Magnetic Actuation of Ultra-Flexible Mesh Structure Probe for 3D Biosensing

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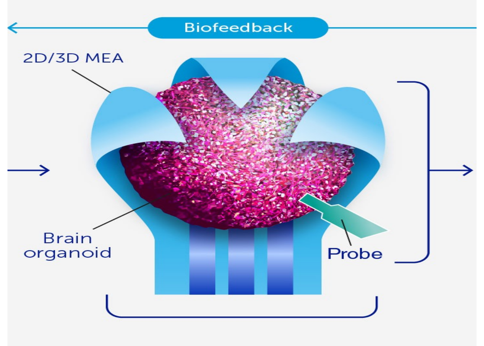
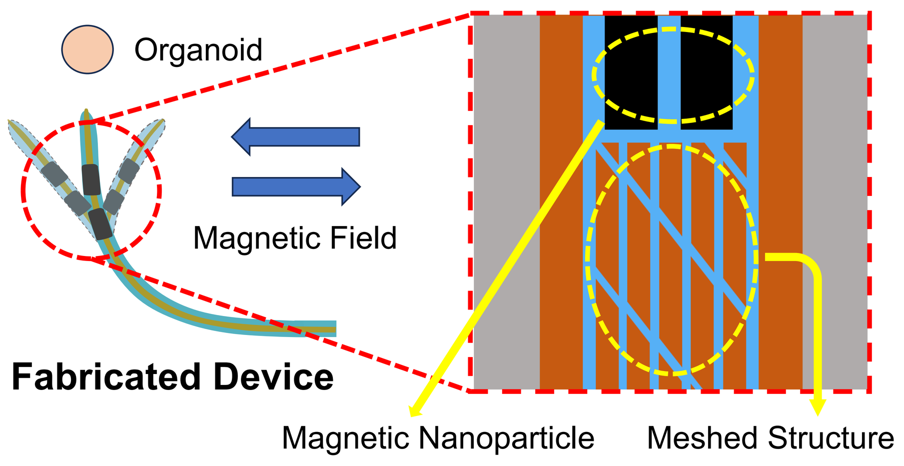
Introduction

Biosensor



Through more precise biosensing, we can increase our understanding on the study of biosystem and have been studied for many decades. Conventional multielectrode array (MEA) such as Utah arrays and Michigan probes are representative biosensing device but face challenges such as characteristics of being rigid and planar. Therefore, our probe suggests a structure which is ultra-flexible and can be magnetically actuated that can detect signals of bent 3D structures such as organoids.

Main Idea



Ultra-Flexible & Magnetic Actuation

Meshed designed structure makes the probe ultra-flexible and allows to have unconstrained movement. Also, the probe is printed with magnetic nanoparticles (MNPs). Therefore, the probe is capable of being magnetically actuated by applying magnetic field. Overall, probe can be manipulated by applying magnetic field while having ultra-flexibility.

Experimental Principle

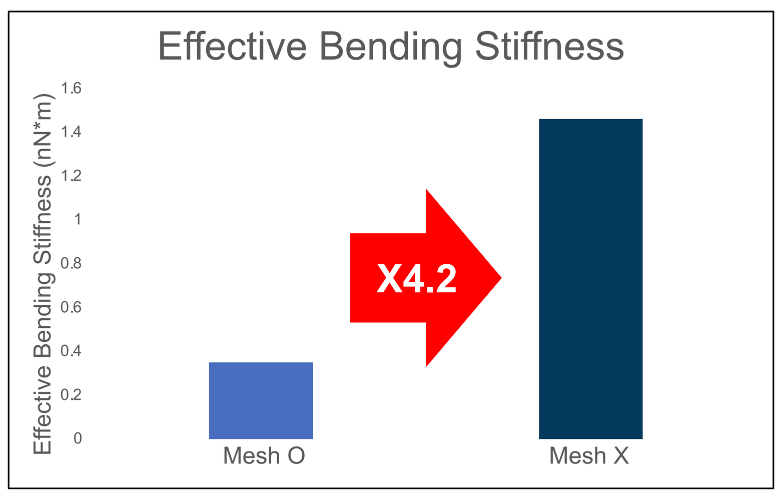
Effective Bending Stiffness

$$D_{mesh} = \frac{2Wl^3}{3d^2b}$$

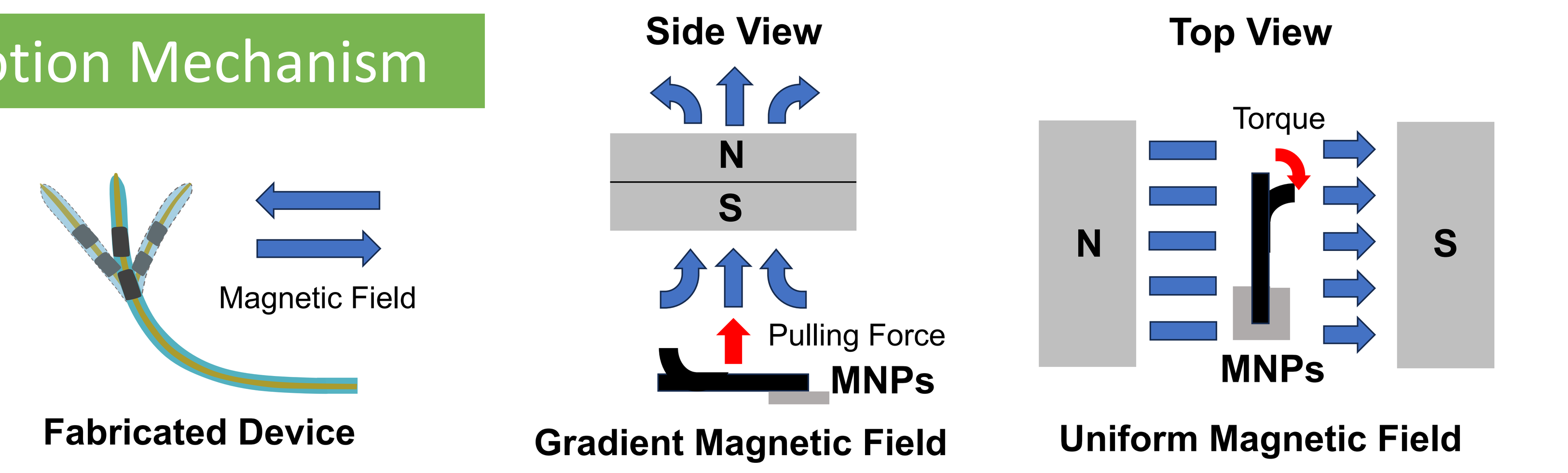
D: Effective Bending Stiffness
W: External Work
l: Thickness of Unit Cell
d: Displacement
b: Width of Unit Cell

$$D_{SU8} = E_{SU8}\frac{h_{SU8}^3}{12}$$

D: Effective Bending Stiffness
E: Young's Modulus
h: Thickness of probe

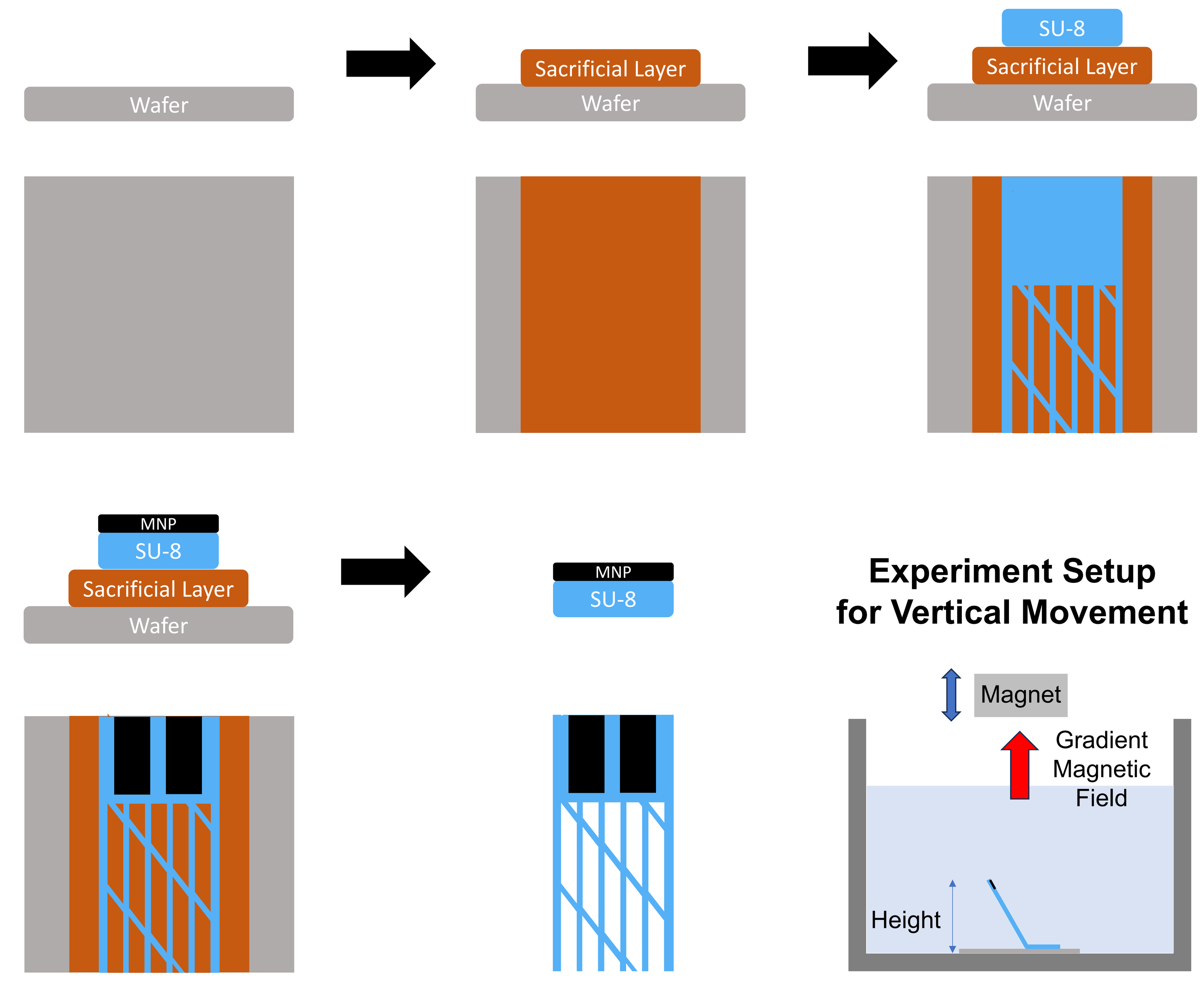


Motion Mechanism



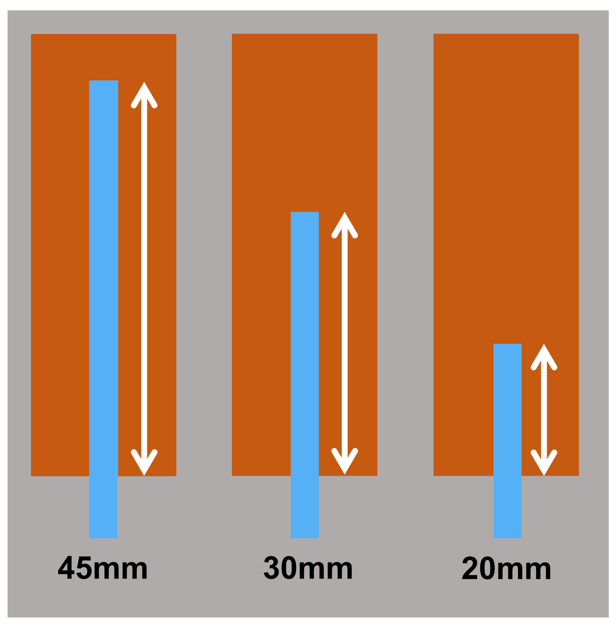
Results

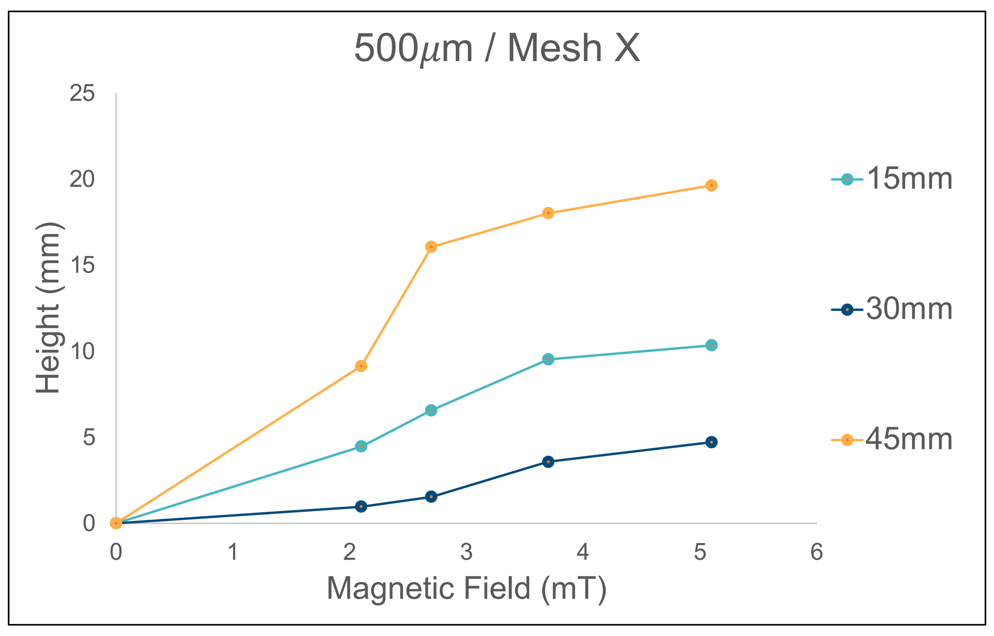
Device Fabrication Process



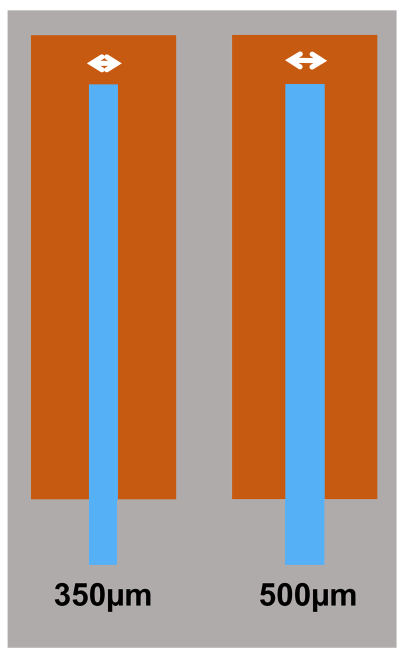
Optimization

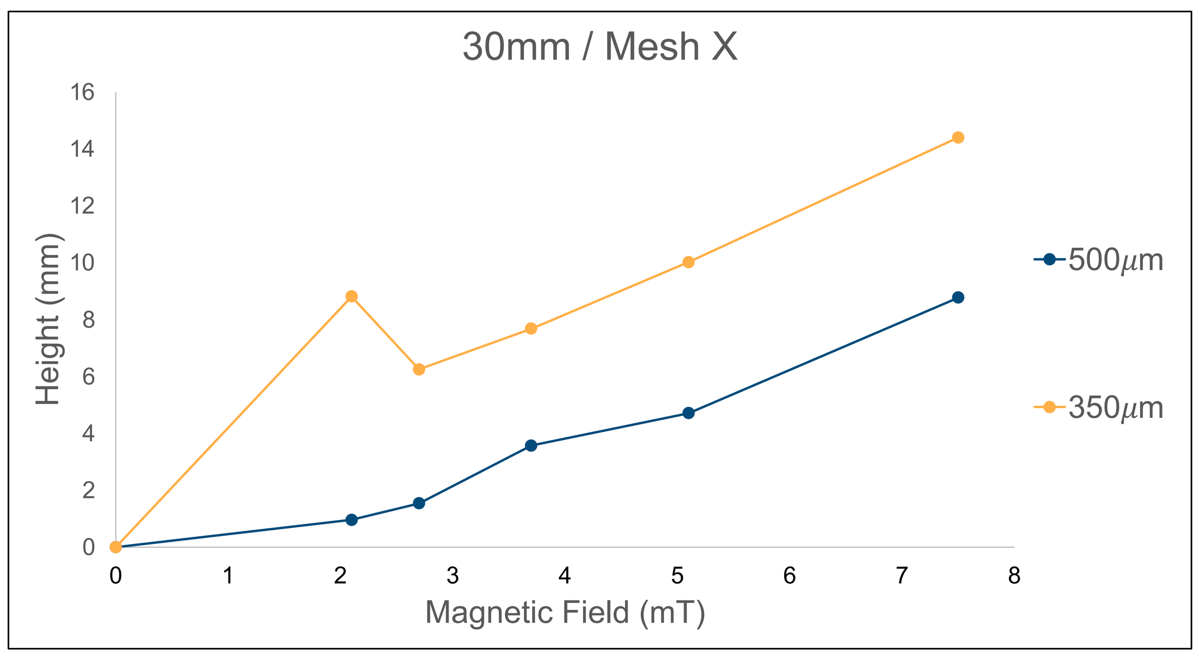
1) Probe Length



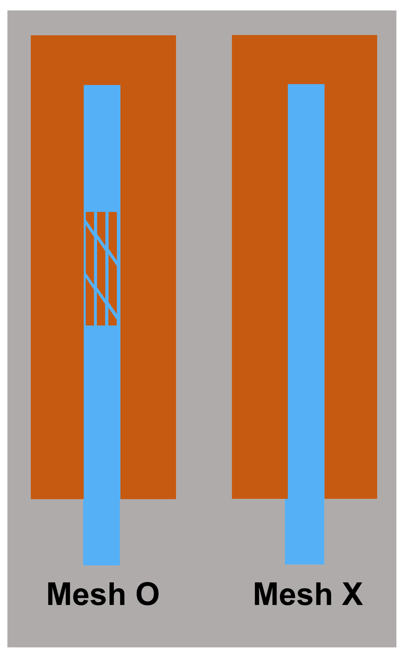


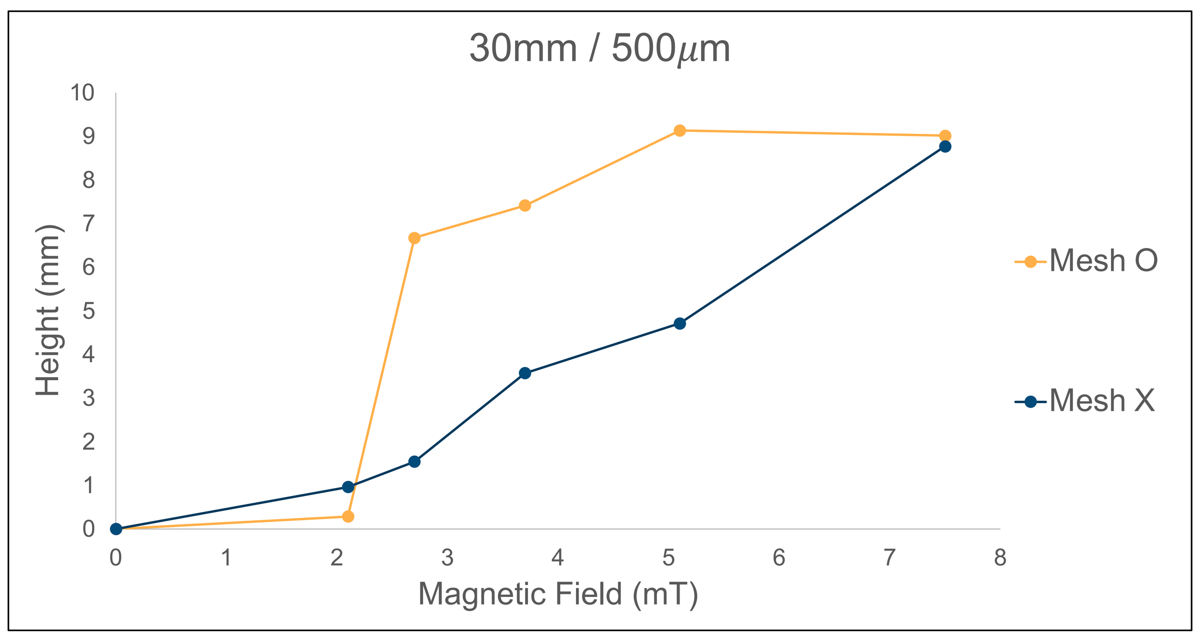
2) Probe Width



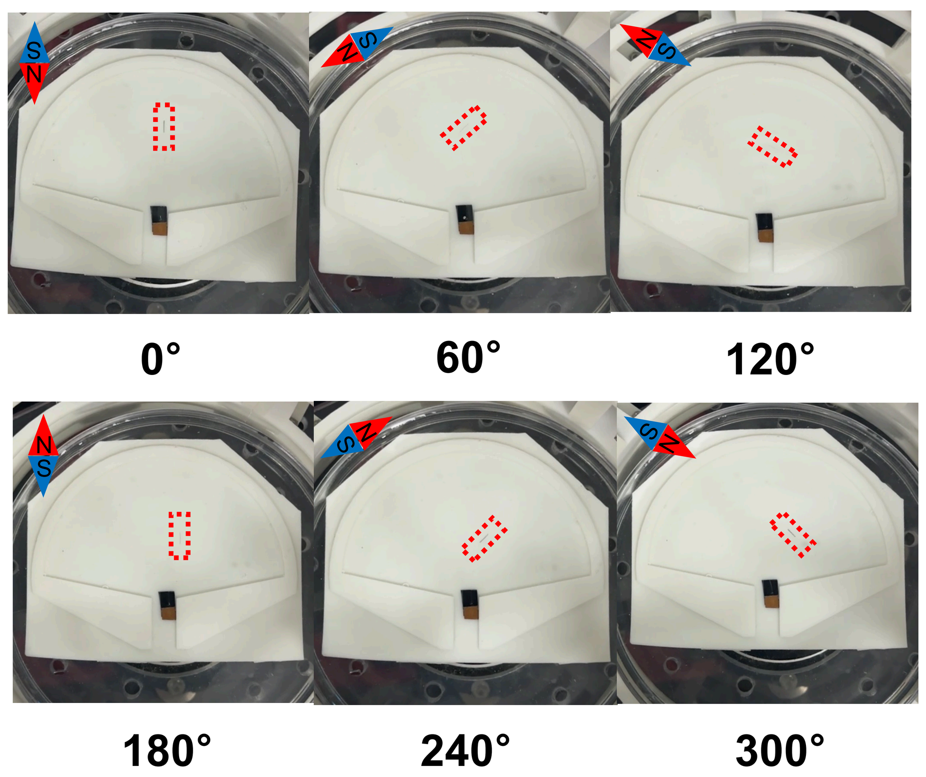


3) Existence of Mesh structure

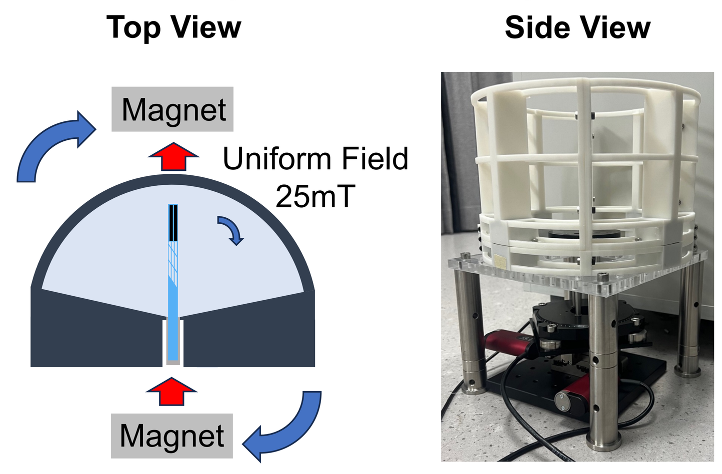




Horizontal Movement



Experiment Setup



Overall, probes show a faster response to ones with longer length, narrower width, and mesh structure which all have a lower bending stiffness compared to the comparison group.

Also, the probe having ultra-flexibility, it is capable of rotating in any kind of angle by applying rotating uniform magnetic field. That being the case, for example, the probe can manage to wrap an organoid and detect its signal.

Conclusion & Further Study

Conclusion

With the device fabrication process and optimization, we have been successful on creating a probe that has developed an ability to move horizontally and vertically due to enhanced flexibility of its mesh structure and magnetic actuation. We were able to conclude that the probe with longer length, narrower width, and mesh structure reacts faster and has an advantage on magnetic actuation.

Further Study

Our probe does not yet contain electrodes to detect signals from organoids. By adding a gold electrode layer in the most flexible part of the probe which is the mesh structure, the probe will be able to make conformal contact with the organoid and detect its signal. Furthermore, by not limiting the count of the mesh structures to only one, we will be able to increase the probe's flexibility. Also, we look forward to detect signals of other biological three-dimensional structures with additional optimization. Altogether, this study will contribute to the growth of the field of biosystem.

Reference

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