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June 26 - 28, 2023

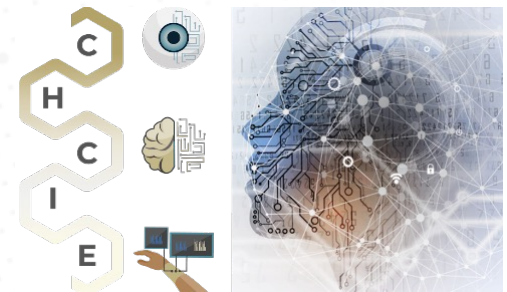


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# Smart and Connected Soft Biomedical Stethoscope and Machine Learning for Continuous Real-Time Auscultation and Automated Disease Detection

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**Director** of IMat-IBB Materials for Biomedical Systems  
Georgia Tech and Emory School of Medicine



# IEN Center for Human-Centric Interfaces and Eng.



# Ongoing Projects – Soft Biosensors and Bioelectronics

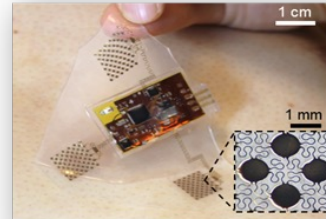
Blepharospasm



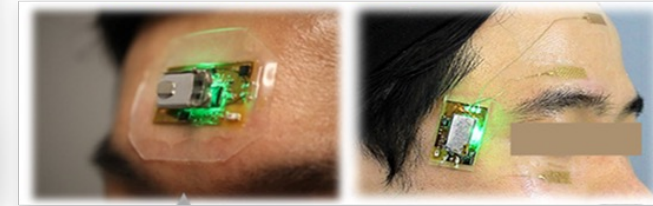
Pediatric Health



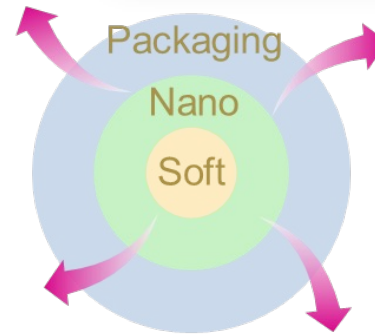
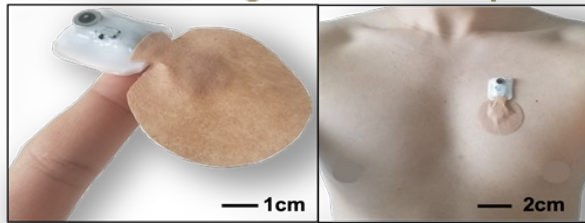
Real-Time Cardiac Monitor



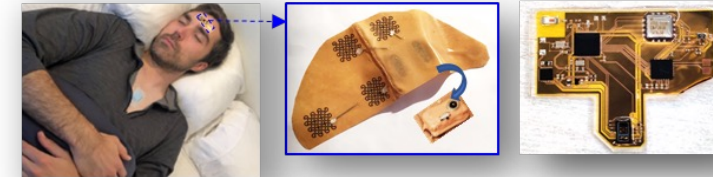
Movement/Muscle Disorders



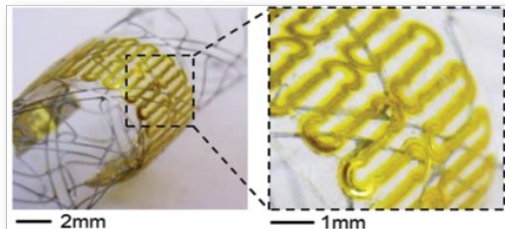
Wearable Digital Stethoscope



Sleep Monitor



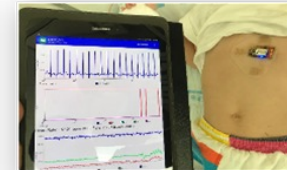
Wireless Implantable Sensor



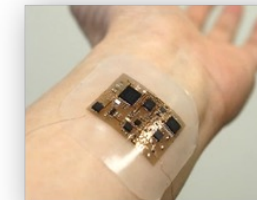
Farmworker Health



Pediatric Cardiac Health

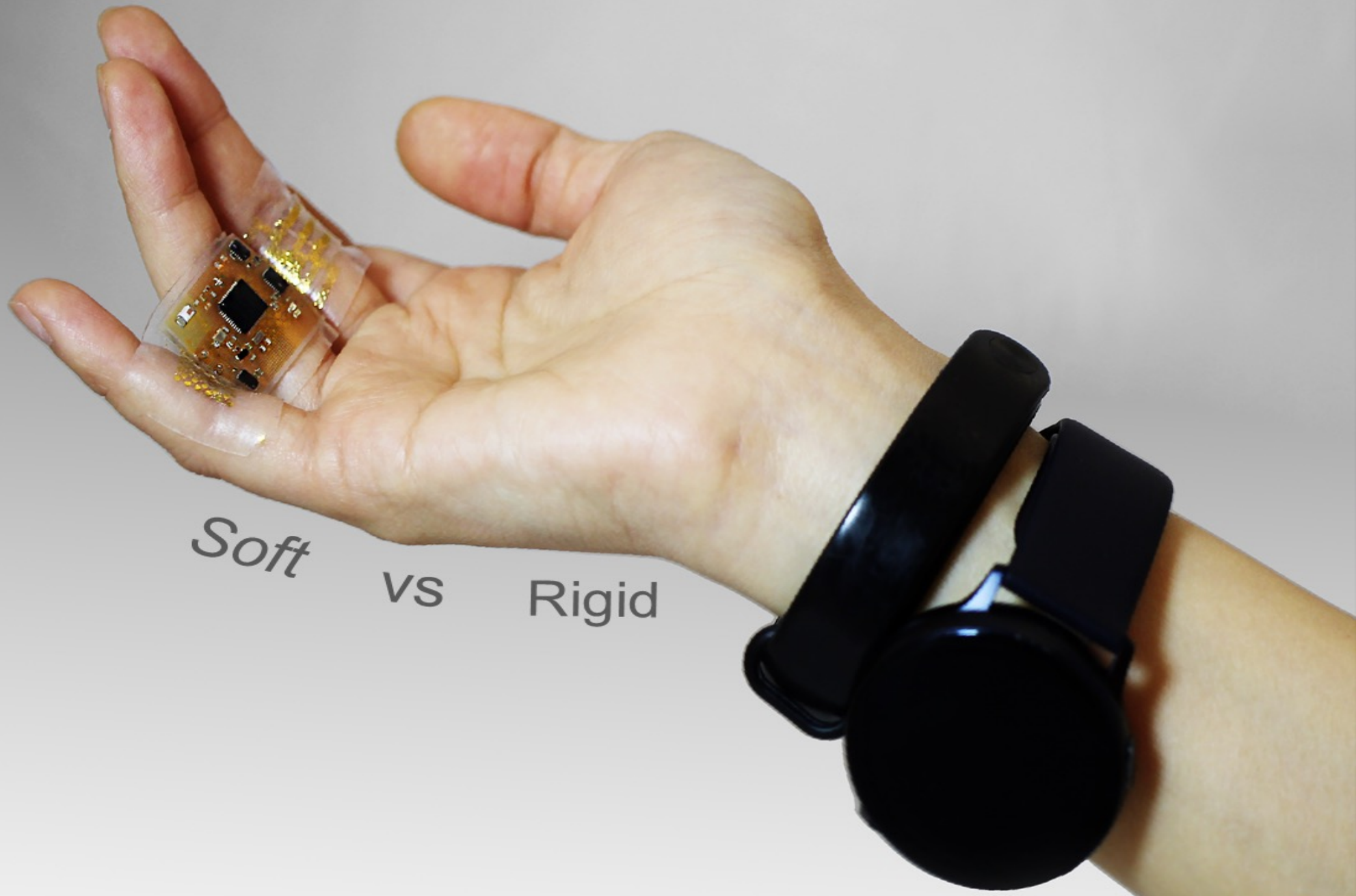


Stress Monitor



Research Sponsors:



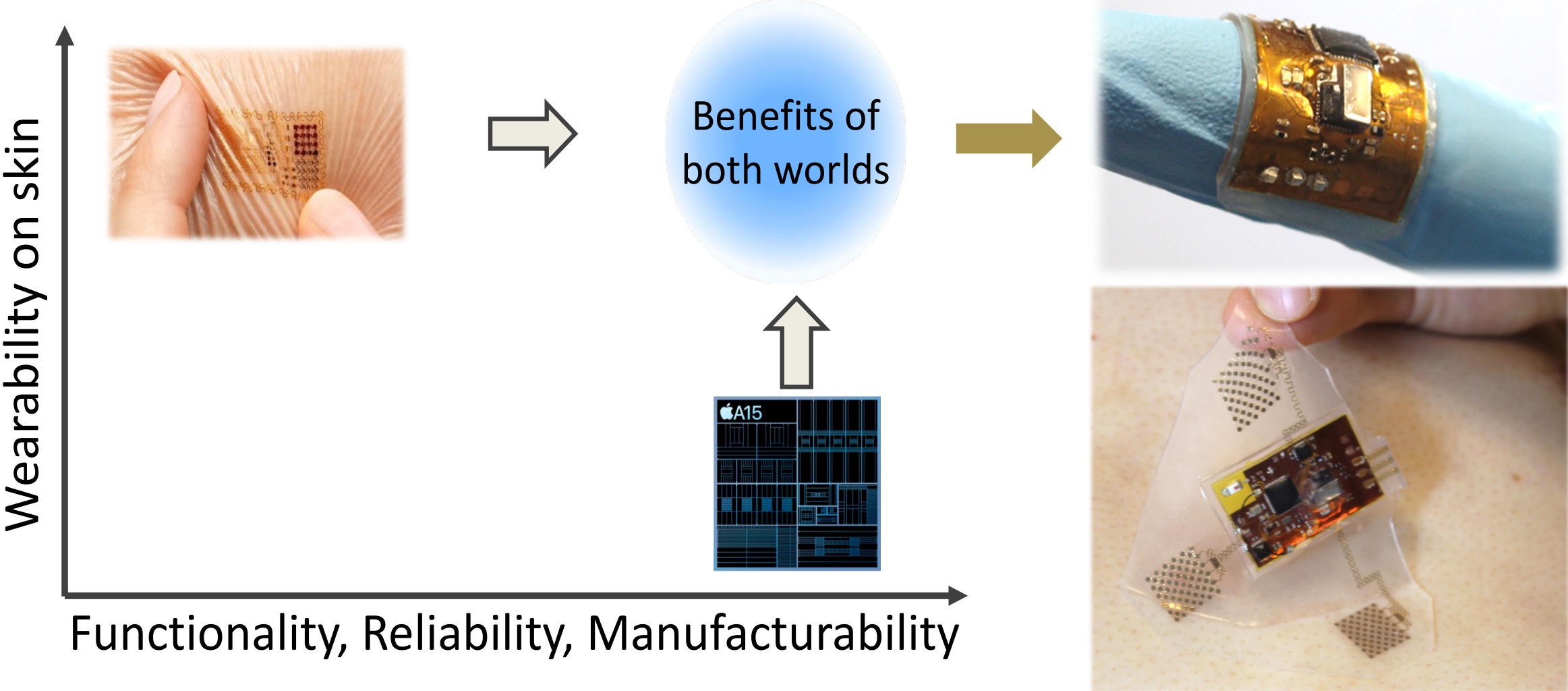


*Soft*

vs

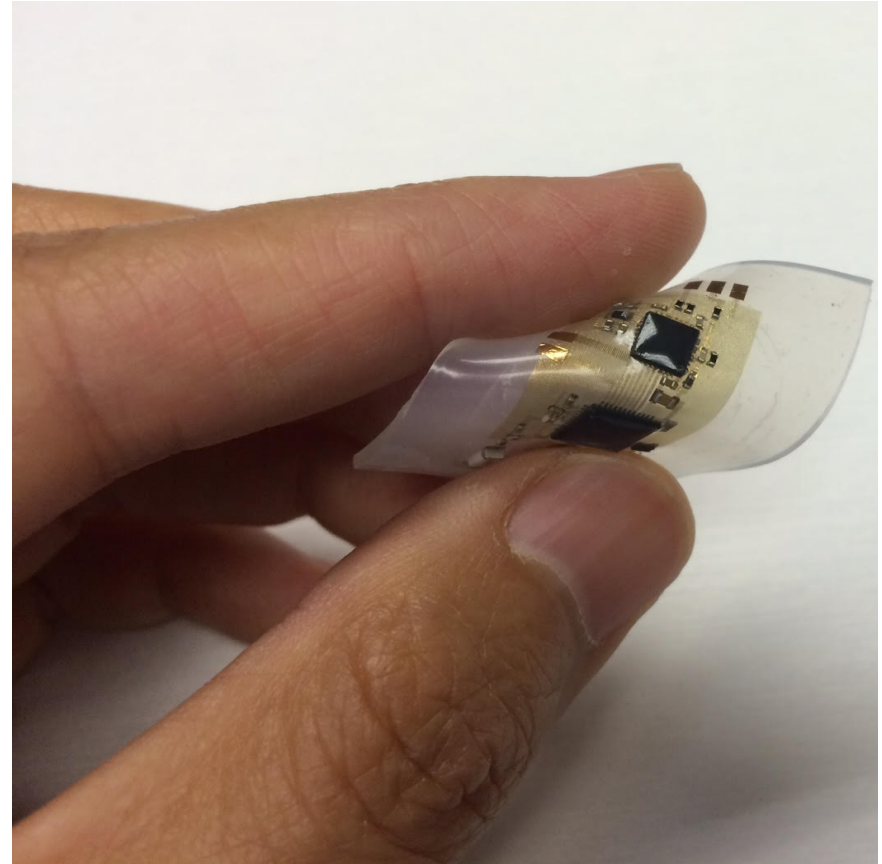
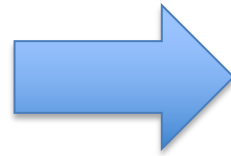
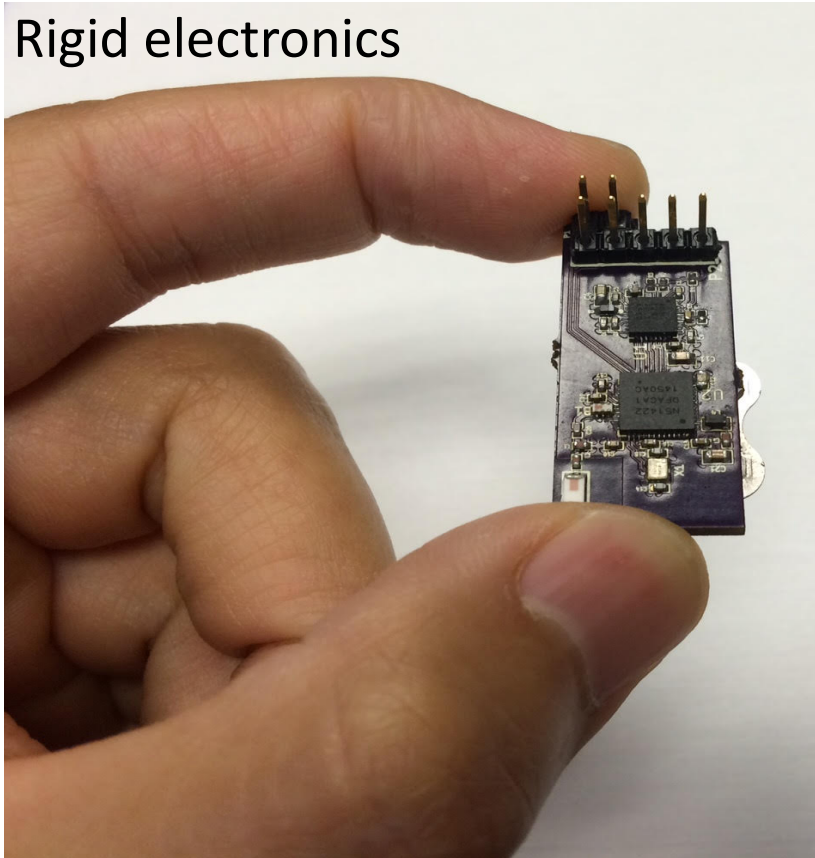
Rigid

# Performance Target of Soft Hybrid Electronics

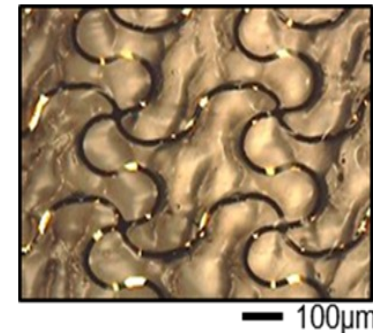
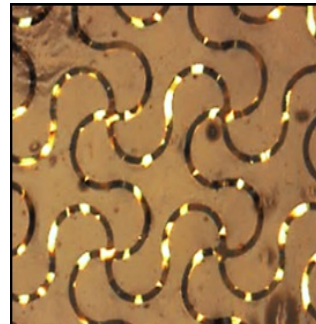
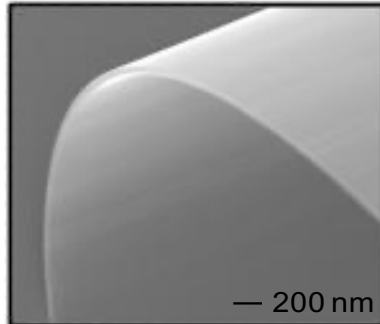


# Simple Idea – Design of Soft Hybrid Electronics

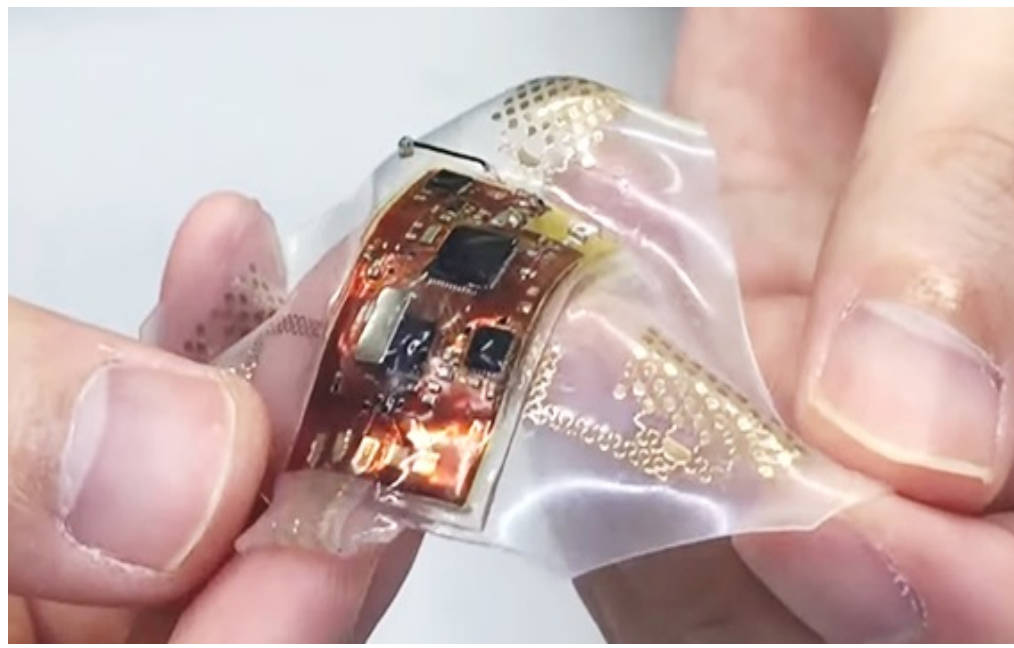
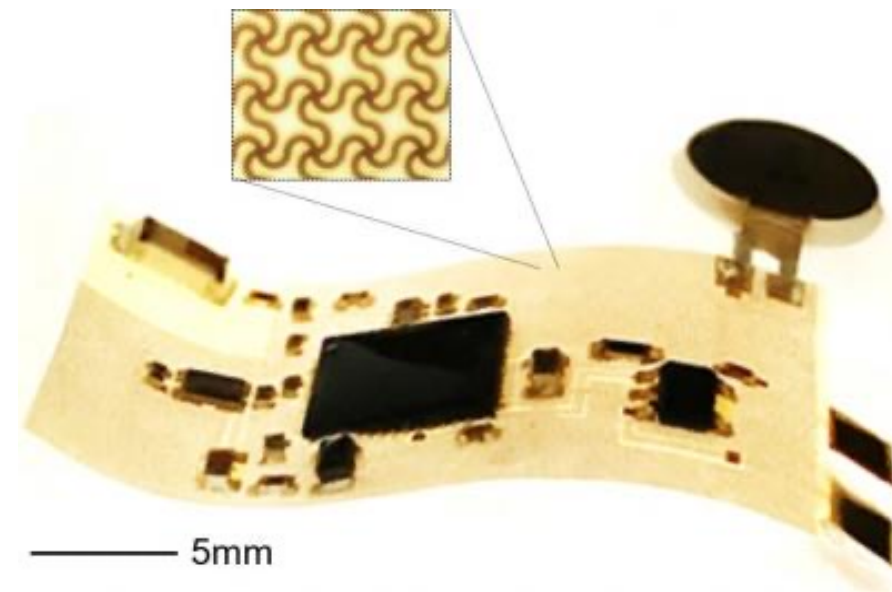
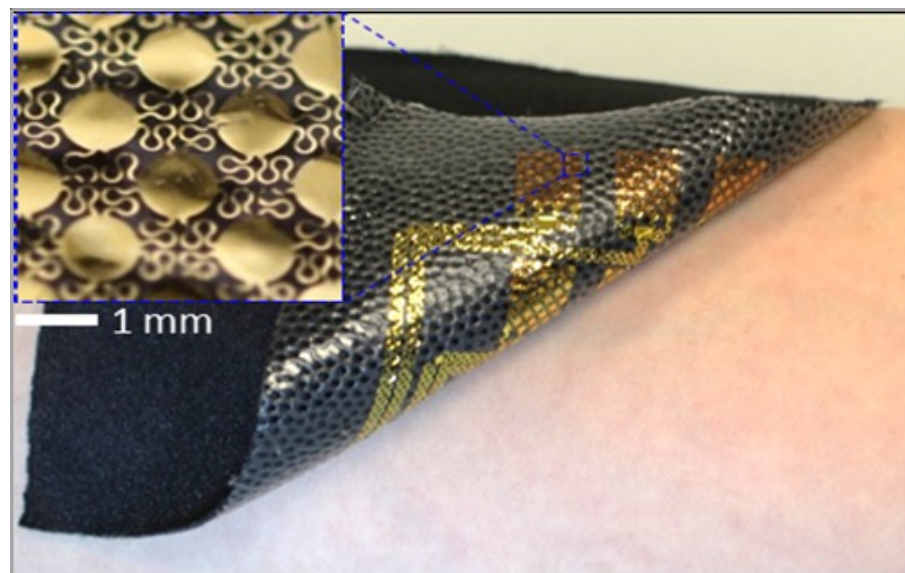
Rigid electronics



Nanomembrane +  
mesh patterns



# Skin Conformal Soft Hybrid Bioelectronics





# Soft Wearable Hybrid Bioelectronics

## Wireless, Real-Time Recording of Non-Invasive Signals

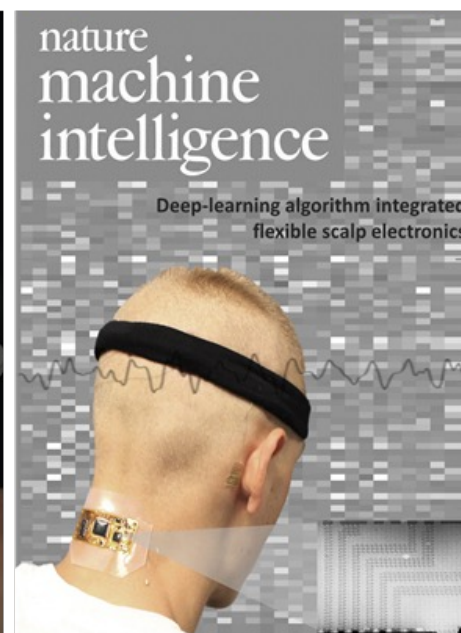
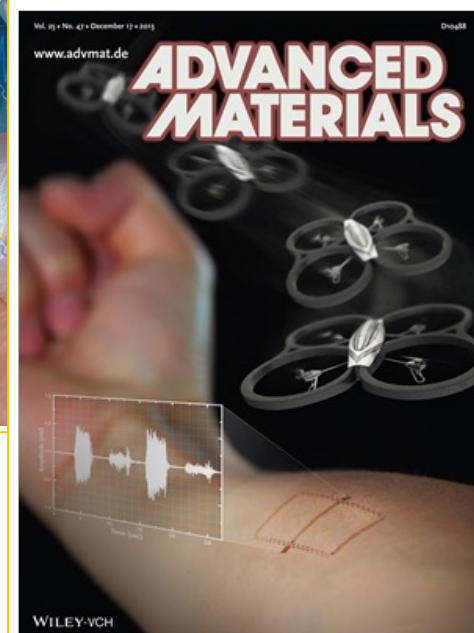
Biopotentials (EMG, ECG, EEG, and EOG) + HR, HRV, RR, SpO2, GSR, Strain, Temperature, Hydration, Pressure, Impedance, Motion activity, and more..



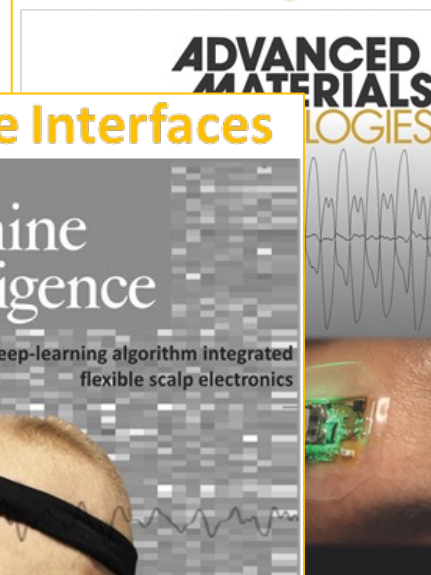
### Portable Health Monitoring



### Persistent Human-Machine Interfaces



### Disease Diagnosis and Therapeutics



# Soft Wearable Stethoscope



PHYSICAL AND MATERIALS SCIENCES | 25 MAY 2022

**Diagnosing lung disease with a soft digital stethoscope**

***Science Advances***

Featured article;  
8, eabo5867, 2022

# Motivation

## Pulmonary Diseases are leading causes of death



< 400 Million worldwide with pulmonary diseases

More than 15 Million Americans affected

More than 150k deaths in the US

1 Death every 4 minutes

WHO, Global Health Estimates / CDC



Asthma (300 Million)

WHO, Asthma Facts



COPD (65 Million)

CDC, Healthline COPD Facts



Pneumonia (450 Million)

WHO, Pneumonia Facts

# Auscultation

To monitor these diseases, **auscultation** is of interest in low cost

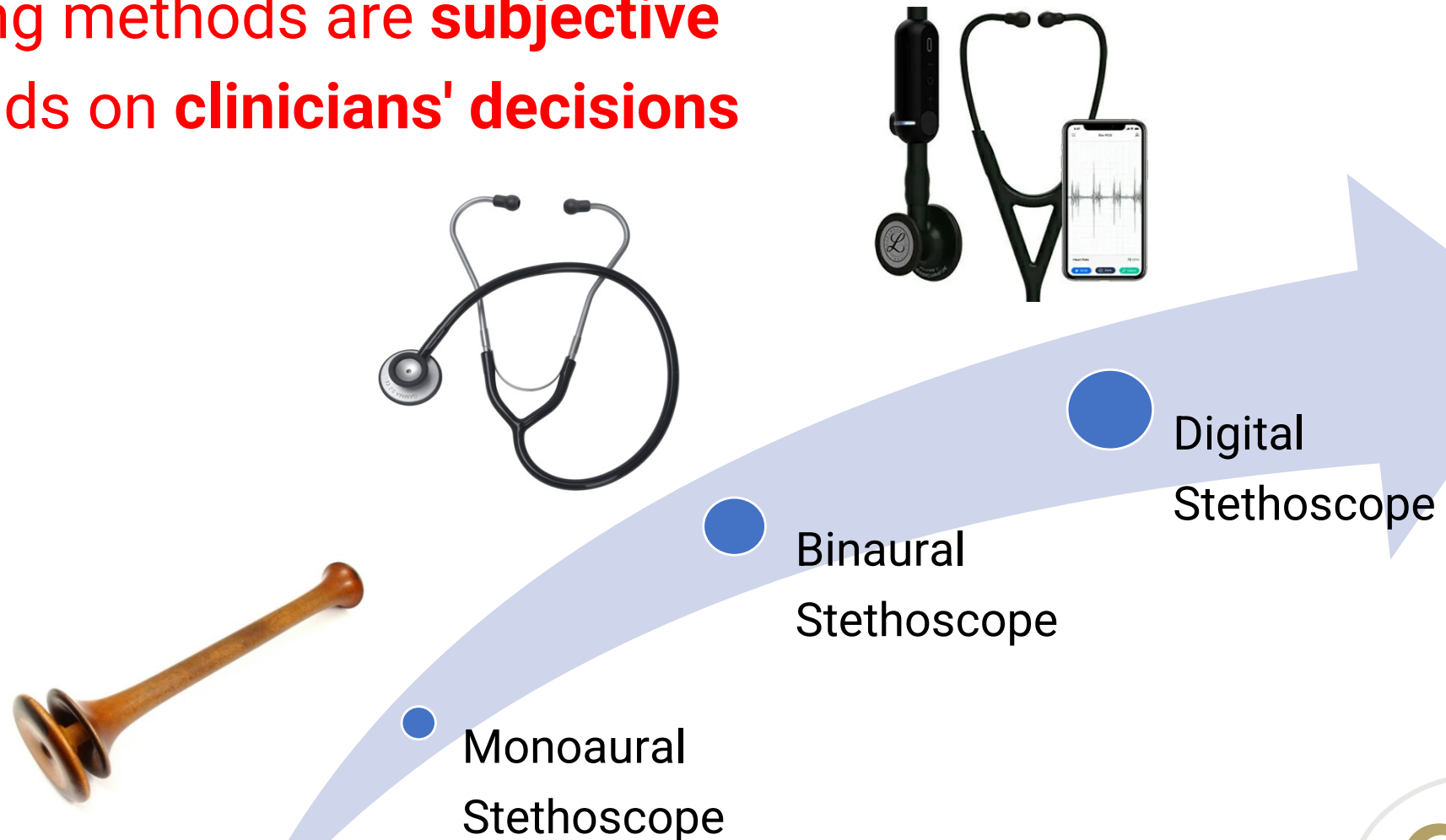


Littmann Indonesia

Healthline

# Existing Methods for Auscultation

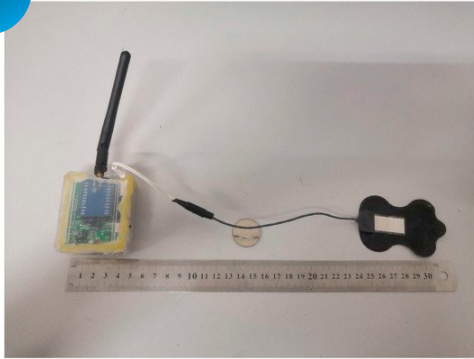
Existing methods are **subjective**  
Depends on **clinicians' decisions**



# Limitation of Existing Technologies

1

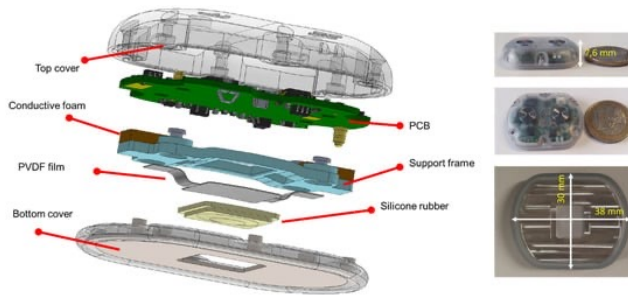
Zhang et al. *Micromachines* 10, 885 (2019).



Motion artifact  
noise

2

Yilmaz et al. *Sensors* 20, 5124 (2020).



Rigidity with  
less skin-  
conformality

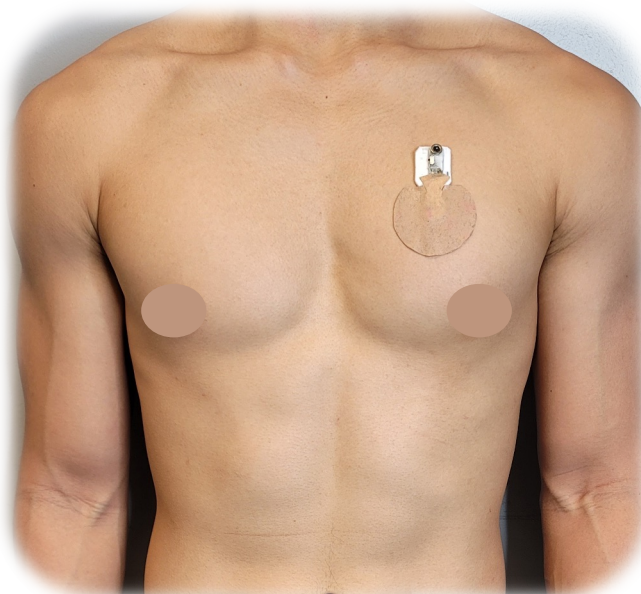
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Chowdhury et al. *Sensors* 19, 2781 (2019).

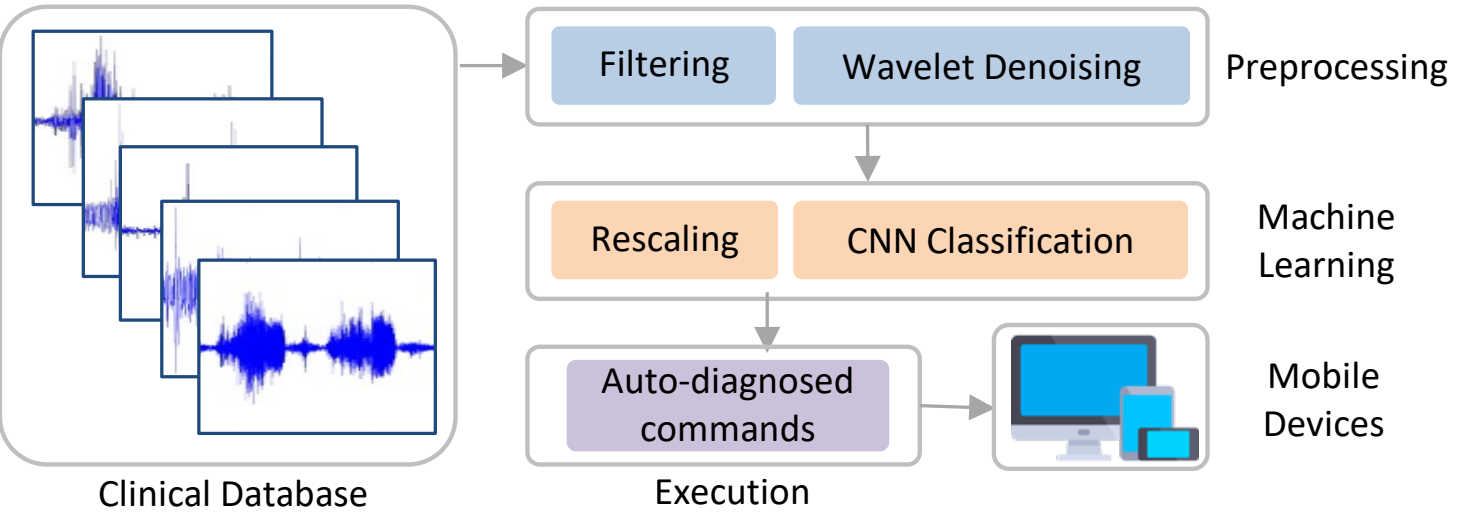
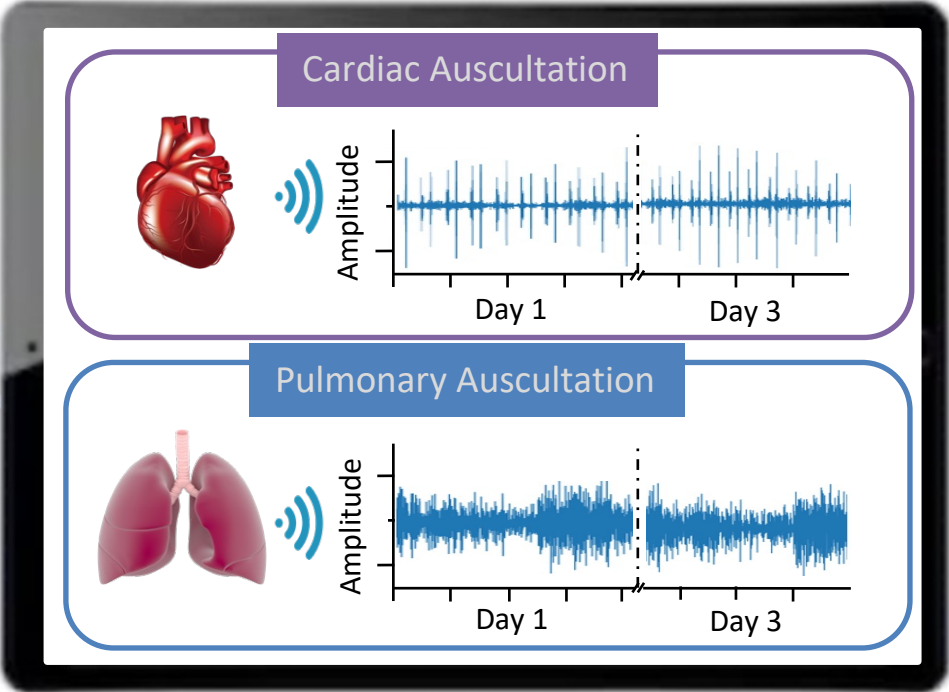
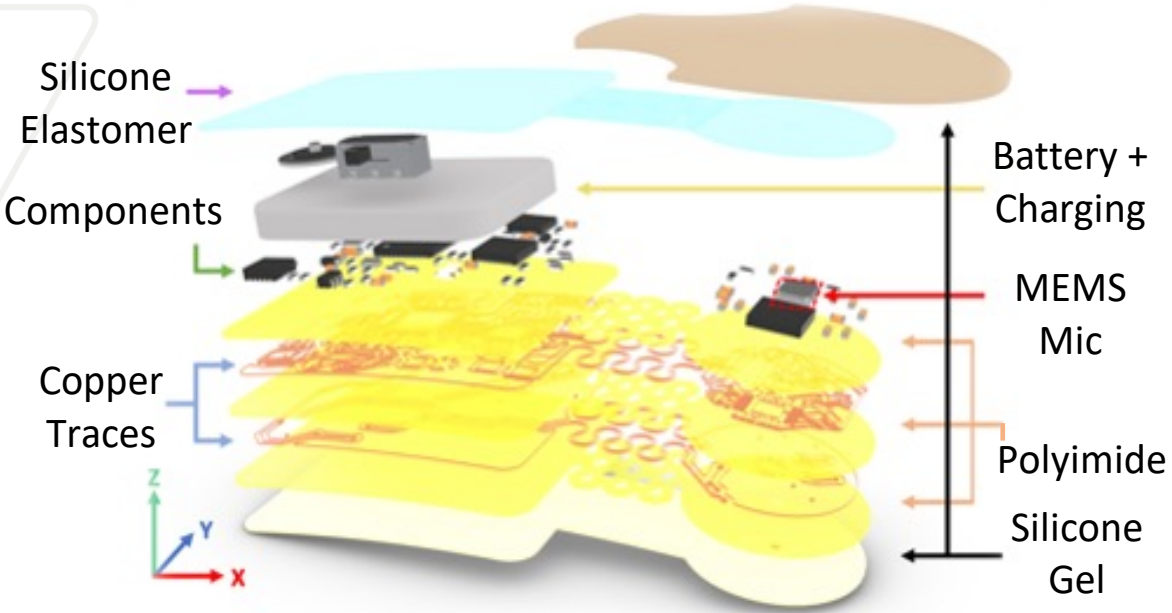


Bulkiness –  
no continuous  
monitoring

# Our Solution

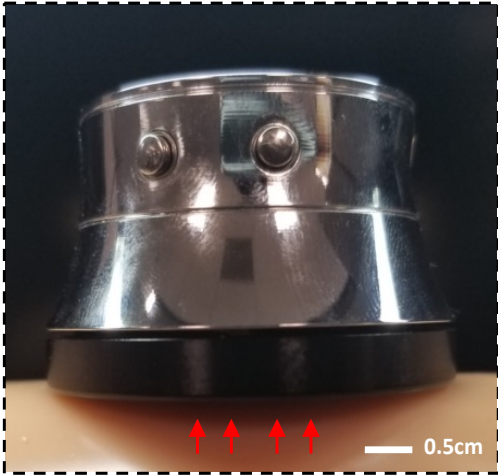
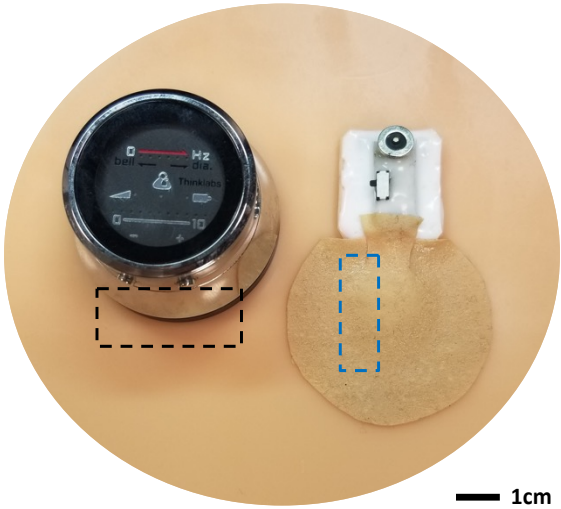


# Our Solution





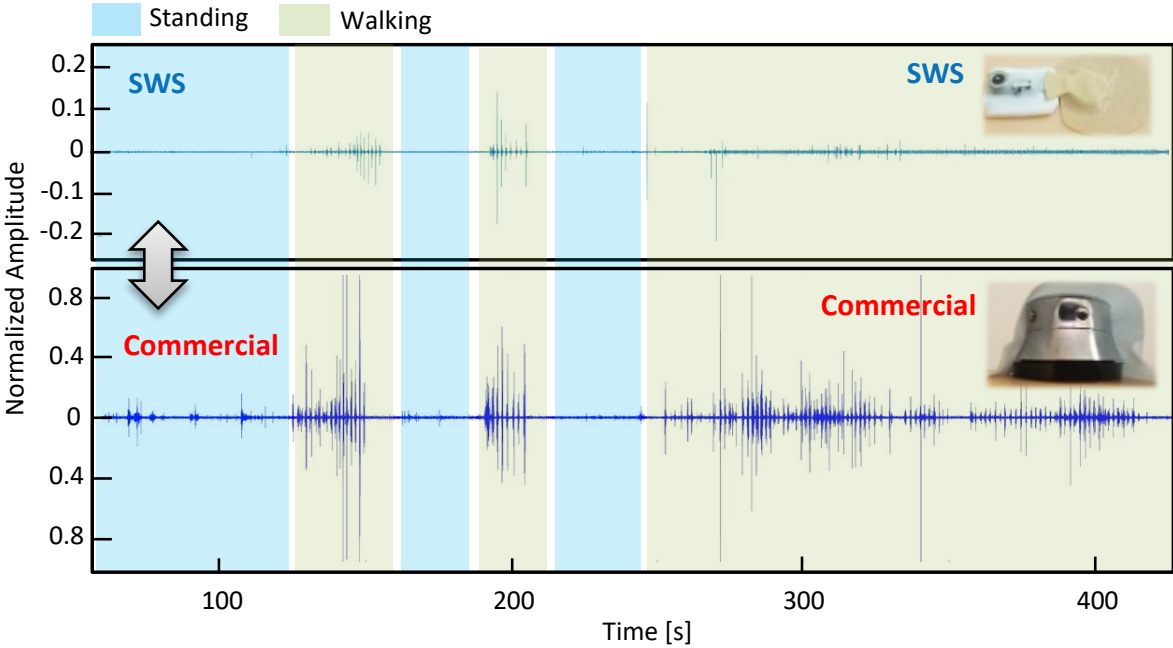
# Performance Comparison



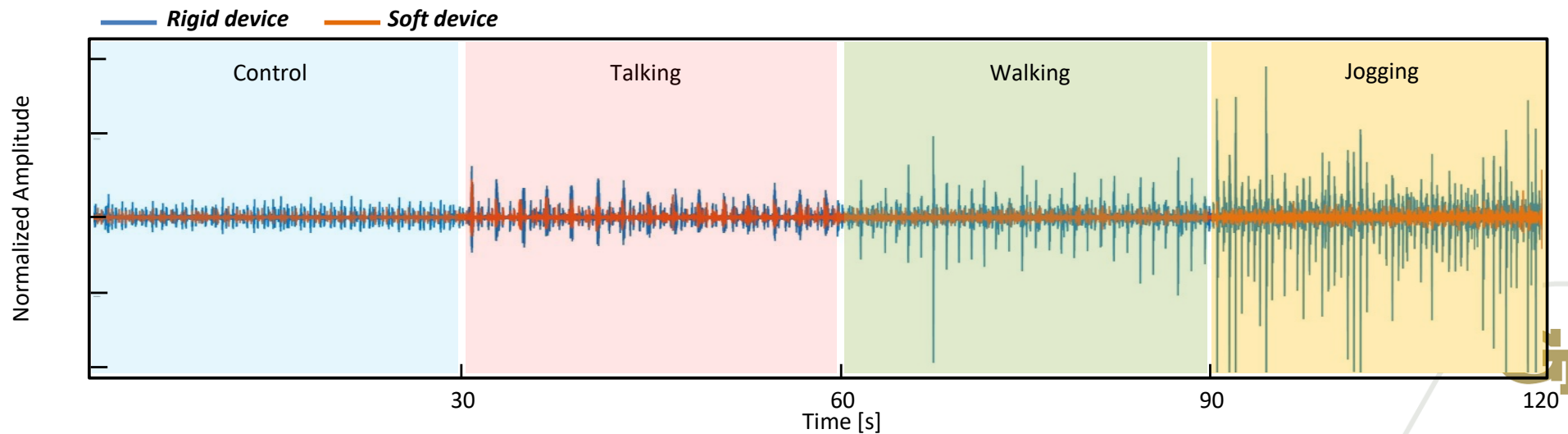
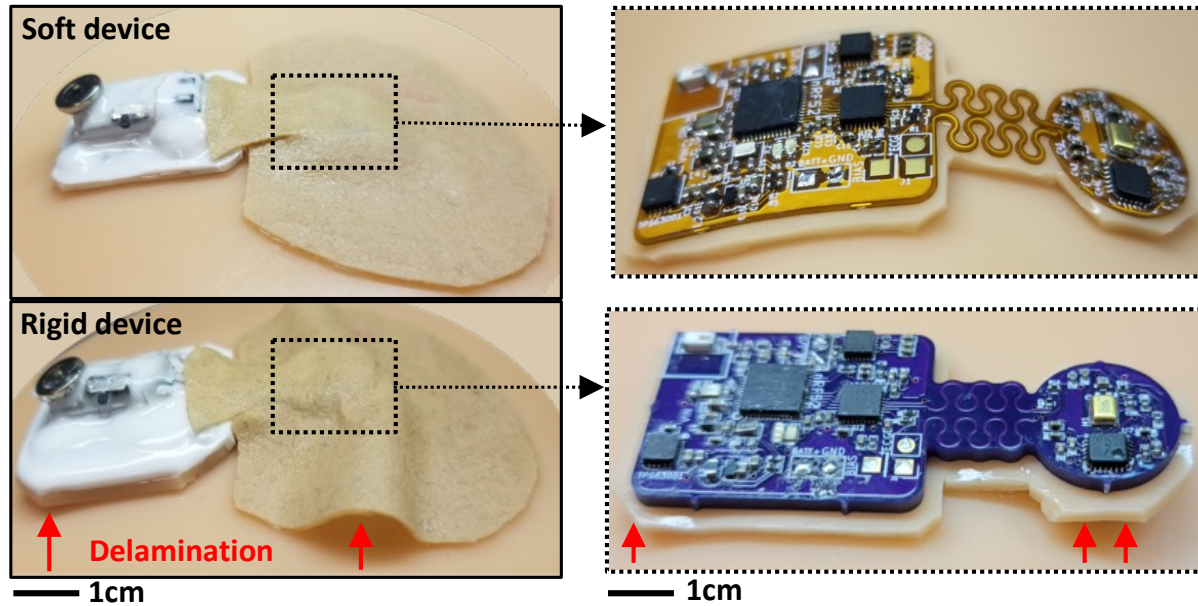
Delamination on curvature



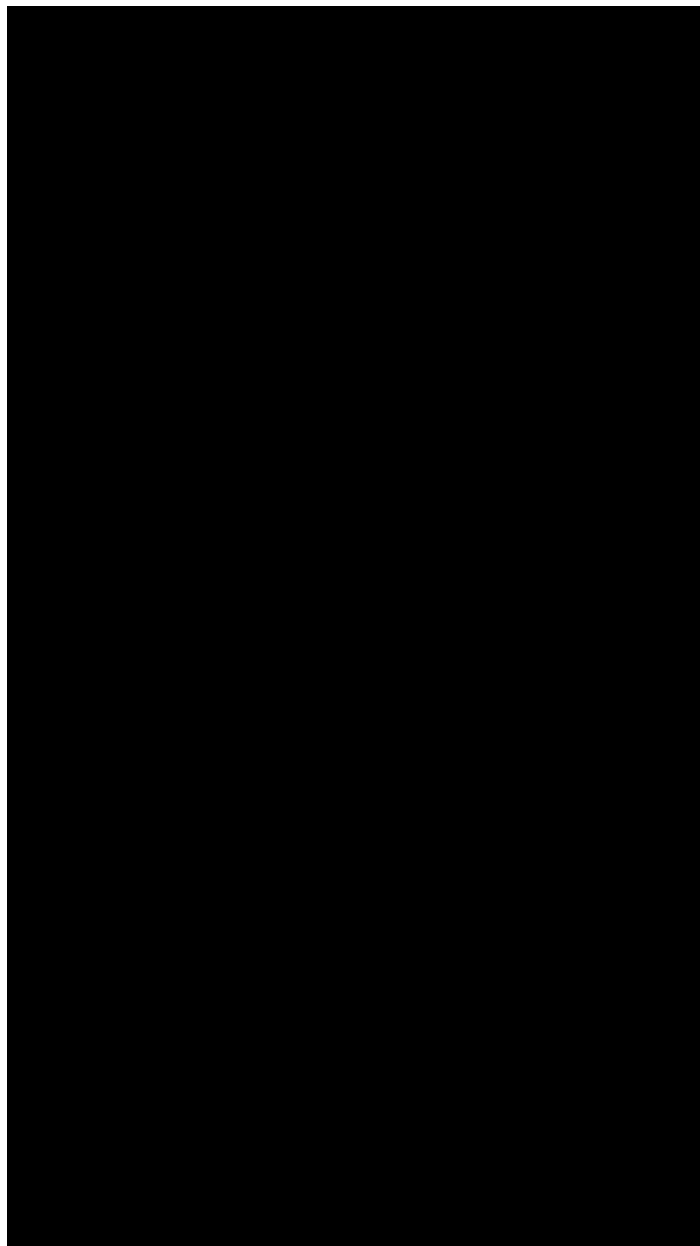
No Delamination



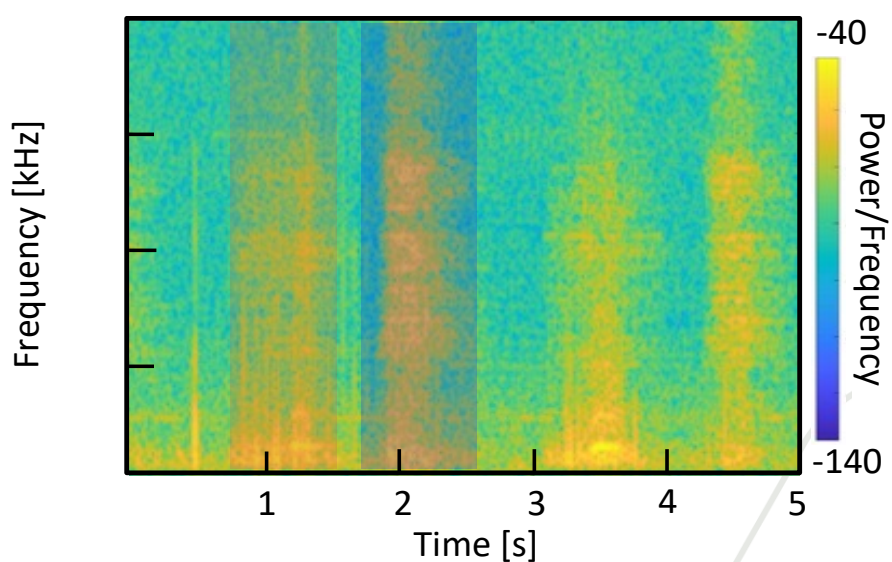
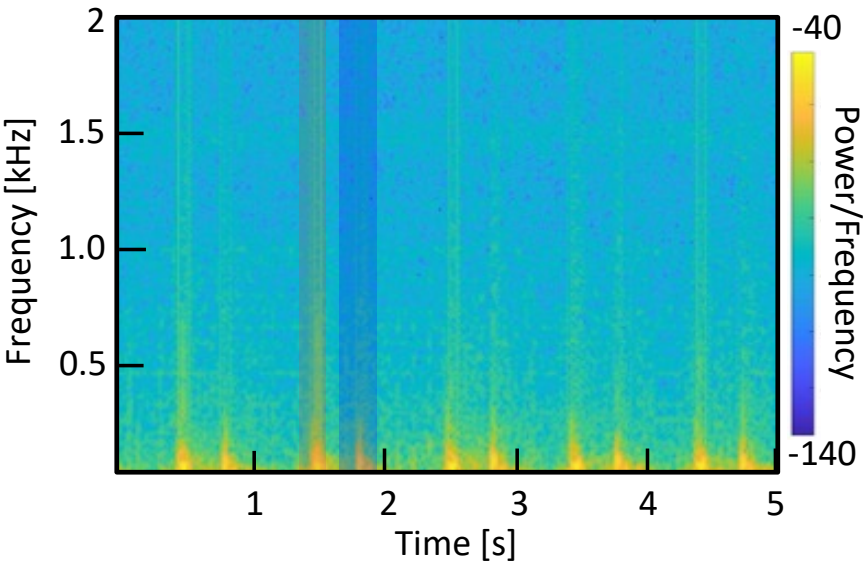
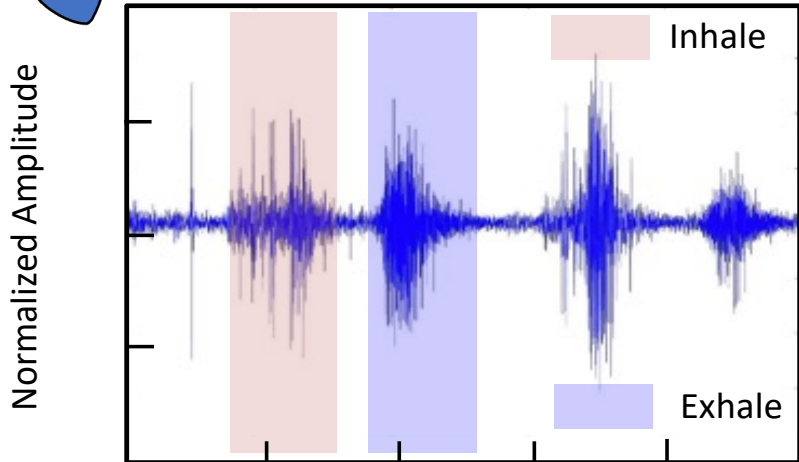
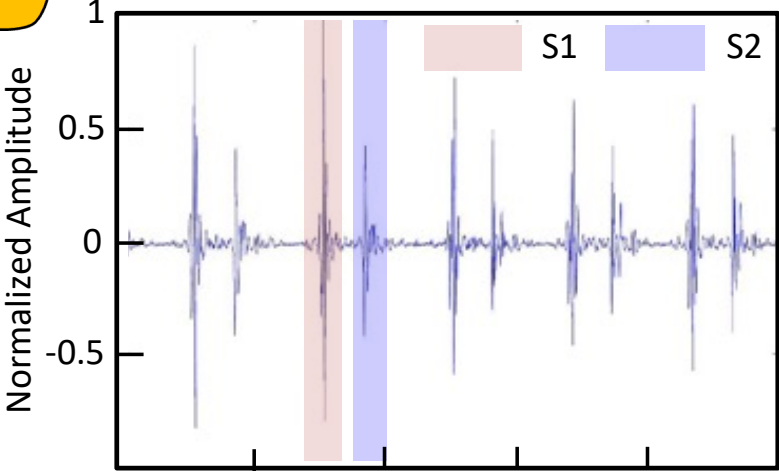
# Performance Comparison



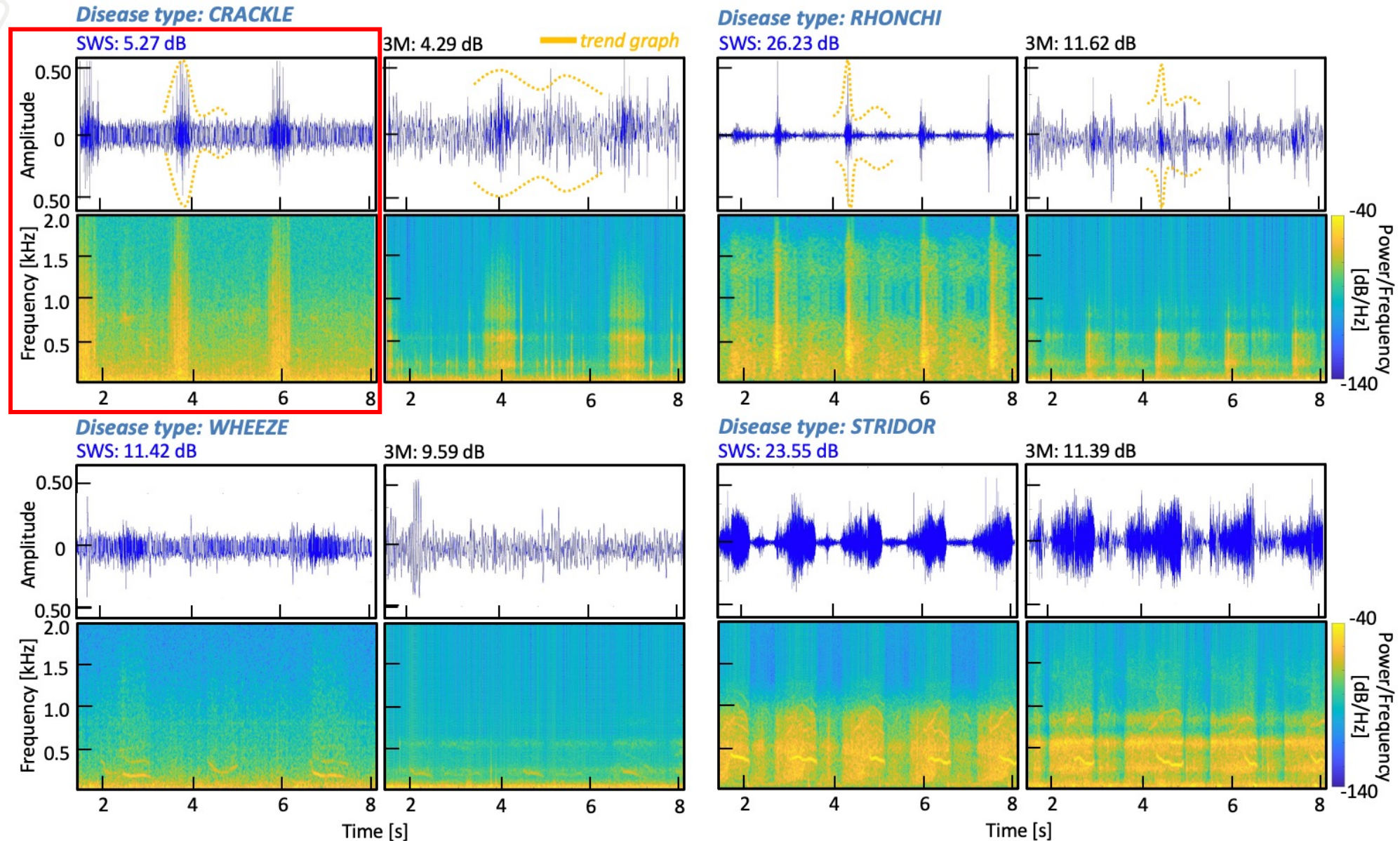
# Video – motion artifact control



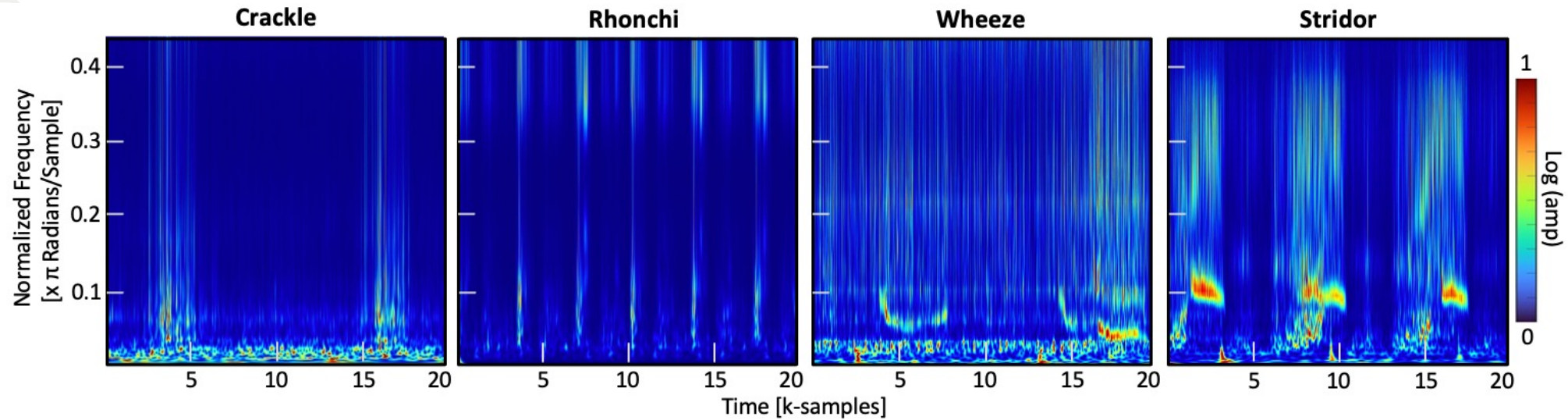
# Detection of Heart and Lung Sounds



# Wavelet Denoising Algorithm for Lung Diseases

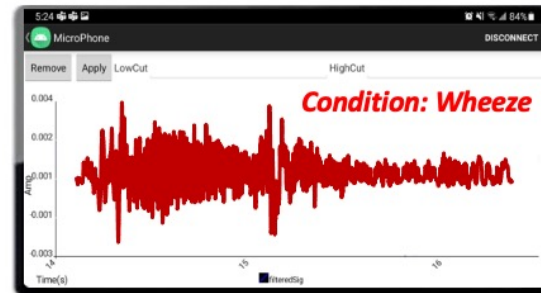
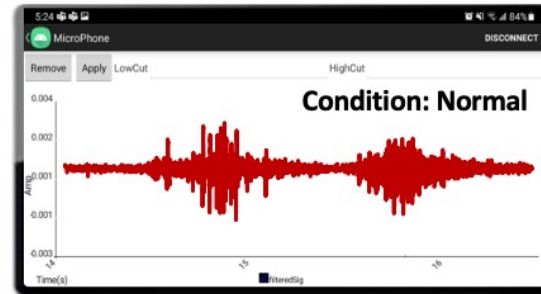


# CNN-Based Automated Detection of Lung Diseases

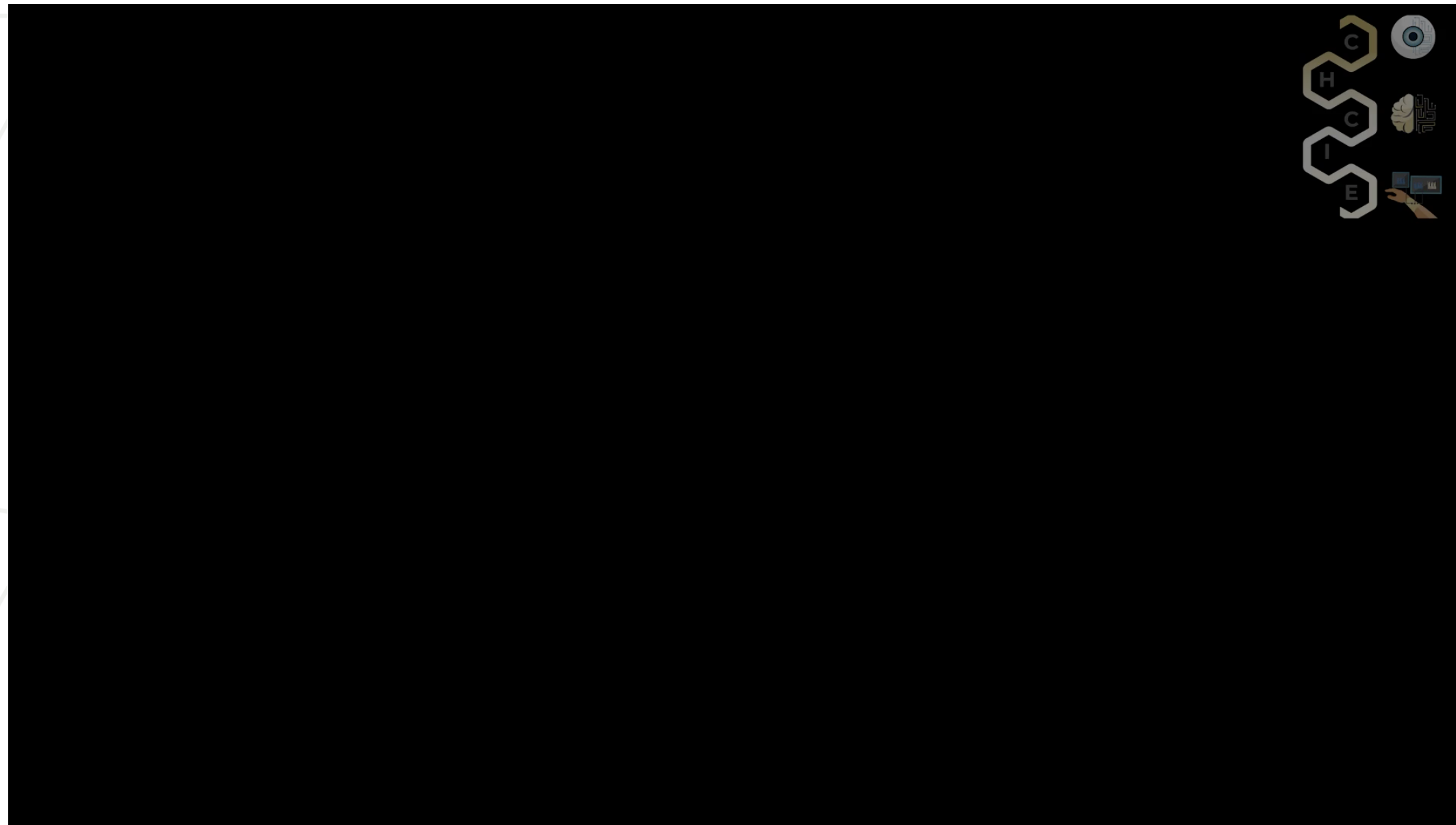


	crackle	rhonchi	stridor	wheeze	normal
crackle	69.2%	11.1%	0.0%	4.8%	0.0%
rhonchi	3.8%	88.9%	0.0%	2.4%	0.3%
stridor	11.5%	0.0%	100.0%	0.0%	0.0%
wheeze	7.7%	0.0%	0.0%	84.3%	0.5%
normal	7.7%	0.0%	0.0%	8.4%	99.2%

Accuracy: **94.78%**



# Demo – Video Clip



# Summary

Materials, mechanics, manufacturing,  
system packaging for  
Soft Biomedical Systems



Advanced Health Monitoring  
Persistent Human-Machine Interfaces  
Wearable Diagnosis and Therapeutics



whyeo@gatech.edu / yeolab.gatech.edu or chcie.me.gatech.edu



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