RFID JOURNAL LIVE!

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MANDALAY BAY | **LAS VEGAS, NV**

New Wireless Sensors Apply Directly to Skin, Improving Collection of Patient Information

Huanyu “Larry” Cheng

Penn State University

ACKNOWLEDGEMENTS

PennState Huck Institutes of the Life Sciences

PennState Institute for Computational and Data Sciences

NSF CORPS NSF Innovation Corps

PennState College of Engineering

PennState Institutes of Energy and the Environment

PennState Materials Research Institute

NIH National Institute on Drug Abuse

NIH National Heart, Lung, and Blood Institute

NIH National Institute of Biomedical Imaging and Bioengineering

NSF

ACS PRF

Meta

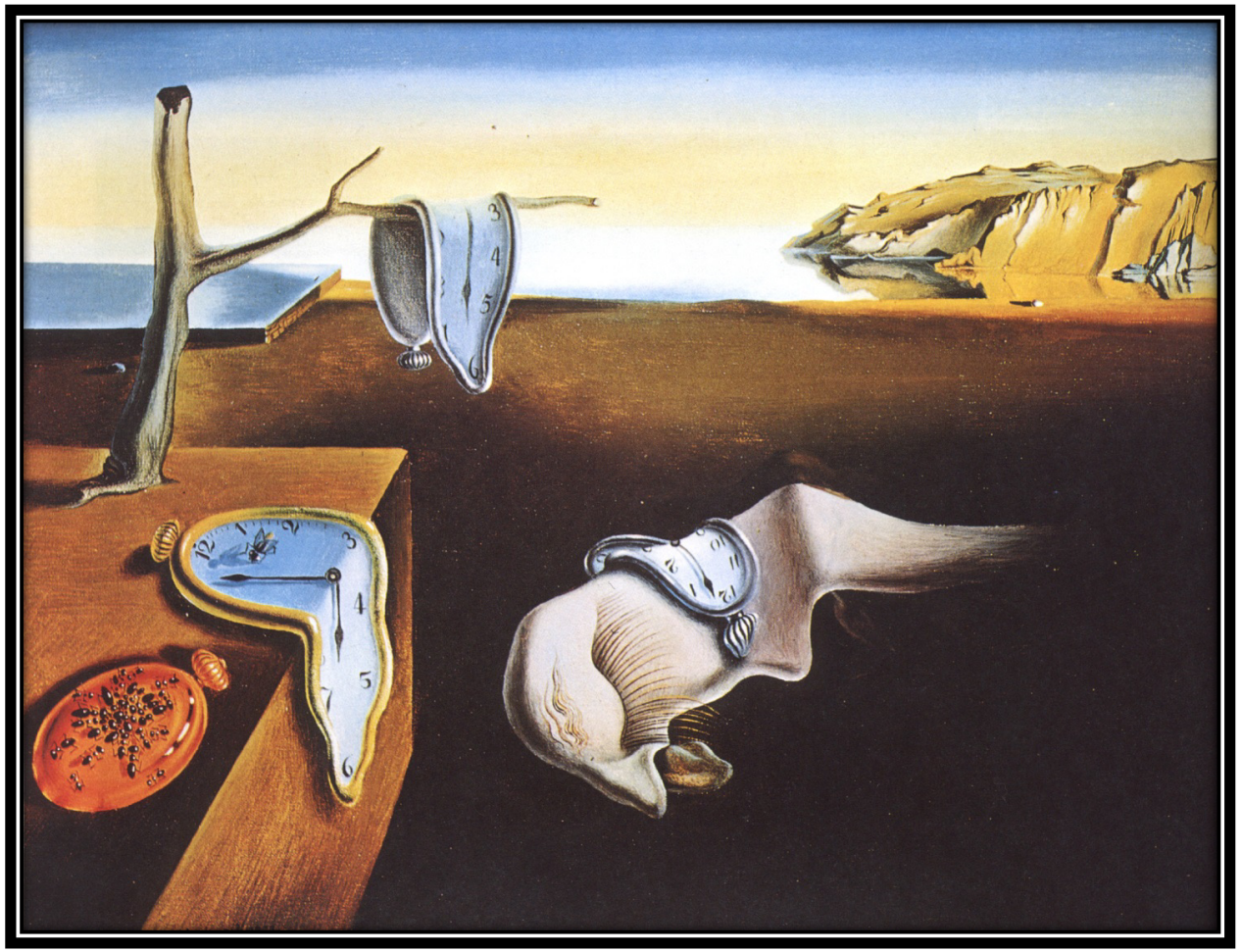
VYVO™ Making Life Wonderful

ASME SETTING THE STANDARD

hhmi Howard Hughes Medical Institute

Ben Franklin Technology PArtners Northeastern Pennsylvania

SOFT APPROACH TO ELECTRONICS



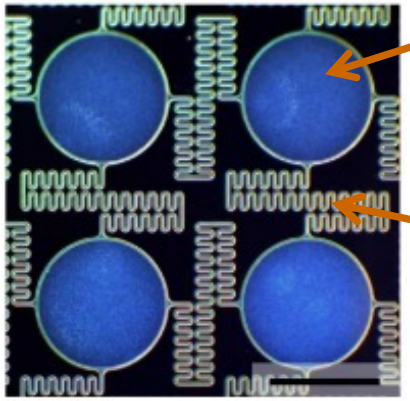
The Persistence of Memory, Salvador Dalí, 1931

DEVICE-INTERCONNECT DESIGN

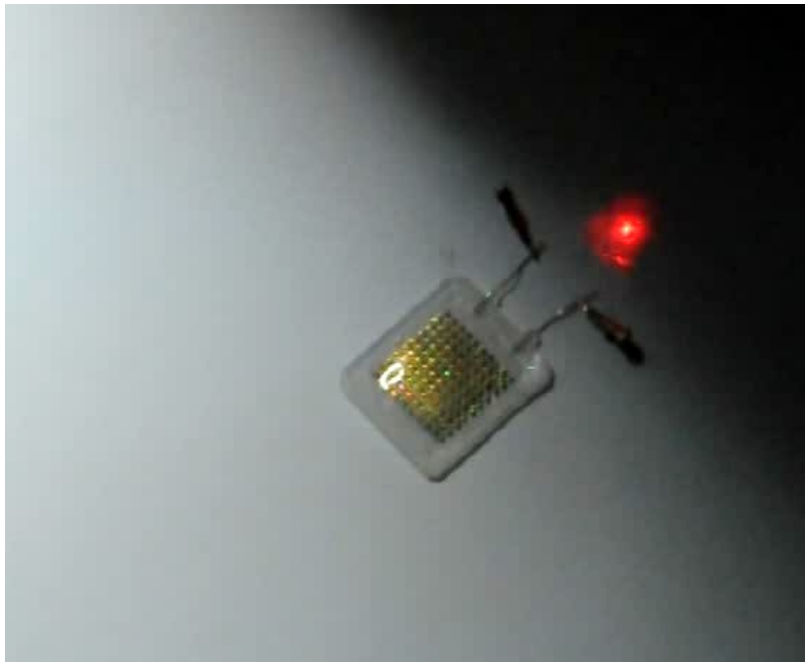
Microscale stretchable battery :

- >300% biaxially, little loss over cycles

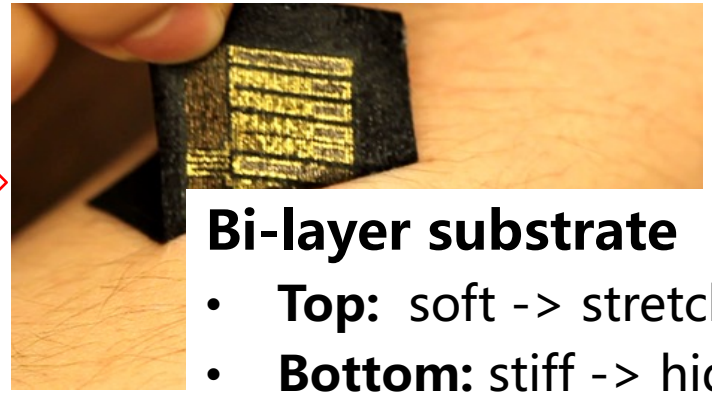
TOP VIEW



SIDE VIEW



Mechanically robust construction for repeatable use:



Bi-layer substrate

- **Top:** soft -> stretchable
- **Bottom:** stiff -> high strength

Nat. Commun. 4, 1543 (2013)
Adv. Mater. 25, 6839 (2013)

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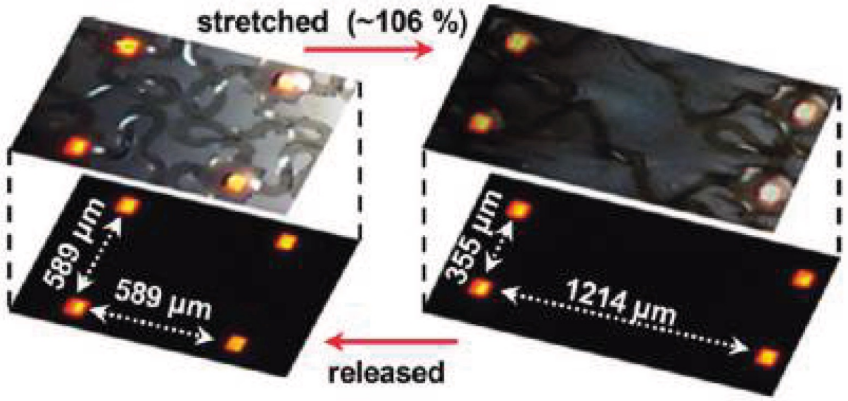
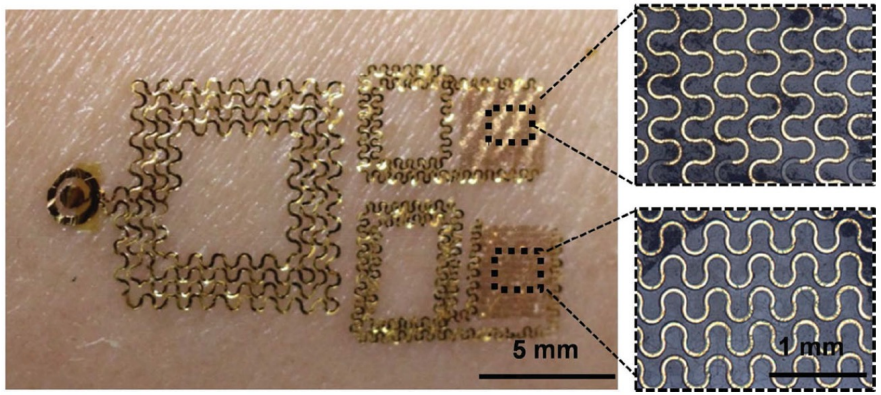
VARIOUS STRETCHABLE SENSORS

Stretchable LEDs



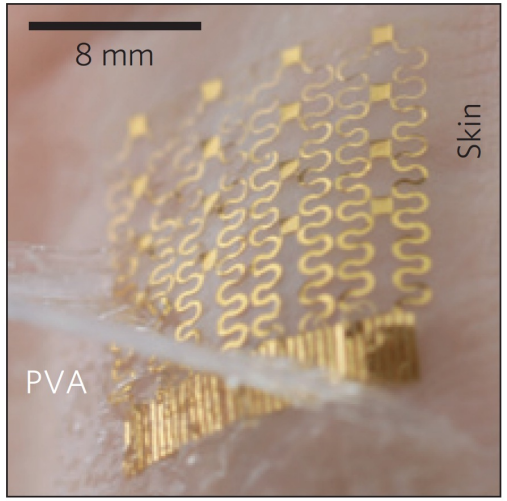
Nano Lett. 11, 3881 (2011)

Hydration and strain



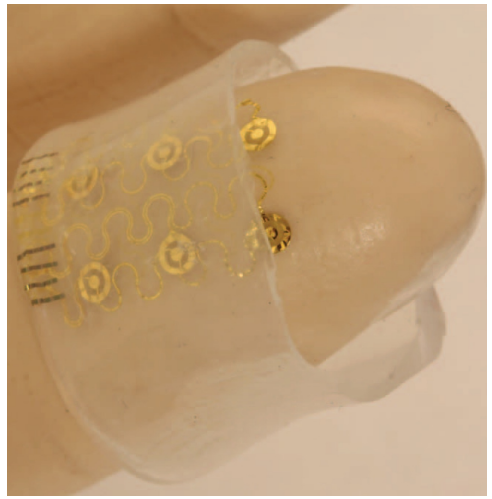
Adv. Funct. Mater. 24, 3846 (2014)

Temperature sensors



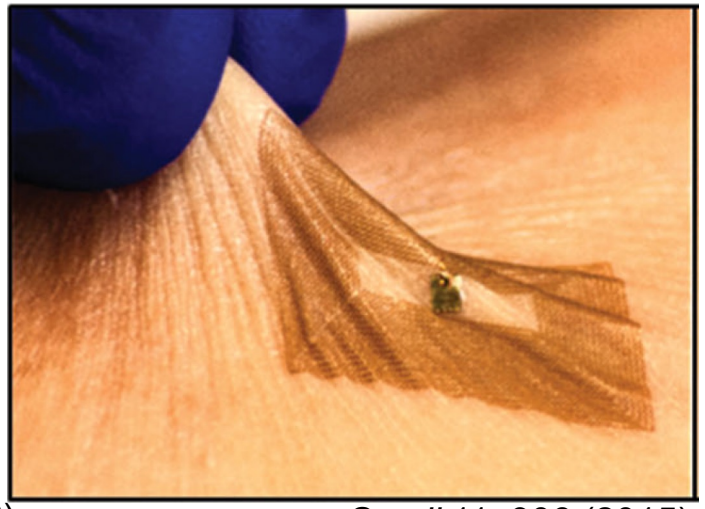
Nat. Mater. 12, 938 (2013)

Fingertip electrode



Nanotechnology 23, 344004 (2012)

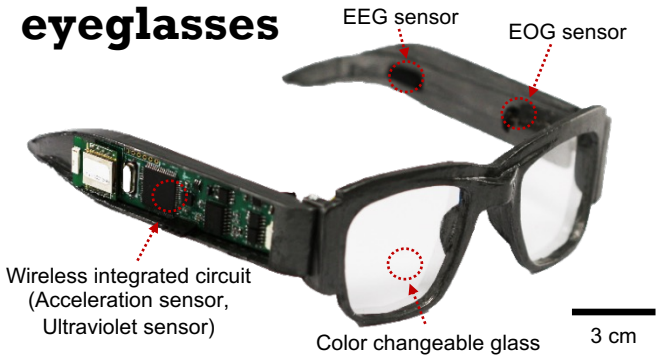
Near field communication



Small 11, 906 (2015)

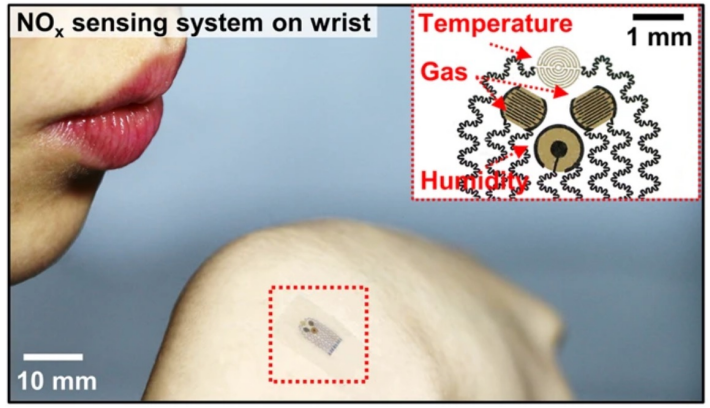
INTEGRATED SYSTEM

Smart electronic eyeglasses



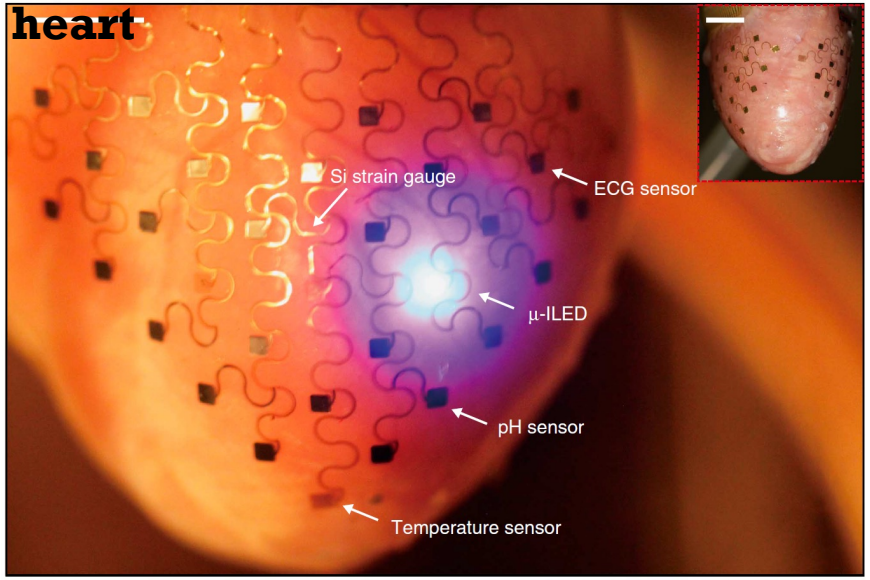
ACS Appl. Mater. Interfaces 12, 21424 (2020)

NO_x gas sensor



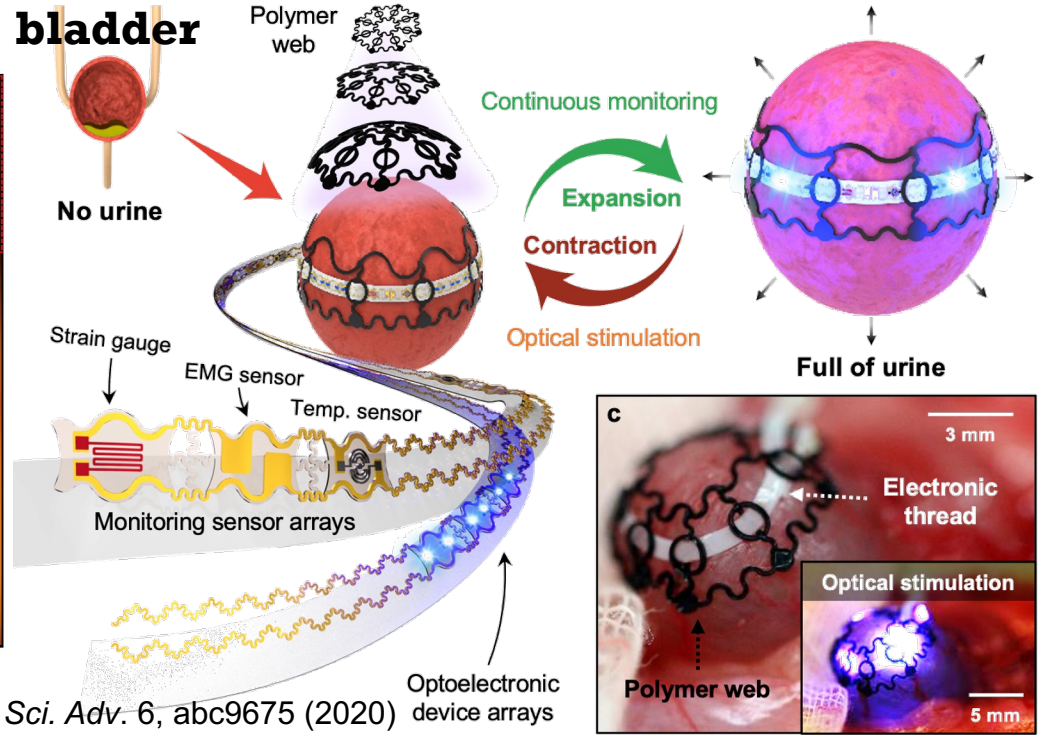
NPG Asia Mater. 12, 17 (2020)

3D integumentary membrane on heart



Nat. Commun. 5, 3329 (2014)

Bioelectronic complex on the urinary bladder



Sci. Adv. 6, abc9675 (2020)

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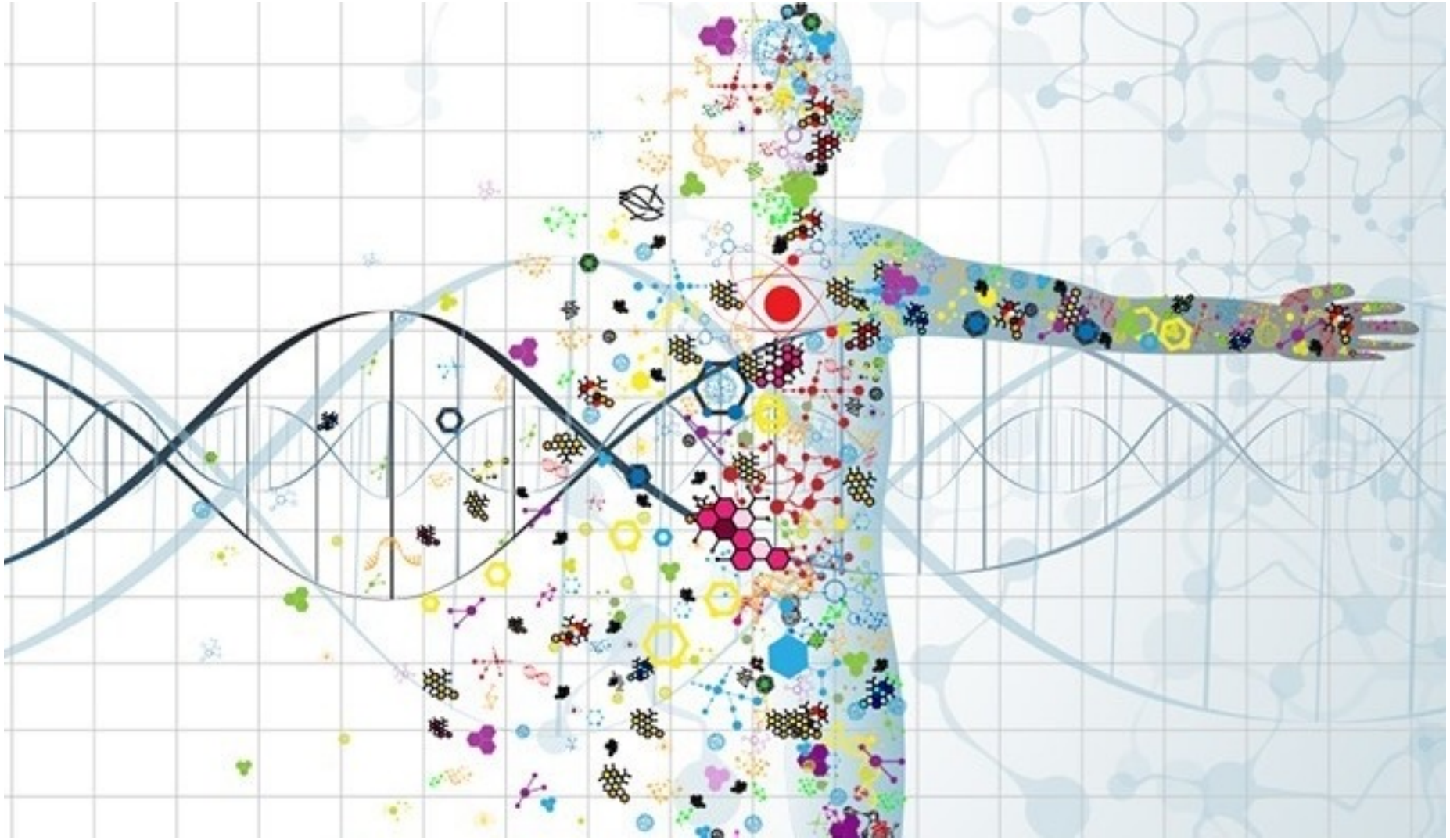
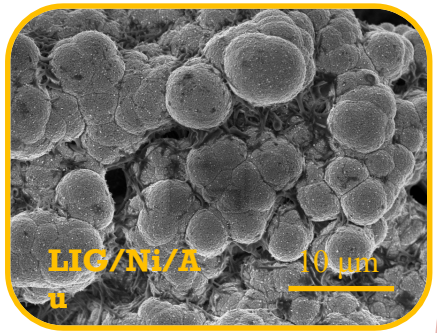
ANICS

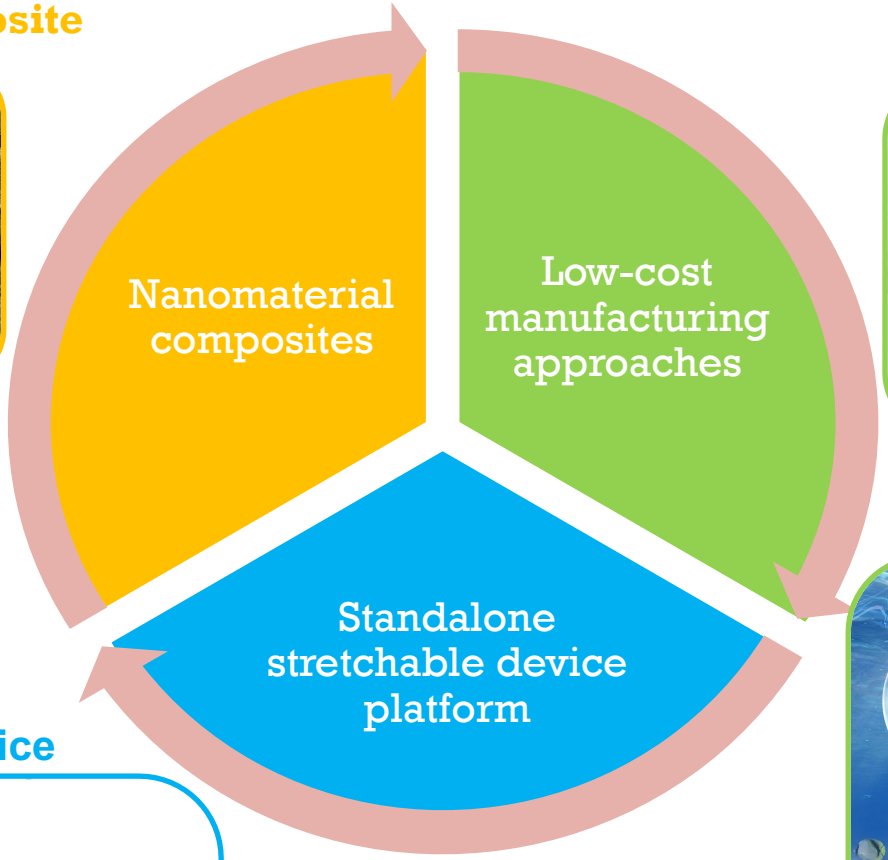
PRECISION MEDICINE AND HEALTHY AGING



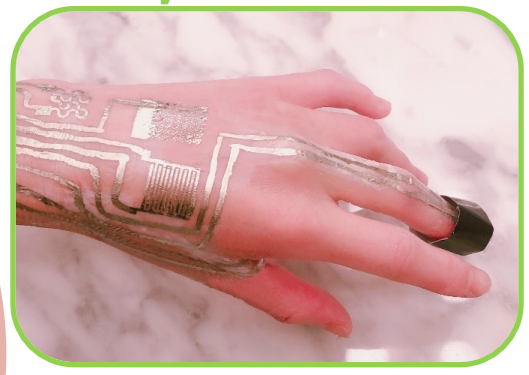
RESEARCH THRUSTS

Nanomaterial composite

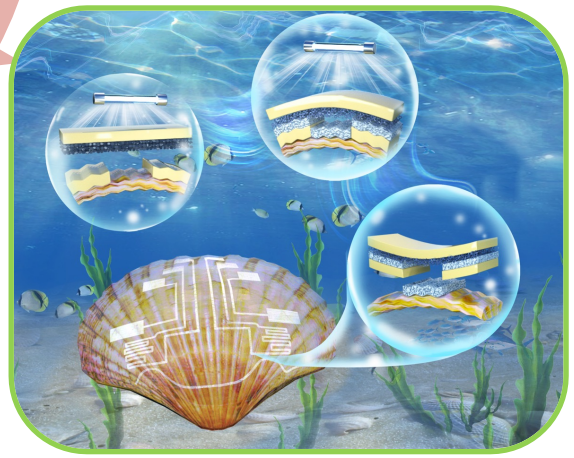




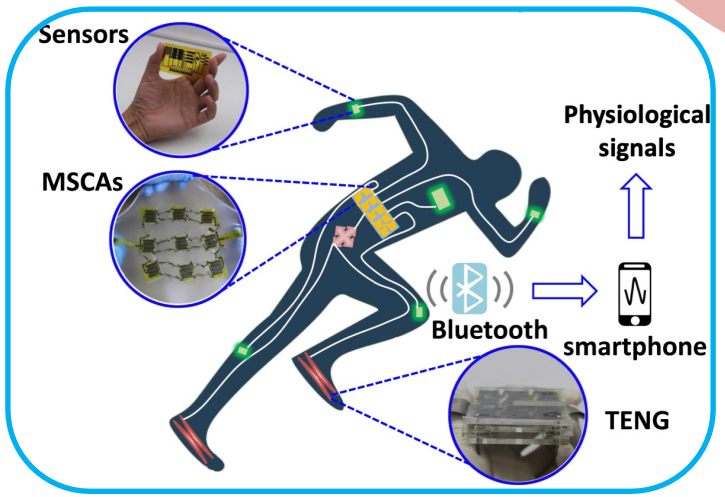
Body area network



3D freeform fabrication



Standalone device



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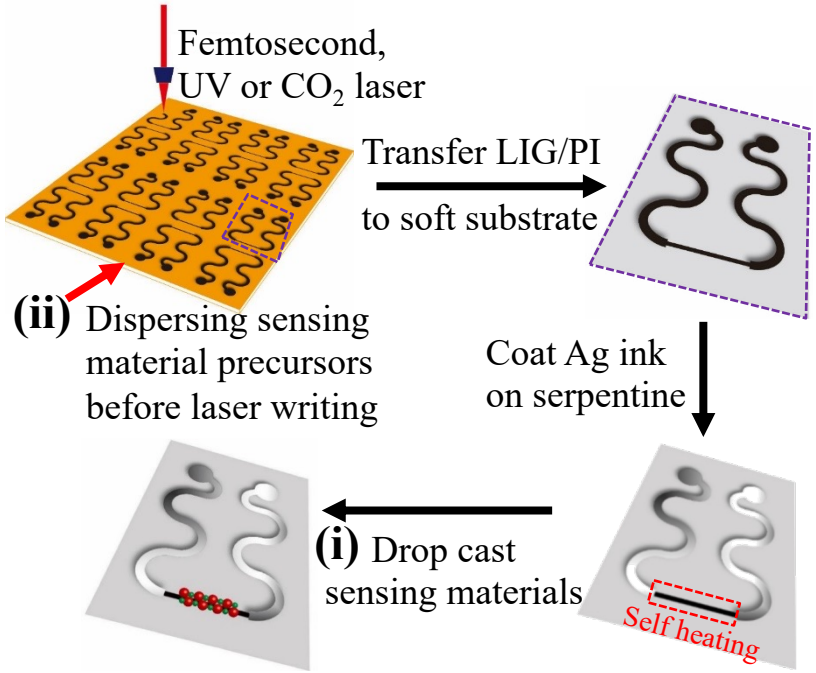
STRETCHABLE GAS SENSORS

Application:

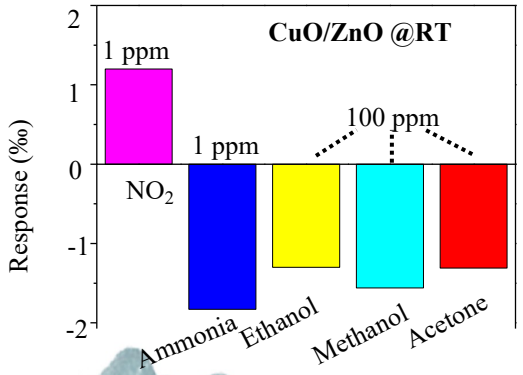
- Health biomarker
- Industry safety
- Environmental monitoring
- Military countermeasures

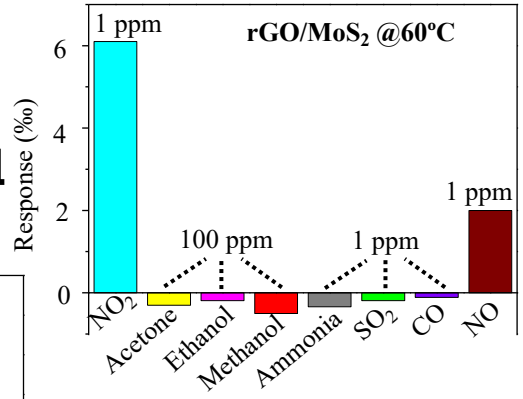
Trends Analyt. Chem. 133, 116085 (2020)

LIG SENSING PLATFORM

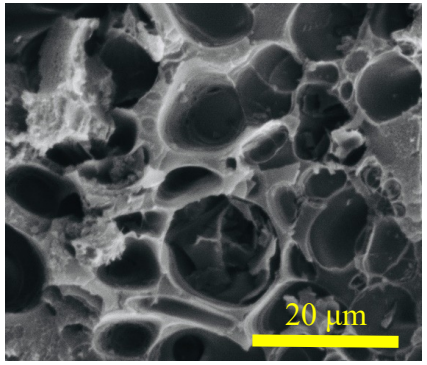


Varying gas specificity for combinatorial sensing

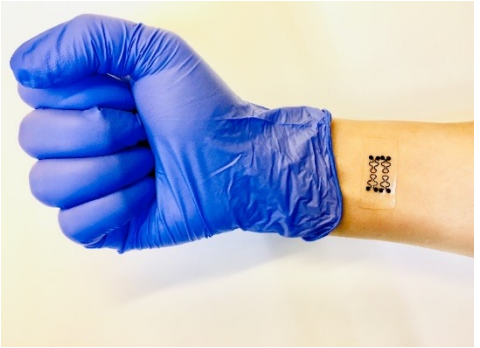




Porous LIG



Skin-conforming



J. Mater. Chem. A 8, 6487 (2020) (**Cover**)

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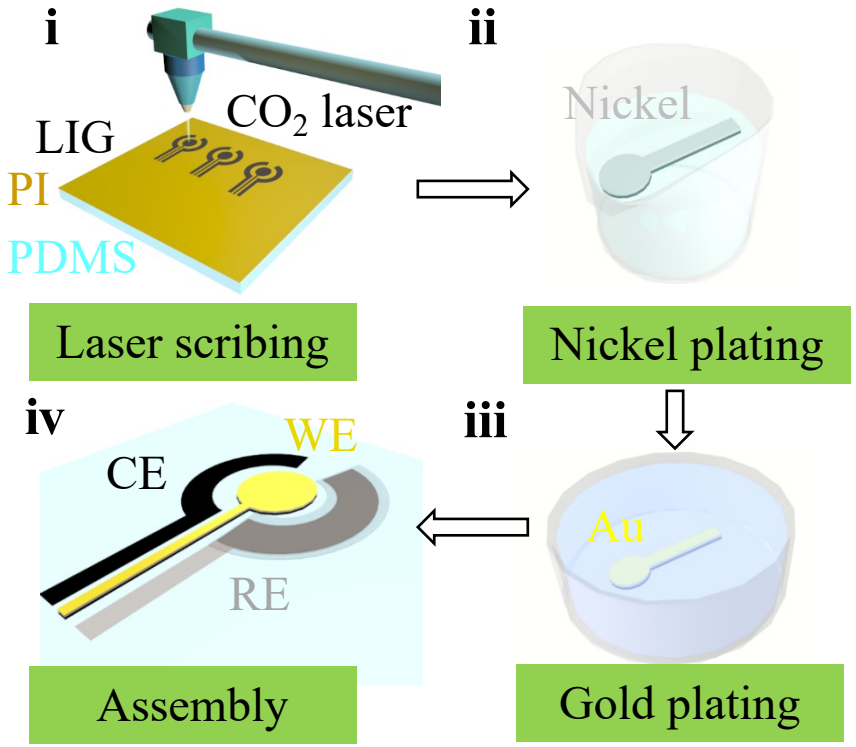
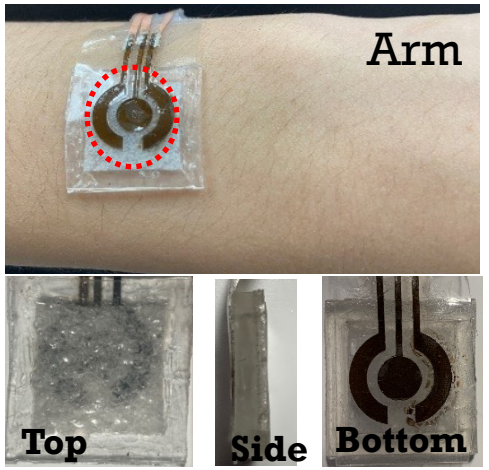
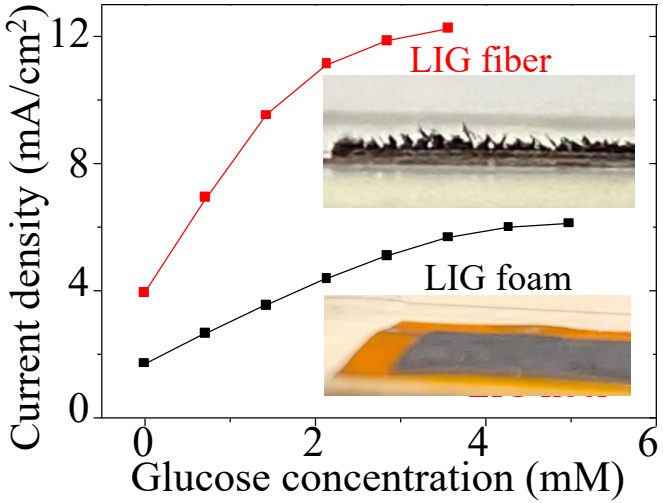
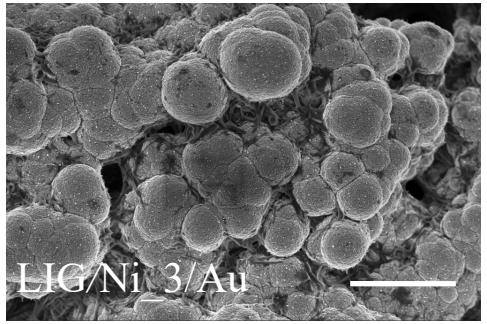
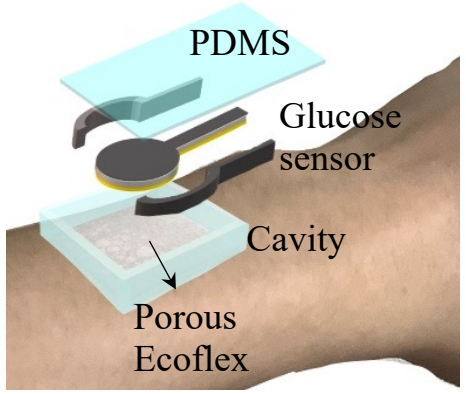
LIG GLUCOSE SENSOR







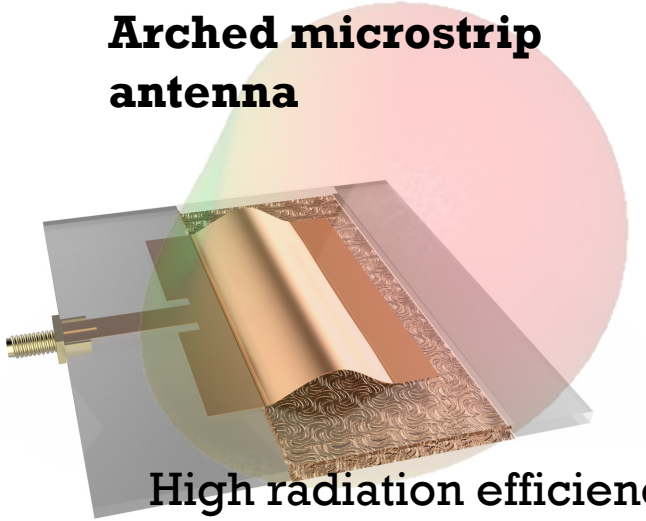




Biosensors and Bioelectronics 193, 113606 (2021)

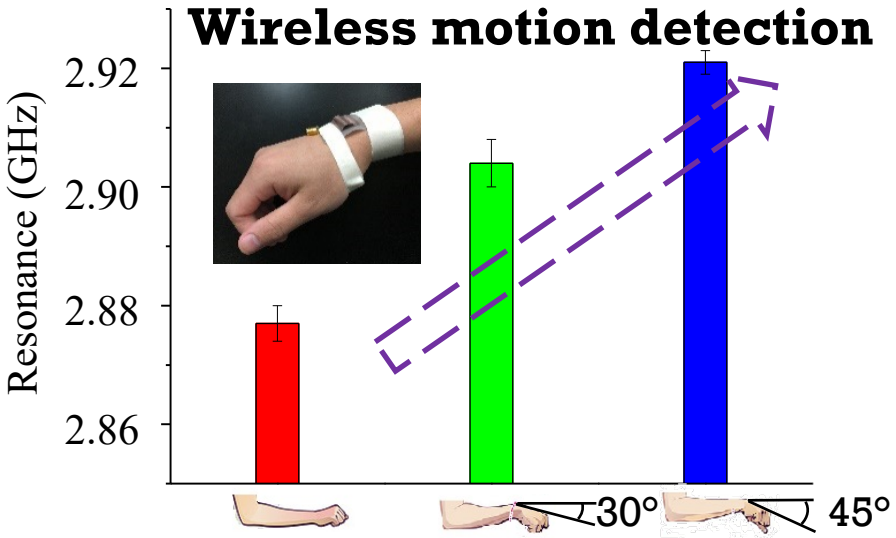
STRETCHABLE METAL ANTENNA

Arched microstrip antenna

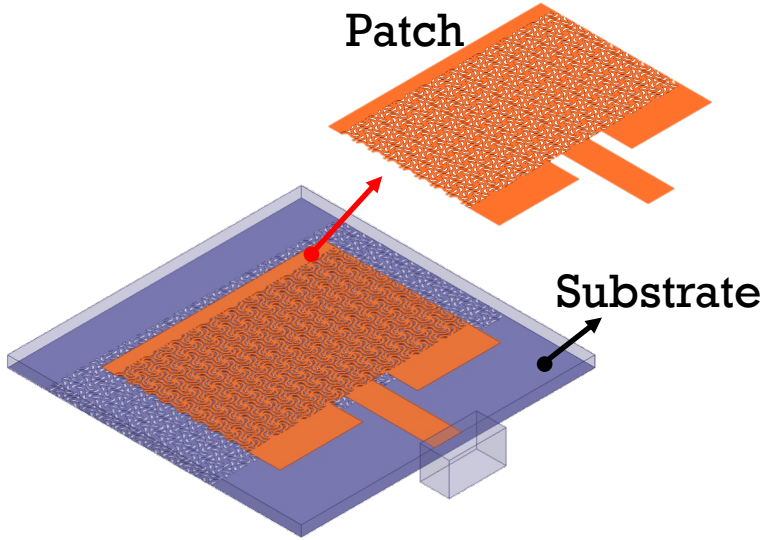


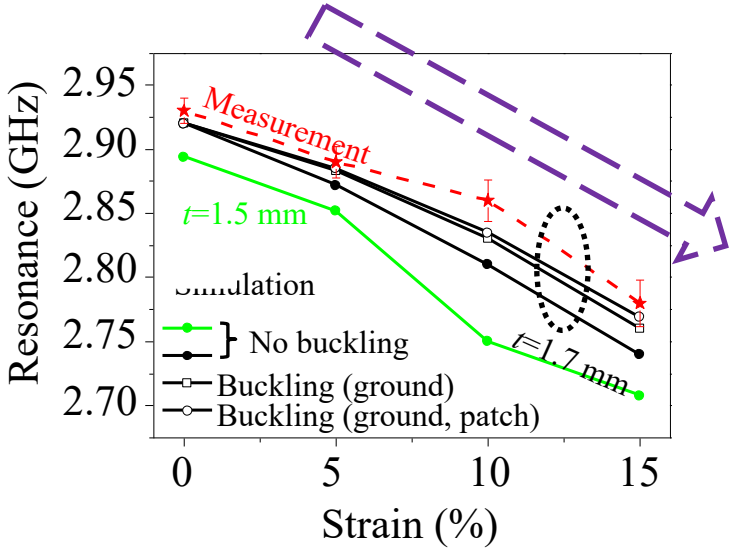
High radiation efficiency of 87 %

Wireless motion detection



Meshed microstrip antenna





ACS Appl. Mater. Interfaces 11, 8867 (2019)

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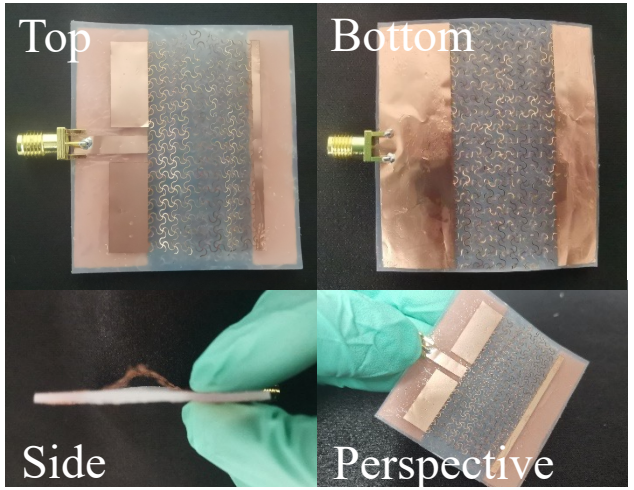
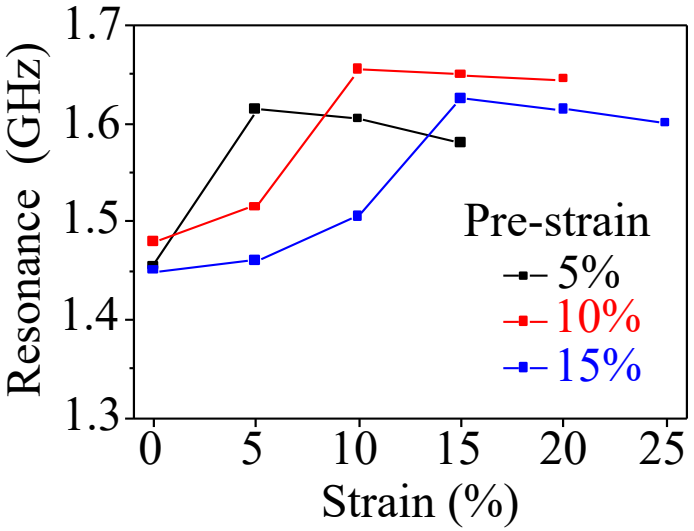
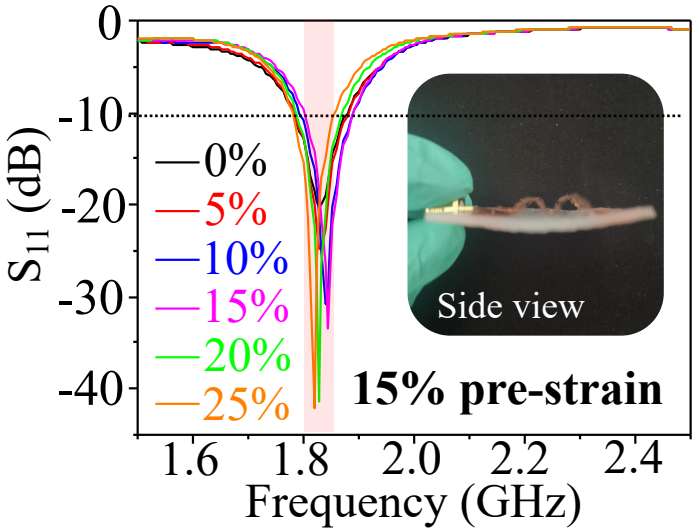
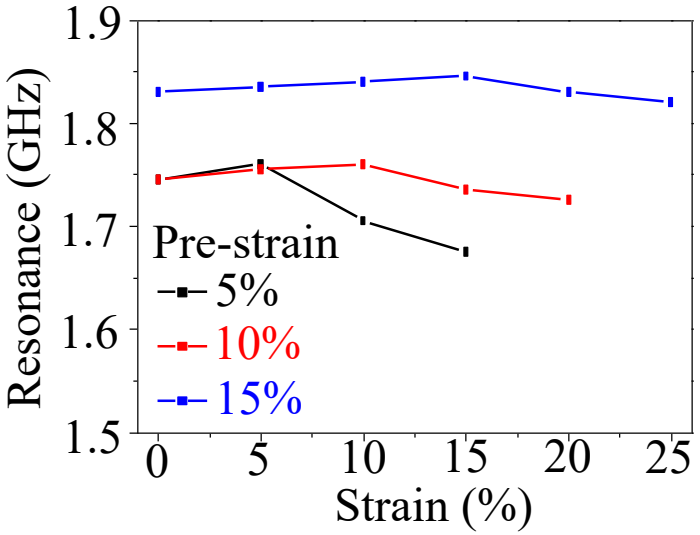
STRAIN-INSENSITIVE ANTENNAS





Hierarchical structured





Nano-Micro Letters 13, 108 (2021) (**Cover**)

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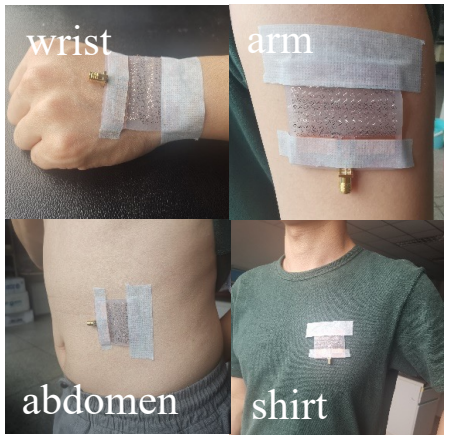
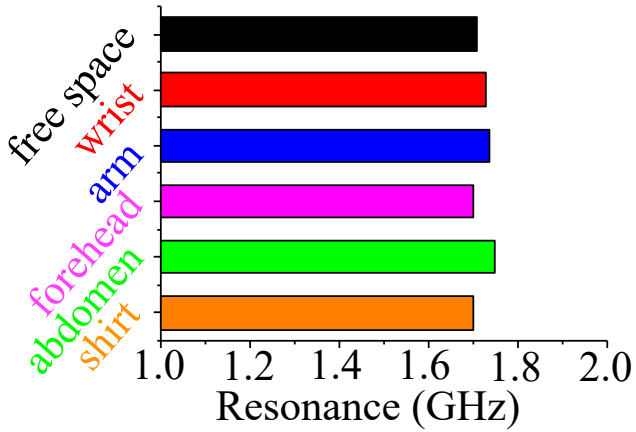
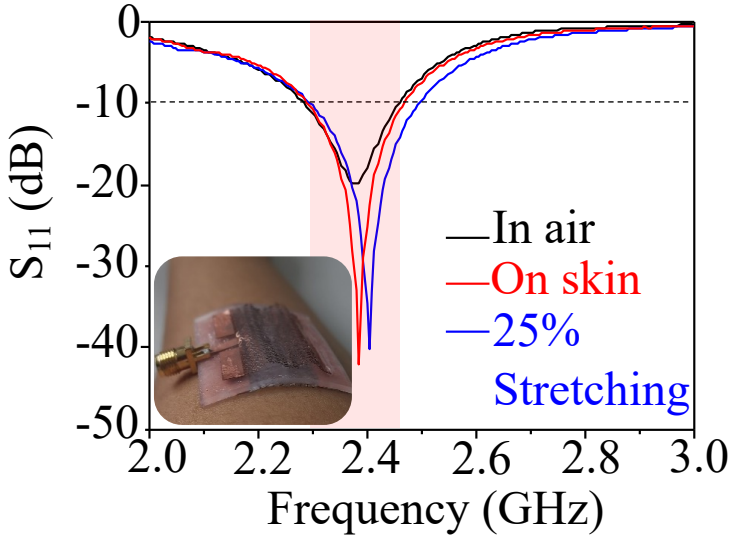
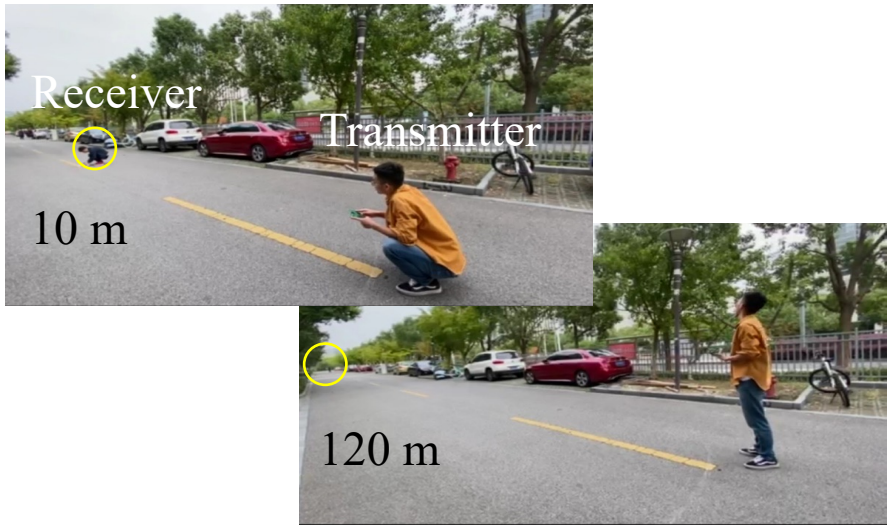
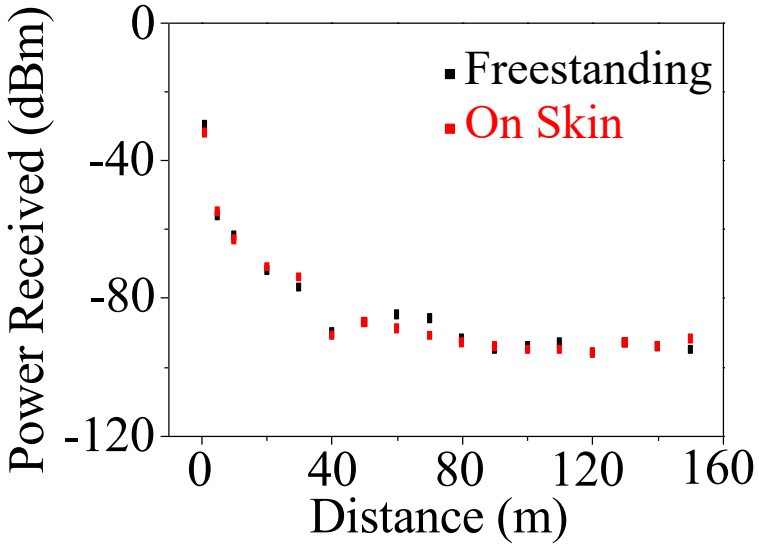
ON-BODY COMMUNICATION











Nano-Micro Letters 13, 108 (2021) (**Cover**)

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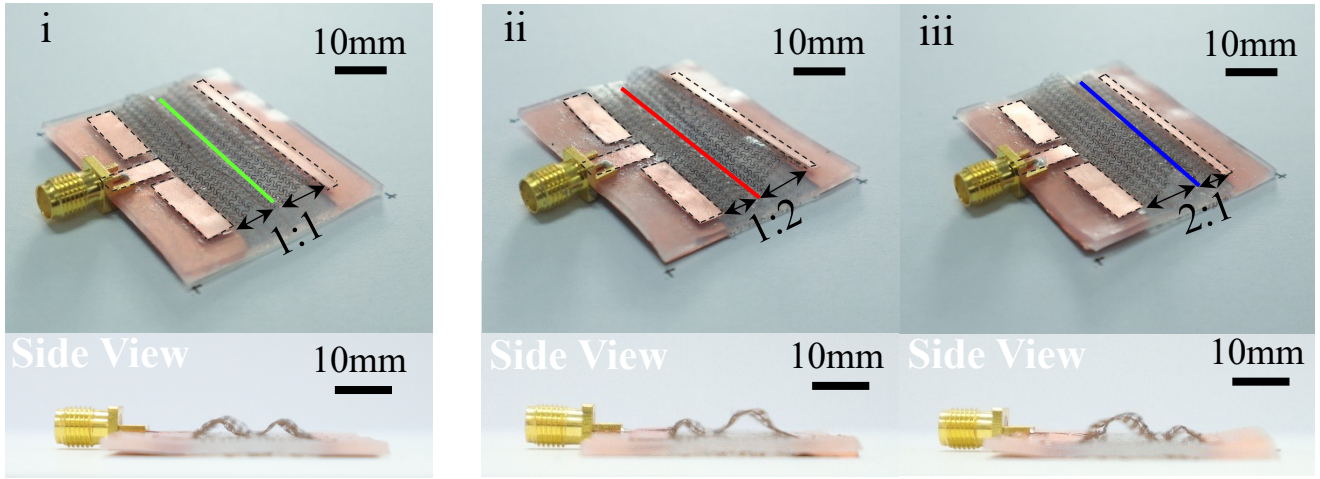
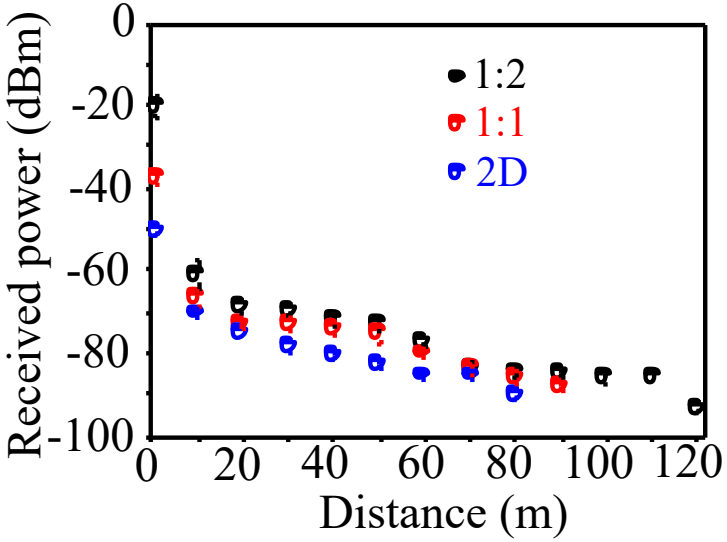
ASYMMETRIC 3D MICROSTRIP ANTENNA

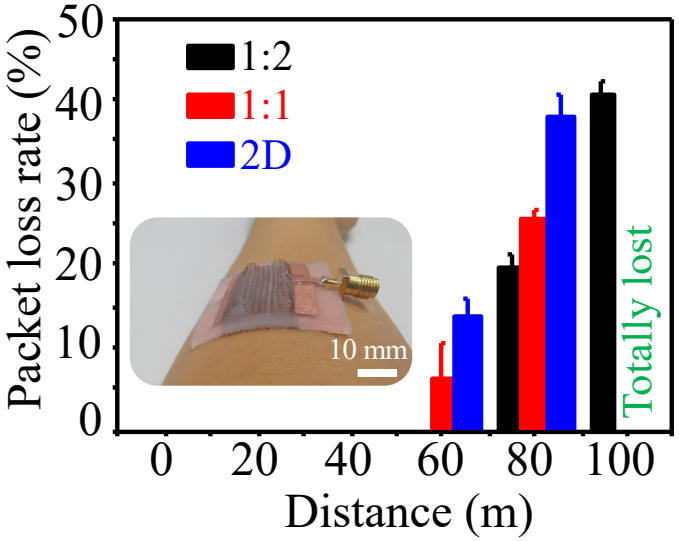
Symmetric **Asymmetric**



Average receiving power



Data packet loss rates



Nano Energy 96, 107069 (2022)

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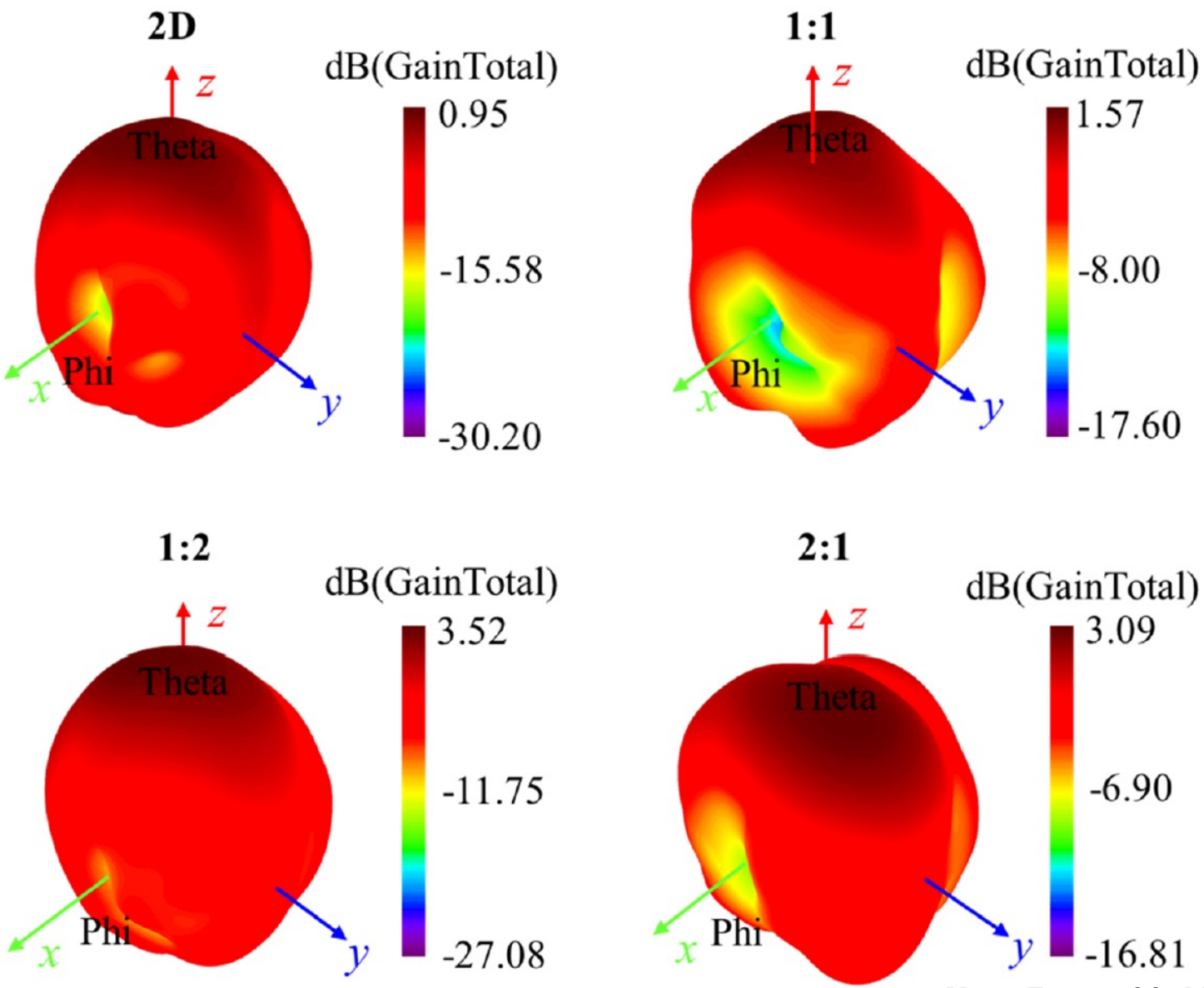
ENHANCED GAIN AND RADIATION



Nano Energy 96, 107069 (2022)

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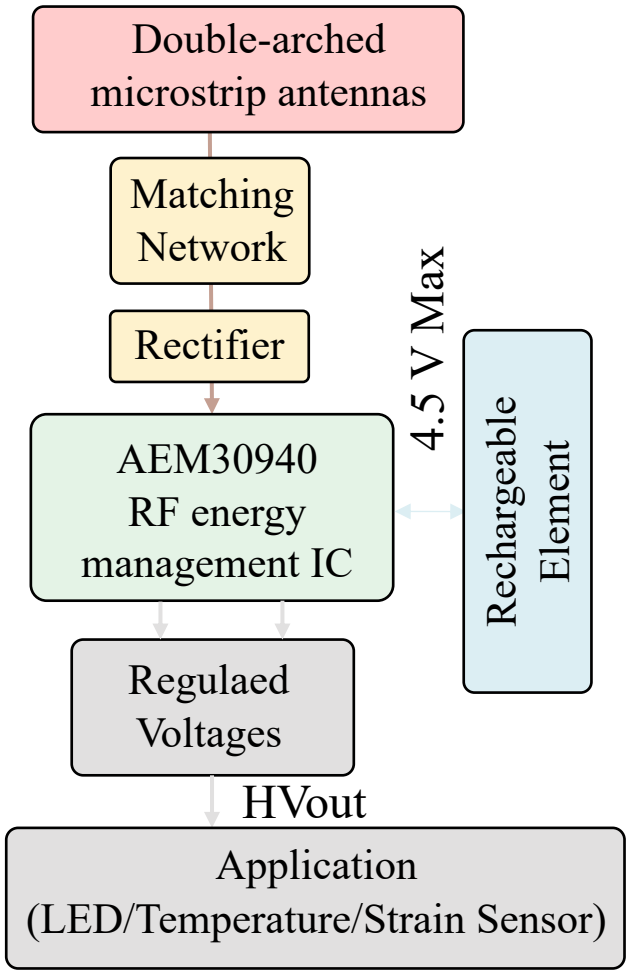
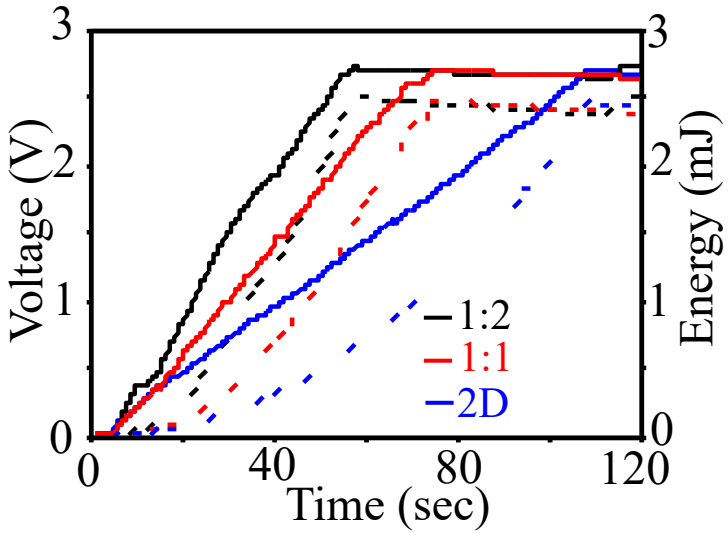
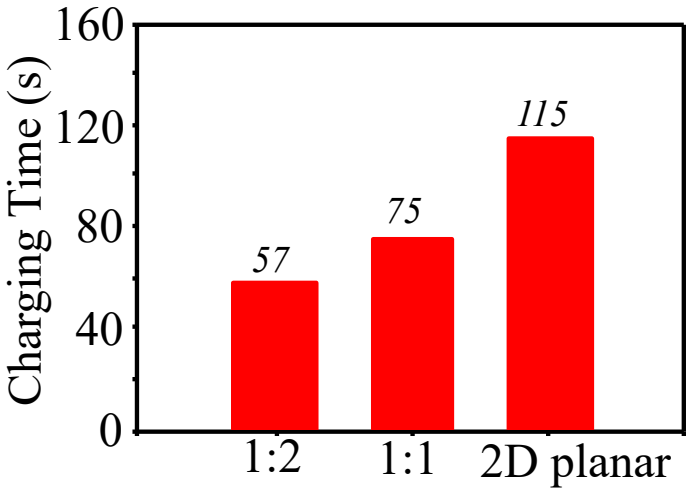
RF ENERGY HARVESTING

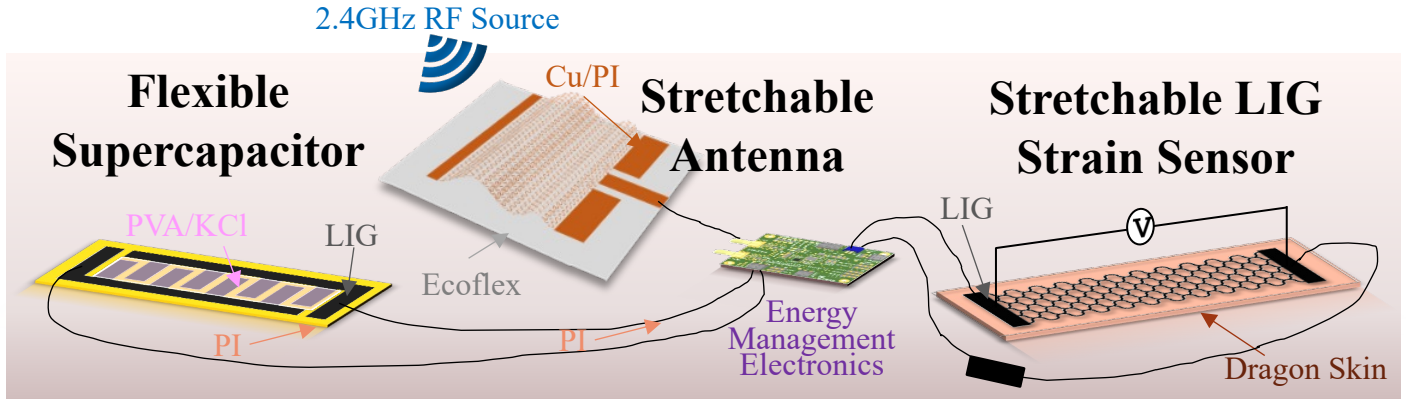


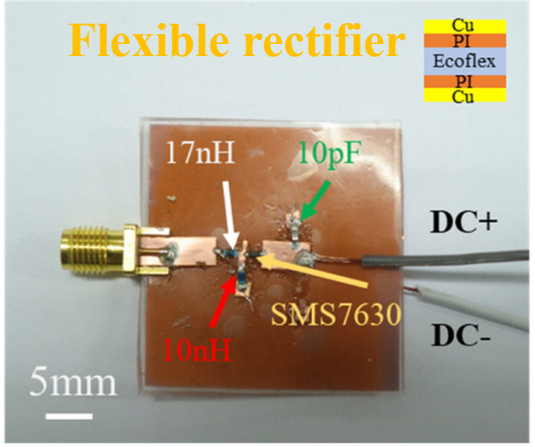


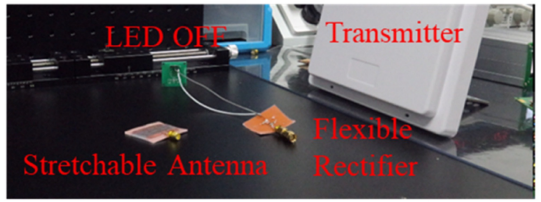


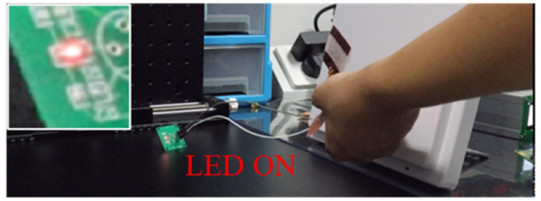
Nano Energy 96, 107069 (2022)

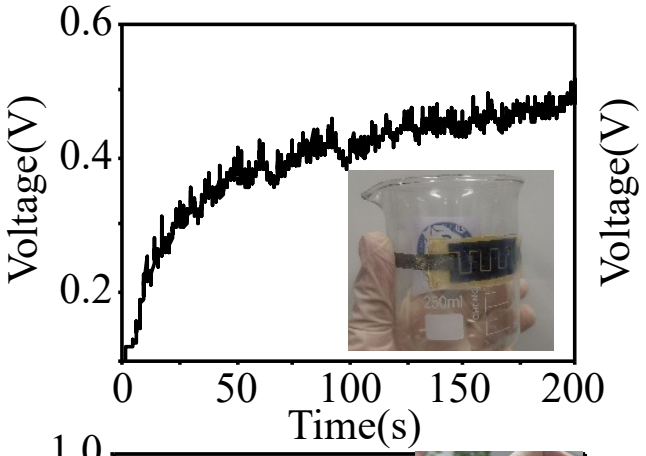
RF ENERGY HARVESTING

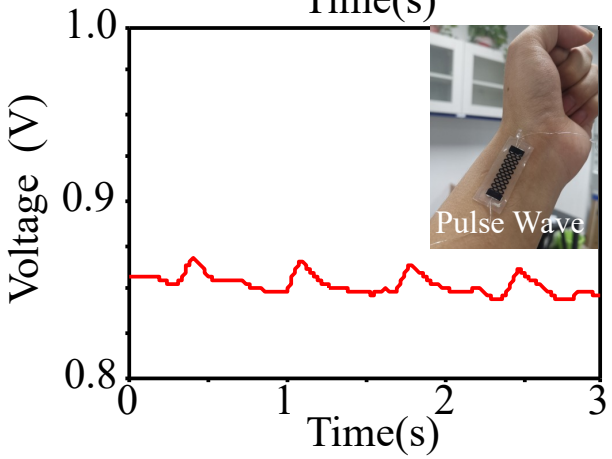












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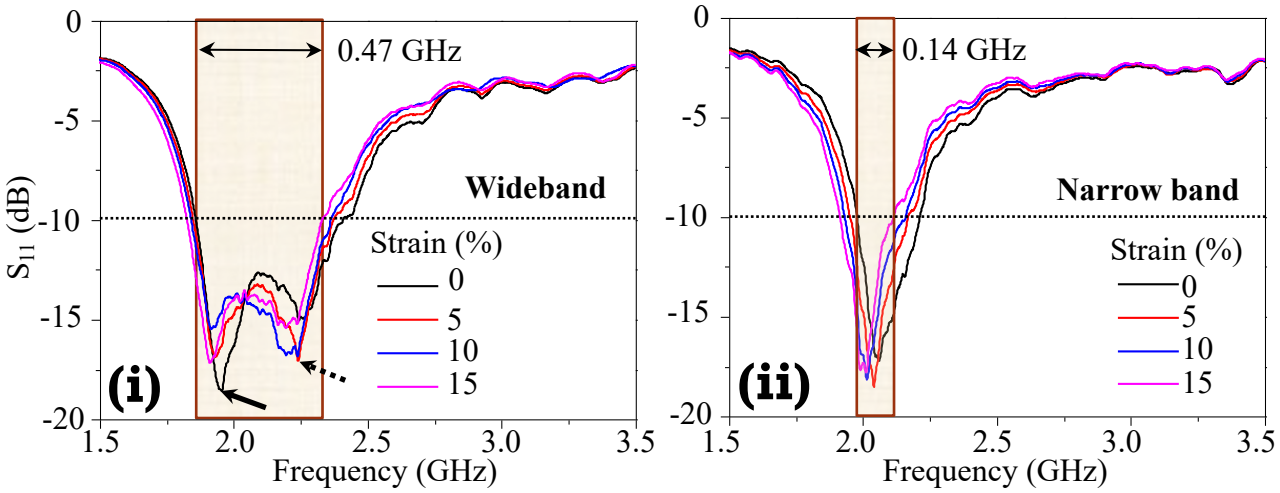
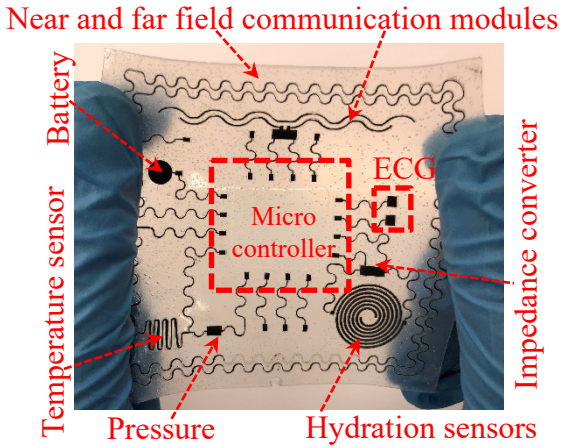
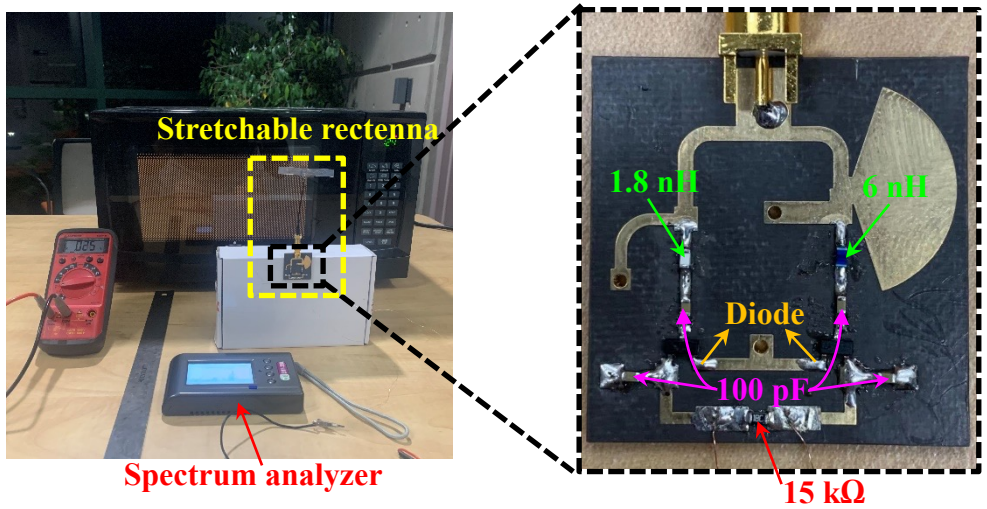
STRETCHABLE WIDEBAND RECTENNA

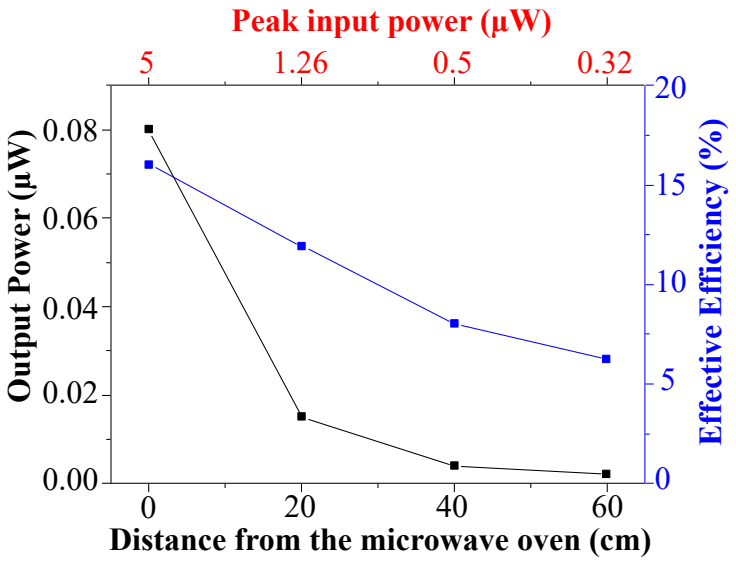
Wide bandwidth stretchable antenna



All-LIG sensing platform







Mater. Today Phys. 18, 100377 (2021)

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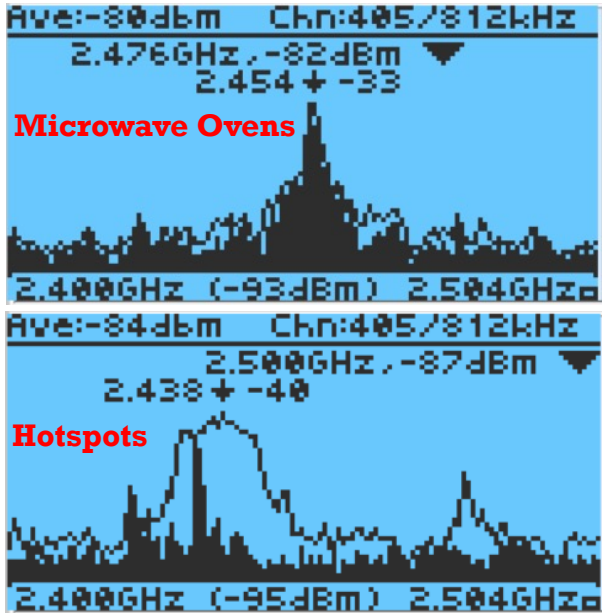
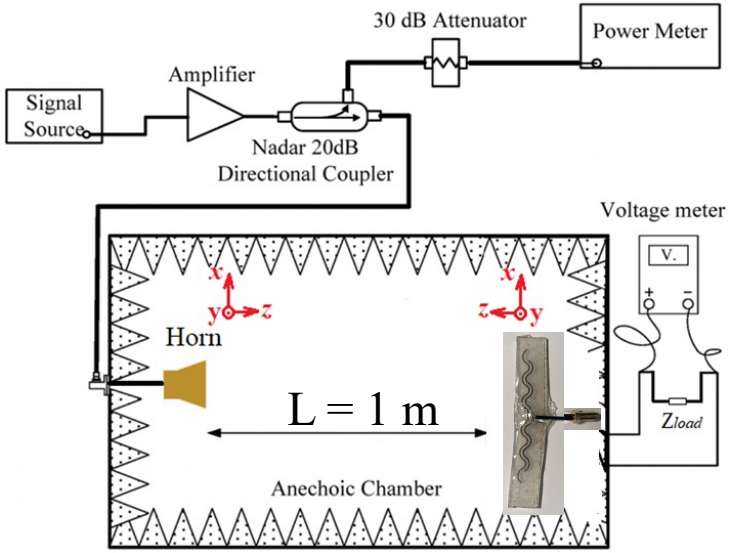
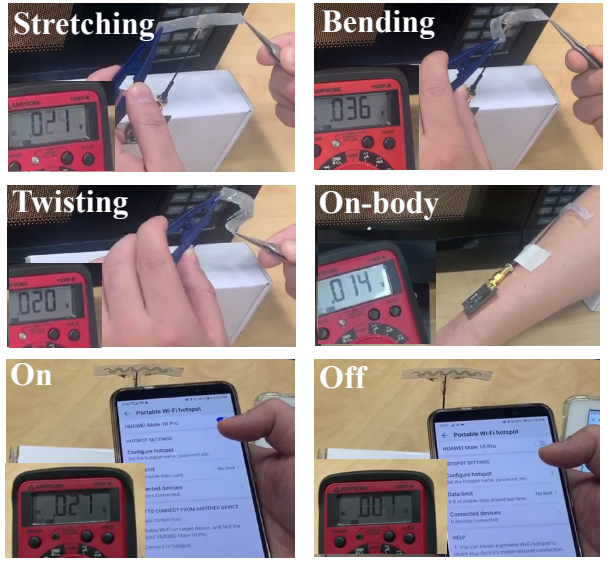
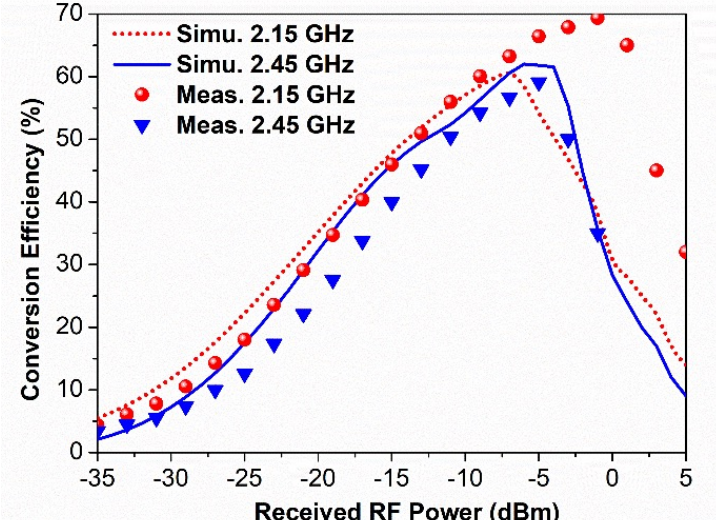
RF ENERGY HARVESTING









Mater. Today Phys. 18, 100377 (2021)

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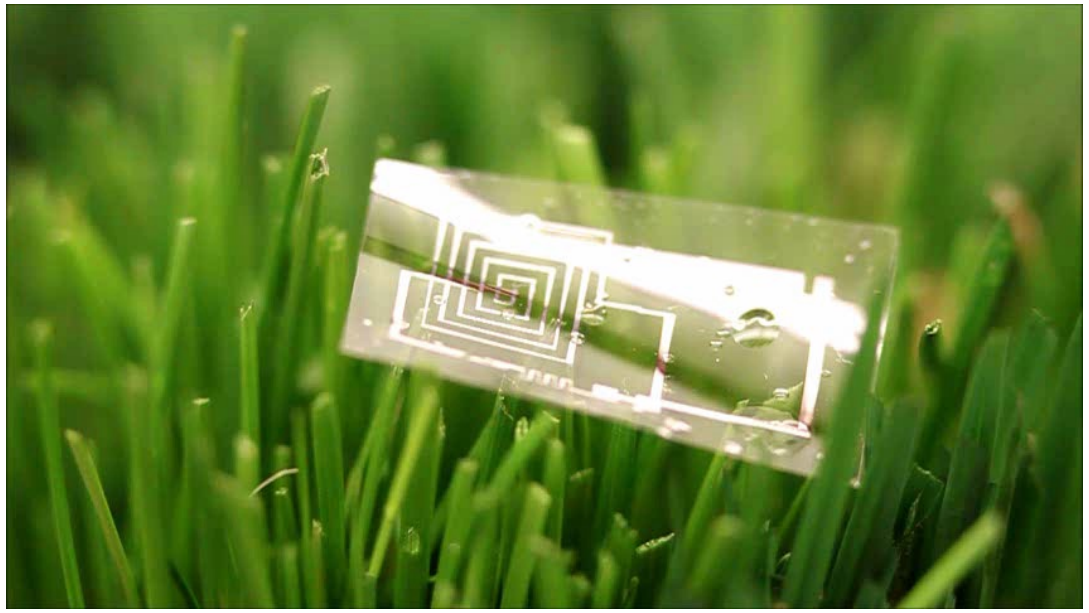
ELECTRONICS THAT DISSOLVE

- **Substrate:** Silk (FDA approved), PLGA
- **Interconnects:** Mg, Fe, Zn, W
- **Electronic components:** Si, SiO_2

Transient Electronics



Mg ~ 100 μg, Si ~ 3 μg

Rec. Daily Intake

Mg ~ 300 mg, Si ~ 10 mg

Science 28, 1640 (2012) (**Cover**);
Adv. Mater. 26, 1992 (2014); *Adv. Funct. Mater.* 24, 645 (2014)

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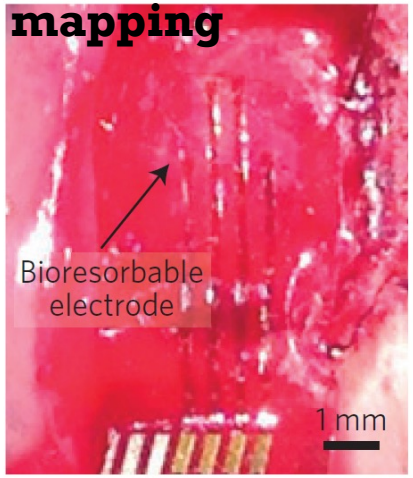
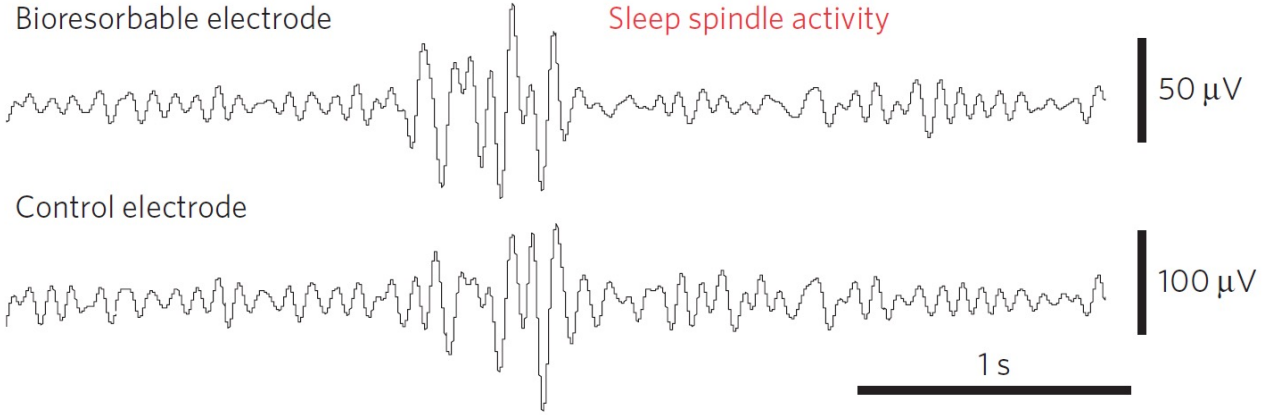
TRANSIENT IMPLANTABLE DEVICES

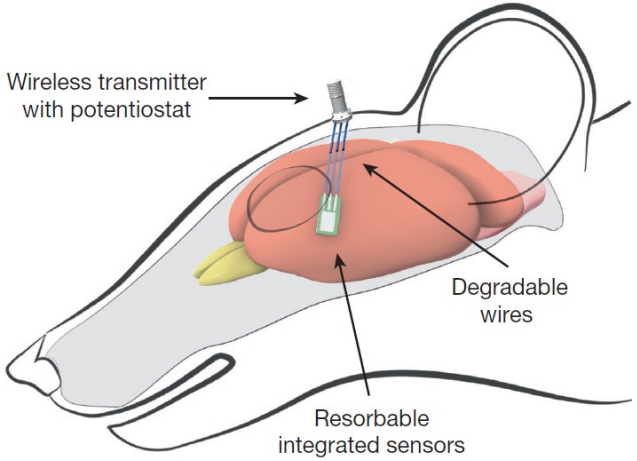
Cerebral cortex spatiotemporal mapping





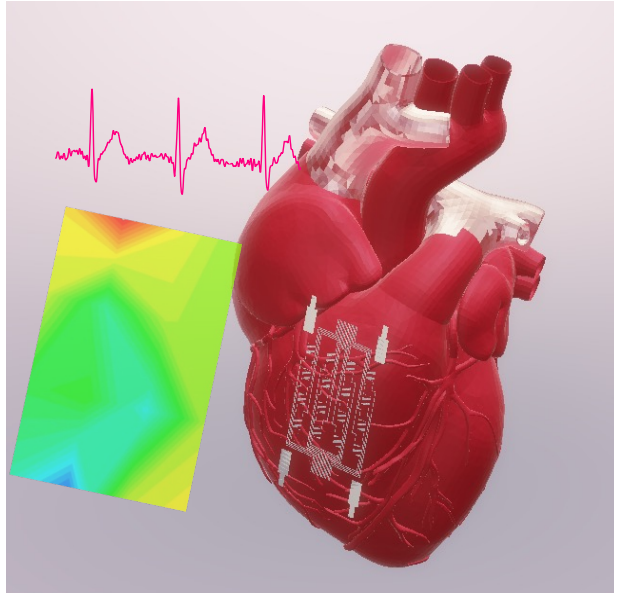
Nat. Mater. 15, 782 (2016)

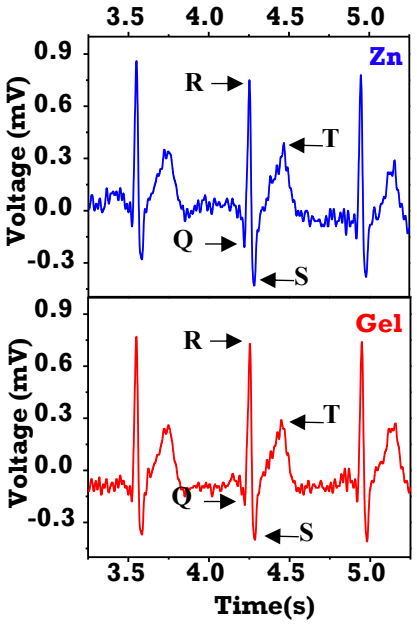
Brain monitor



Nature, 2016, 530, 71

Low-cost transient sensors





ACS Appl. Mater. Interfaces 10, 36664 (2018)

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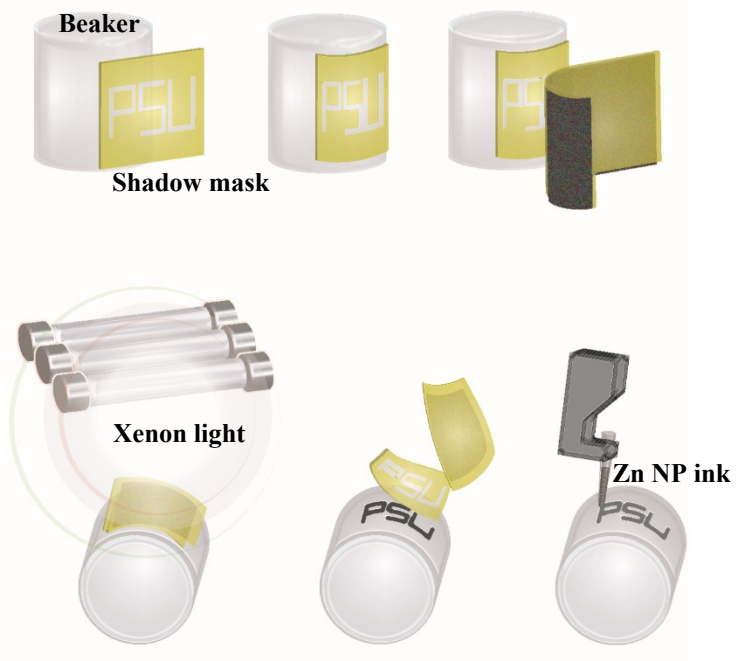
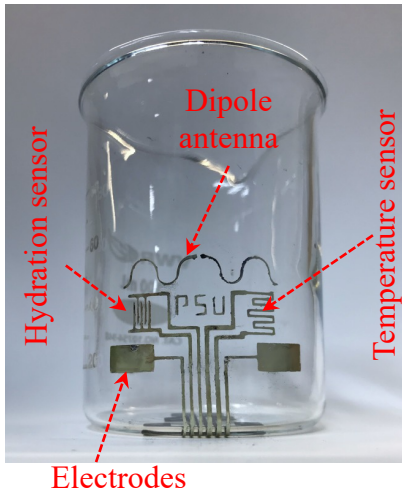
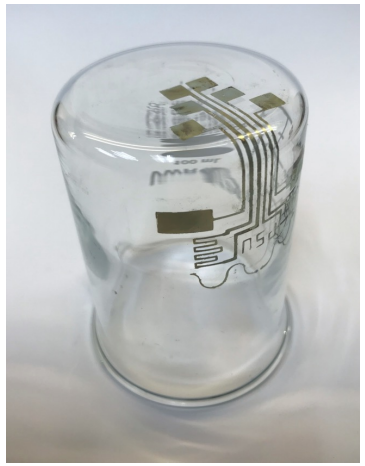
3D BIODEGRADABLE SENSORS

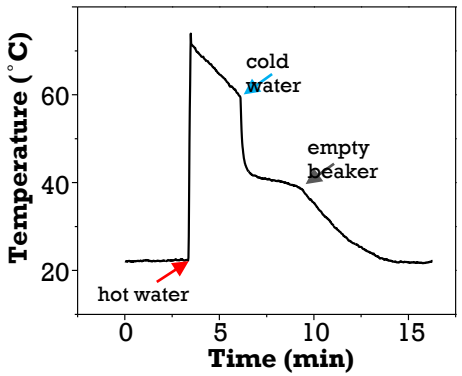


Smart Internet-of-Things

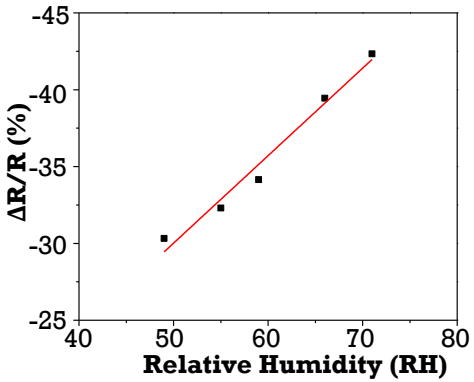




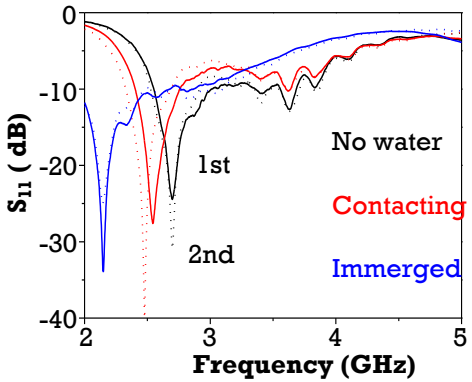
Temperature sensor



Humidity sensor



Dipole antenna



Materials Today 50, 24-34 (2021) (**Front Cover**)

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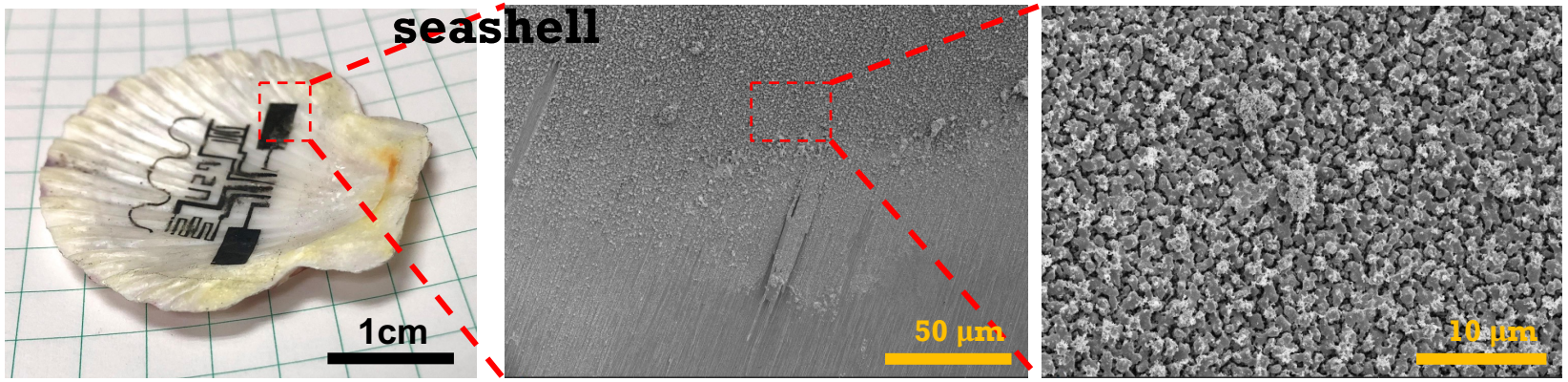
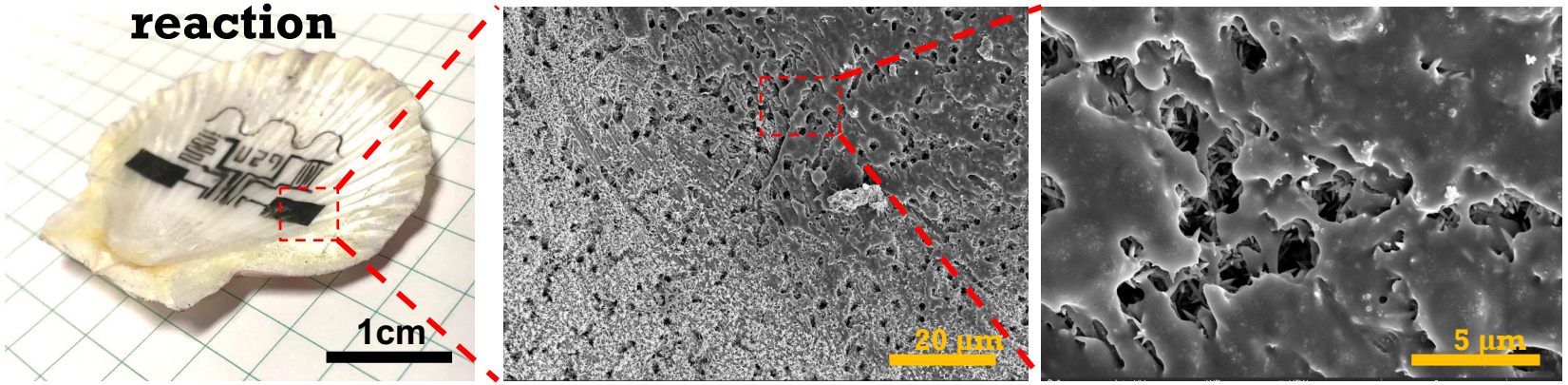
CIRCUITS ON COMPLEX SEASHELL

Zn layer patterned on the seashell



Ag layer on the seashell by a single-replacement reaction



Materials Today 50, 24-34 (2021) (**Front Cover**)

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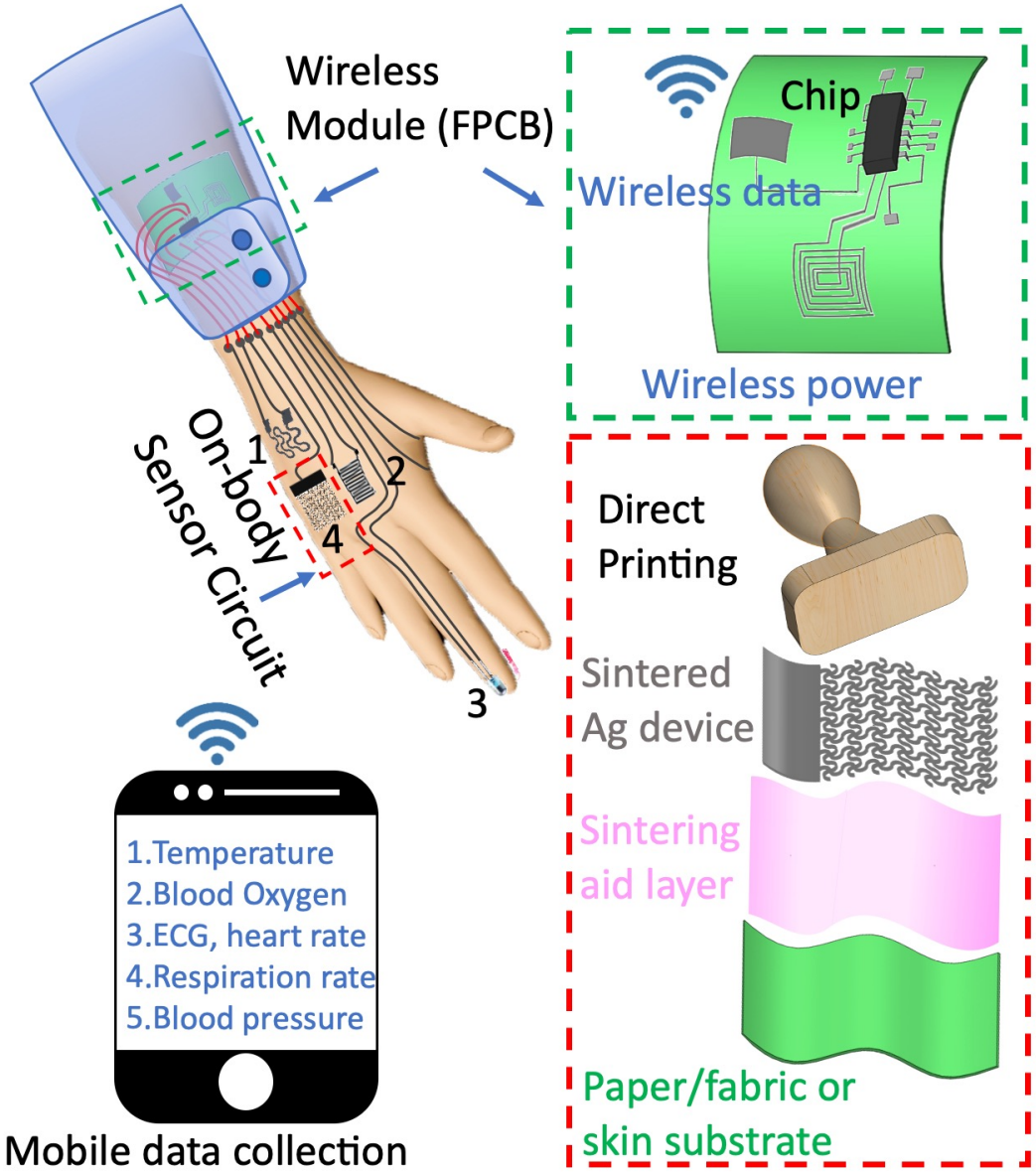
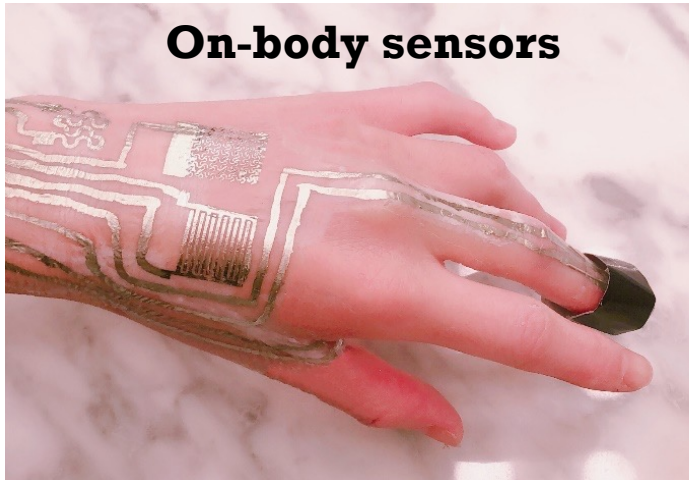
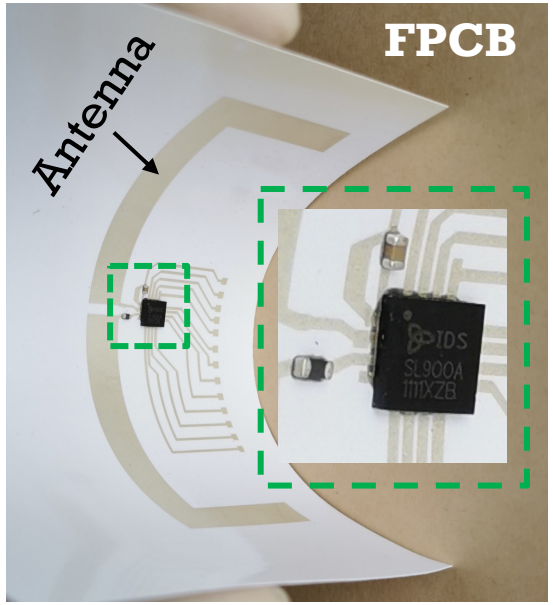
BODY AREA SENSOR NETWORK





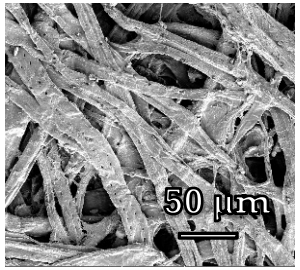


ACS Appl. Mater. Interfaces 12, 45504 (2020)

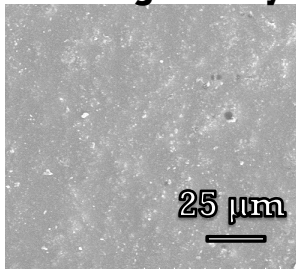
SIMPLE FABRICATION PROCESS

Reduced roughness

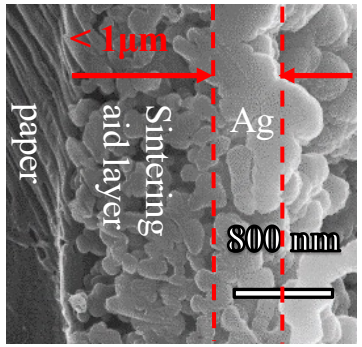
Before

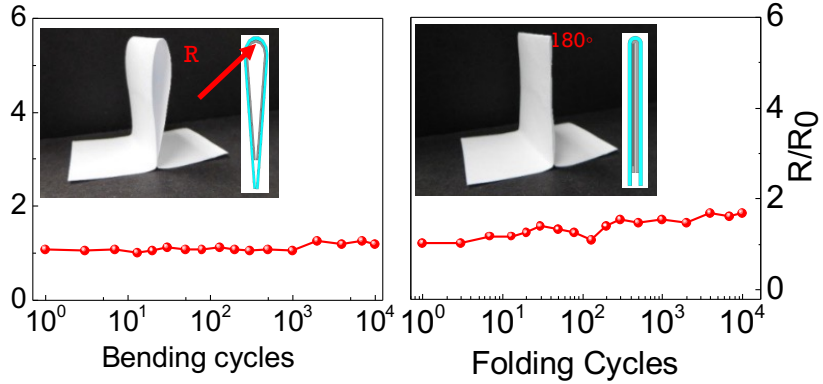


After sintering aid layer

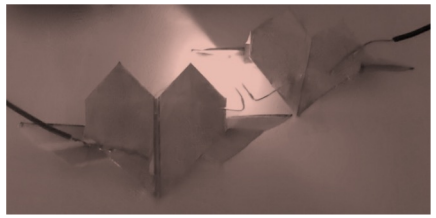


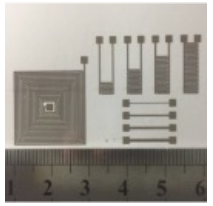
Interfacial sintering at room temperature



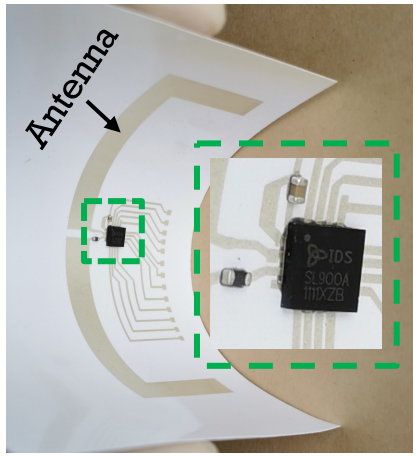


3D origami paper structures

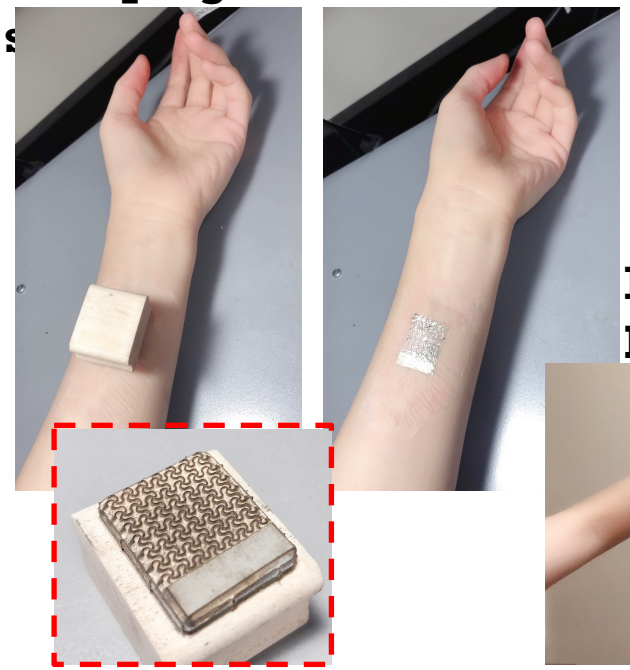




Flexible printed circuit board (FPCB)



Stamping on the textured skin



Drying with hairdryer

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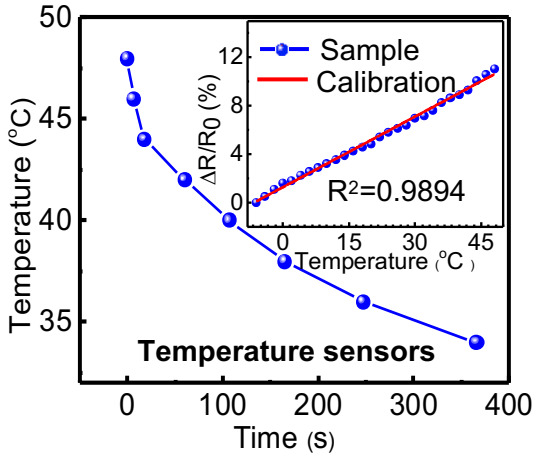
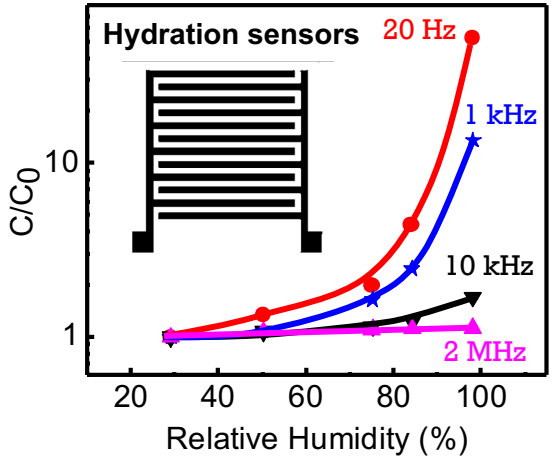
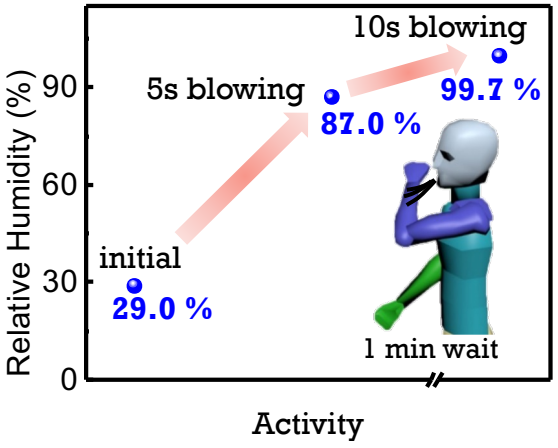
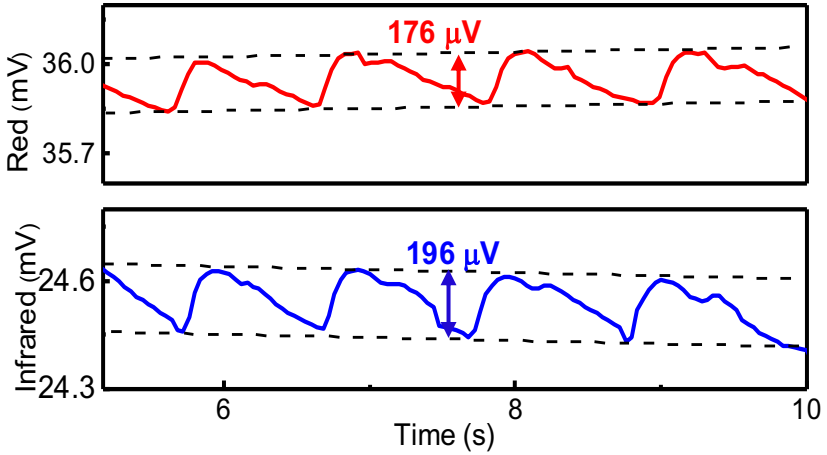
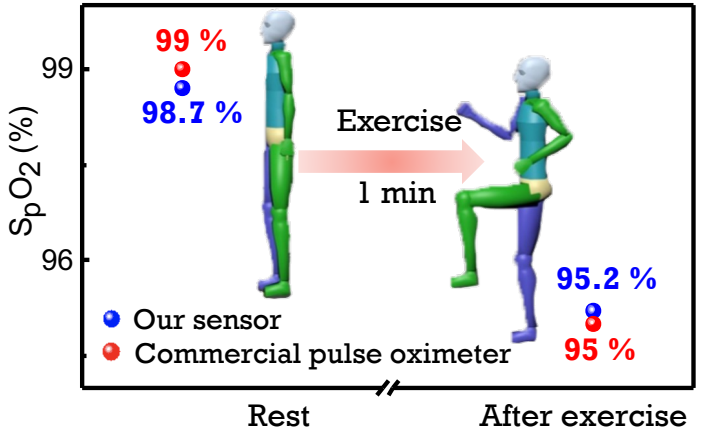
ON-BODY SENSORS











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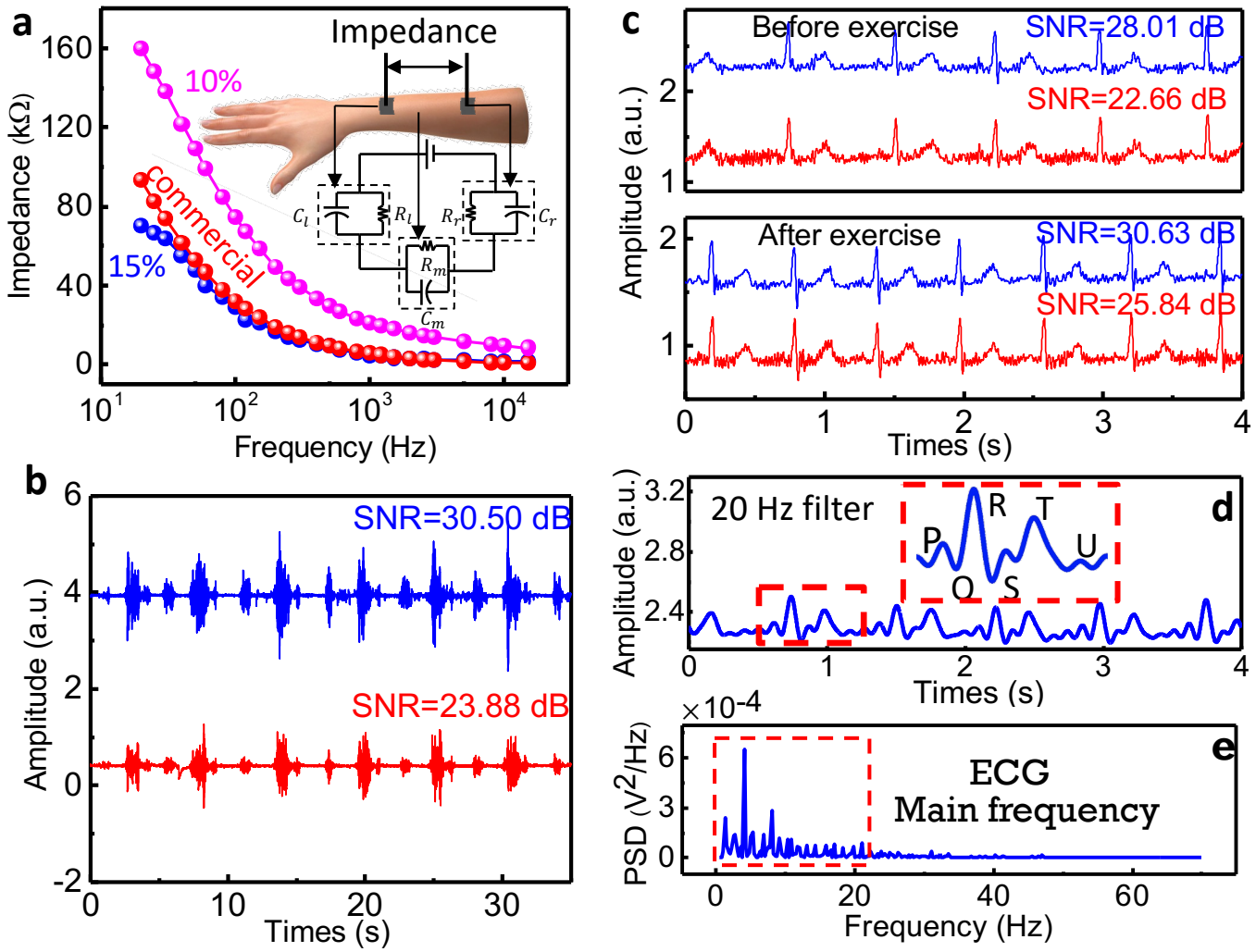
ENHANCED CONTACT QUALITY



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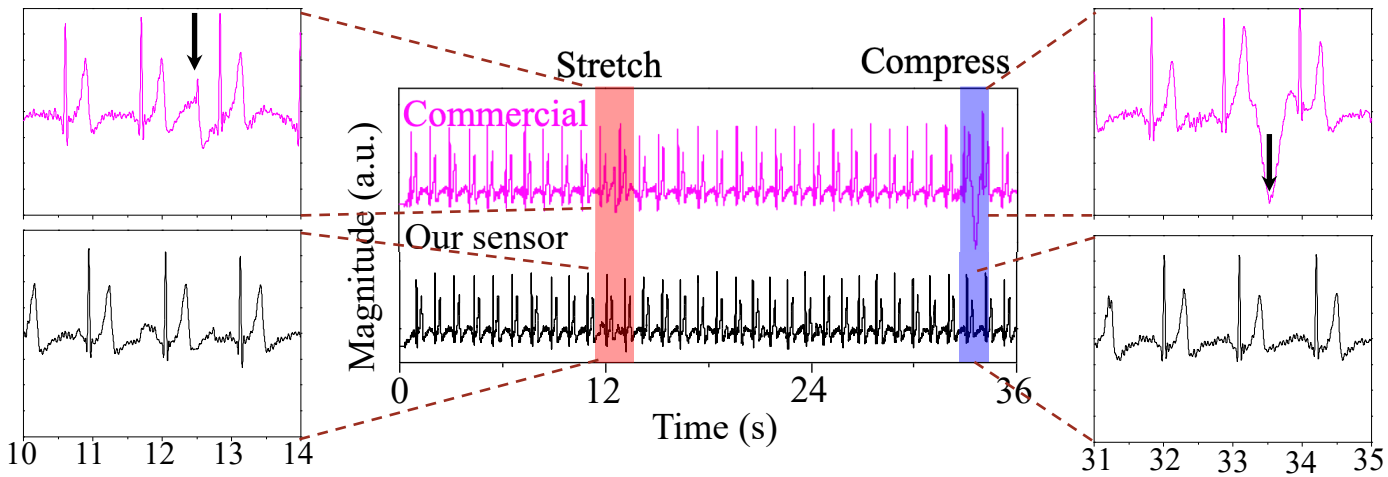
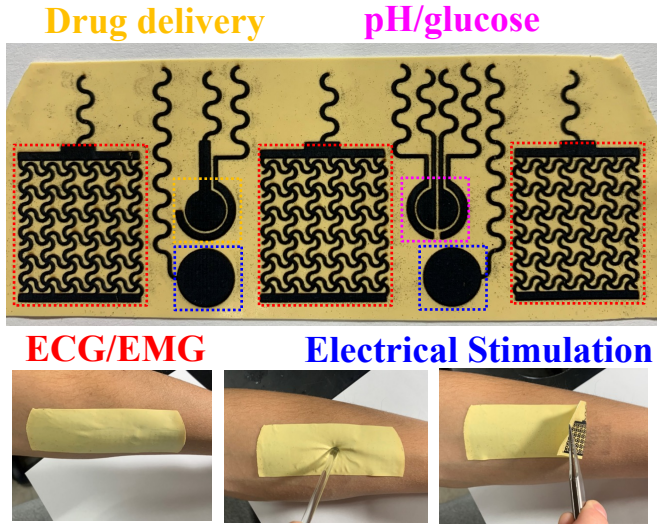
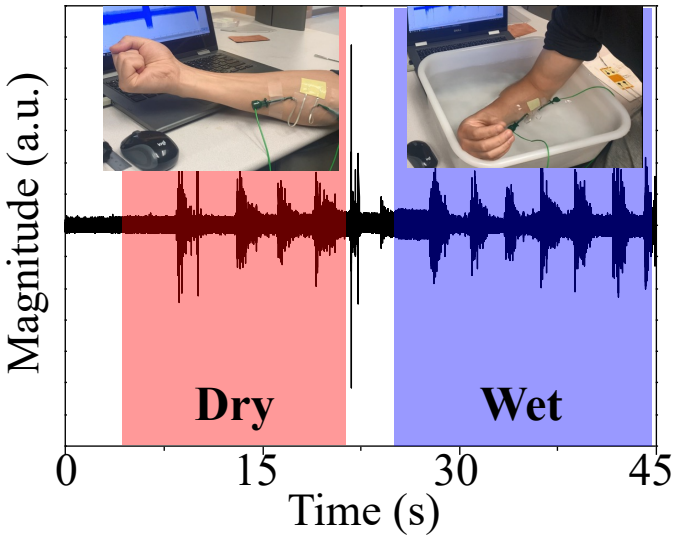
MOTION ARTIFACT-FREE SENSING







Unpublished

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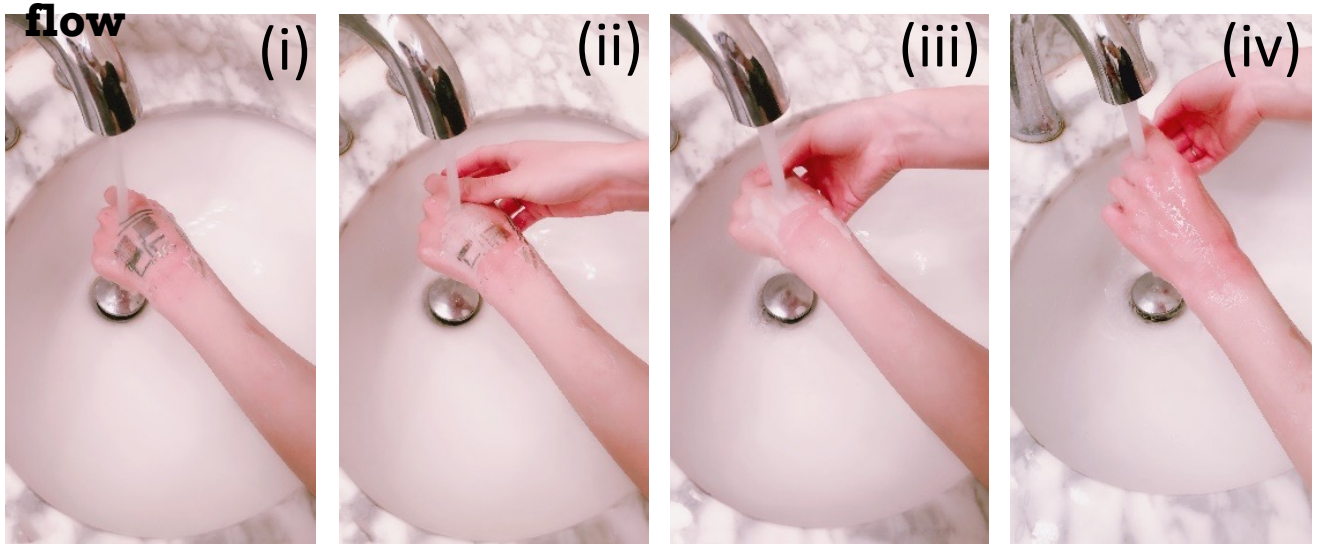
EASY REMOVAL OF SENSORS

Removal of the device from the skin in warm water flow



ACS Appl. Mater. Interfaces 12, 45504 (2020)

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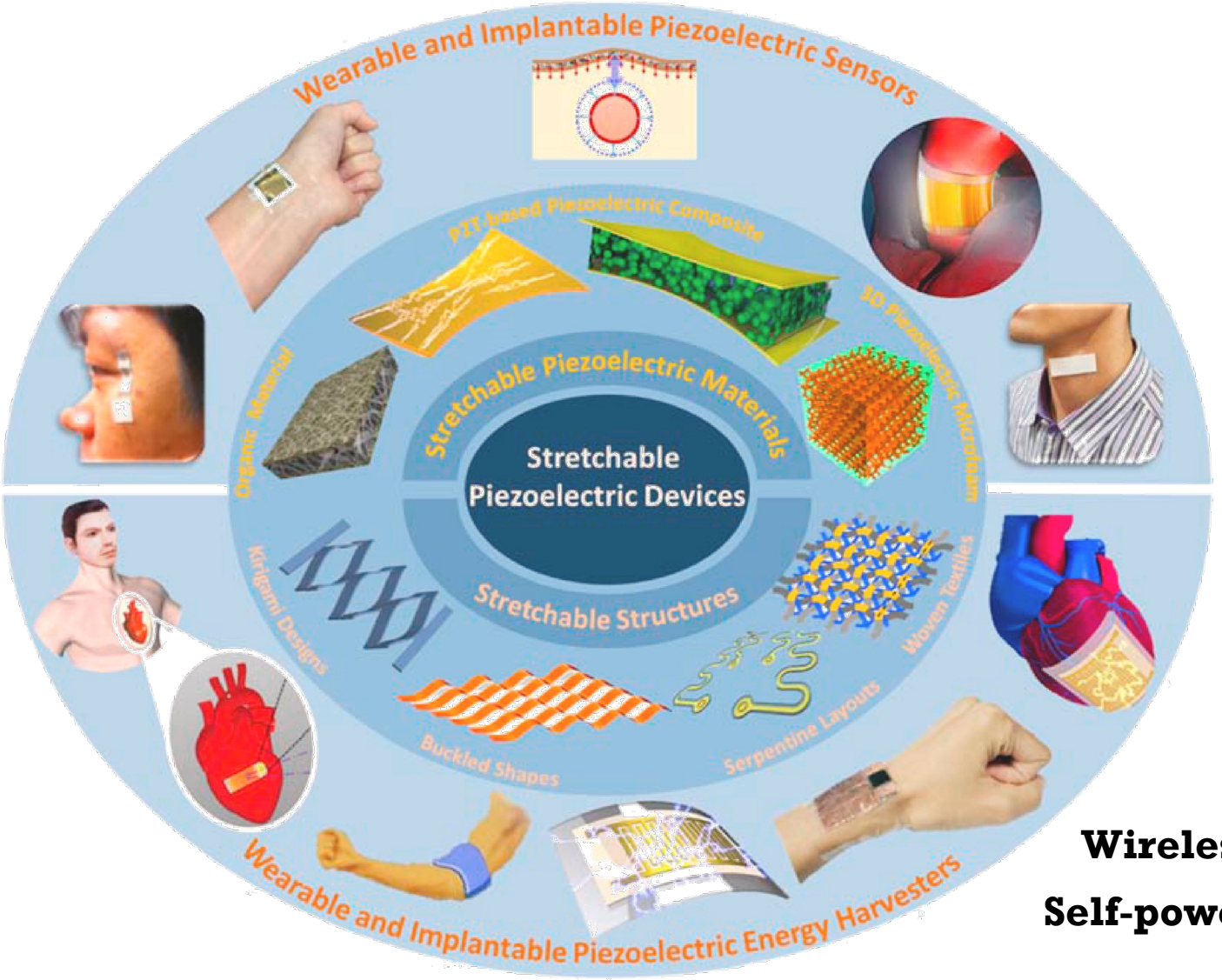
FUTURE PERSPECTIVE



Wireless

Self-powered

Biosens. Bioelectron. 168, 112569 (2020)

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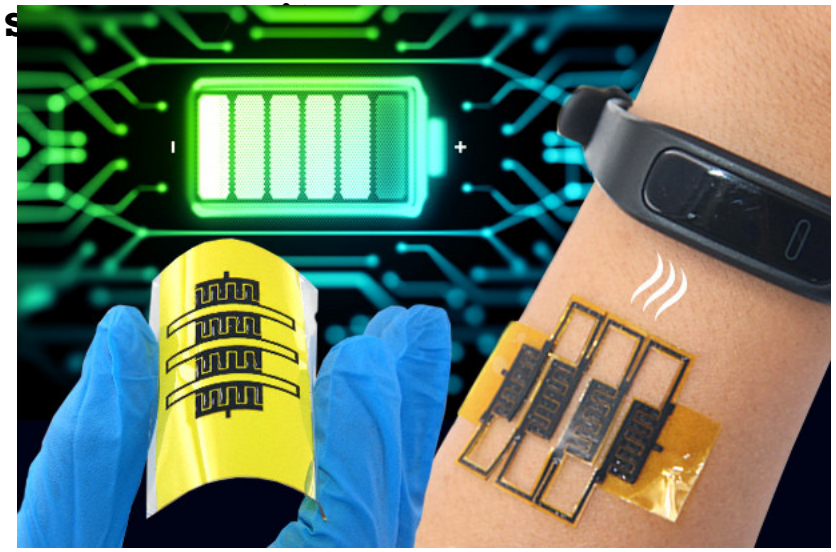
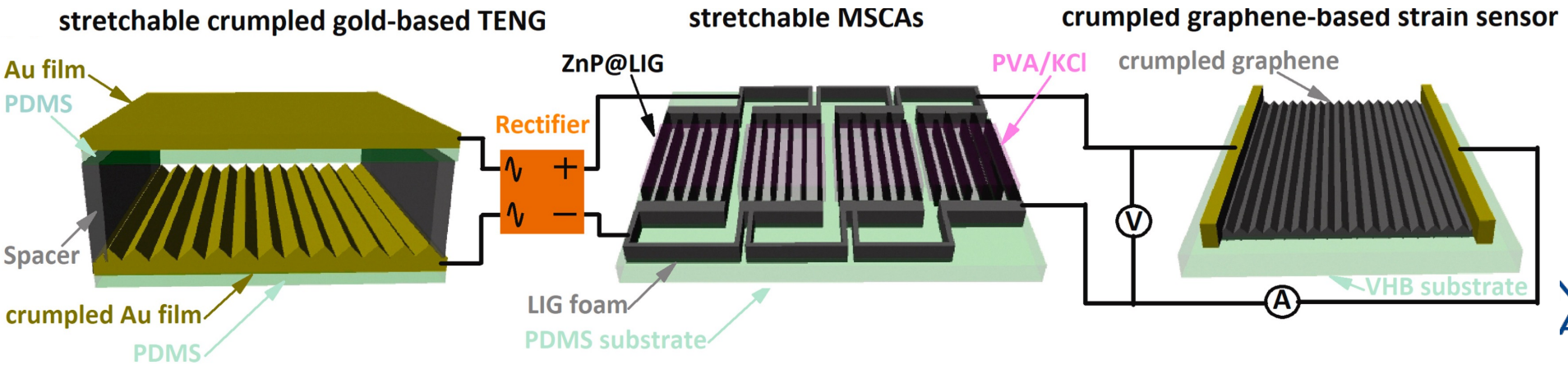
SELF-POWERED STRETCHABLES

Stretchable ZnP@LIG



Nano Energy 81, 105609 (2021)



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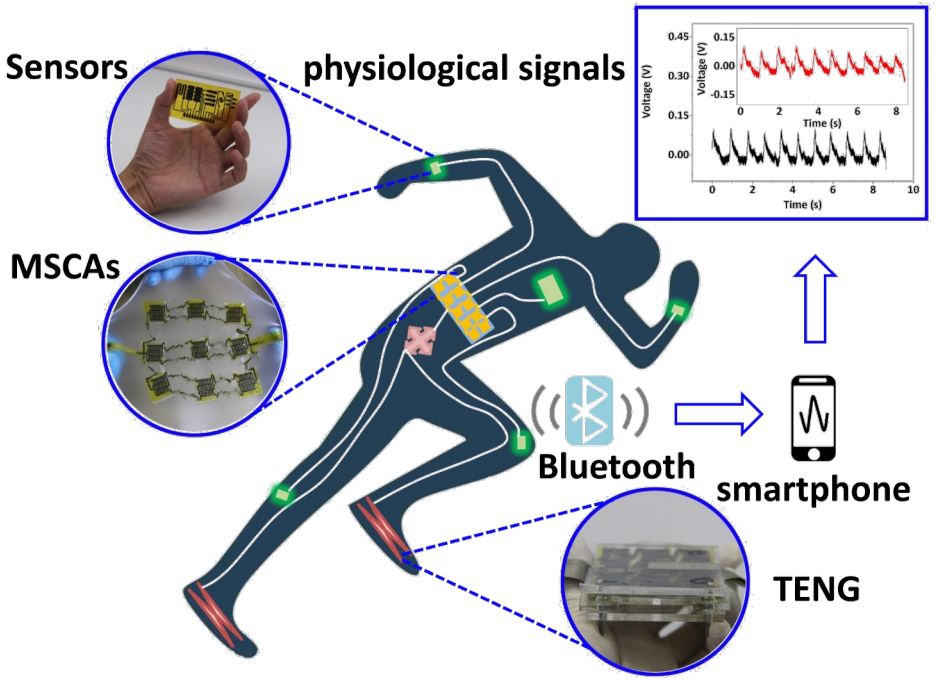
STANDALONE STRETCHABLE SYS.

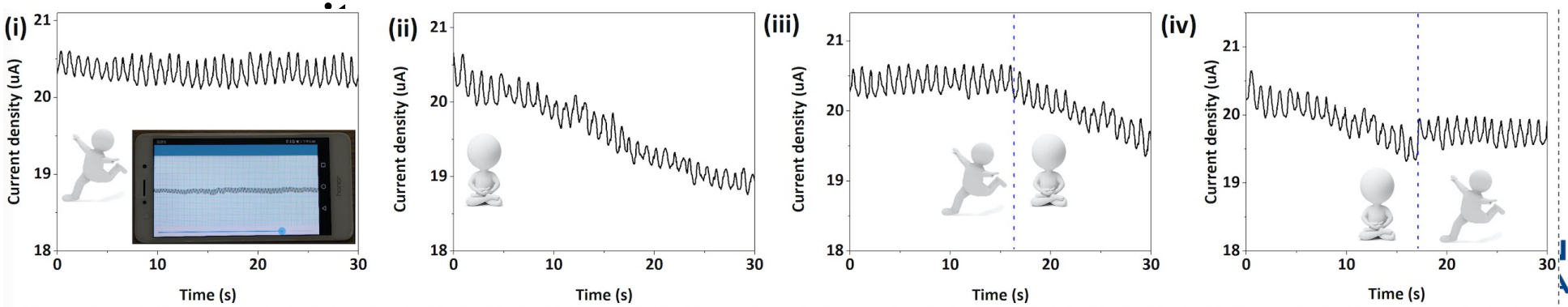


Appl. Phys. Rev. 9, 011413 (2022), **Featured Article**

RF charging

Nano Energy 96, 107069 (2022)

Pulse sensor powered by the self-charging



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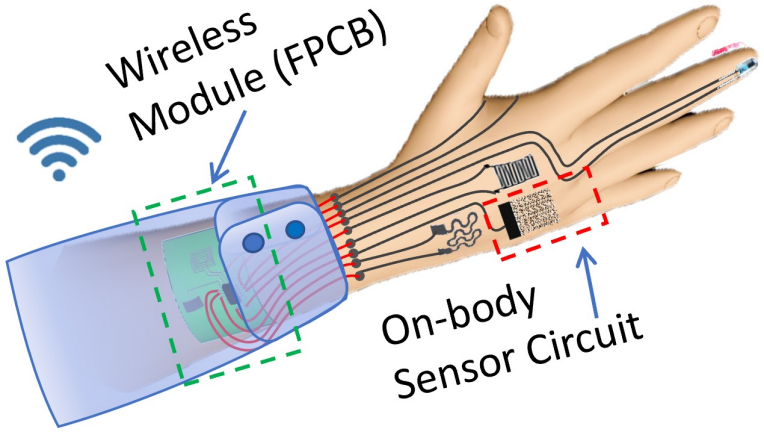
ANICS

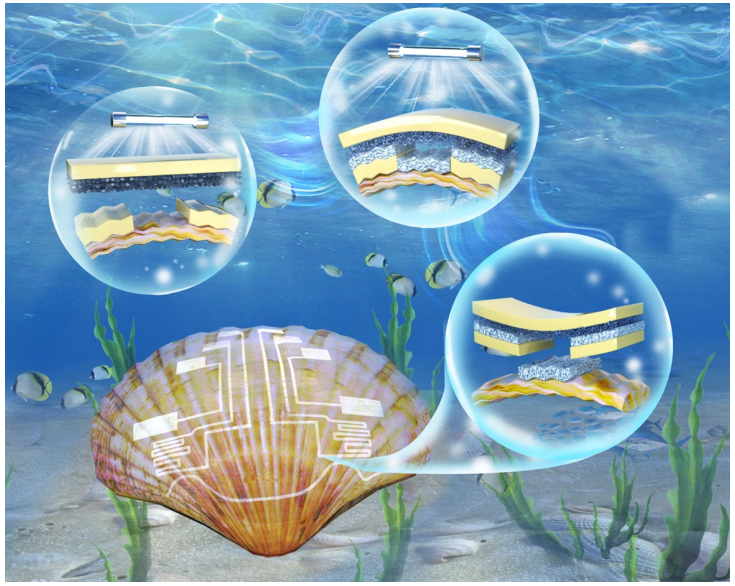
THANK YOU FOR YOUR ATTENTION!

LIG composites

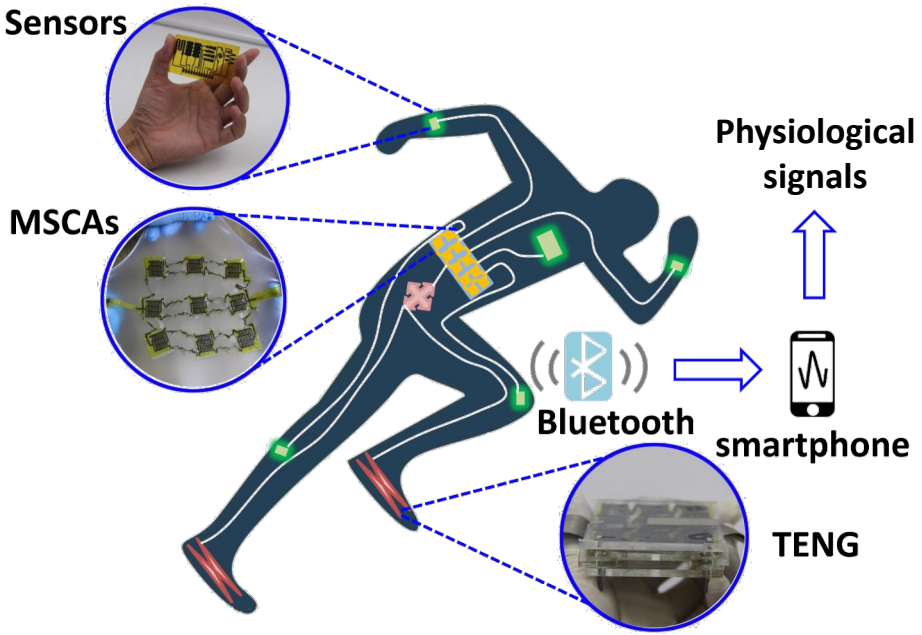
Body area sensor network



3D freeform fabrication



Standalone stretchable platform



THANK YOU

RFID JOURNAL LIVE!

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