sensitivity is around the attogram. The device would be the first portable biosensor with a sensitivity over the picogram range sensitive portable device
- It doesn't require any lab equipment to either locate the virus or to read the output by expensive instruments such as network analyzer
- Designing CMOS compatible biosensor allows a very cheap, low noise and portable device.
- Designing low noise, low power, high tunable bandwidth resonator for cell phones, PC, wireless systems, PLL, ADC, CPU, GPS, etc.

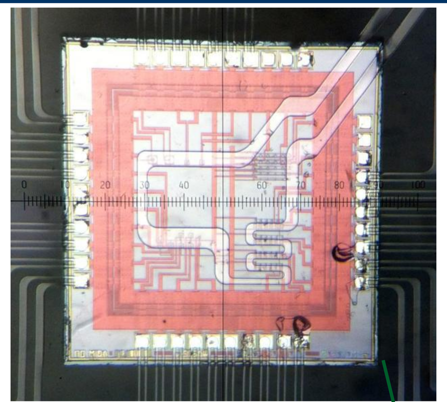
Considerations for Portable Design

1) Packaging Technology

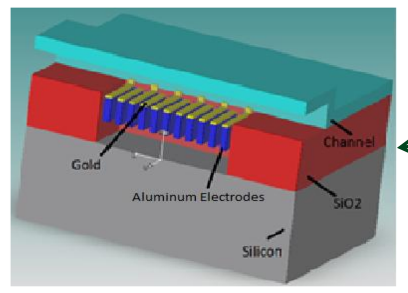


Traditional method to locate the virus on to the cantilever by using the lab equipment. The picture is taken from [1]

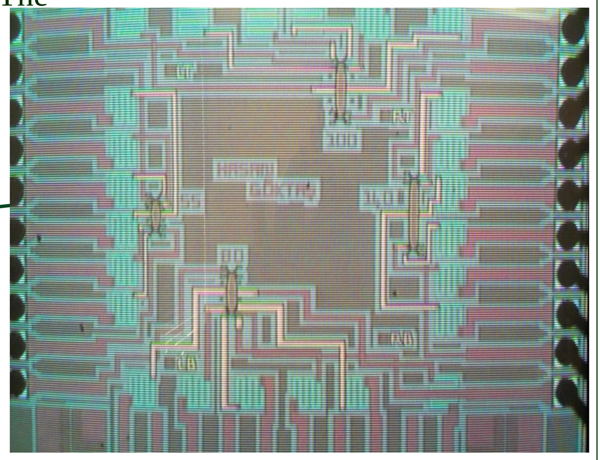
Solution



The picture is taken from [2]



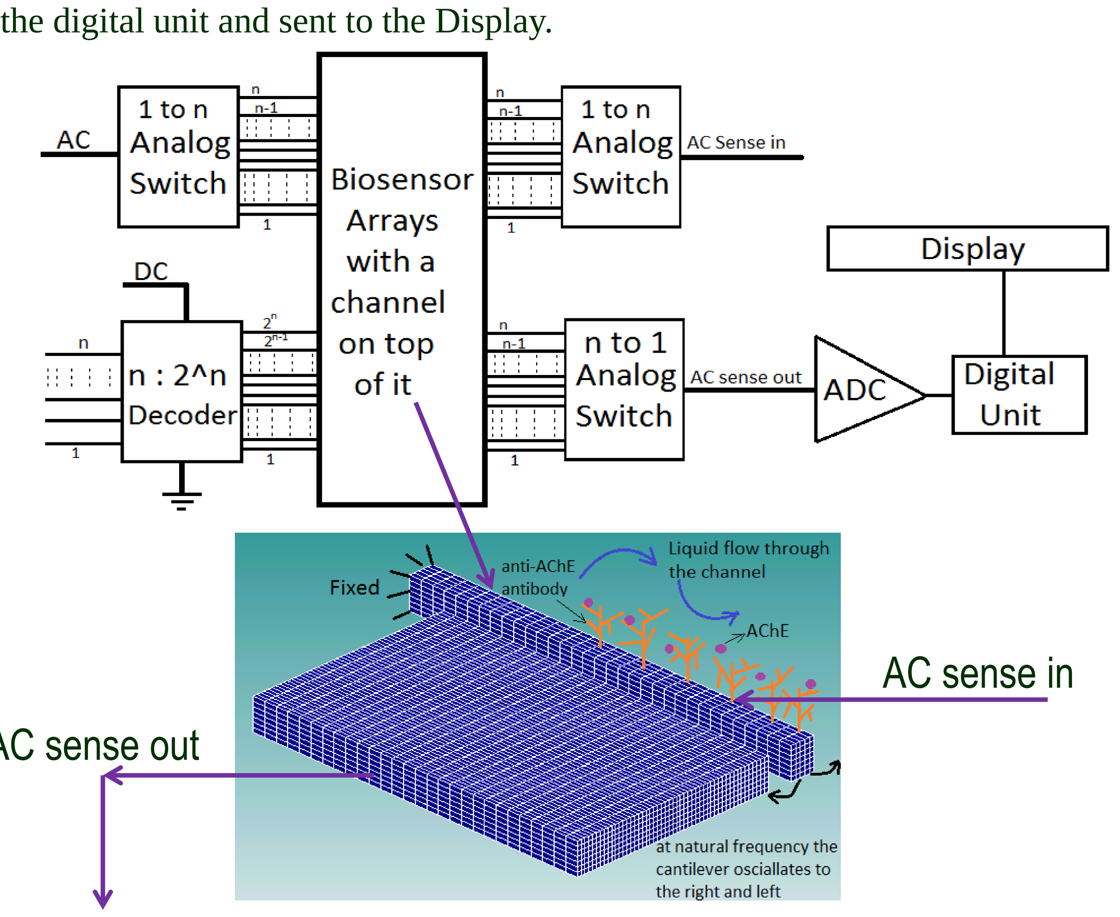
After applying the same packaging technology

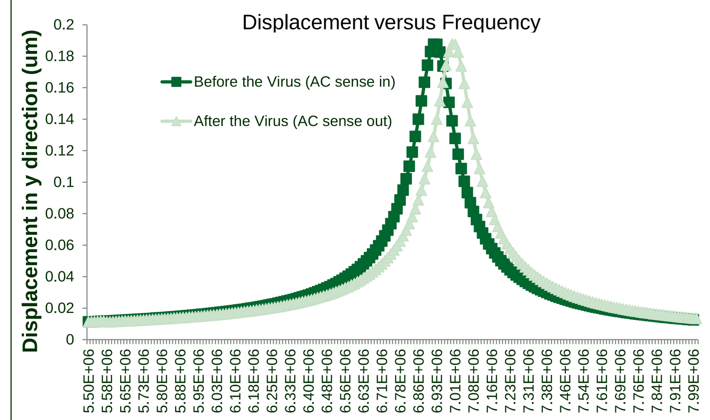


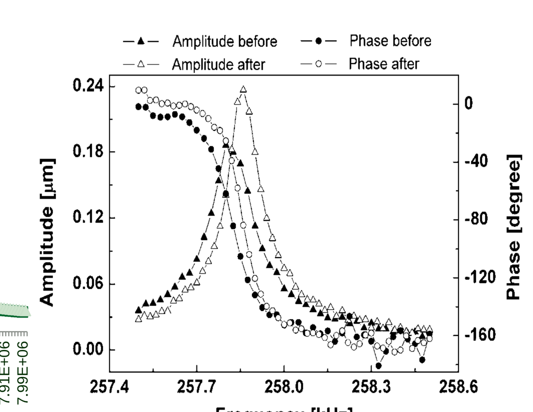
CMOS Biosensor Chip in [6]

2) System on a Chip (SOC) in CMOS technology for portable design

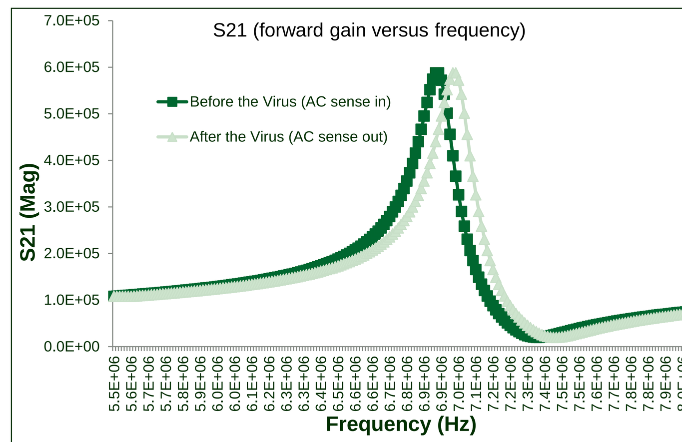
Having the circuit and display on the same device by using CMOS process enables us to get a real cheap and portable device. The biosensor consists of the channel, Aluminum electrodes, control circuit and reading circuit. Channel carries the blood over the Aluminum electrodes. The device is using the antibody/antigen method to capture the viruses. The resonance frequency of the electrodes changes when the viruses are trapped on the electrodes. The signal is then converted into the digital data via ADC. The frequency shift is then sensed by the digital unit and sent to the Display.

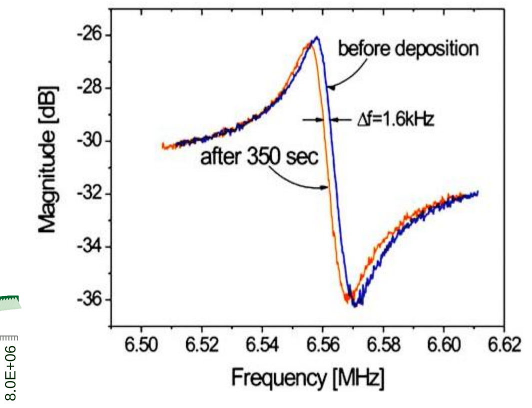






The frequency change can be sensed by using the Spectrum/Signal analyzer. Displacement/amplitude represents the average capacitance value between the resonator and the sense electrode during the oscillation. The graph on the left side shows an example result from the Coventor Simulation and the graph on the right side shows an example from the real results published in [3]

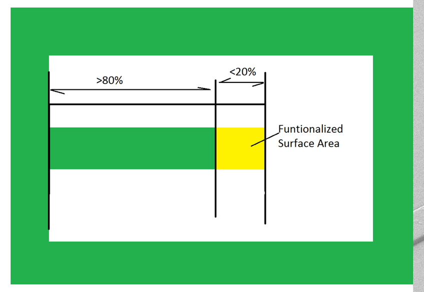




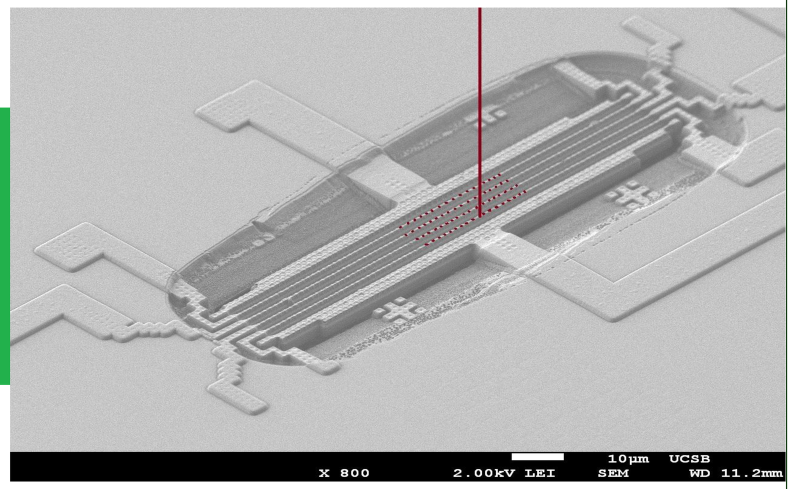
The frequency change can also be sensed by using the Network analyzer. S21 represents the forward gain by taking into account the capacitance value between the resonator and the sense electrode during the oscillation. The graph on the left side shows an example result from the Coventor Simulation and the graph on the right side shows an example from the real results published in [4]

Increasing the Functionalized surface area

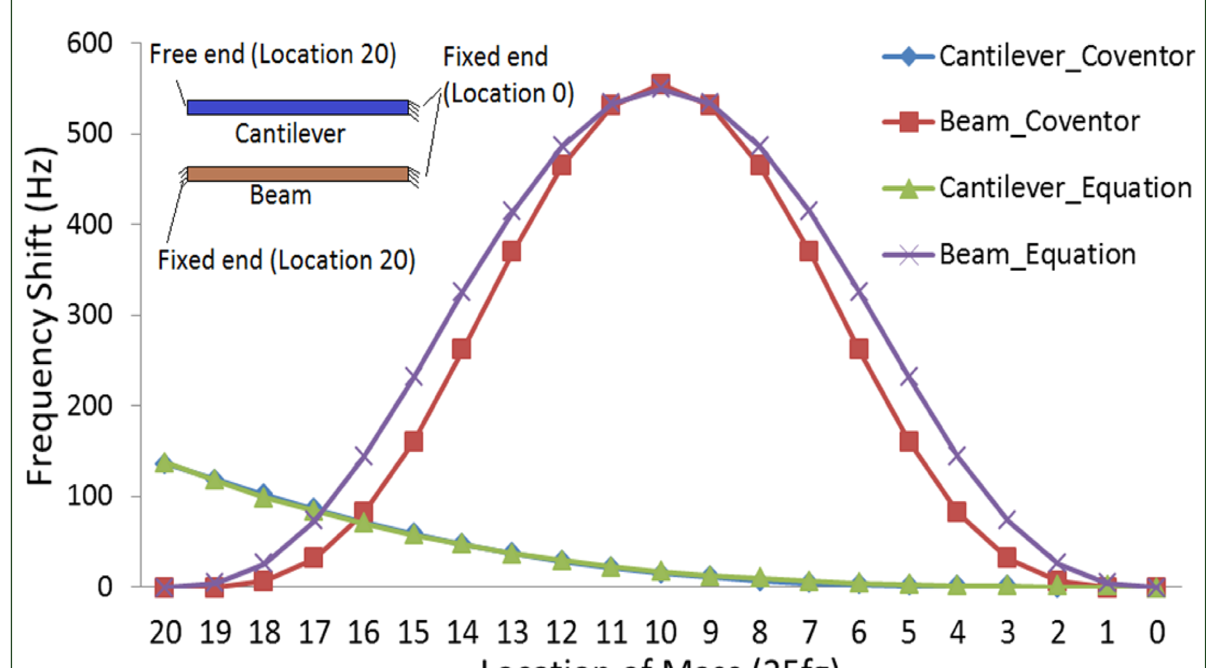
Drawback of cantilever : The functionalized surface area is less than 20%. Our novel design modified the structure and has a functionalized surface area around 90% of the single device



Cantilever



Beam Type design was built [6]



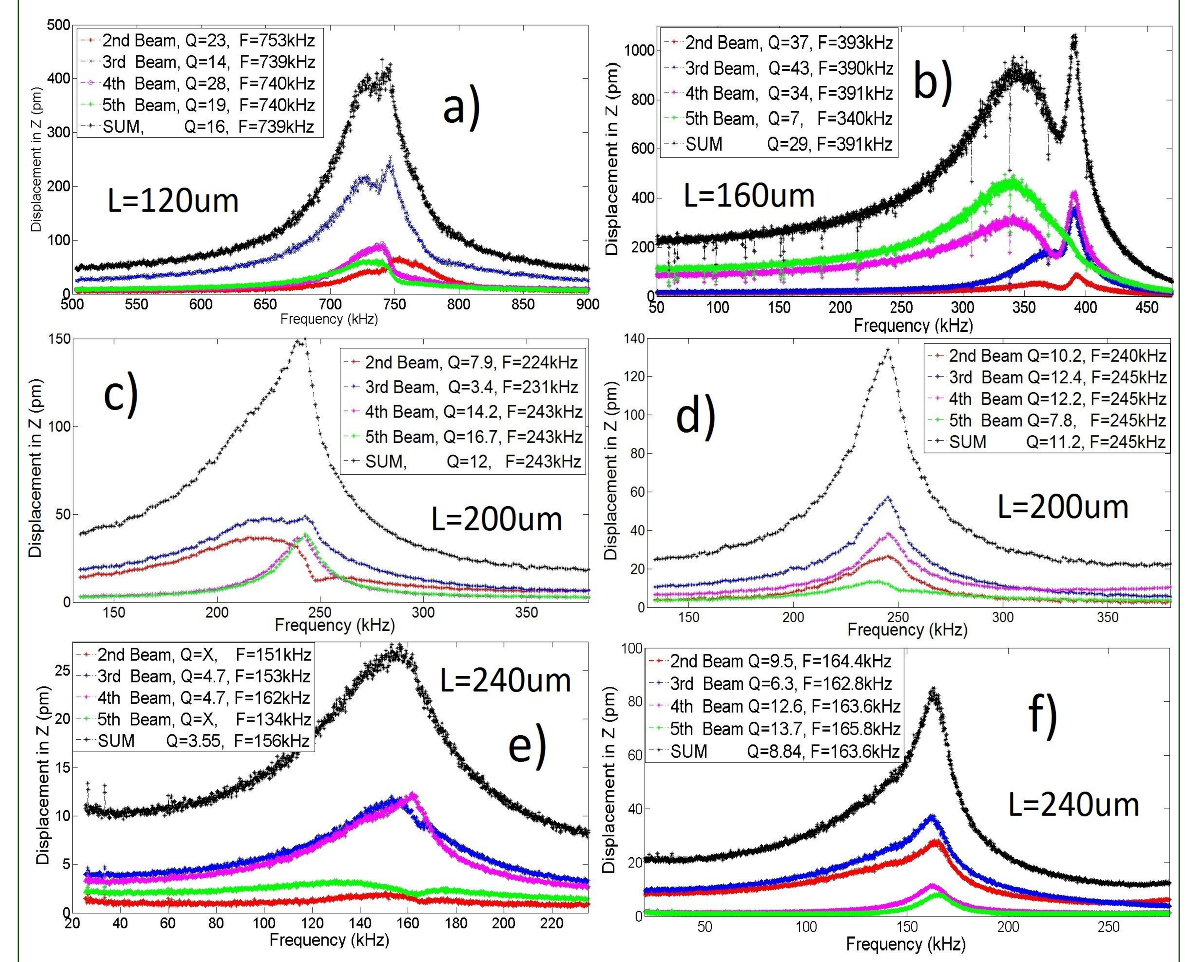
Mass versus Frequency shift for beam and cantilever in [5]

Array Structure: We used the array structure with a novel circuit configuration. The functionalized surface area covers the 65% of the whole channel for the AMI 0.6um and around 80% for the TSMC 0.18um tech. The chip area is 1mmx1mm. The total functionalized area on the chip would be around 50% for the AMI 0.6um and 65% for the TSMC 0.18um. The circuit allows to select different electrodes to use it as a single biosensor. In this way device is checking all single electrodes throughout the channel . On the other hand most designs from the literature has only few devices on the whole chip. The functionalized areas is even less than 1% especially for the nanowire device

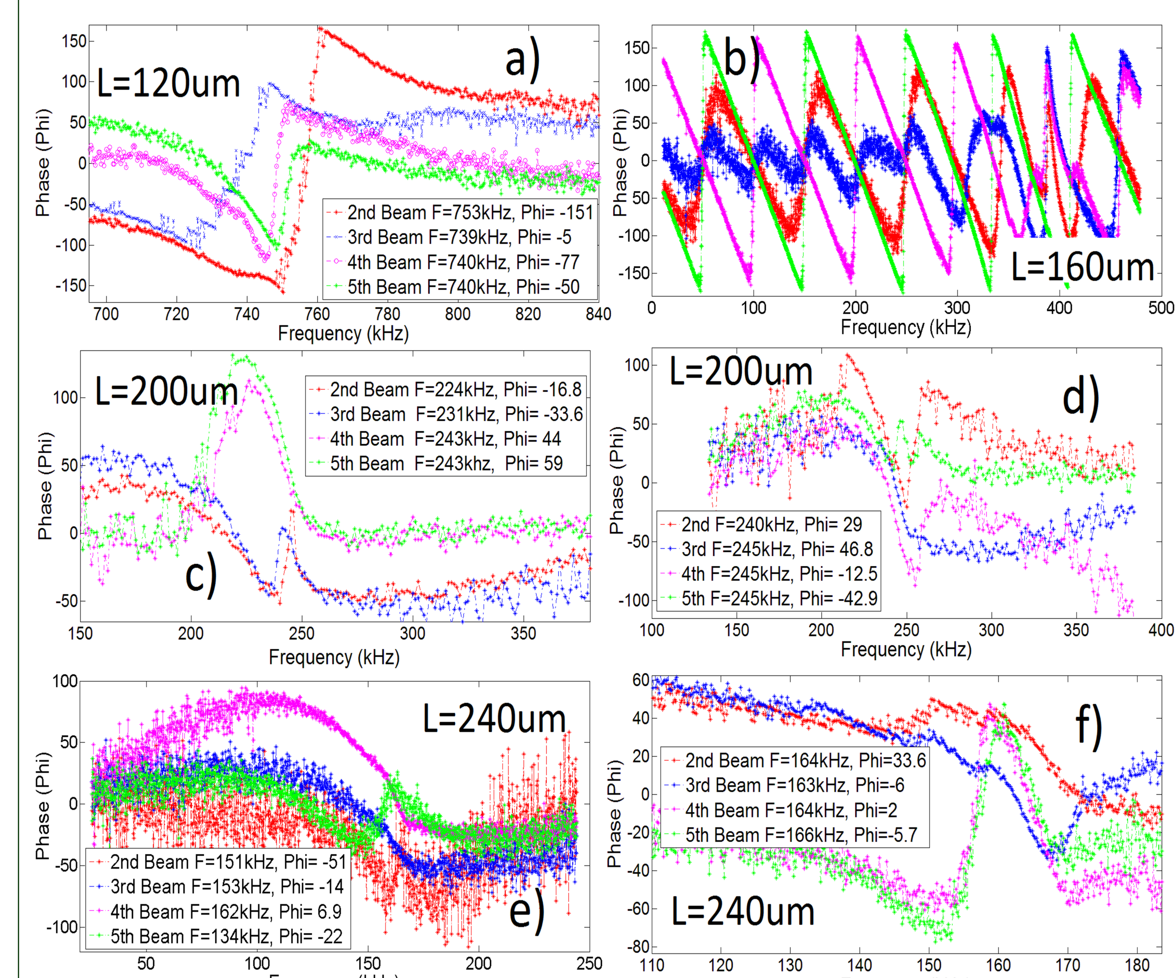
Final Design for CMOS Technology

CMOS AMI 0.6um	Sensitivity for Frequency shift=27Hz	CMOS TSMC 0.18um	Sensitivity for Frequency shift=27Hz
D1	7.5 femtogram	D7	150 attogram
D2	23 femtogram	D8	350 attogram
D3	43 femtogram	D9	700 attogram
D4	75 femtogram	D10	1.2 femtogram
D5	120 femtogram	D11	1.9 femtogram
D6	180 femtogram	D12	2.8 femtogram

Measurement Results with Laser Doppler Vibrometer



Frequency Response of the devices in [6]



Phase Response of the devices in [6]

References

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2) Flexible packaging of solid-state integrated circuit chips with elestomeric microfluidics, Bowie Zhang, Quan Dong, Can E Korman, Zhenyu Lii & Mona E Zaghloul
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5) Hasan Goktas and Mona Zaghkoul, High Sensitive CMOS Portable Biosenosr with Flexible Microfluidic Integration, IEEE Sensor 2013
6) Resonator Cell (RC) with Phase shift in CMOS Technology, Journal of Micromechanics and Mircoenegineering 2014 Submitted and under review

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