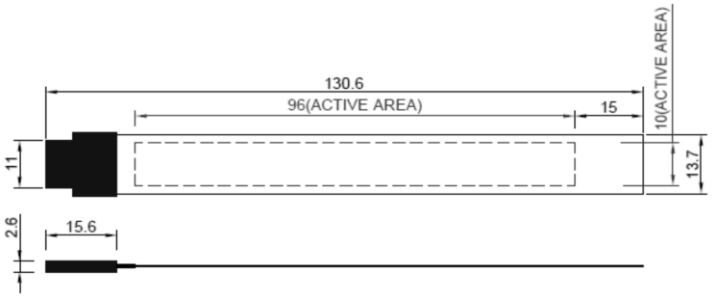
NEST 5 – Capacitive Strain Sensor: Specifications, Encapsulation, and Performance on Benchtop Test Setup.

Revision 1 (17 June 2023)

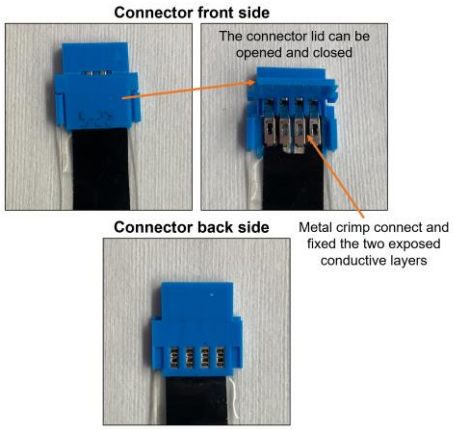
1. Commercial capacitive strain sensor (EC100, Taiwan Alpha Company)

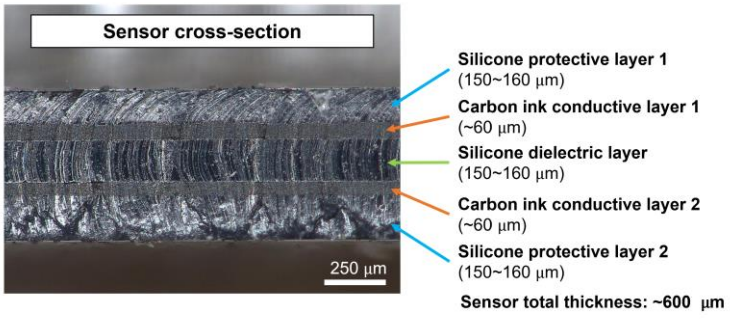
To measure the motility at end organ, we selected a type of commercially available capacitive strain sensor made by Taiwan Alpha company. Purchase location: https://www.mouser.com/ProductDetail/Alpha-Taiwan/EC100-N-421-A01?qs=A6eO%252BMLsxmSLU5nXtf%2FWPg%3D%3D

Order Code	Outline Drawing
EC100-N-421-A01 	

SPECIFICATION

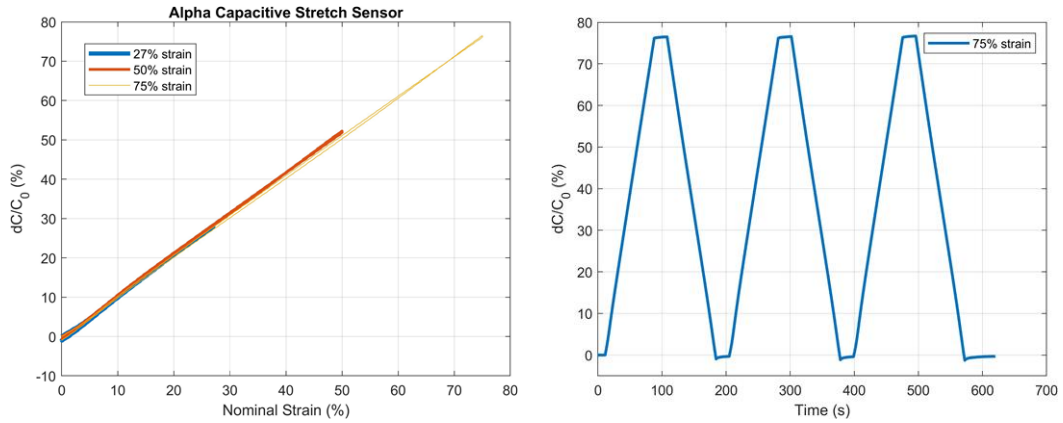
MODEL	**EC100-N-421-A01**
STRETCHABLE RANGE	0 ～ 100%
ACTIVE SENSING ZONE	96mm * 10mm
CAPACITANCE (UN-STRETCHED)	160pf ～ 240pf
OPERATION TEMPERATURE	10˚C ～ 50˚C
Life Cycle	500,000 cycles





Initial tensile test results of the capacitive strain sensor:

- Gauge factor ($GF = \frac{\Delta C/C_0}{\varepsilon}$) ≈ 1
- Degree of hysteresis: 1.30% at 75% strain.



2. Fabrication steps of stretchable encapsulation for the strain sensor

Step 1: Pre-stretching the strain sensor

Equipment: custom-made stretcher machine

1. Fix both ends of the strain sensor on the stretcher machine's fixture points.
2. Displace the stretcher machine and stretch the strain sensor to ~70% strain.
3. Fix the stretcher machine's displacement.

Step 2: Parylene coating

Material: Parylene C dimer

Equipment: Parylene PVD coating machine

1. Clean the strain sensor's surface and cover its connector using tapes.
2. Place the stretcher with the strain sensor into the Parylene coating machine.
3. Deposit ~3.2 μm of Parylene C (6.5g according to our previous records) on the strain sensor's surface.

Step 3: Forming wrinkled encapsulation layer and connector encapsulation

1. After taking out the stretcher with the strain sensor from the parylene coater, slowly loosen the fixtures that hold the sensor's two ends to gradually release the sensor. The

parylene layer, which is flat during the sensor's stretched state, quickly buckles into wrinkles as the sensor shrinks back to its original length.

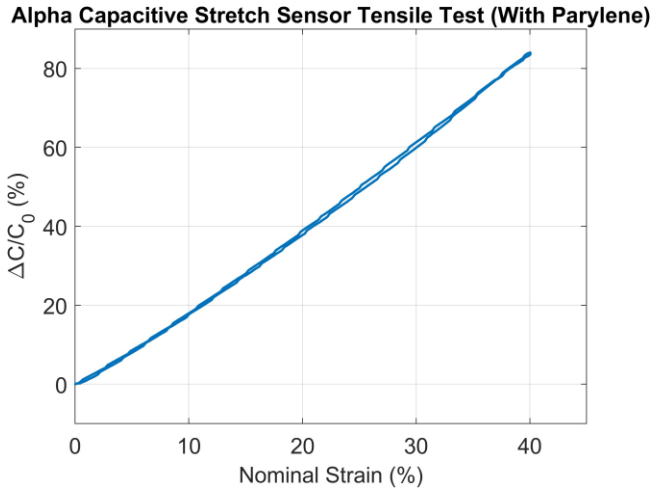
2. Connect two signal cables to the sensor's connector, then apply epoxy to seal the remaining gaps around the connector.

Before encapsulation

After encapsulation (70% prestrain)

2. Testing the encapsulated strain sensor

3.1 Tensile test results of the capacitive strain sensor after coating Parylene encapsulation:

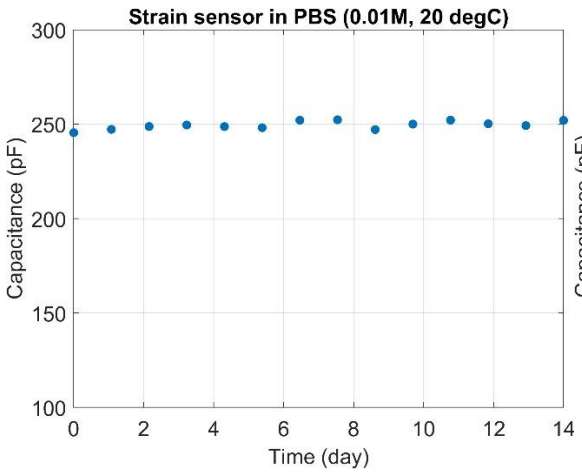


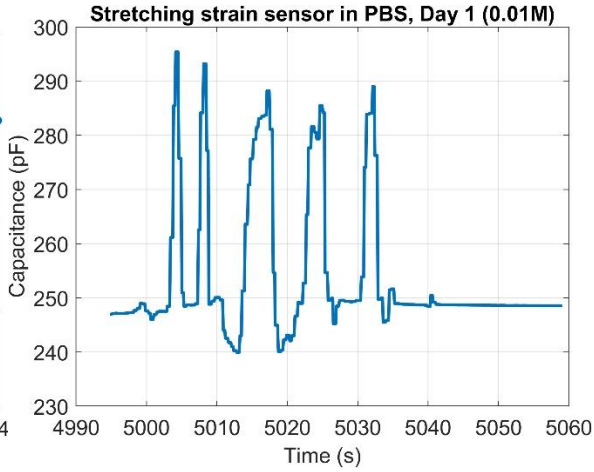
3.2 Initial encapsulation test:

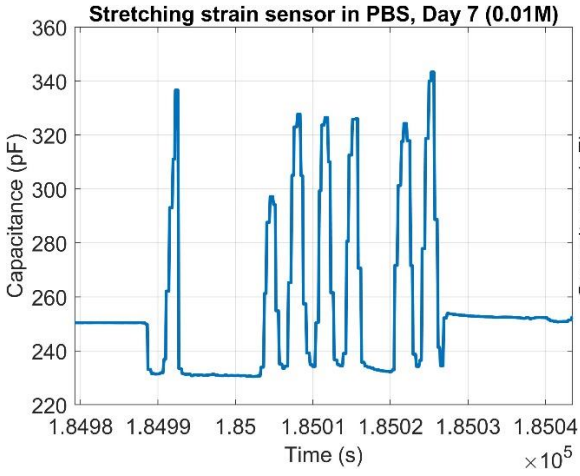
Material: 0.01 M, 1L PBS solution

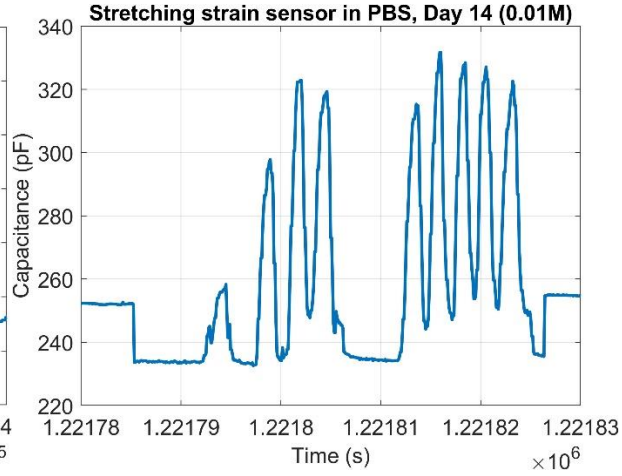
Equipment: LCR meter and temperature probe.

Note: the sensor was completely submerged in the PBS solution. Only the wire heads are above the solution for capacitance measurement. To verify the sensor's functionality, the sensor was stretched manually every day to see if the capacitance value can still go back to its original values after stretching.


Strain sensor in PBS (0.01M, 20 degC)
Capacitance (pF)
Time (day)


Stretching strain sensor in PBS, Day 1 (0.01M)
Capacitance (pF)
Time (s)


Stretching strain sensor in PBS, Day 7 (0.01M)
Capacitance (pF)
Time (s)
×10^5


Stretching strain sensor in PBS, Day 14 (0.01M)
Capacitance (pF)
Time (s)
×10^6