Design and Simulation of Cantilever Array for Fluid Flow Sensing Applications

Kavitha K.[1], Manjoosha Y R.[1], SelvaSukanya C.[1*], Saranya K.[1], Anju Gupta[1], Chandra Devi K.[1], Alagappan M.[1]
[1] PSG College of Technology, Coimbatore, Tamil Nadu, India.

Introduction: The biological hair-cell is a modular building block of a rich variety of biological sensors responsive to vibration, touch, gravitational forces, etc., especially flow. These can be mimicked to get the artificial hair cell that are used widely today, from accelerometers in an automotive airbag deployment system to pressure sensors in patient-monitoring and micro fluidic devices. The artificial hair cell constructed as an array has higher sensitivity.

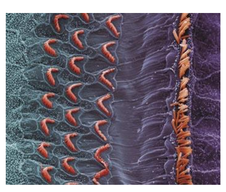

Figure 1. SEM image of the mammalian cochlea hair cells.

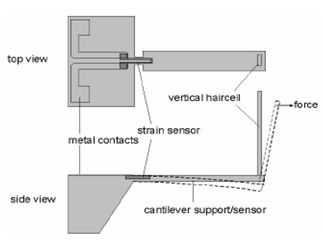

Figure2. Schematic diagram of a single artificial hair cell sensor

Computational Methods: The Hair cell array and conventional cantilever for flow sensing was modeled and simulated using COMSOL Multiphysics 4.2a. The conventional cantilever was made of silicon as fixed end and PMMA/Si as movable end, whereas the cantilever hair cell array was made of Silicon, Poly Si and PMMA. The block encapsulating the geometry represented the fluid (Water)

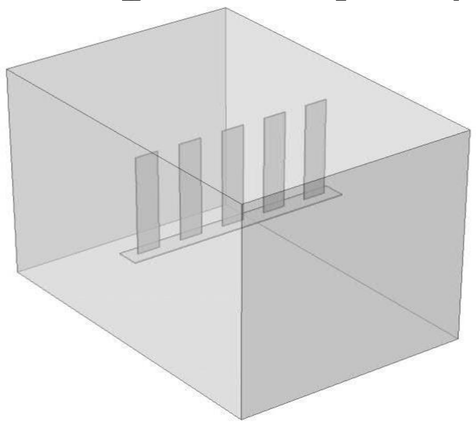

Figure3. Conventional cantilever

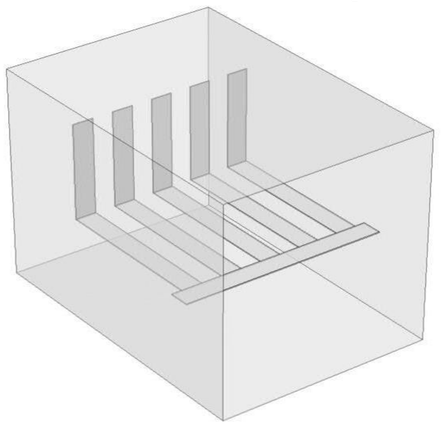

Figure4. Cantilever Hair cell geometry

The Fluid structure interaction (*fsi*) physics was used to apply a fluid flow. The magnitude of the induced strain (ε) is largest at the base, where the PMMA is located.

Results: The simulation results for both the conventional and hair cell design was obtained as shown:

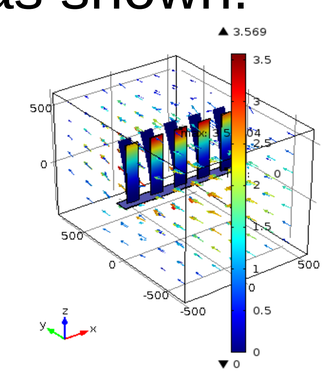

Figure 5: A conventional cantilever sensor with lower deflection efficiency of only 3.569 µm displacement.

DIFFERENT DIRECTION SENSING COMPARISON WITH SI(C)

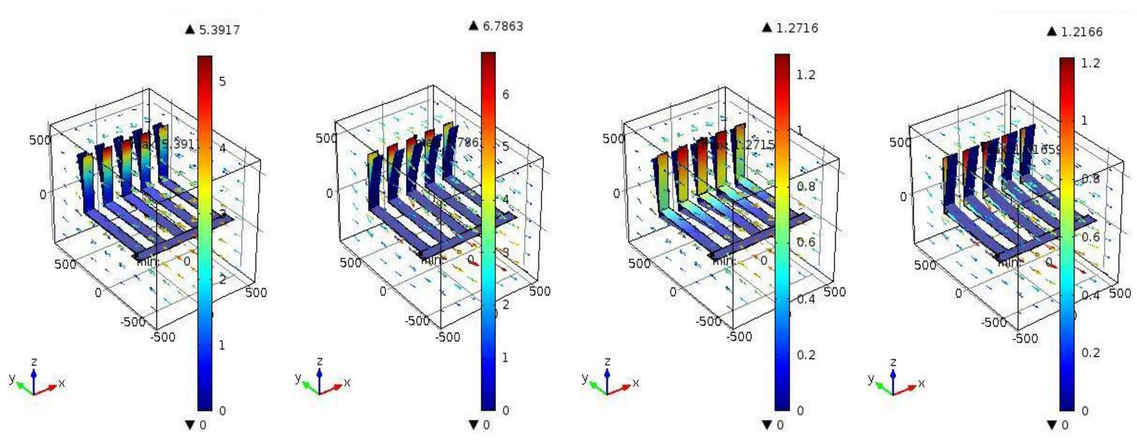

Figure6. A cantilever hair cell sensor with higher deflection efficiency of 5.3917 µm displacement

Figure7. Simulation of the sensor based on PMMA polymer cilium, Backward fluid flow (Larger displacement

Figure8. Simulation of sensor based on Silicon cilium, Frontal fluid flow (Smaller displacement).

Figure9. Simulation of sensor based on Silicon cilium, Backward fluid flow (Smaller displacement).

PARAMETRIC SWEEP

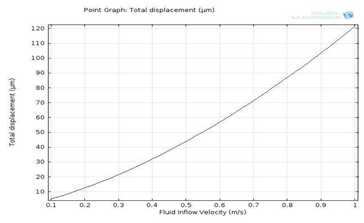

Figure10. Graph showing the change in displacement when fluid flow was increased from 0.1 to 1ms^{-1}.

ENERGY HARVESTING

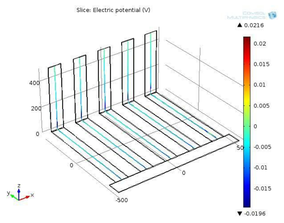

Figure 11. Potential slice plot indicating the output voltage obtained due to bending of the beam, when PZT was used as a material

Conclusions:.

1) The response of each sensor is bidirectional—i.e. the sensor response changes signs depending on the direction of the applied flow.
2) The response sensitivity is a function of the presence of the PMMA hair.
3) A self-powered micro fluidic device is a possibility.

Reference(s):

Chang Liu, Micromachined biomimetic artificial haircell sensors, Bioinspiration&biomimetics, Volume 2, S162–S169, 2011