Artificial Intelligence Biosensor: Endless Frontiers

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个 人 简 介

Professor Xueji Zhang

- Fellow of the American Institute for Medical and Biological Engineering (AIMBE)
- Fellow of the Royal Society of Chemistry (RSC)
- Foreign academician of the Russian Academy of Engineering (RAE)
- Vice Chairman for Chinese Center of the RAE
- Member of Academia Europaea (MAE)
- Chairman of China Biological Testing and Monitoring Industry Innovation Alliance
- Outstanding Talent of Shenzhen: A . Category Outstanding Talent of Nanjing: A
- World's Top Scientists of Stanford
- National Endowed Professor

The Vice President of Shenzhen University, Director of Shenzhen Key Laboratory of Nano-Biosensing Technology, Executive Dean of Beijing Institute of Precision Medicine and Health, and Director of Beijing Key Laboratory of Biosensing. In 2008, serving as the deputy director of the Clinical Biochemistry Department of 301 Hospital. 1999-2012, researcher, chief scientist and senior vice president of World Precision Instruments Corporation. 2011-2016.Beijing University of Science and Technology, Dean of Nanjing University of Science and Technology

More than 700 SCI papers have been published in prestigious journals such as Science, Nature, JACS, and Advanced Materials. More than 200 patents have been applied for (more than 30 industrialization projects). 9 books has published in both Chinese and English , and work has been cited more than 30,000 times. Serving as the editor-in-chief, deputy editor-in-chief, and editorial board member of 24 international journals including "Sensors & Diagnostics" of the Royal Society.

BEST Team, Best Dream, Dream Team, Best Dream Team.

- "Perfect integration of industry, academia and research
- Simultaneous development of education, scientific research, results transformation and business incubation
- Both working and earning; both "heavenly" and "earthly".
- From bookshelf to shelf.

Innovative Talent Cultivation Centre,
Comprehensive Backbone Transportation Ba
Theory and technology source creation centr
international and domestic exchange base
High-tech Achievement Transformation Centre,
Incubation Base for Featured Enterprises

a large domestic teams in production, academia, research, application

- **Total headcount exceeding 1,000 individuals (including teachers, students, and staff**
- **Spanning multiple research institutes: NIH， Harvard, MIT, Stanford, UC Berkeley, UCSD, UCI, UCLA, UF, USF, Columbia, NYU, U of Tokyo, ETH, U of W Australia, Hospital 301， Beijing Cancer Hospital， Peking Univ、Tsinghua， NJU，WHU，Nankai Univ，HNU，NJUST，SDU、HFUT，HIT， SMU， QDU，AHSTU，some institutes of CAS**
- **Owning educational institutions (university) ,CBDBM**
- **Owning an entrepreneurial investment fund (fund) and two high-tech business incubation parks (technology parks), as well as an overseas innovation cencter.**
- Owning and participating in multiple innovative high-tech enterprises:**Xueji Bo Chuang、Jiangsu xiehe，ZJTK， Princekin ， Yixin Bo Chuang、ZHKY， HHF、Jiangsu MDK、Shangpin Tech、Refresh et al.)**

What we have?

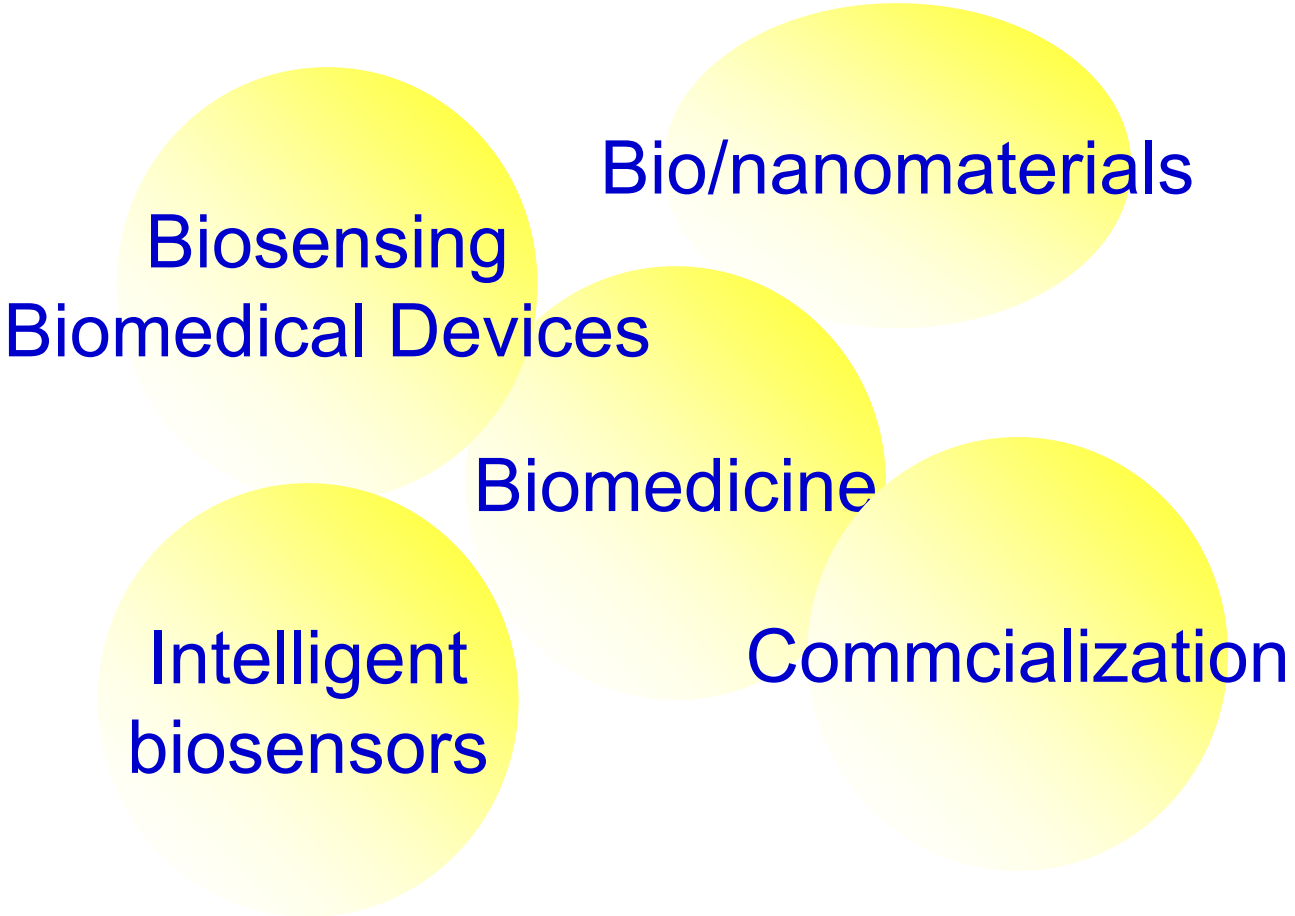
Beijing Key Lab for Bioengineering and Sensing Technology
Research Center for Bioengineering and Sensing Technology

Bioengineering Sensing Technology Lab

Research Center for Intelligent and Wearable Technology

Future AI lab

What we are doing?

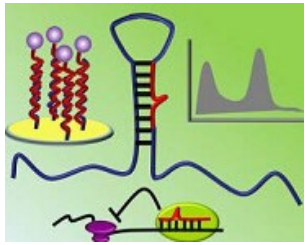


Research Field

1. Nucleic Acid Analysis and Diagnostic System
2. Portable Analysis and Detection Method
3. Fluorescent Gold Cluster Sensing
4. Smart Micro-Nanomotors
5. Smart Biomimetic Interface Sensing
6. Smart wearable Sensor

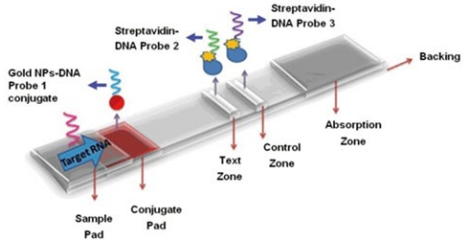
1,2,3,Tumor biomarker Analysis

- Designed Various Micro/Nano Probes for Trace Detection of Tumor miRNA
- Developed various new rapid analysis methods and technologies
- Developed a Novel Biomarker Analysis Method using Luminescent Nanomaterials



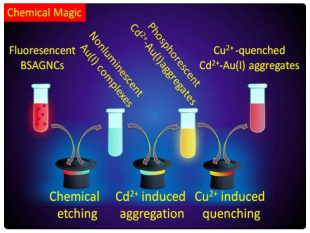
High-Sensitivity miRNA Probes and Nanotherapeutics

Anal. Chem. 2023, 95, 30, 11236–11242
Adv. Healthcare Mater. 2023, 12, 2300367.
ACS Nano 2023, 17, 2, 1174–1186
ACS Appl. Mater. Interfaces 2023, 15, 19, 22977
ACS Nano 2022. 10.1021/acsnano.2c08687
Anal. Chem. 2022, 94, 6599-6606.
Small 2022, 18. 2106281
Chem. Eng. J. 2022, 444.
Biomaterials 2022, 287, 121603-121603.
Biosens. Bioelectron. 2022, 213.
Nano Today 2021, 40.
Nat. comm. 2020, 11 (1), 1735.
Adv. Mater. 2019, 31, e1807888
Chem. Rev. 2013, 113, 6207
Anal. Chem. 2017, 89, 648
Adv. Funct. Mater. 2017, 1605592



Portable Rapid Analysis Chip

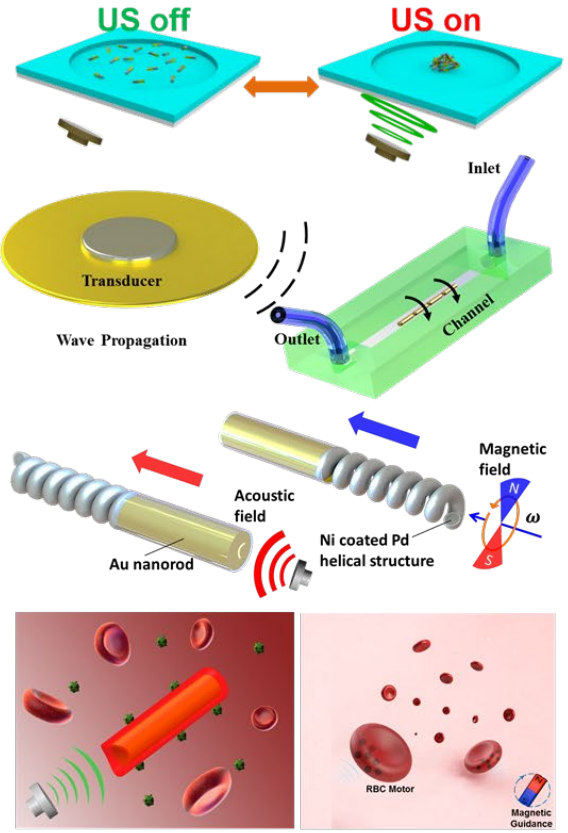
Anal. Chem. 2023, 95, 29, 11164–11171
Anal. Chem. 2022, 94, 1325-1332.
ACS AMI, 2022, 14, 52684-52690.
Chem. Commun. 2022, 58, 1701
Acs Sensors 2022, 7, 2654
Biosens. Bioelectron. 2022, 211.
Sens. Actuator B Chem. 2021, 344.
ACS Nano 2020, 14, 4654-4661.
Nat. Comm, 2019, 10, 1036.
Adv. Mater. 2014, 26, 1771
Biosens. Bioelectron. 2015, 396
Adv. Mater. 2015, 27, 6878
ACS Nano 2017, 11, 621

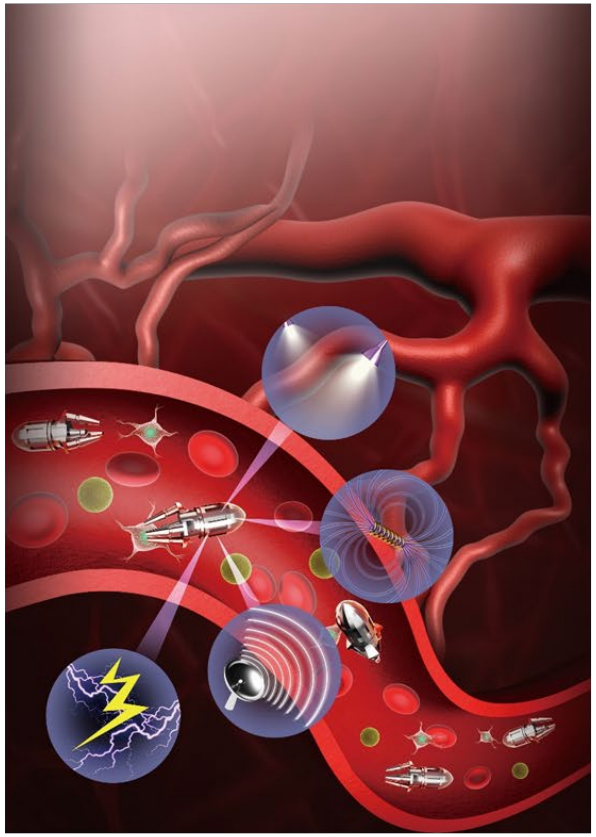


Novel Fluorescent Probe for biomarkers

Anal. Chem. 2023, 95, 14, 5886–5893
Anal. Chem. 2022, 94, 7, 3408–3417
NPG Asia Mater 14, 97 (2022).
J. Am. Chem. Soc. 2022, 144, 14388.
Biosens. Bioelectron. 2022, 197.
Sens. Actuator B Chem. 2022, 370.
Anal. Chem. 2022, 94, 5838-5845.
Anal. Chem. 2022, 94, 3408-3417.
Anal. Chem. 2021, 93, 16718-16726.
Biosens. Bioelectron. 2021, 192.
Biosens. Bioelectron. 2015, 66, 155
Anal. Chem. 2016, 88, 6071
Anal. Chem. 2016, 88, 11193
J. Mater. Chem. C 2016, 4, 11482
ACS AMI 2016, 8, 3107

4 Smart Micro-Nanomotors

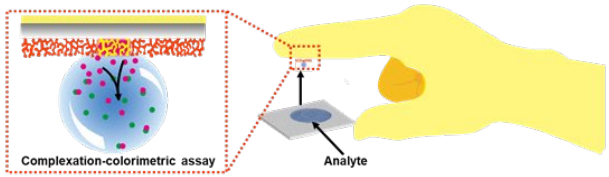


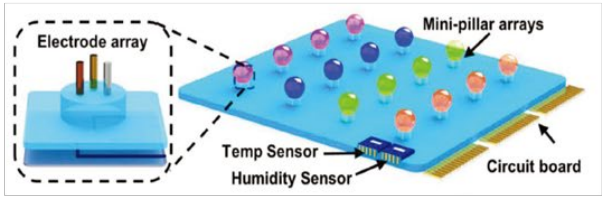


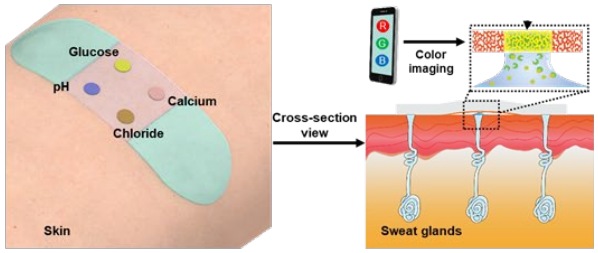
Biosens. Bioelectron., 2023, 220. Adv. Mater. 2022. 2201042
Anal. Chem. 2022, 94, 4135. Appl. Mater. Today 2021, 23, 101034.
Talanta 2021, 233, 122517. Biosens. Bioelectron. 2020, 158, 112185,
Nano Res. 2021, 14, 654-659. Anal. Chem. 2020, 92, 7816
ACS AMI, 2018, 10, 42979, Appl. Mater. Today 2019, 17, 85
AMT, 2020, 18, 100504; Adv Funct Mater, 2015, 25, 3881
JACS.2015.137. 2163; JACS, 2014,136. 8552
Adv. Mater.2017,29, 1603250; ACS Nano, 2014, 8, 12041

Applications of Driving and Controlling Micro-Nanoparticles in Aggregation Analysis and Detection

5 Smart Biomimetic Interface Sensing

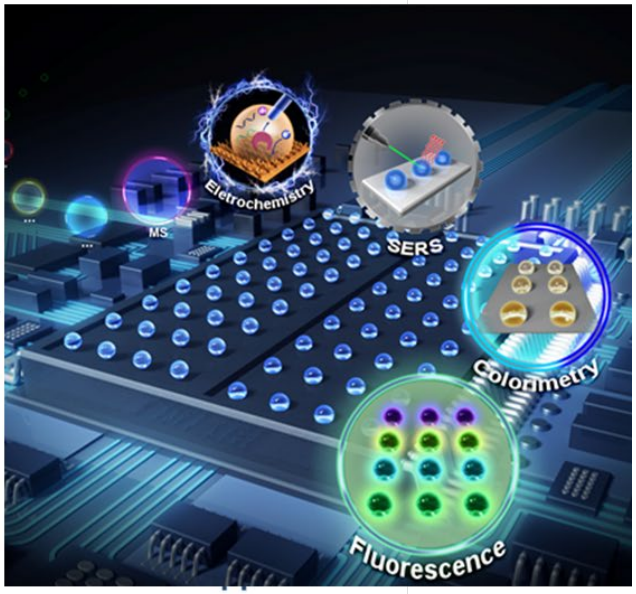






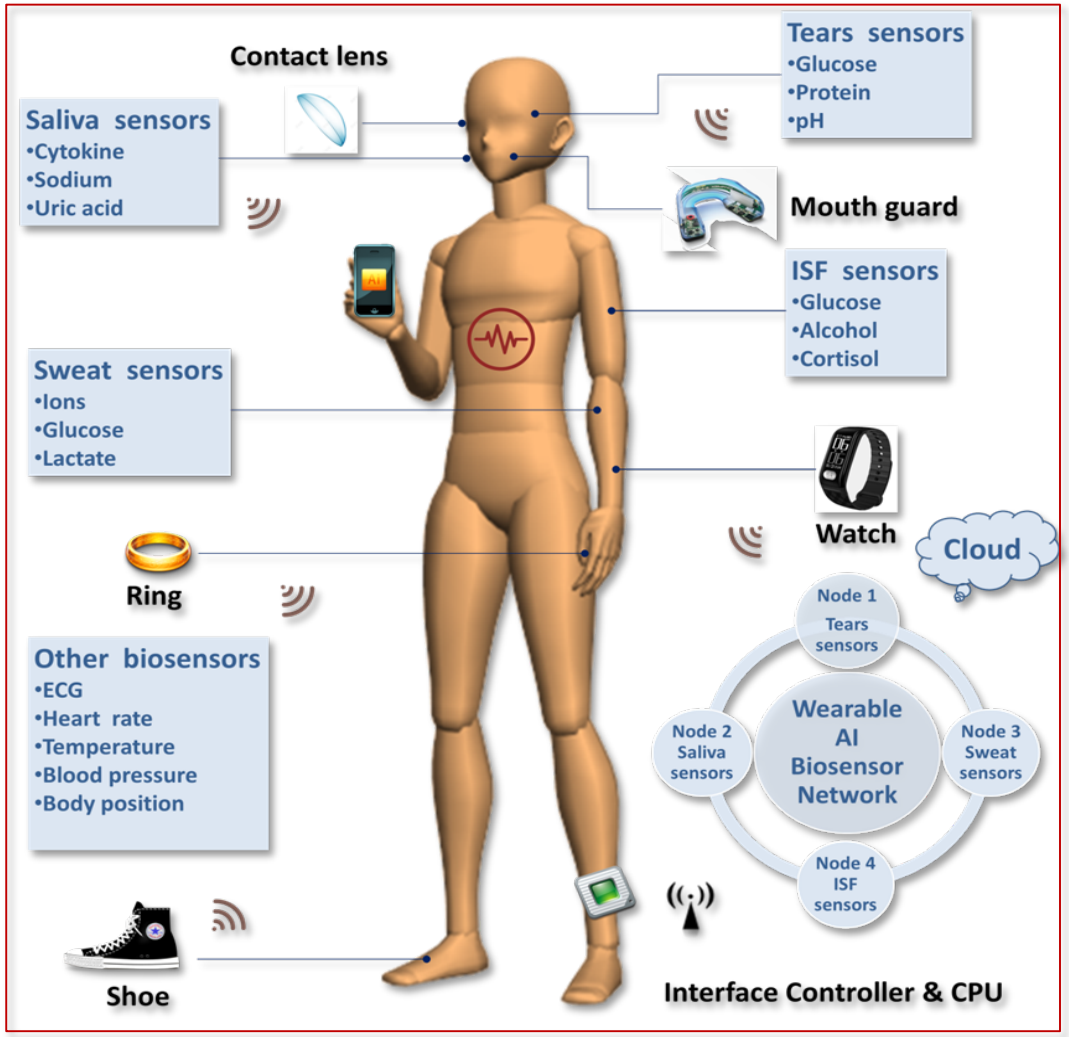
BB, 2023, 220, 114903; Chin. Chem. Lett. 2022, 33, 3879-3882.
Anal. Chem. 2022, 94, 4135; Nanoscale 2021, 13, 739-745.
Anal. Chim. Acta 2022, 1234, 340523.AFM,2020, 30, 1910329.
ACS Sens 2020, 5, 1548； ACS Nano 2020, 14, 559
ACS Nano, 2017, 11, 621; Nanoscale, 2016, 8, 18612
Biosens. Bioelectron, 2016, 86,951; ACS Sens 2018, 3, 72
Nanoscale, 2018, 10, 20990,； Chem. Soc. Rev. 2019, 10,
Anal. Chem. 2019, 91, 4296； Anal. Chem. 2018, 90, 14105

Chem. Soc. Rev. 2019



Smart Biomimetic Interface for biosensing

5. Smart wearable Sensor



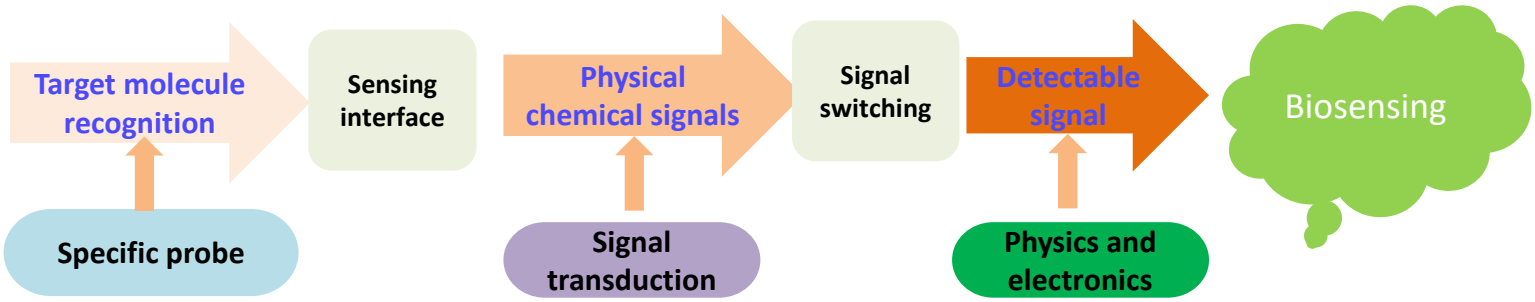
Nano Lett. 2019, *19* (9), 6592-6599.
Anal. Chem. 2019, *91* (7), 4296
Anal. Chem. 2018, *90* (24), 14105
ACS Sens 2020, *5* (6), 1548-1554.
Biosens. Bioelectron. 2020, *152*, 112013.
ACS Nano 2020, *14* (1), 559-567.
Talanta 2020, *212*, 120801.
iScience 2021, 24 (1), 102028.
Trends Anal. Chem. 2021, 134, 116130.
Nano Lett. 2021, 21, 8880-8887.
Chem. Eng. J. 2022, 433, 134625.
Sens. Actuator B-Chem. 2022, 359, 131586.
Anal. Chim. Acta 2022, 1208, 339843.
J. Mater. Chem. C, 2022,10, 14027-14052
ACS Appl. Mater. Interfaces 2021, 13, 14, 17110
Chem. Eng. J , 2022, 430,132605.
Macromol. Mater. Eng.2021,306, 2100478.
Analytica Chimica Acta, 2022, 1208, 339843
Nano Lett. 2021, 21, 19, 8126–8134
Biosens. Bioelectron. 2022, 210, 114297.
ACS Appl. Mater. Interfaces 2021, 13, 47, 56607–56619
npj Flexible Electron. 2022. 6, 60
Adv. Fiber Mater. 2022, 4:361–389
Sens. Actuator B Chem.,2022, 359,131586.
Nano Energy, 2022, 101,107559.
Nano Lett. 2022, 22, 2, 740–750
Nano Energy, 2022, 97,107114.
Nano Energy, 2021, 85,105941.
Talanta 259: 124507.
Applied Physics Reviews 2023, 10(1).
Biosens. Bioelectron. 2023, 237, 115434.
ACS Sens. 2023, 8, 4, 1766–1773

Designed and developed wearable sensors, textile-based flexible mechanical sensors, and some of these sensors have undergone multiple rounds of financing

Introduction to biosensors

What is biosensing?

A biosensor is an instrument that is sensitive to biological substances and converts its concentration into electrical signals for detection. Such biosensor composes of a bio-sensitive material as a **recognition part**, **a physical and chemical transducer**, and **a signal amplifying device**.

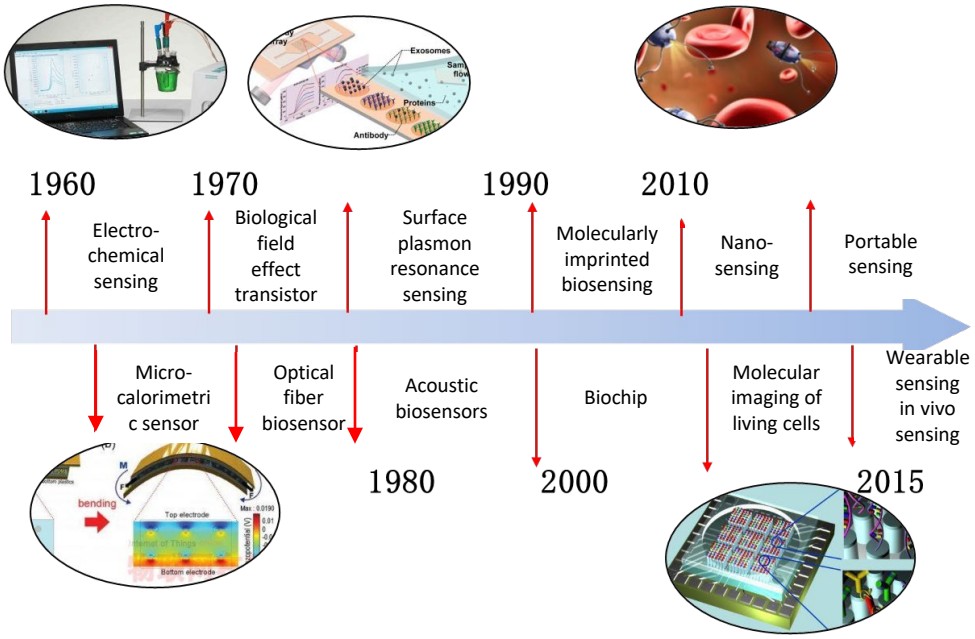


Biosensor schematic

Biosensor type According to the identification elements: enzyme sensor, microbial sensor, cell sensor, tissue sensor, and immunosensor.

- According to transducers of biosensors: bioelectrode sensors, semiconductor biosensors, photobiosensors, thermal biosensors, piezoelectric crystal biosensors.
- According to the recognition element: bioaffinity biosensor, metabotropic or catalytic biosensor.

Evolution of Biosensor

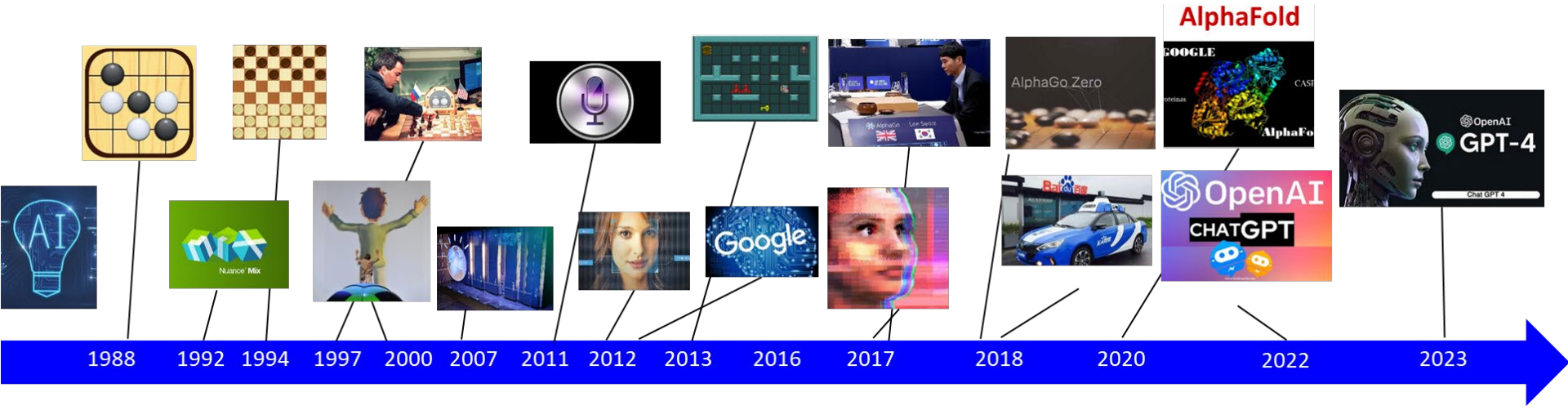


History of biosensor

Biosensors + internet

- The main players in the global biosensor market include: Abbott, Siemens Medical, Nova Biomedical, Bayer, Johnson & Johnson, Medtronic, Roche and more.
- Geographically, North America is the world's largest market for biosensors. The compound annual growth rate (CAGR) is 8.9% during the forecast period. The Asia Pacific region will be the fastest growing region due to the expanding medical insurance penetration rate, large population base and continuous upgrading of the health care system.

AI-biosensing is the future trend



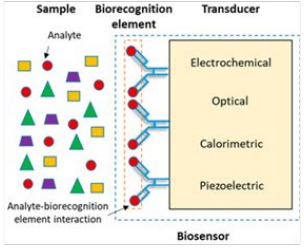
Big data and artificial intelligence

5G

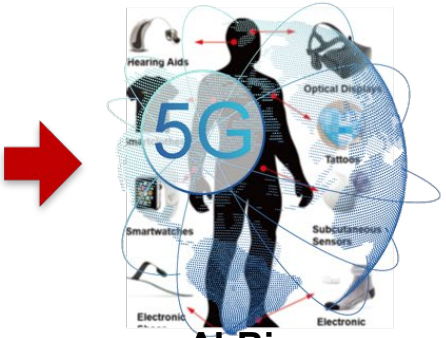
+

Big data and AI

+



Biosensors



AI-Biosensors

Trend:

- **Miniaturization**
- **Integrated**
- **Intelligent**
- **Networking**
- **Diversification**

The artificial intelligence technology system is gradually improved, and the combination of artificial intelligence technology and 5G will promote the rapid development of intelligent biosensors.

What is Intelligent Biosensors

Intelligent Sensor

WHAT IS AN INTELLIGENT SENSOR?

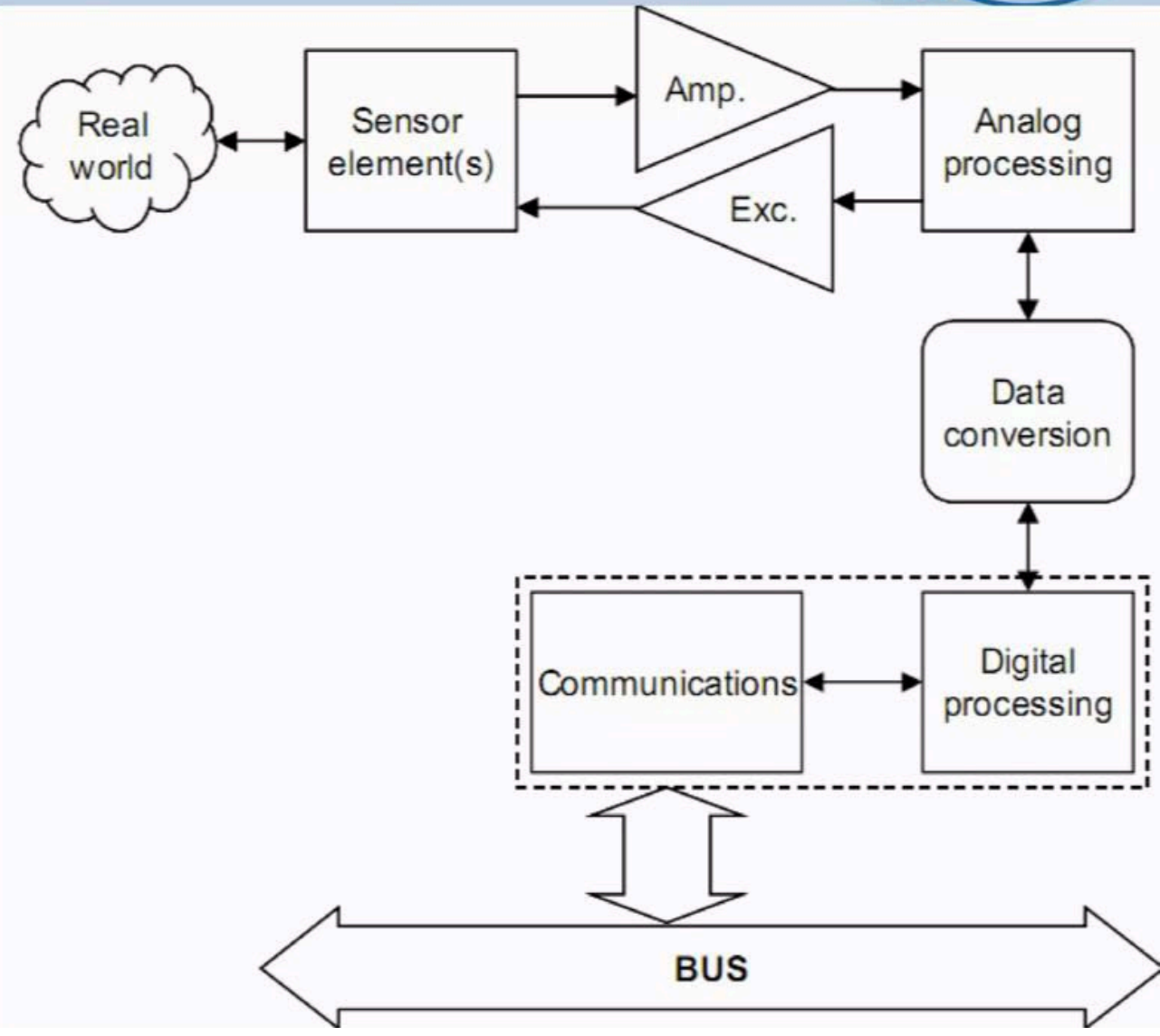
- A sensor that is capable of modifying its internal behavior to optimize the collection of data from external world along with advanced learning capabilities.

OR

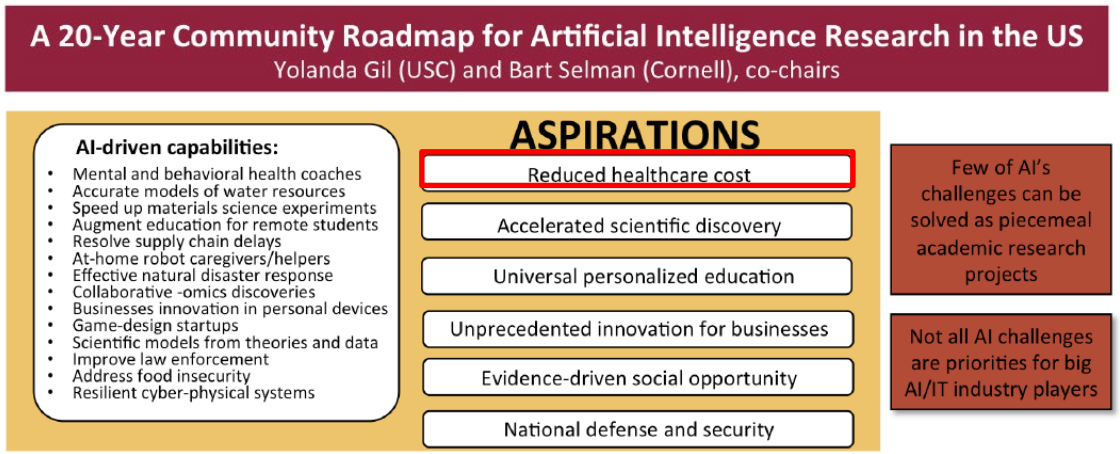
- A device that combines a sensing element and a signal processor on a single integrated circuit

- Basic integrated electronics (signal conditioning, ADC)
- A micro-processor
- Logic functions and decision making

Architecture of intelligent sensors.



Opportunities for AI-biosensing research

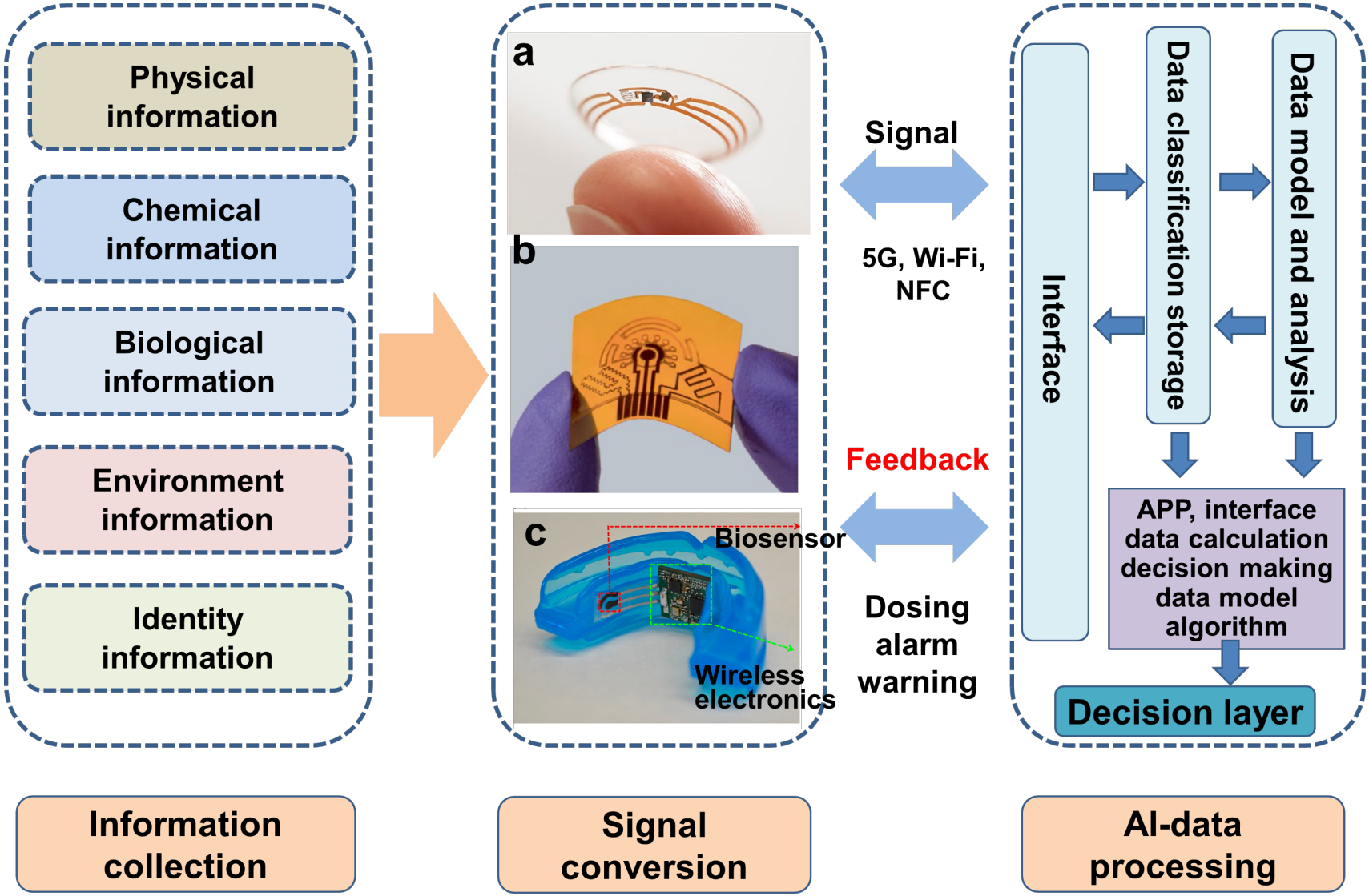


- **The "America's Artificial Intelligence for the Next 20 Years Research Roadmap" clearly lists "improving health care and quality of life" as the first of the six future developments of artificial intelligence.**
- **An analysis by Frost & Sullivan suggests that this cross-use of AI "may increase patient prognosis by 30% to 40% while reducing treatment costs by 50%.**

- The State Council issued the <Opinions on promoting the development of "Internet + medical health">, clearly stating that "**Internet + Healthcare**" supports the development of medical health-related artificial intelligence technology, medical robots, large medical equipment, and emergency medical, bio 3D printing and wearable devices. Comply with the development trend of industrial Internet innovation, improve intelligent manufacturing level of medical and health equipment, and promote industrial upgrading.
- Beijing, Shanghai, and Guangzhou have published policies to promote artificial intelligence medical care. Shenzhen issued the <organisation and implementation of the 2018 "Internet+", artificial intelligence innovation and development and digital economy pilot major projects>, which listed artificial intelligence medical treatment as an important development direction.

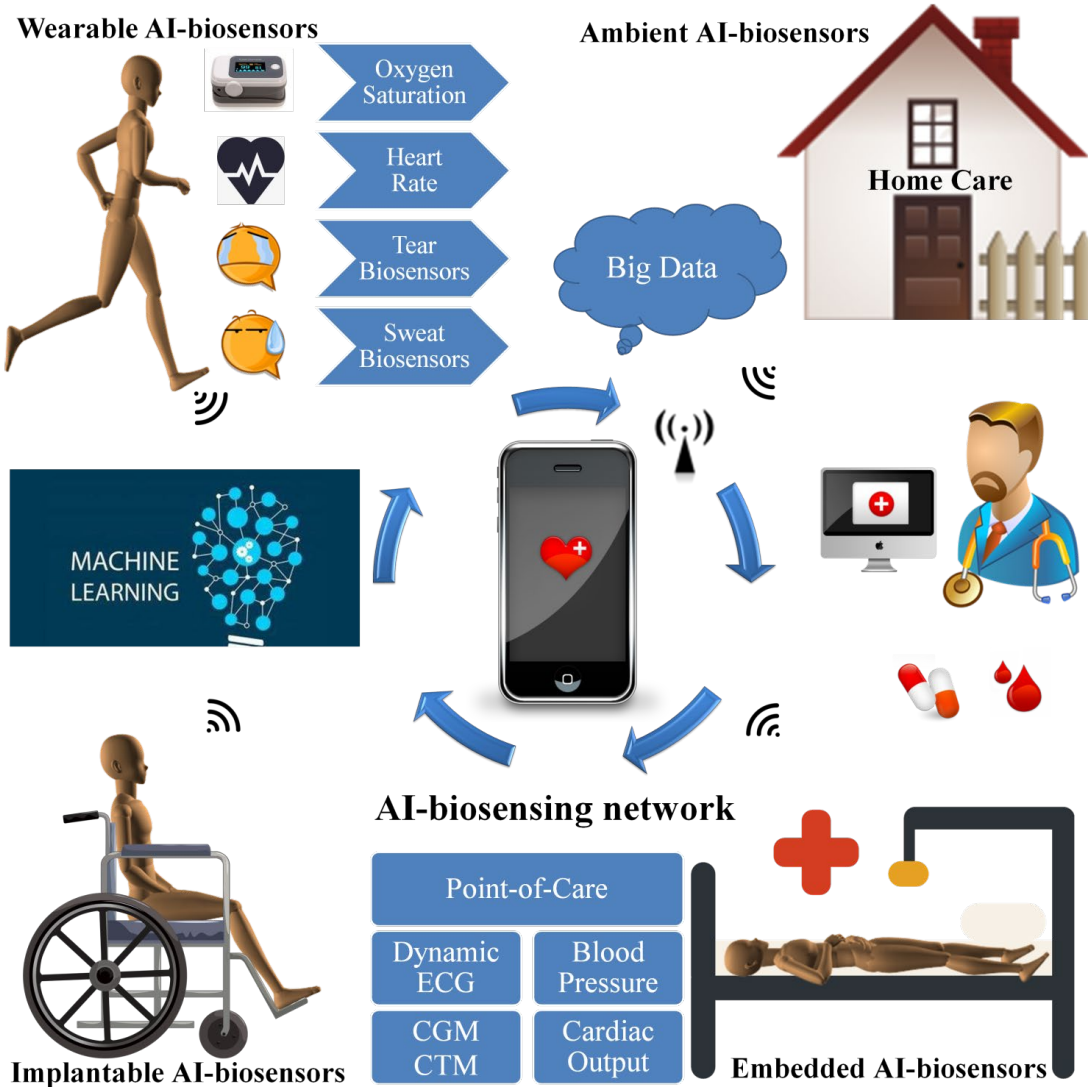
Through accurate diagnostic technology, medical efficiency can be greatly improved, and the high cost caused by unreasonable medical treatment can be reduced, which has wide social benefits.

Basic architecture of AI-biosensor networks

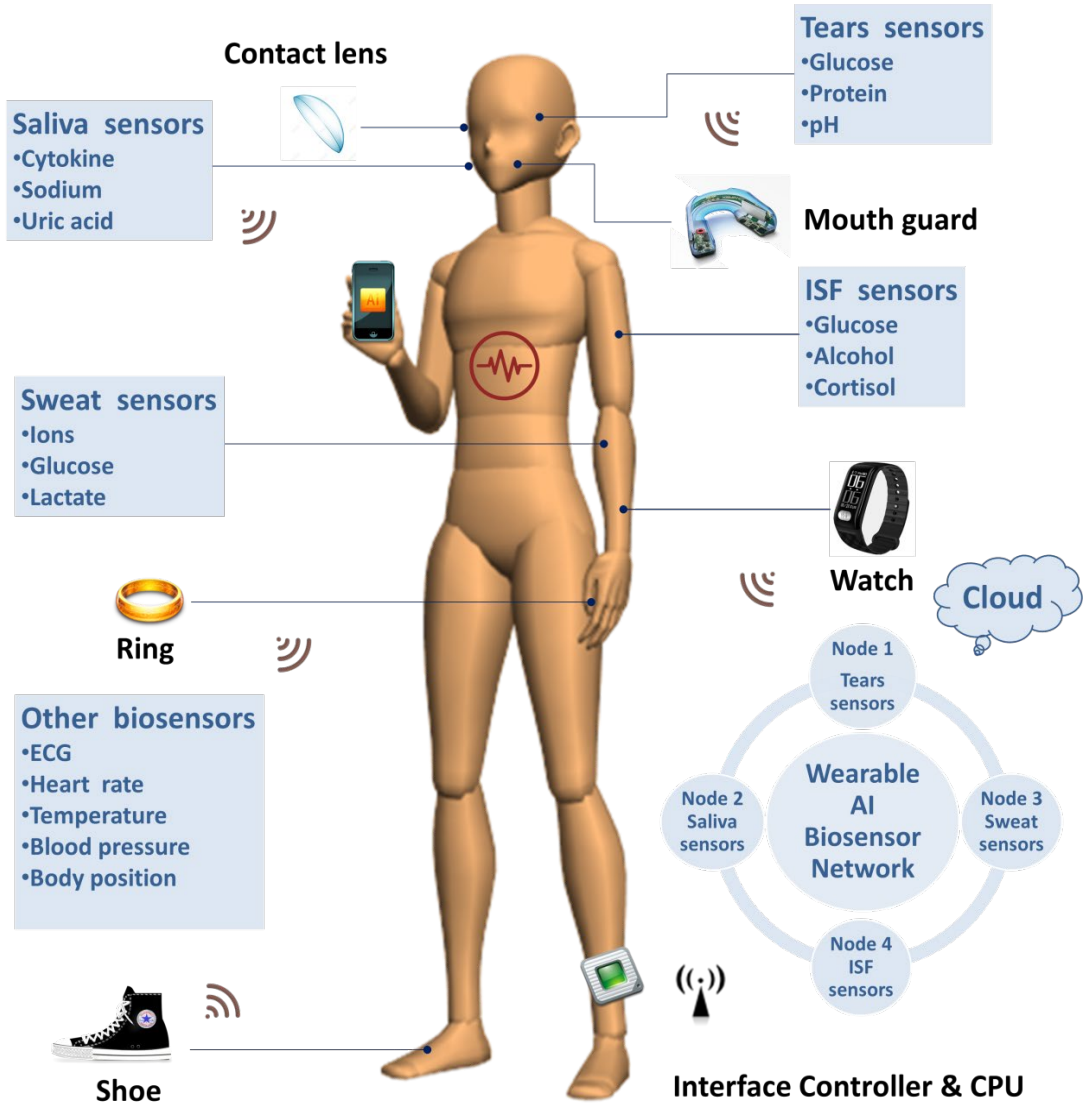


Biosens. Bioelectron. ***2020****. 165*, 112412.

AI-biosensor networks (AIBN)

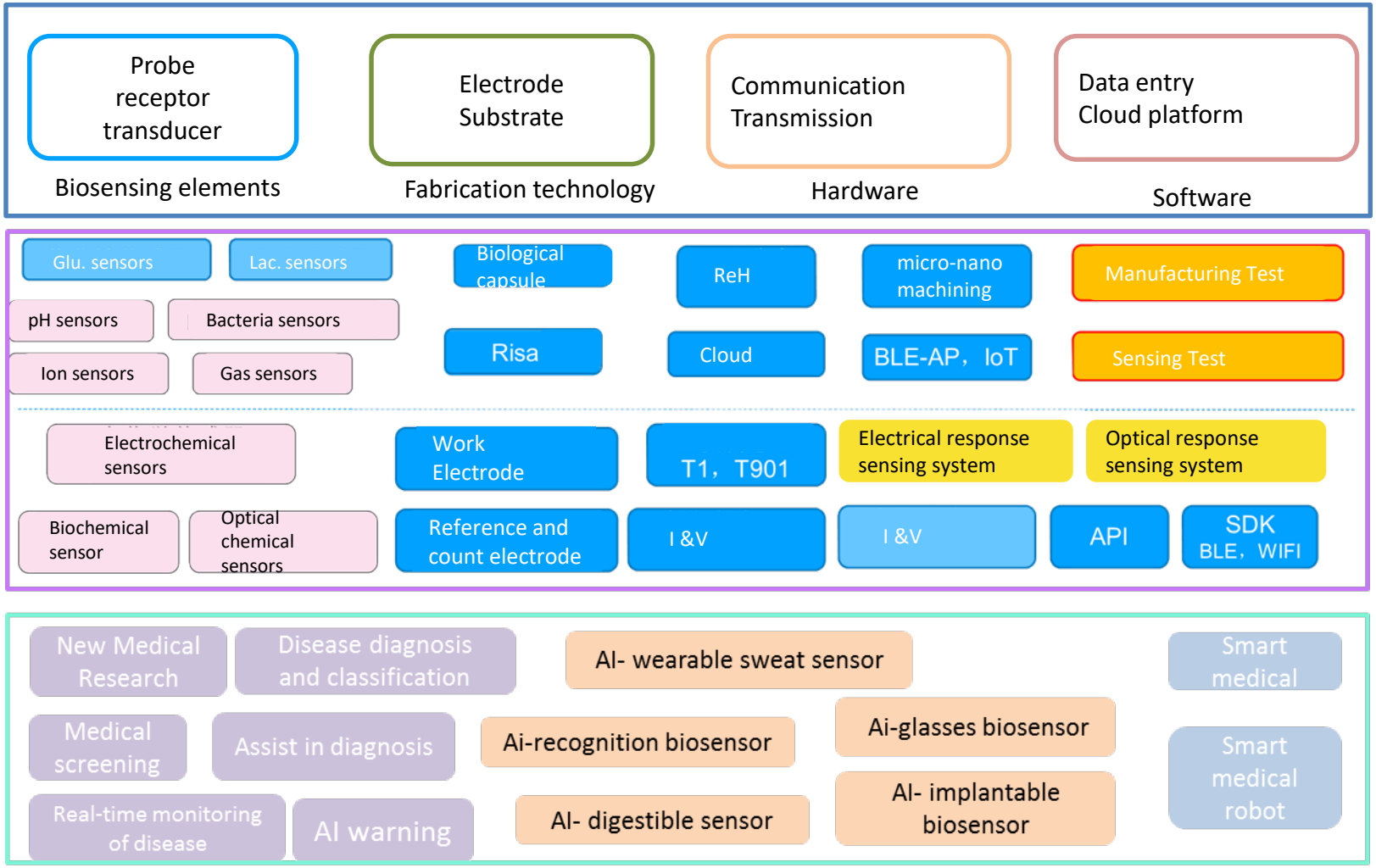


Wearable AI-biosensor networks



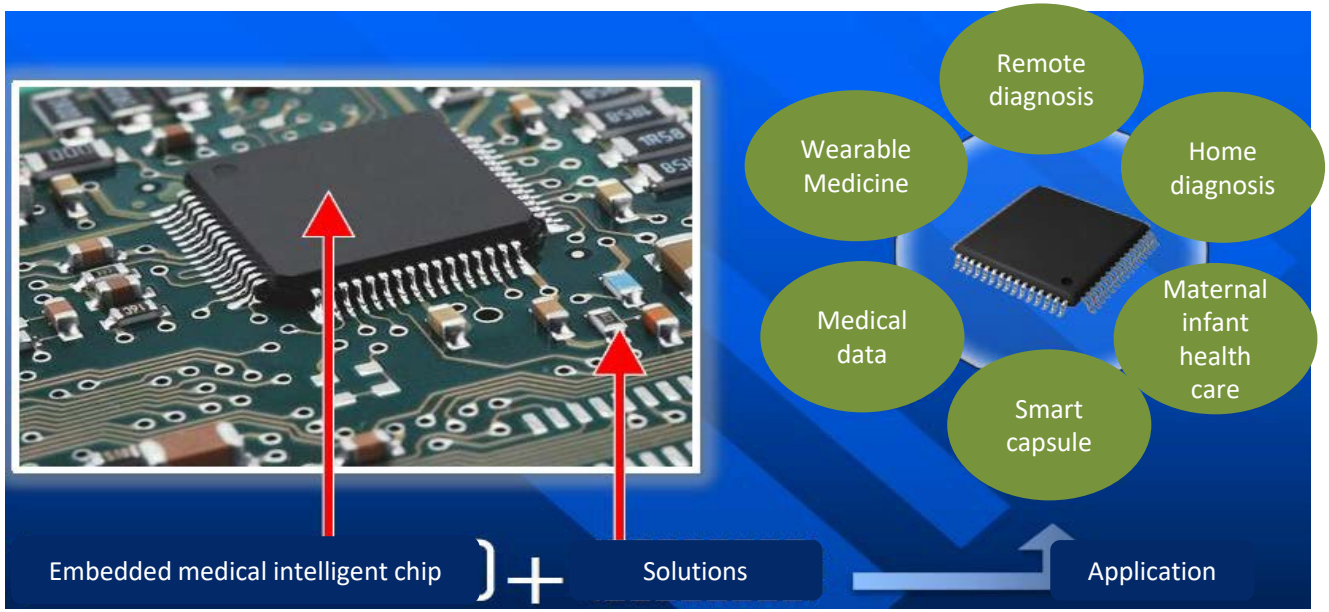
Biosens. Bioelectron. **2020,** *165*, 112412.

AI-Biosensor Development Program



Features of AI-biosensor

- **AI-diagnosis:** The diagnostic algorithm in the microprocessor can verify the output of the sensor and present the diagnostic information.
- **Big data processing**: The use of self-contained space for historical data and various necessary parameters of data storage, greatly improving the performance of the controller.
- **Self-learning/adaptive**: Embedded microprocessor with advanced programming function. In the working process, the AI-biosensor can reconstruct the structure and parameters according to certain behavioral criteria, and has adaptive functions.

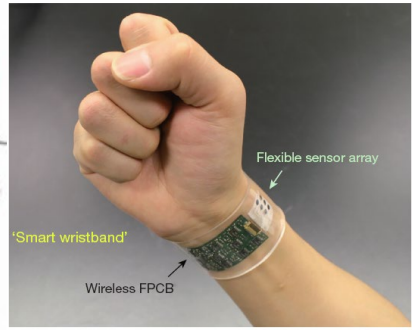


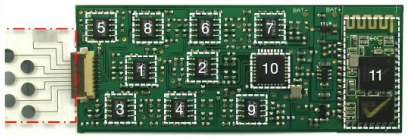
Internet + medical health

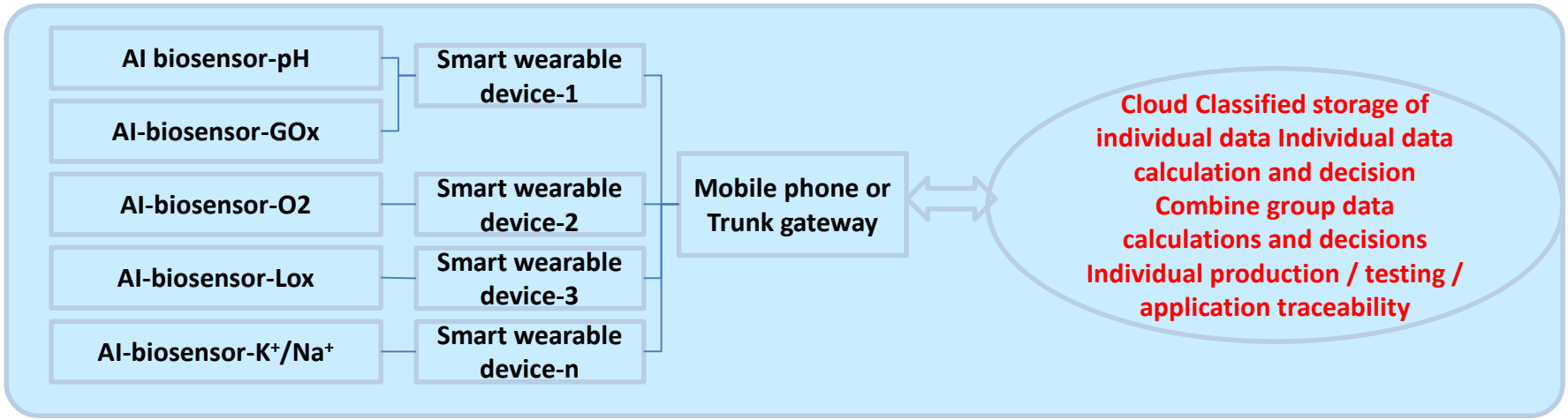
Future AI-biosensor: AI wearable sweat biosensor

AI-biochemical sweat sensor

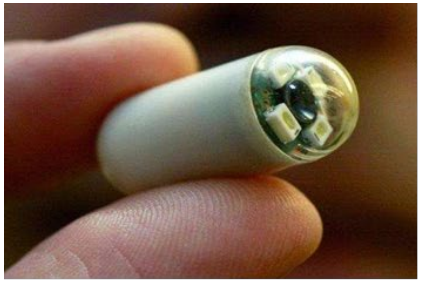
- Structure: integrating biosensing, microelectronics, micro-flow, materials, miniaturization, array, multi-scene implantation;
- Function: without the need for complex signal processing on the application side;
- System: Each sensor has a unique serial number, each sensor can enter the network, and even interact with the cloud control system, including status and algorithm;
- Application: Sensors can be used in arrays, mutually corrected, and can coordinate decisions with big data and artificial intelligence algorithms in the cloud.

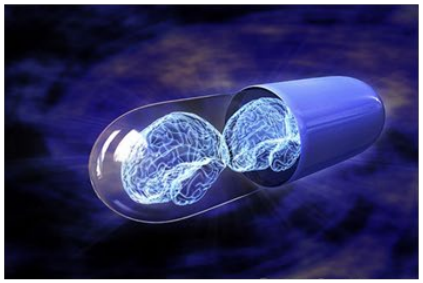


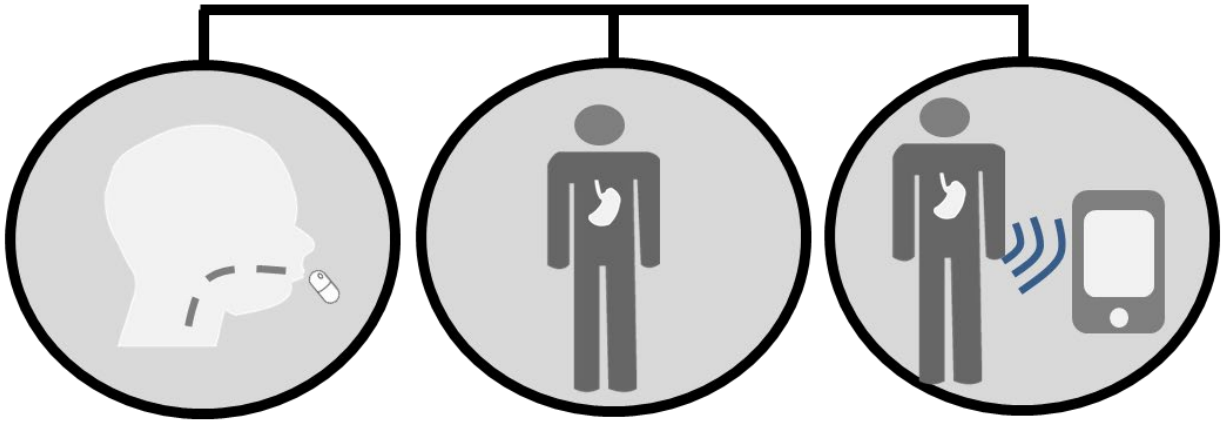




Future AI-biosensor: AI- swallowable biosensor



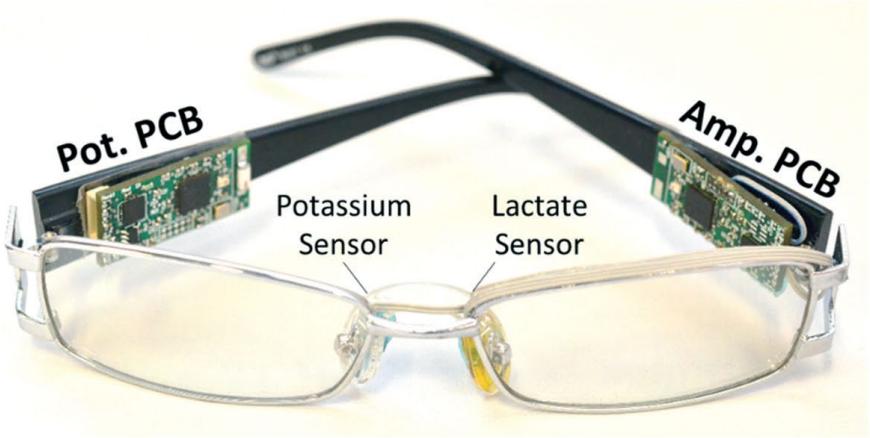




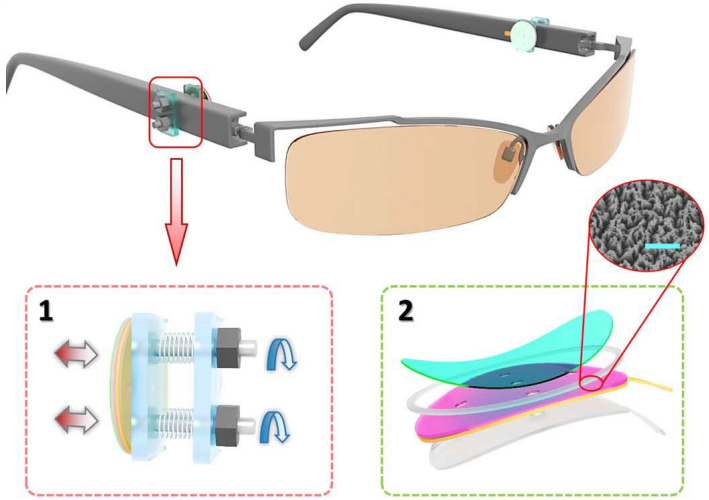
Consisting of a smart phone, smart pills and other accessory items, the digestible sensor is attached to the inside of the smart pill, and is powered by the interaction of the pill itself and the digestive tract liquid. The sensor transmits the detected data to the smartphone through the communication module. Or other terminals.

- Detect gastrointestinal tract breathing
- Monitored food intake
- Wound healing in vivo
- Rhythmic contraction of the digestive tract
- Drug delivery
- Detection of intestinal gas

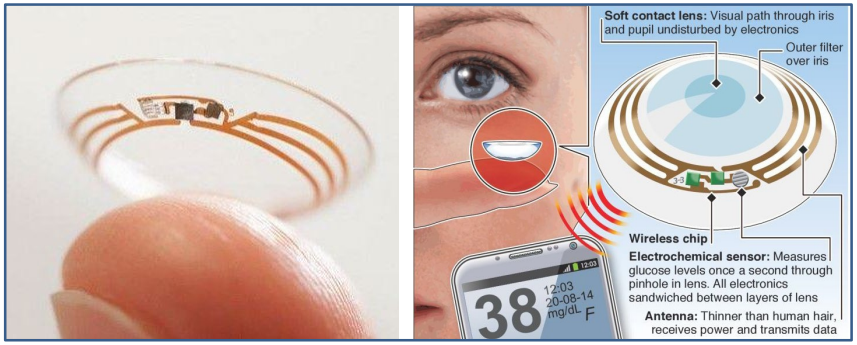
Future AI-biosensor: AI-glasses biosenser



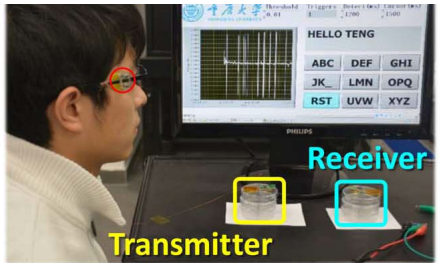
Real-time detection of electrolytes and metabolites



Self-powered wireless hands-free typing



Non-invasive tear blood glucose test



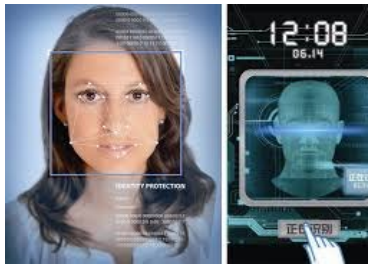
Future AI-biosensor: AI-recognition biosensor

AI-biosensor for identification

- Fingerprint recognition

→ Fingerprint, because of its lifetime invariance, uniqueness and convenience, has become almost synonymous with biometrics.

- Face recognition



→ including face image acquisition, face location, face recognition preprocessing, identity confirmation, identity search, etc.

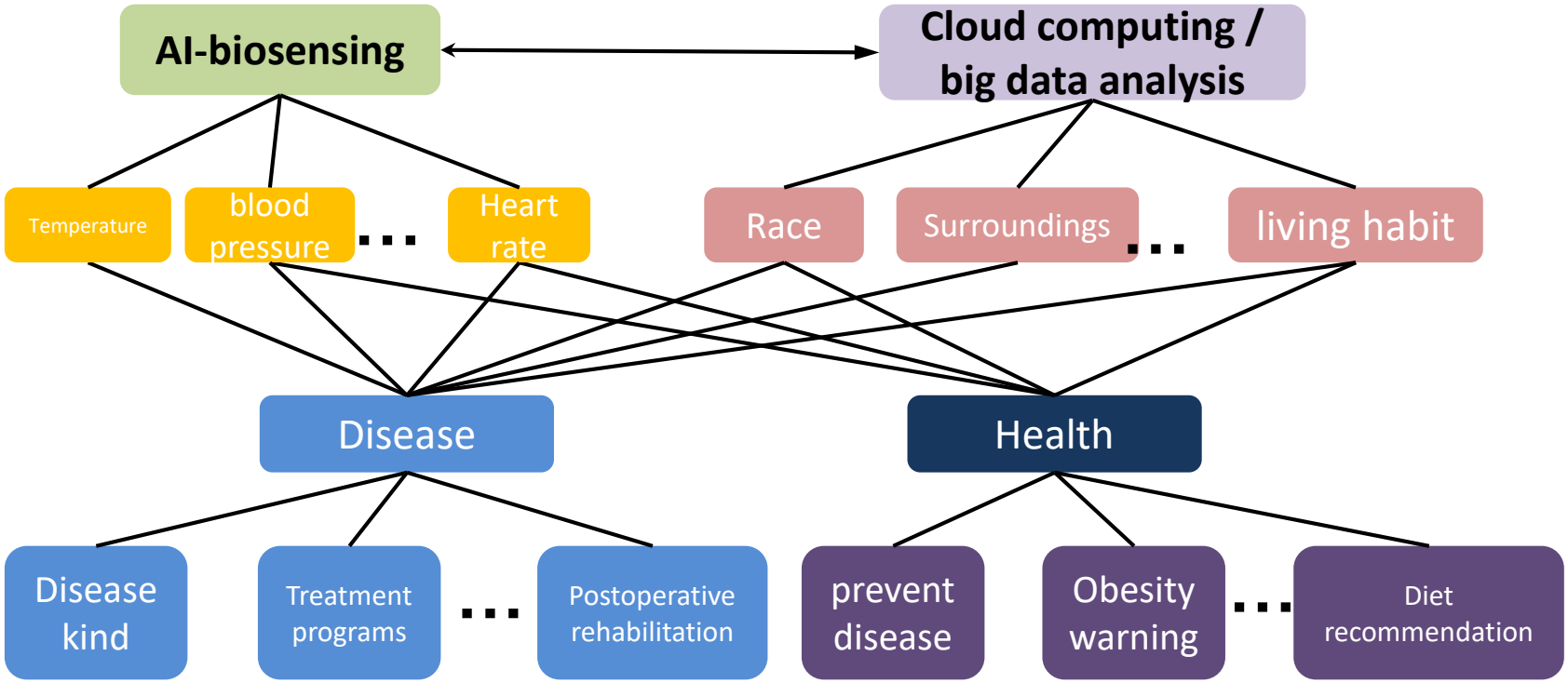
- Iris recognition

→ Iris recognition technology is widely regarded as the most promising biometric authentication technology in the 21st century.

- Gesture recognition

→ The process of recognizing the movement of the human body according to the change of the position of the joint point in the human body

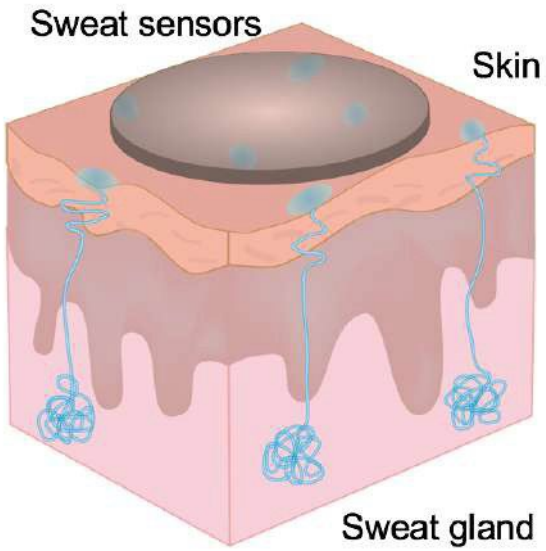
Database of AI-biosensor

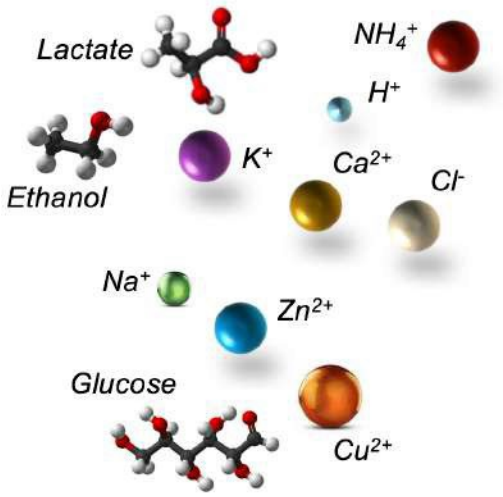


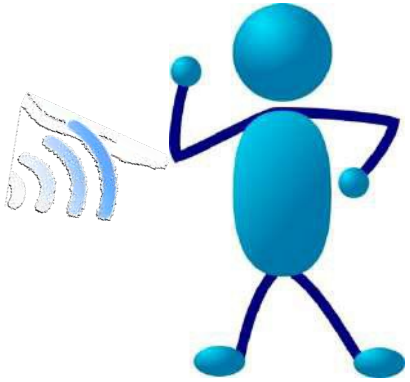
Using AI-biosensors to analyze various physiological indicators, study the changes and development trends of metabolic status and health risk factors of health, sub-health and disease population, establish information base, develop big data search engine and cross-database search analysis for precision medical research and application. Technical system that provides health warnings and personalized medical services.

Our group works in wearable biosensors

Wearable Sweat Biosensors



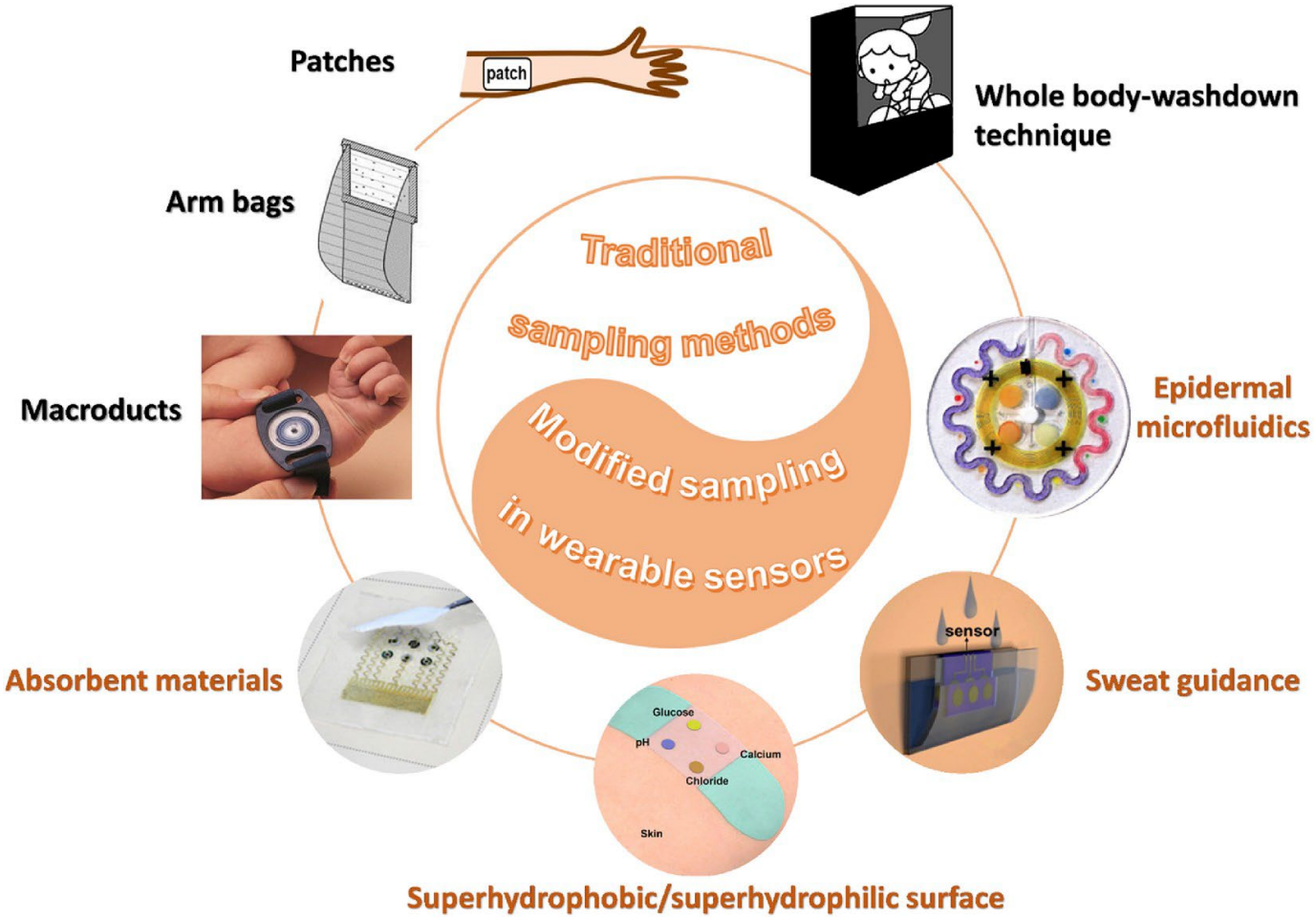




Gao et al. nature 2016.

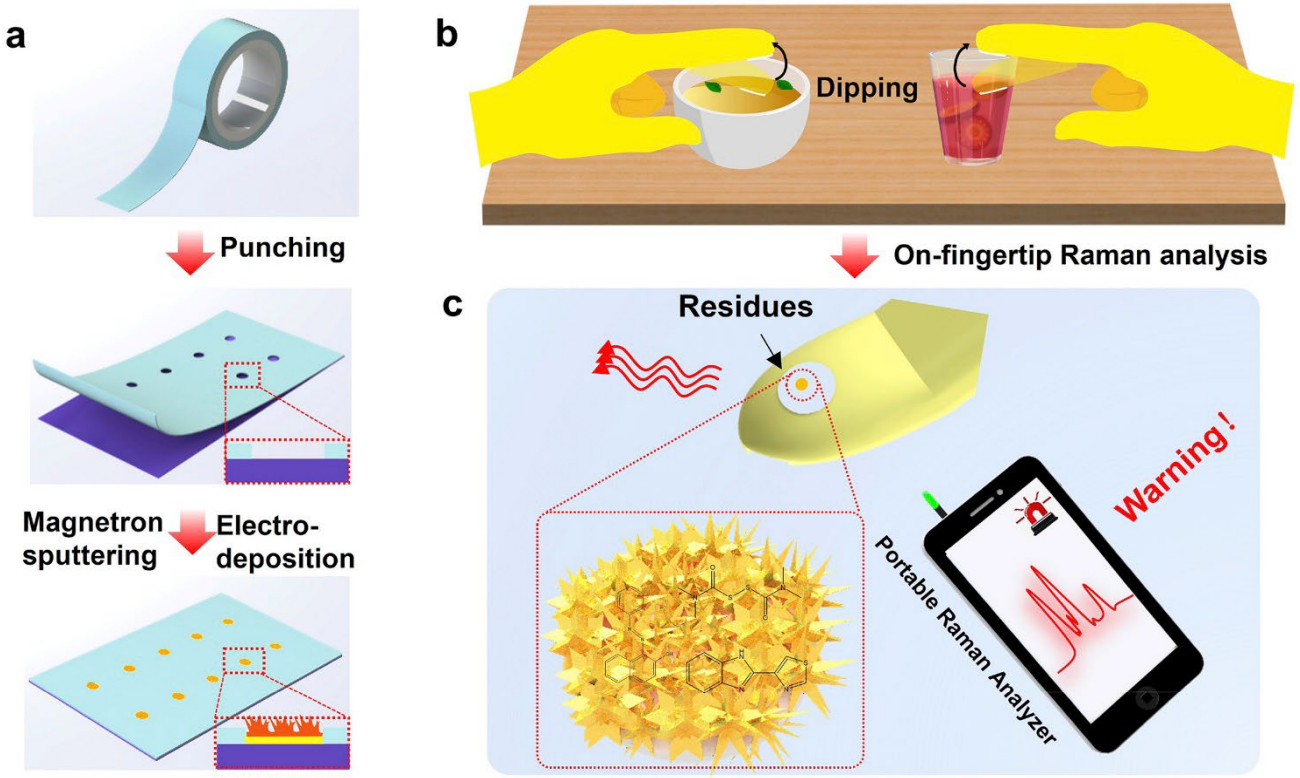
Real-time, non-invasive, continuous health monitoring

The role of sampling in wearable sweat sensors



Talanta **2020,** *212*, 120801.

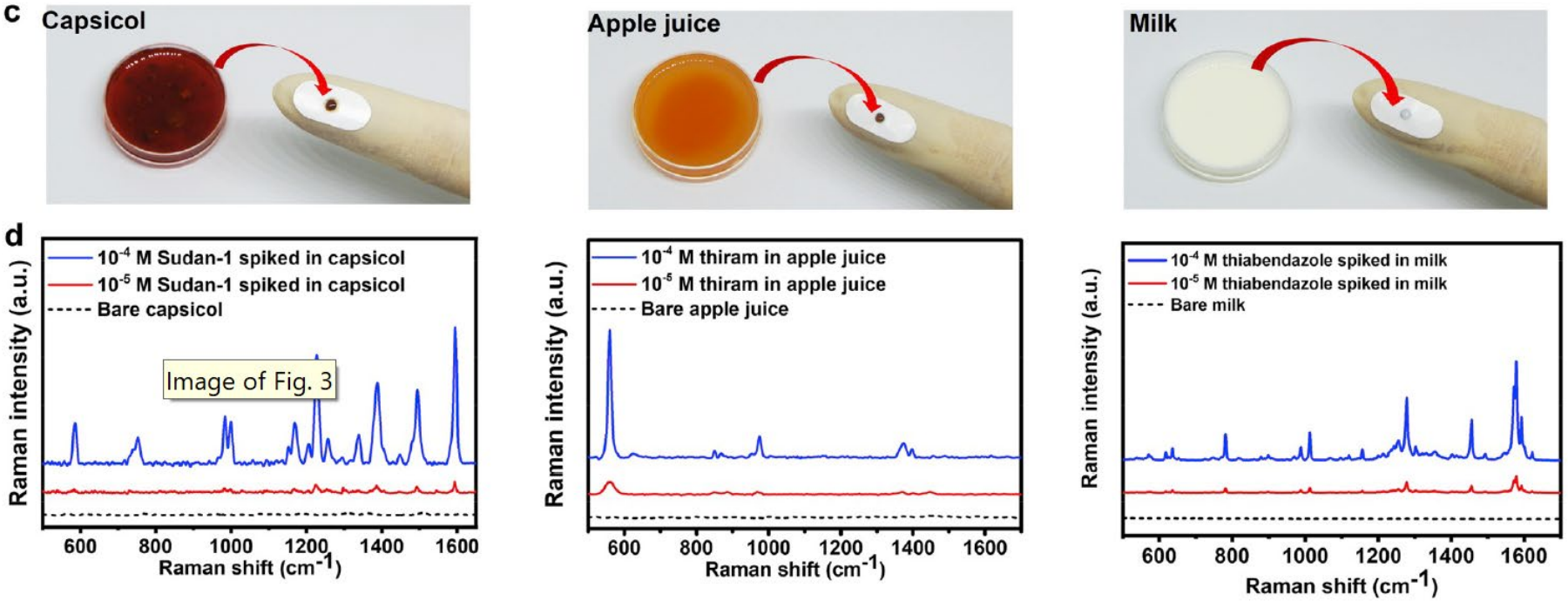
Tapes for rapid sampling and SERS detection



The tape-based sensors not only possess highly branched Au nanodendrites in microwell for promoting SERS activity, but also enable anchoring the microdroplets via direct dip-pulling from pristine analytes solutions upon sticky incorporated on a glove.

Biosens. Bioelectron. **2020,** *152*, 112013.

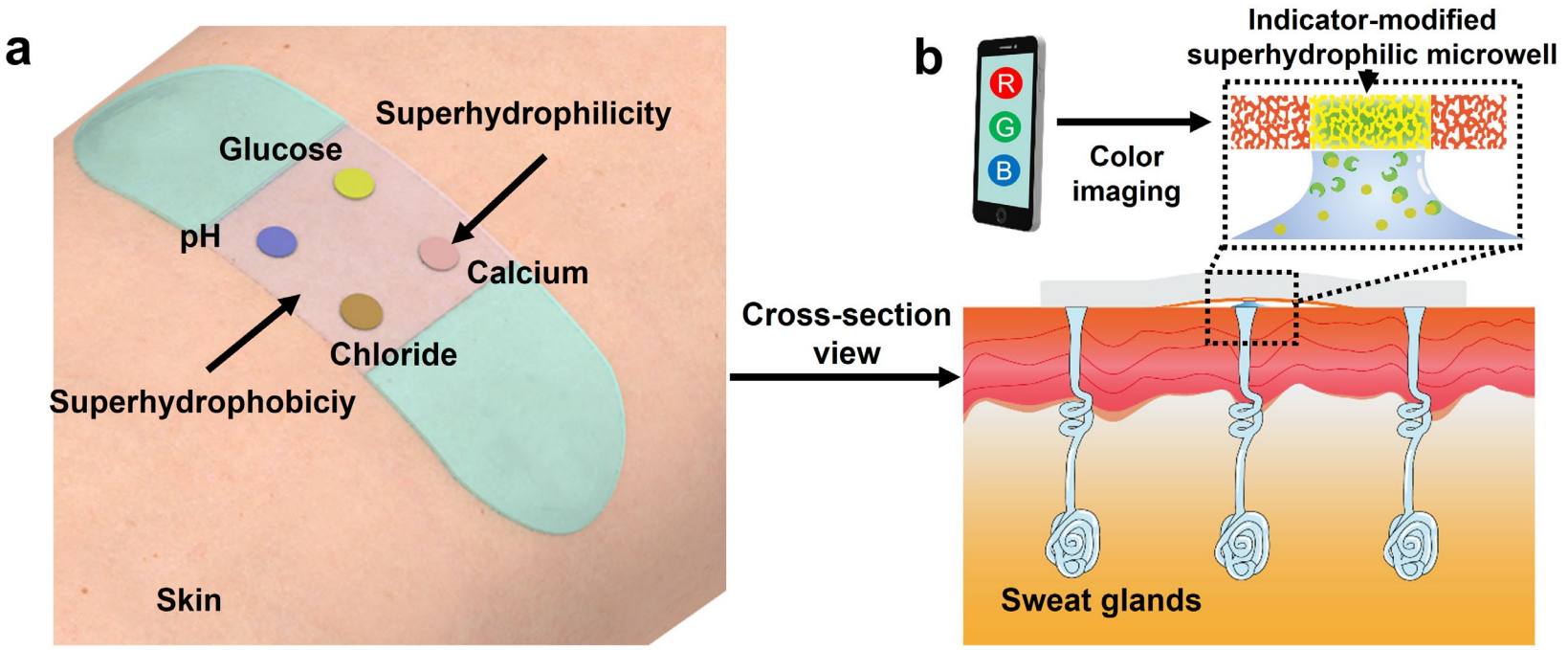
Tapes for rapid sampling and SERS detection



SERS detection of Sudan-1, thiram and thiabendazole in capsicol, apple juice and milk, respectively were implemented to ensure the feasibility and versatility of the tape-based sensors.

Biosens. Bioelectron. **2020,** *152*, 112013.

Flexible and Superwettable Bands as a Platform toward Sweat Sampling and Sensing



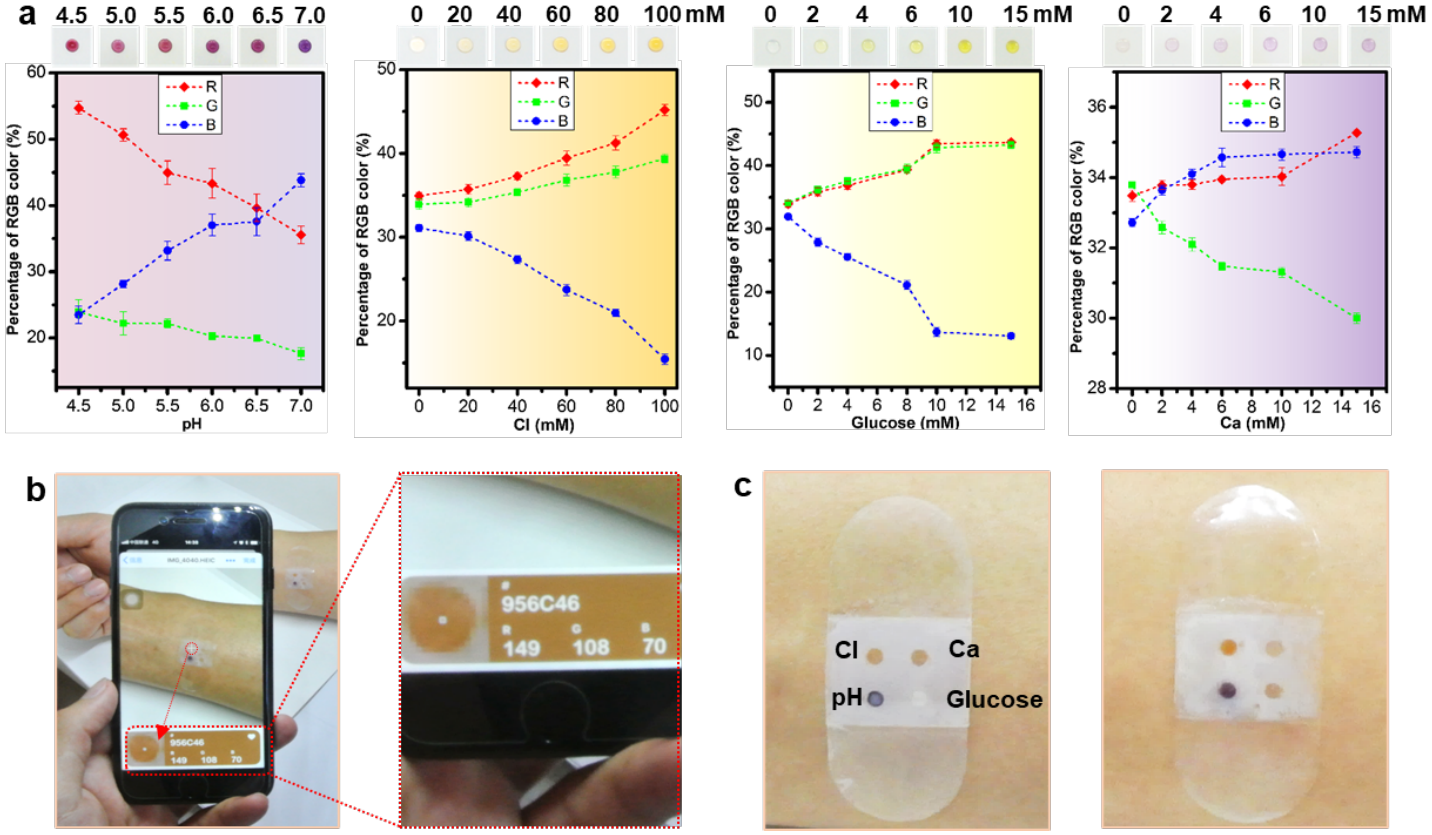
When sweat passes through the subcutaneous sweat glands to the surface of the skin, it will be accurately enriched on the superhydrophilic sites modified by the colorimetric reagent, resulting in a color response, which can be combined with smartphone imaging to analyze sweat biomarkers

Anal. Chem. **2019**, *91*, 4296-4300

Flexible and Superwettable Bands as a Platform toward Sweat Sampling and Sensing

Calibration

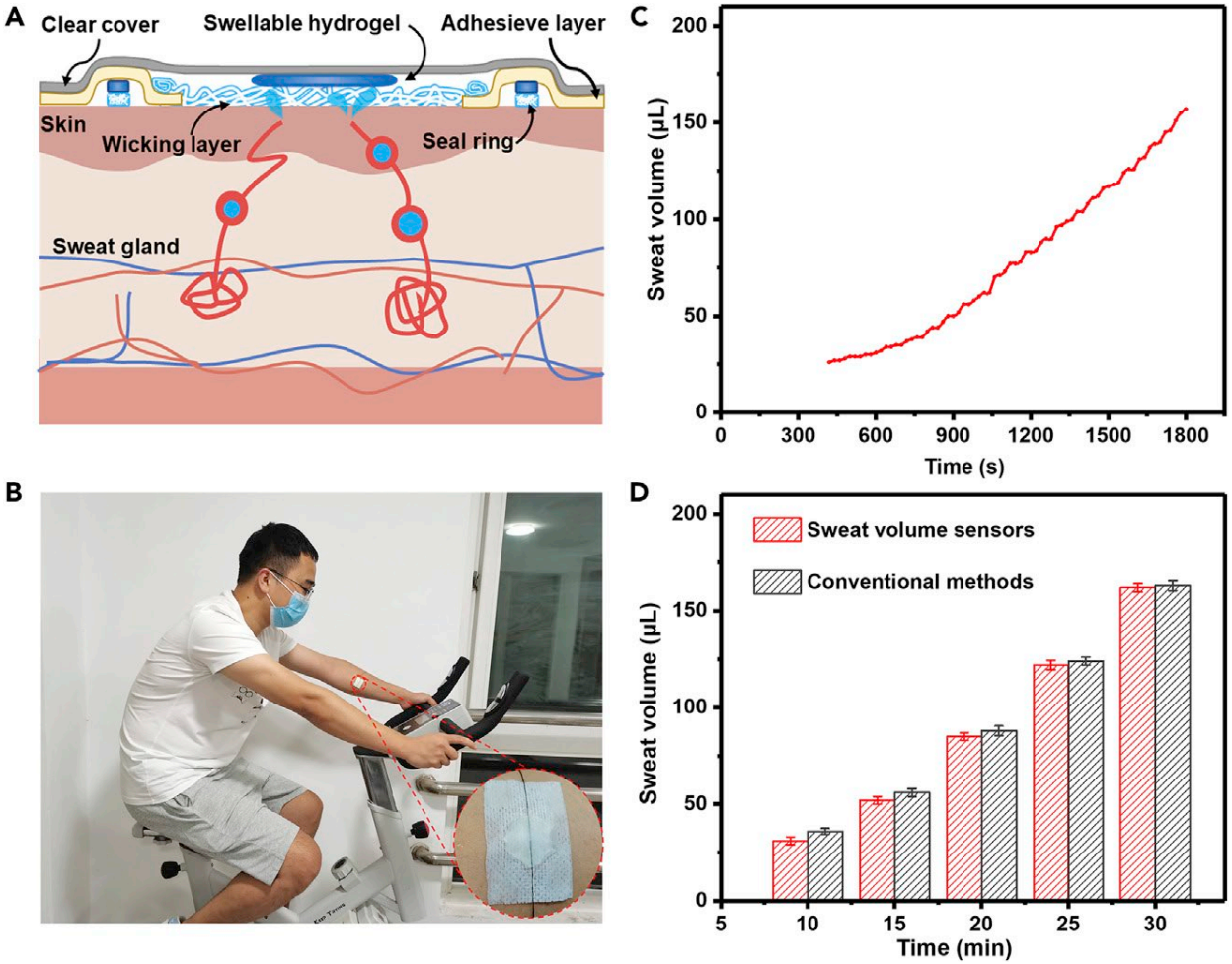
Results



Sweat collection accurately collects and wets the super-hydrophilic sites to achieve detection and analysis. The results indicate that sweat has a pH of 6.5-7.0, a chloride concentration of 100 mM, and contains trace amounts of calcium and glucose, which are consistent with the values reported in the literature.

Anal Chem **2019,** *91*, 4296.

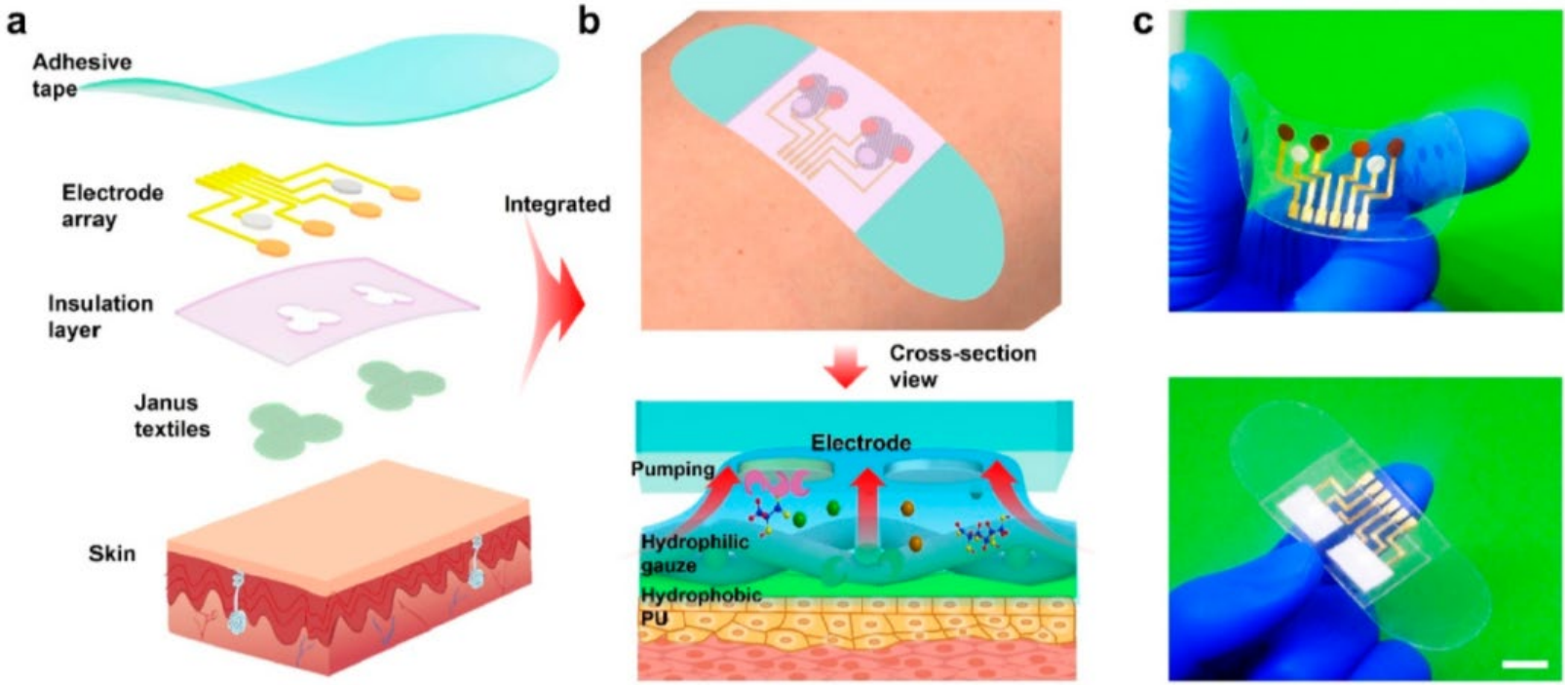
Hydrogel-based sweat volume sensing



The measurement of the sweat volume obtained from the patch we designed is basically consistent with that measured by traditional methods. T

iScience 2021, 24 (1), 102028.

Smart Janus Textile Bands

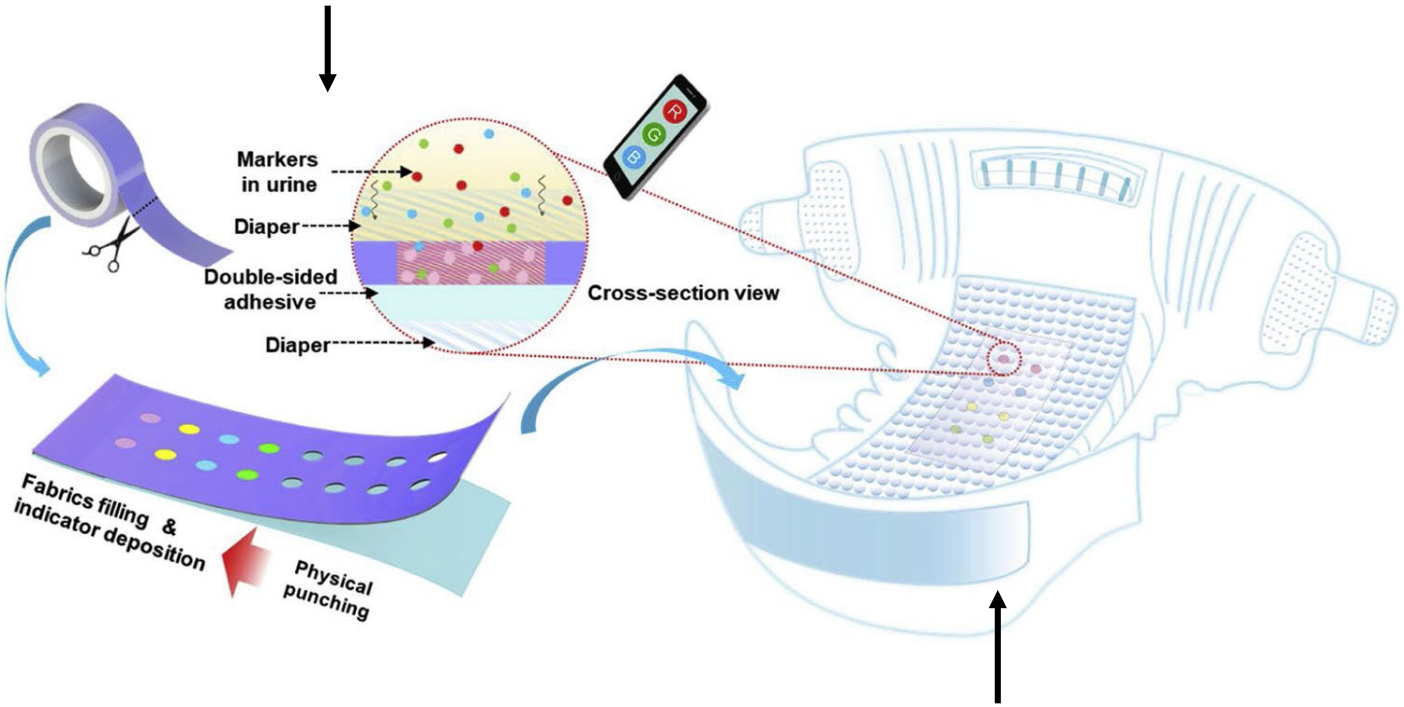


Janus textile for sweat sampling and detection

ACS Sens **2020,** *5* (6), 1548-1554.

Smartphone-based tape sensors

The micropattern was obtained by physical punching on adhesive tapes



The Indicator-functionalized microarrays for rapid urinalysis

Sens. Actuator B Chem. 2020, 304, 127415.

5. 融合尿片的尿液传感监测系统

刷新传感
Refresh
AI Biosensor

功能介绍

- 检测小便次数、尿量、是否有大便;
- 生化检测功能：全定量检测尿液PH、抗坏血酸、蛋白、尿液葡萄糖四项尿常规指标；输出与用户生理指标相关的检测结果与行为建议。

技术优势

- 可配置多种多生物传感器，实现多通道多物质的检测；
- 全自动监测、分析、上传、数据展示。

应用场景

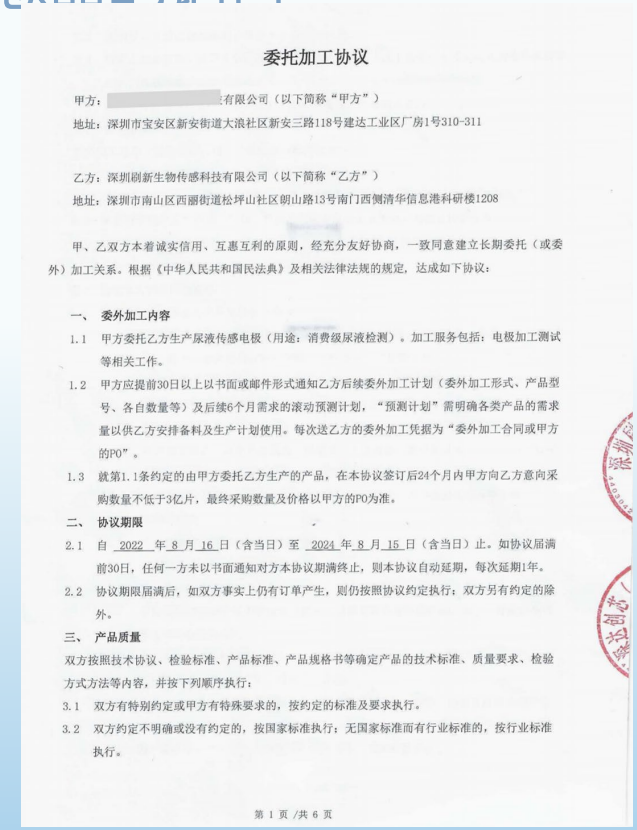
- 家用智能马桶、智能尿片;
- 特定场所公 共卫生间尿液样本分析;
- 戒毒所的戒毒效果监测。

刷新传感
Refresh
AI Biosensor

（一）产品与生物传感器的销售

尿液传感器

目前已经签署的传感器委托研发量产合同，订单数量3亿支，合同执行期在2023年9月起，2023年-2024年预计合同额2亿多。



委托加工协议

甲方：[redacted]有限公司（以下简称“甲方”）

地址：深圳市宝安区新安街道大浪社区新安三路118号建达工业区厂房1号310-311

乙方：深圳刷新生物传感科技有限公司（以下简称“乙方”）

地址：深圳市南山区西丽街道松坪山社区朗山路13号南门西侧清华信息港科研楼1208

甲、乙双方本着诚实信用、互惠互利的原则，经充分友好协商，一致同意建立长期委托（或委外）加工关系。根据《中华人民共和国民法典》及相关法律法规的规定，达成如下协议：

一、 委外加工内容

1.1 甲方委托乙方生产尿液传感电极（用途：消费级尿液检测）。加工服务包括：电极加工测试等相关工作。

1.2 甲方应提前30日以上以书面或邮件形式通知乙方后续委外加工计划（委外加工形式、产品型号、各自数量等）及后续6个月需求的滚动预测计划，“预测计划”需明确各类产品的需求量以供乙方安排备料及生产计划使用。每次送乙方的委外加工凭据为“委外加工合同或甲方的PO”。

1.3 就第1.1条约定的由甲方委托乙方生产的产品，在本协议签订后24个月内甲方向乙方意向采购数量不低于3亿片，最终采购数量及价格以甲方的PO为准。

二、 协议期限

2.1 自 2022 年 8 月 16 日（含当日）至 2024 年 8 月 15 日（含当日）止。如协议届满前30日，任何一方未以书面通知对方本协议期满终止，则本协议自动延期，每次延期1年。

2.2 协议期限届满后，如双方事实上仍有订单产生，则仍按照协议约定执行；双方另有约定的除外。

三、 产品质量

双方按照技术协议、检验标准、产品标准、产品规格书等确定产品的技术标准、质量要求、检验方式方法等内容，并按下列顺序执行：

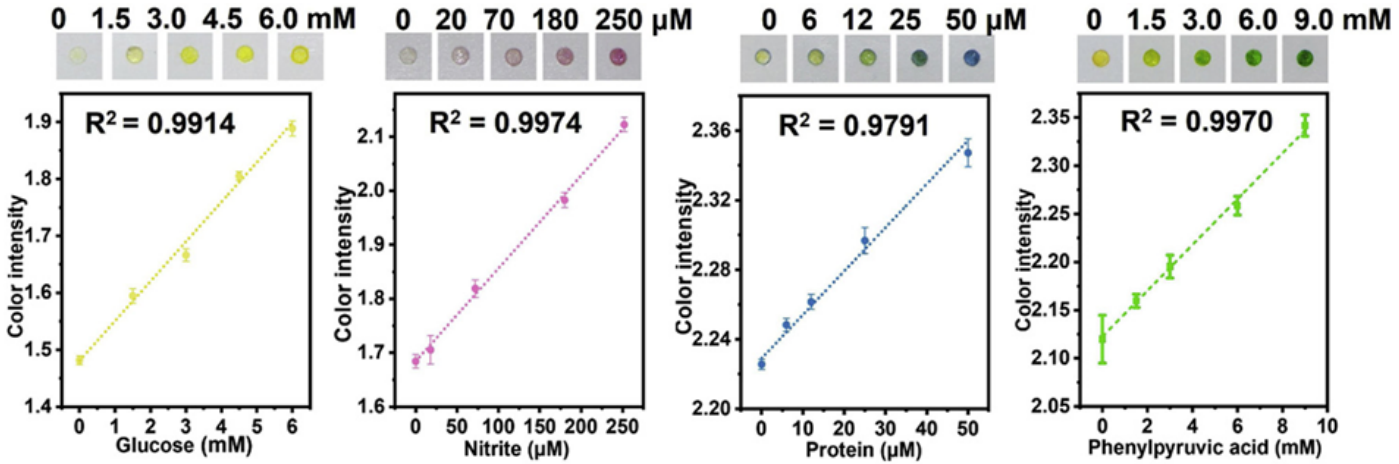
3.1 双方有特别约定或甲方有特殊要求的，按约定的标准及要求执行。

3.2 双方约定不明确或没有约定的，按国家标准执行；无国家标准而有行业标准的，按行业标准执行。

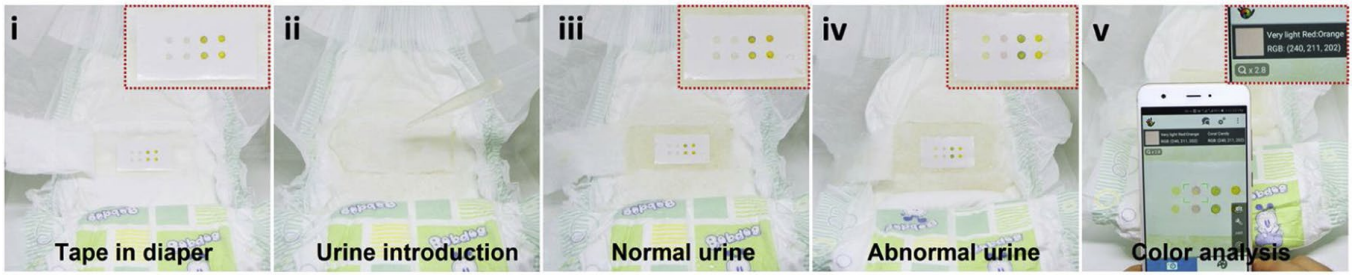
第 1 页 /共 6 页

Smartphone-based tape sensors

Calibration

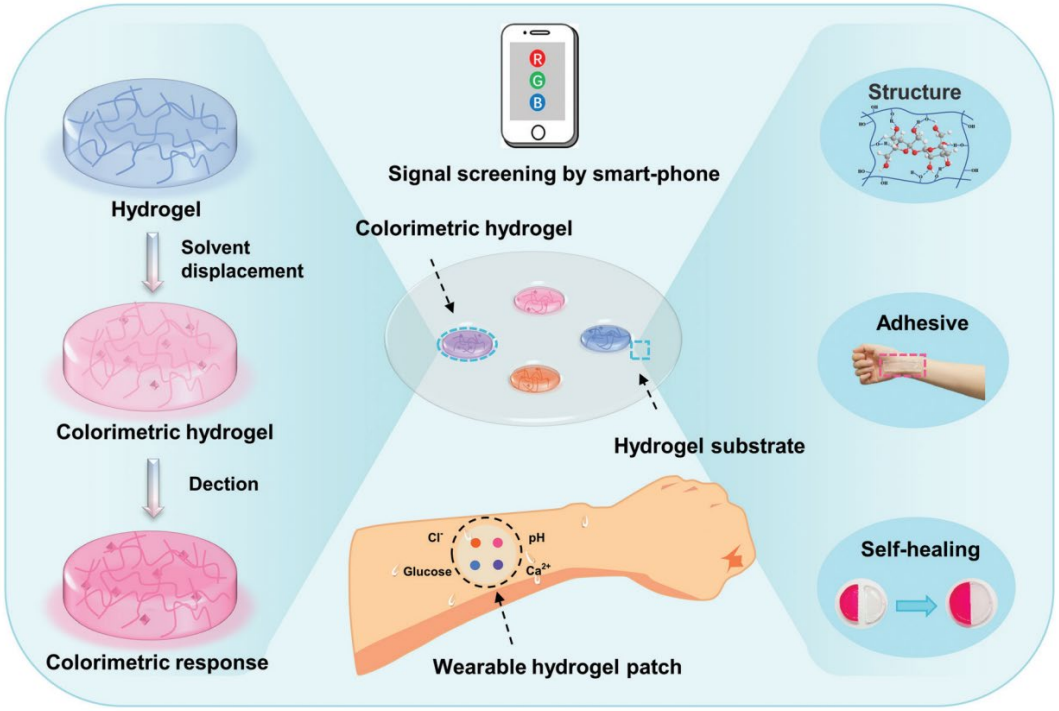


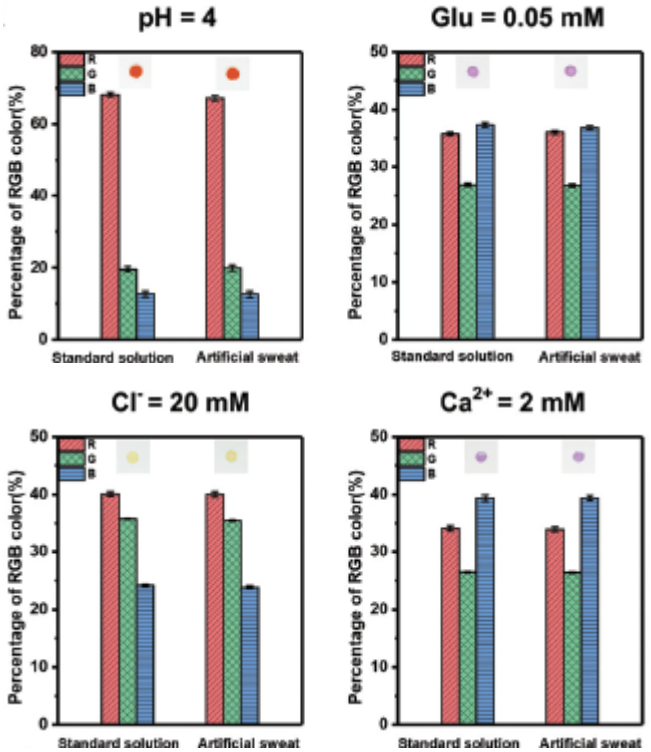
Results



The simulated urine flow can be captured and penetrated in the tape-based microarrays for rapid detection of multiplexed markers such as glucose, nitrite, protein and phenylpyruvate with a smartphone-assisted colorimetric screening method.

Flexible, self-healable, adhesive and wearable hydrogel patch for colorimetric sweat detection

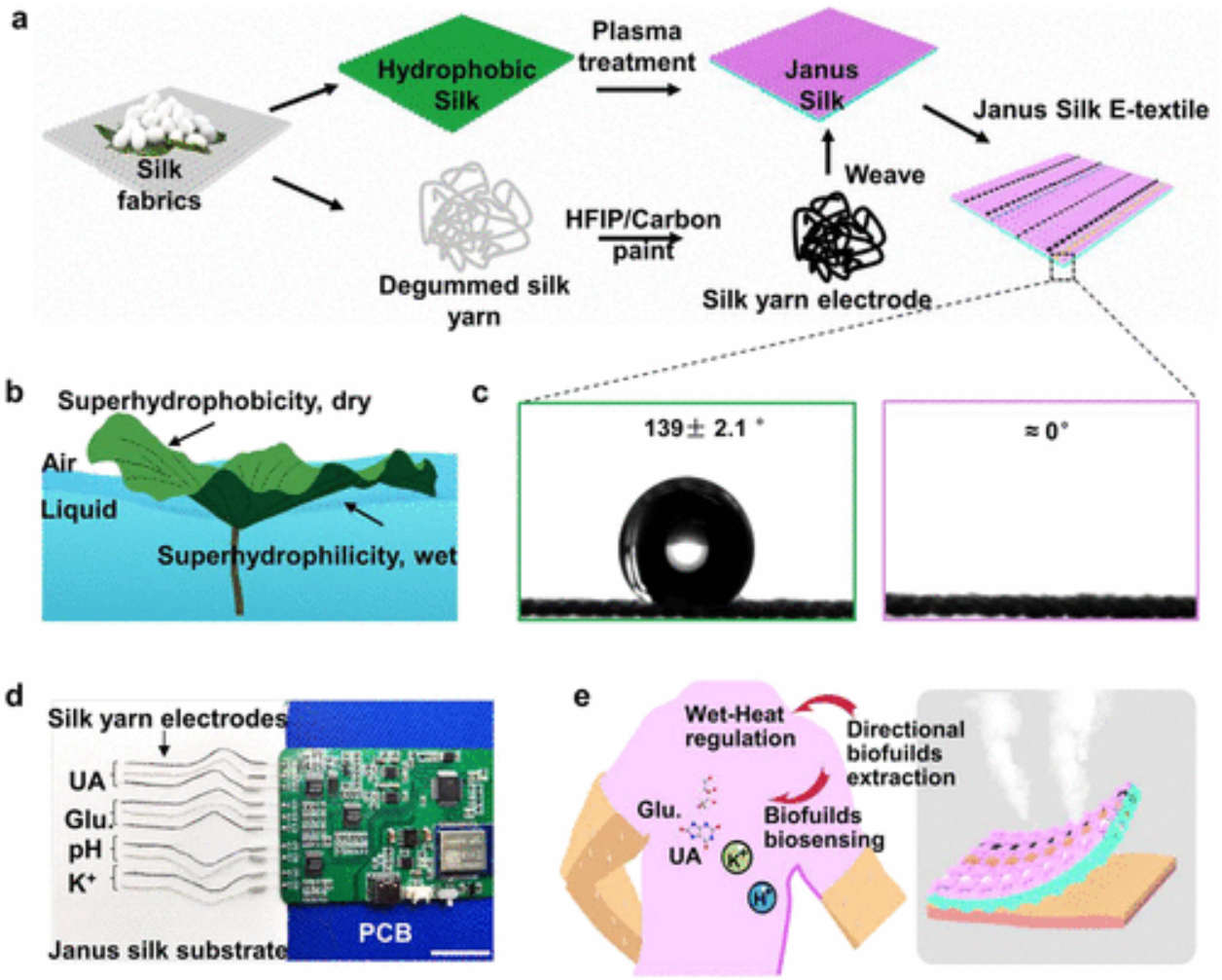




We present a flexible, self-healable, adhesive and wearable hydrogel patch for on-demand sweat colorimetric detection. Such a user-specific wearable hydrogel patch is simply prepared by the solvent displacement method, and can directly attach to human skin for in situ sweat sampling and colorimetric analysis without any complicated preparation steps.

L.R. Wang, T.L. Xu, X.J. Zhang* et al. J. Mater. Chem.C, 2021, 9,14938 - 14945*

Biospired Janus Silk E-Textiles with Wet–Thermal Comfort for Highly Efficient Biofluid Monitoring

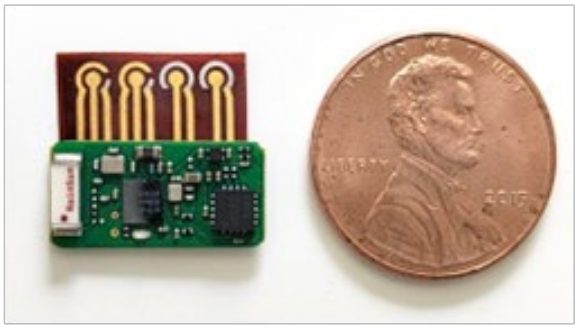


We propose a skin-comfortable Janus electronic textile (e-textile) based on natural silk materials for managing and analysis of biofluid. The unidirectional biofluid behavior of such Janus silk substrate facilitates a comfortable skin microenvironment, including weakening the undesired wet adhesion and avoiding excessive heat or cold on the epidermis.

X.C. He, C. Fan, T.L. Xu, X.J. Zhang* et al. Nano Lett. 2021, 21, 8880–8887*

Ultra-small Wearable Flexible Sweat Biosensor

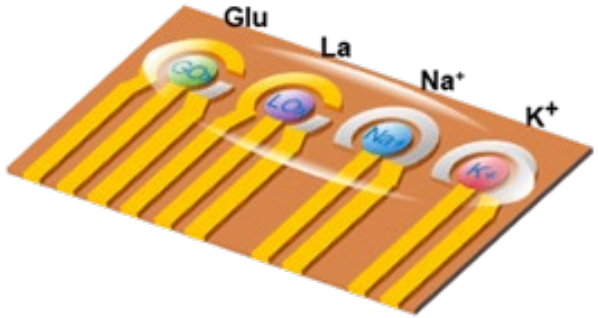
a



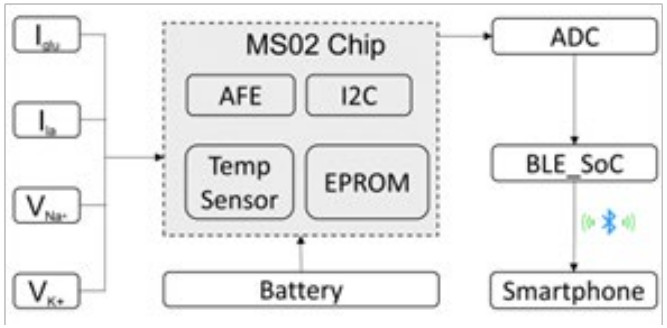
Wearable Sweat Sensor System

b

c



d

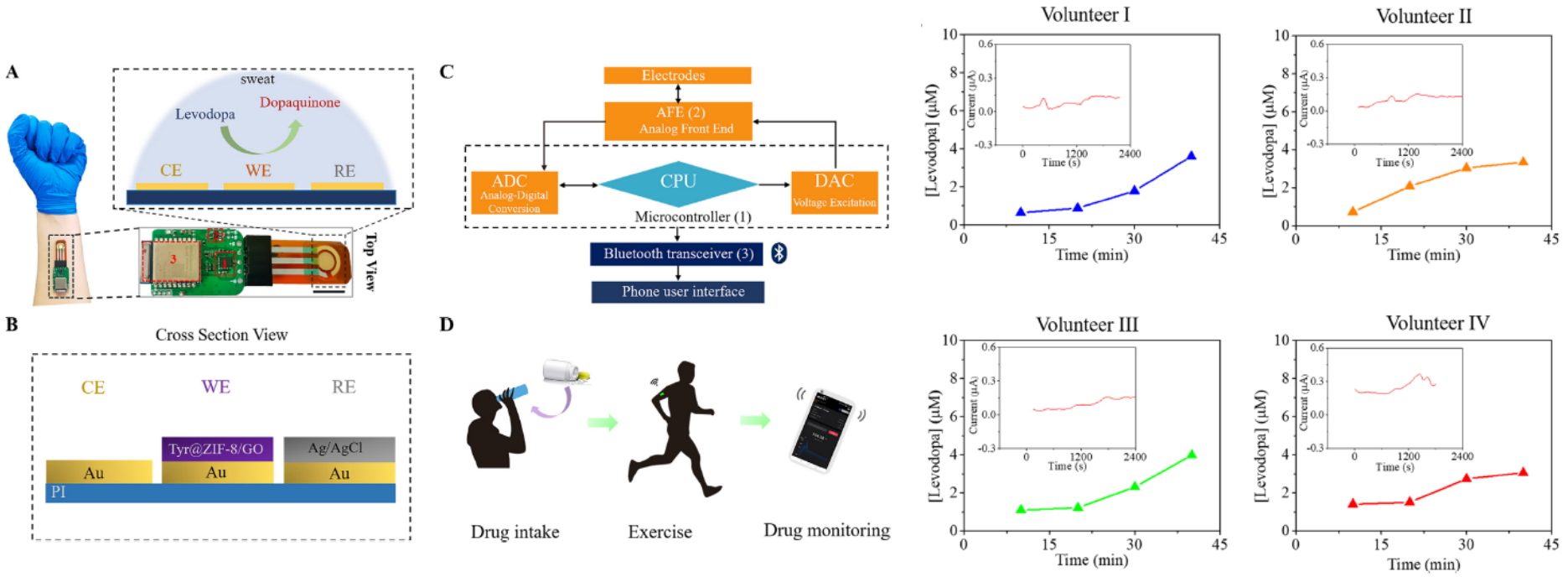


e

The whole system main includes flexible electrodes and printed circle board (PCB), and the size of PCB is only 1.5cm × 0.8cm. The core processing MS02 chip, only 1.2mm × 1.1mm

ACS Sens. 2022，https://doi.org/10.1021/acssensors.2c01533

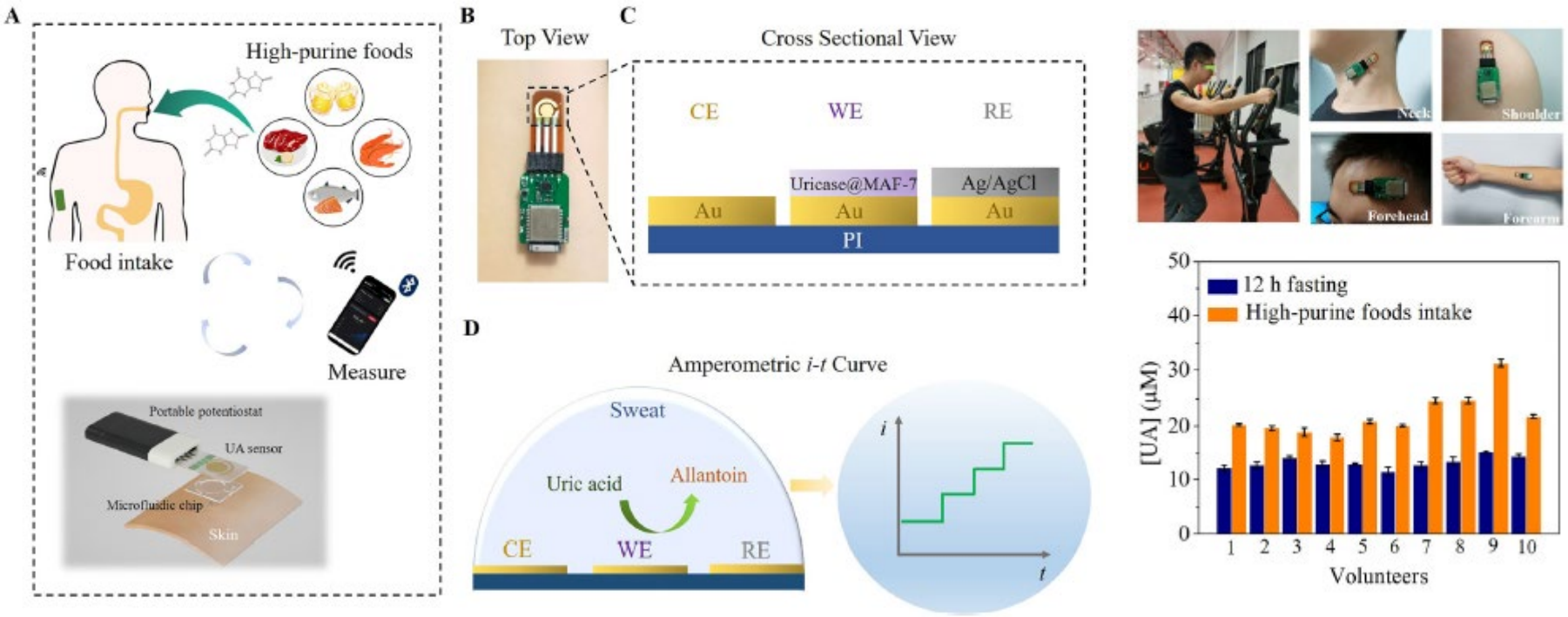
electrochemical wearable sensor for levodopa quantification



we report a simple, wearable, noninvasive, and portable metal organic framework (MOF)-based electrochemical sensor with integrated enzymes for monitoring the concentration of levodopa in sweat, which can be used as a proxy for L-dopa levels in the body. In addition, the sensor showed high sensitivity and good stability as a result of the anchoring of the enzyme. Thus, the sensor shows promise for continuous, noninvasive point-of-care drug monitoring and management.

J. Xiao, C. Fan, T. Xu, L. Su, X. Zhang, Sens. Actuator B Chem. 2022, 359.

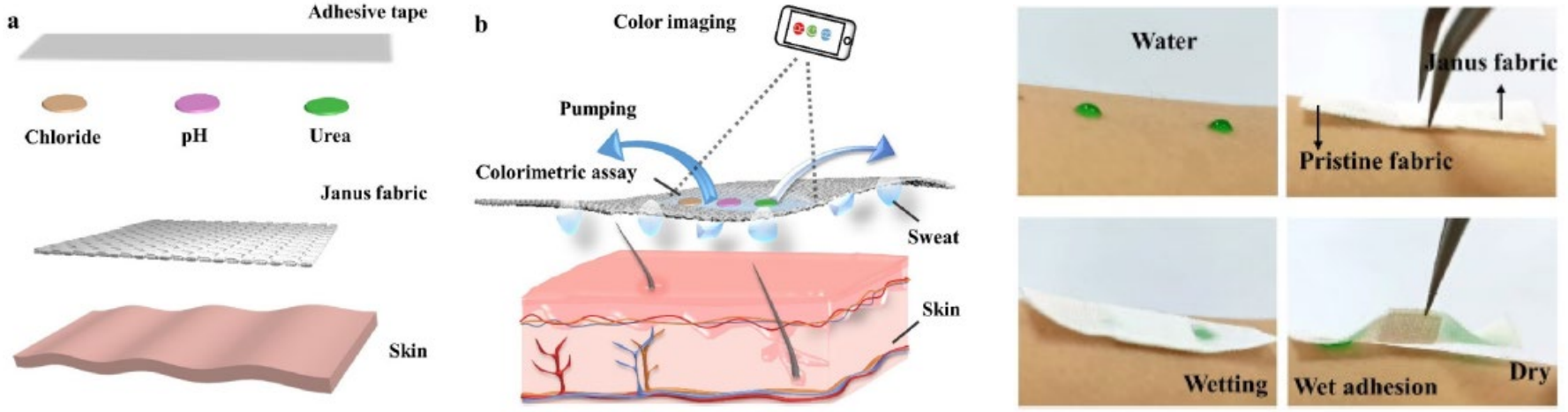
Hydrophilic metal-organic frameworks integrated uricase for wearable detection of sweat uric acid



We conducted this study to prepare a non-invasive wearable uircase@MAF- 7-based electrochemical sensor that can achieve accurate and sensitive detection of UA levels in sweat by integrating a flexible microfluidic chip and wireless electronic readout device. The flexible microfluidic chip enabled an easy and effective collection of sweat samples. We evaluated the utility of the sensor for monitoring UA levels in real sweat samples by means of a high purine dietary challenge.

J. Xiao, Y. Luo, L. Su, J. Lu, W. Han, T. Xu,* X. Zhang,* Anal. Chim. Acta 2022, 1208.*

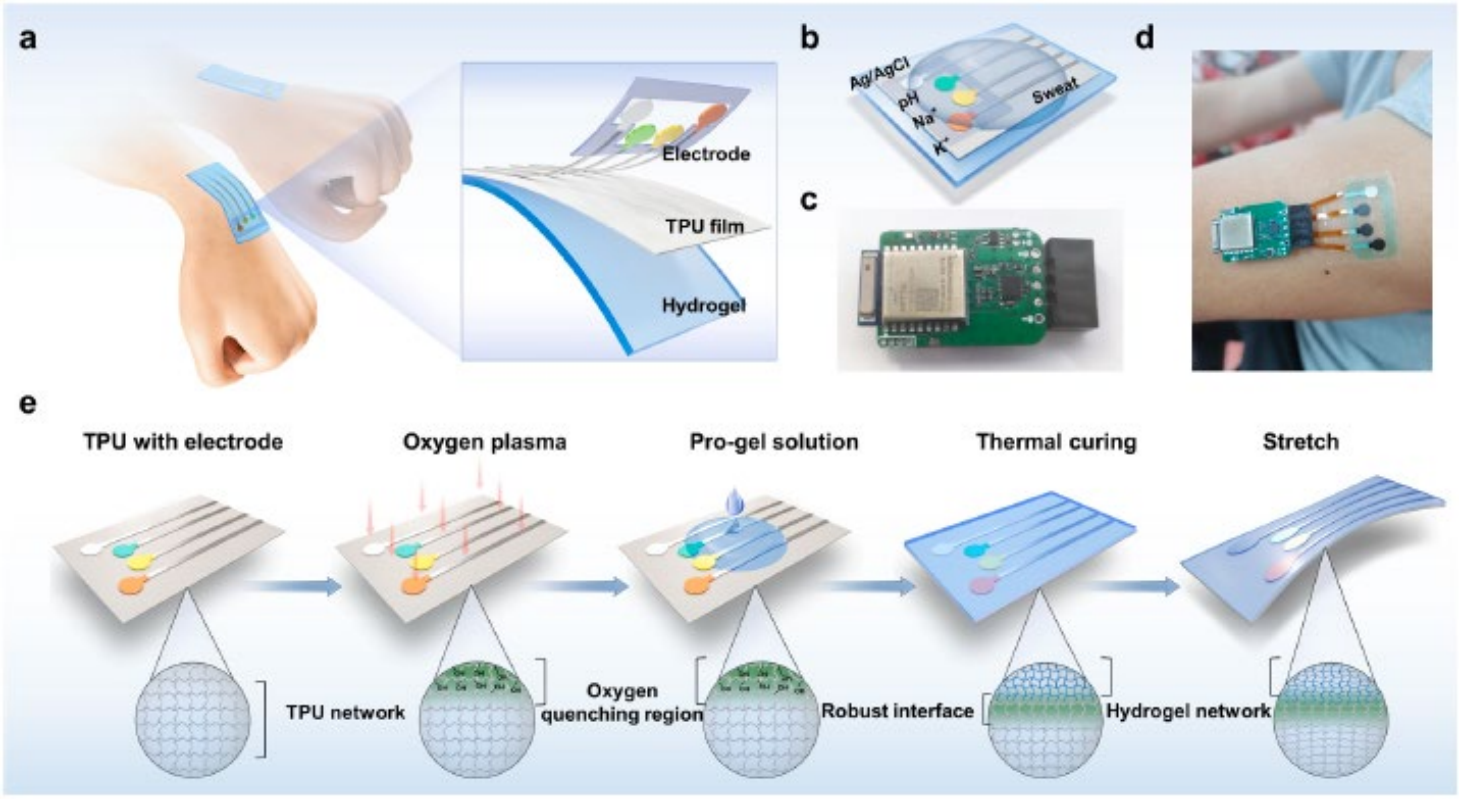
Smart Janus fabrics for one-way sweat sampling and skin-friendly colorimetric detection



we propose a one-way colorimetric sweat sampling and sensing system based on a Janus fabric using interfacial modification techniques. The opposite wettability of Janus fabric enables sweat to be quickly moved from the skin surface to the hydrophilic side and colorimetric patches. Visual and portable detection of sweat biomarkers including chloride, pH, and urea is also achieved. The results show that the true concentrations of chloride, pH, and urea in sweat are ~10 mM, ~7.2, and ~10 mM, respectively.

Talanta **2023,** *259*, 124507.

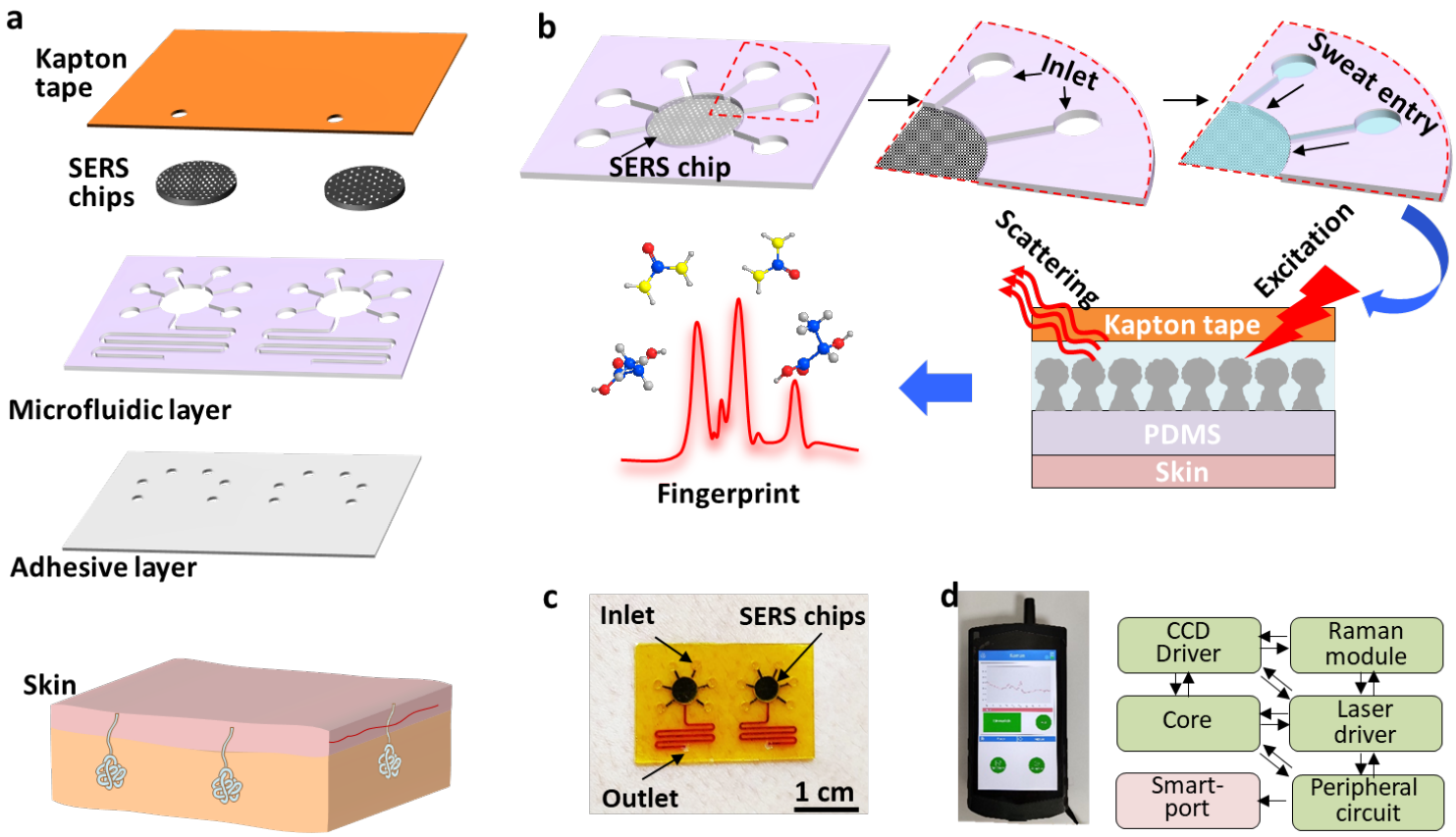
Skin-like hydrogel-elastomer based electrochemical device for comfortable wearable biofluid monitoring



a skin-like hydrogel-elastomer based electrochemical device for comfortable wearable biofluid monitoring is proposed. The prepared electrochemical device has a Young's modulus (0.37 MPa) similar to that of the skin, thereby greatly improving the conformality with the curved surface of the skin and the wearing comfort during exercise. The device can achieve monitoring pH, Na+ and K+ in sweat with high sensitivity (58.14 mV/pH for pH, 58.89 mV/ decade for Na+, and 59.11 mV/decade for K+),

Chem. Eng. J. 2023, 455, 140609.

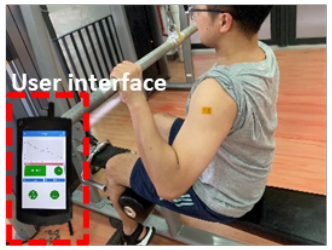
Wearable SERS sweat sensing

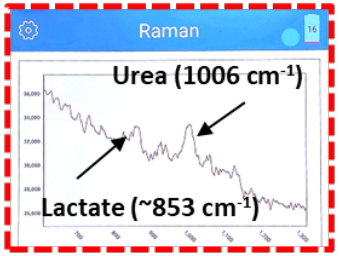


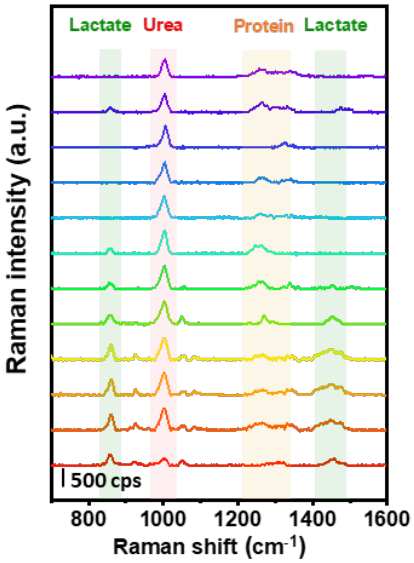
we demonstrate a wearable microfluidic nanoplasmonic sensor capable of refreshable and portable recognition fingerprint information of targeted biomarkers including urea, lactate, and pH in sweat.

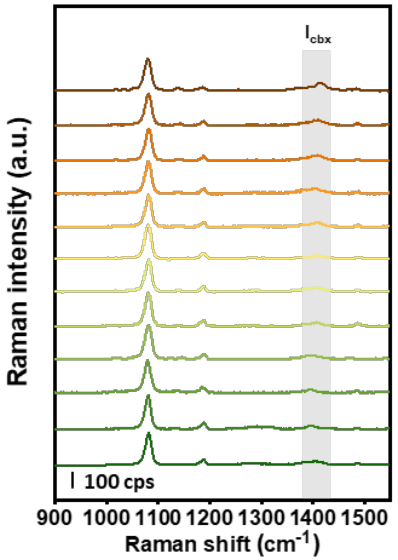
npj Flexible Electron. 2022. 6 (1), 60.

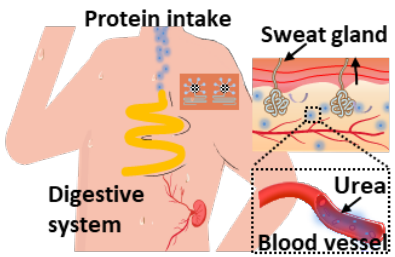
On-body evaluation

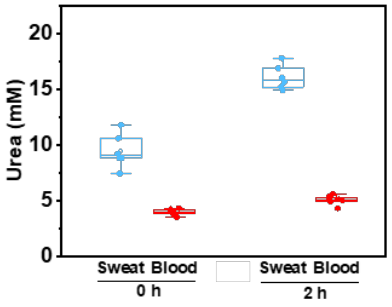


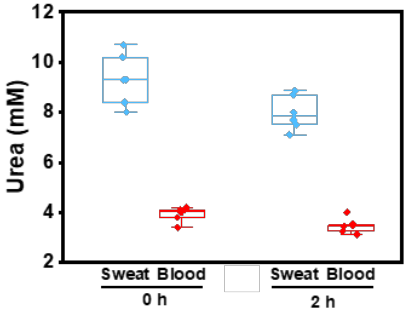






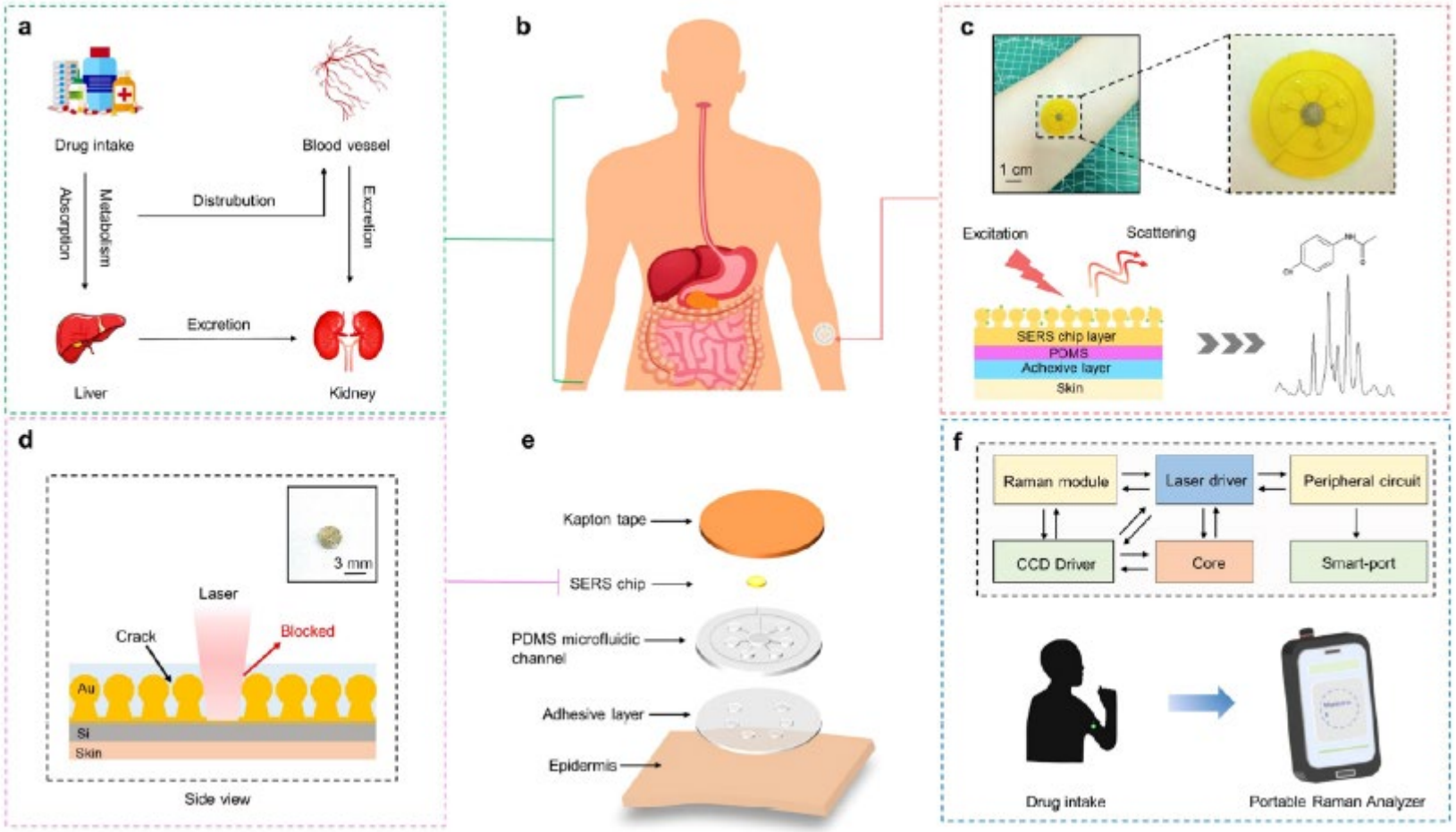






On-body evaluation of the microfluidic sweat SERS system:
The characteristic molecular fingerprint of urea at 1005 cm−1 can be found almost throughout the whole exercise. The standardized pH spectroscopic signatures did not change significantly, and the corresponding pH value was calculated to be 5.5–7.0, indicating that the extracted sweat was weakly acid.

Wearable Plasmonic Sweat Biosensor for Acetaminophen Drug Monitoring

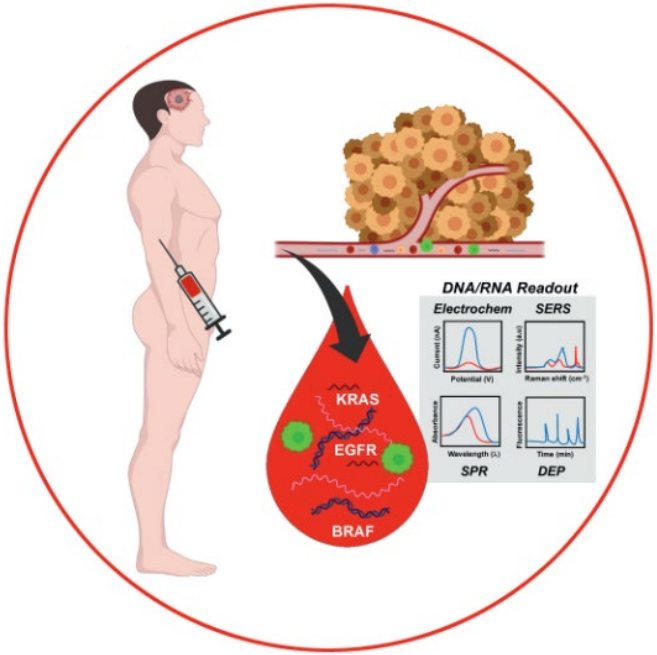


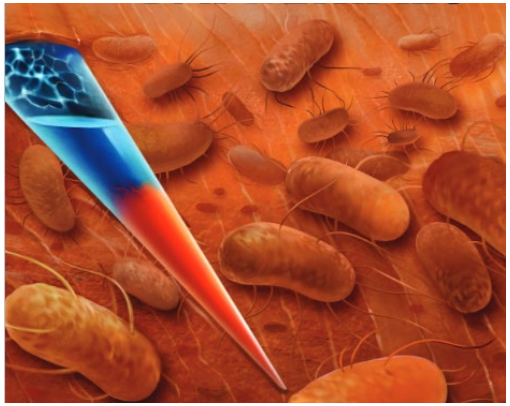
we developed a noninvasive microfluidic-based wearable plasmonic sensor to achieve simultaneous sweat sampling and acetaminophen drug monitoring for vital signs. The developed sensor enabled the sensitive detection and quantification of acetaminophen at concentrations as low as 0.13 μM in drug-administered subjects. These results indicated that the sweat sensor could measure acetaminophen levels and reflect drug metabolism.

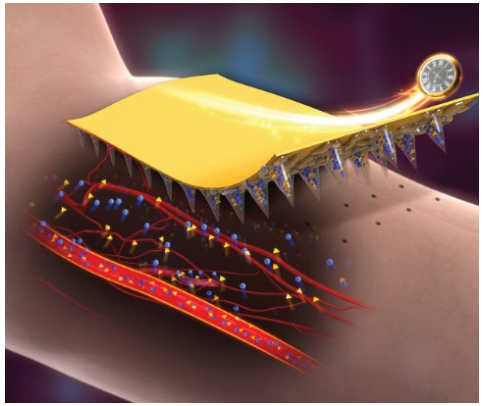
ACS Sens **2023,** *8* (4), 1766-1773.

Intelligent monitoring of blood and wound markers

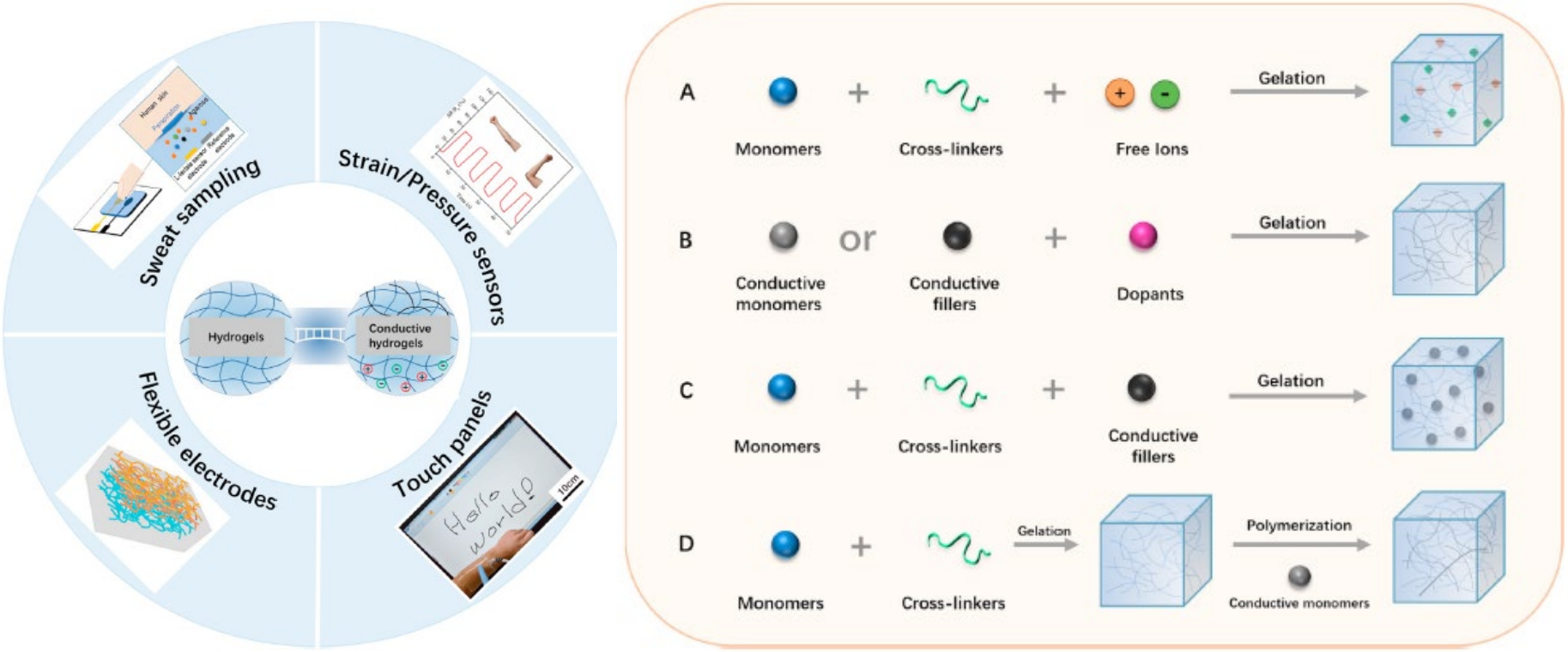
Real-time detection and monitoring of various markers in body fluid, including glucose, sodium and potassium ions, lactic acid, protein and nucleic acid, can effectively achieve disease detection and health monitoring.







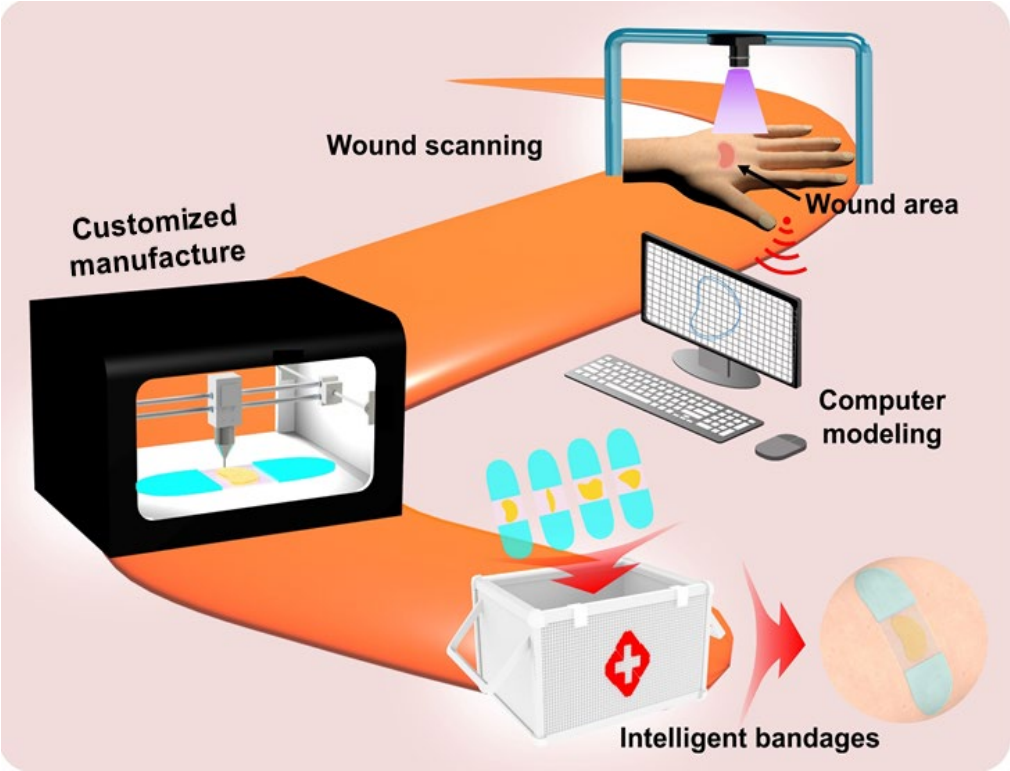
Multifunctional conductive hydrogel-based flexible wearable sensors



This review summarizes recent advances of applications of hydrogels in flexible wearable sensors, such as sweat sampling and flexible electrodes, strain/pressure sensors and touch panels, focuses on the multifunctional conductive hydrogels-based flexible wearable sensors with self-healing, self-adhesion, or anti-freezing capabilities.

L. Wang, T. Xu, X. Zhang, TrAC, Trends Anal. Chem. 2021, 134, 116130.

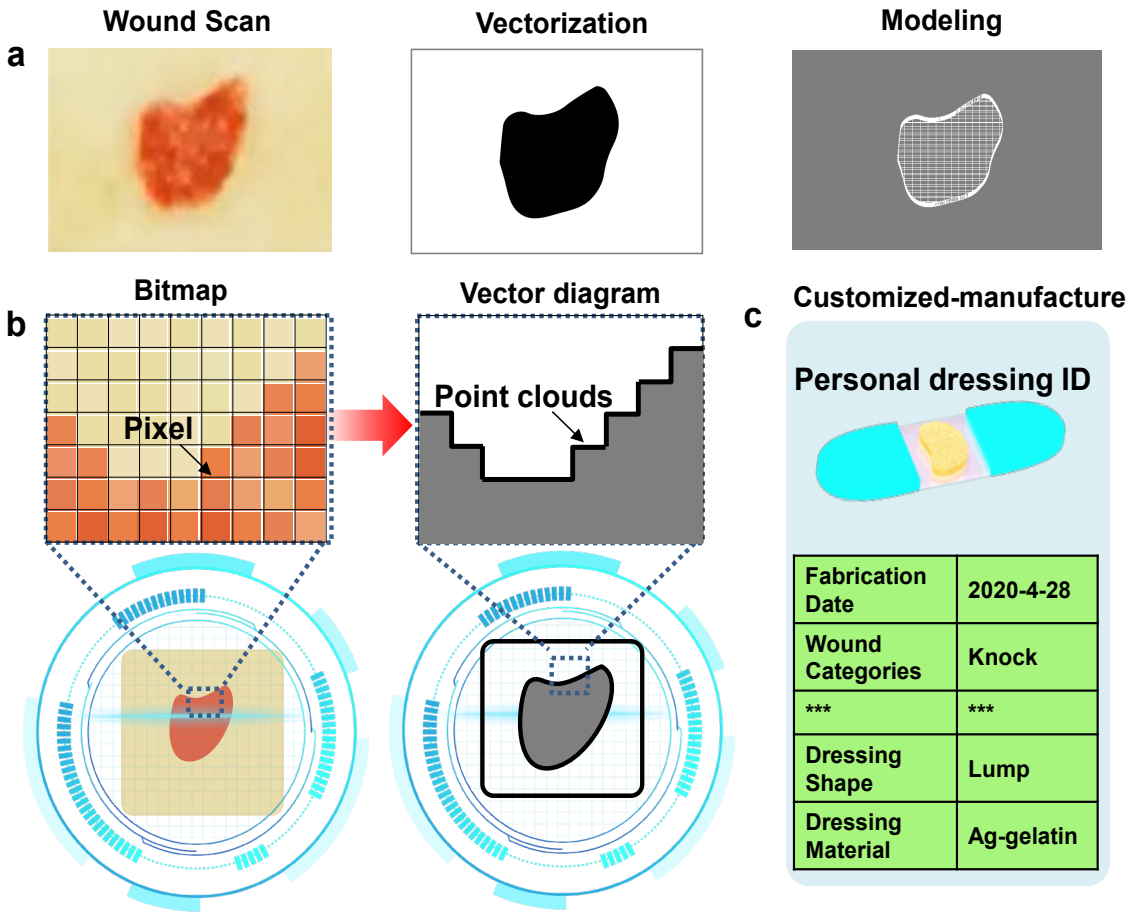
Intelligent Bandage



The intelligent “bands” consists of streamlined wound scanning, computer modeling, and customized manufacture (3D) printing.

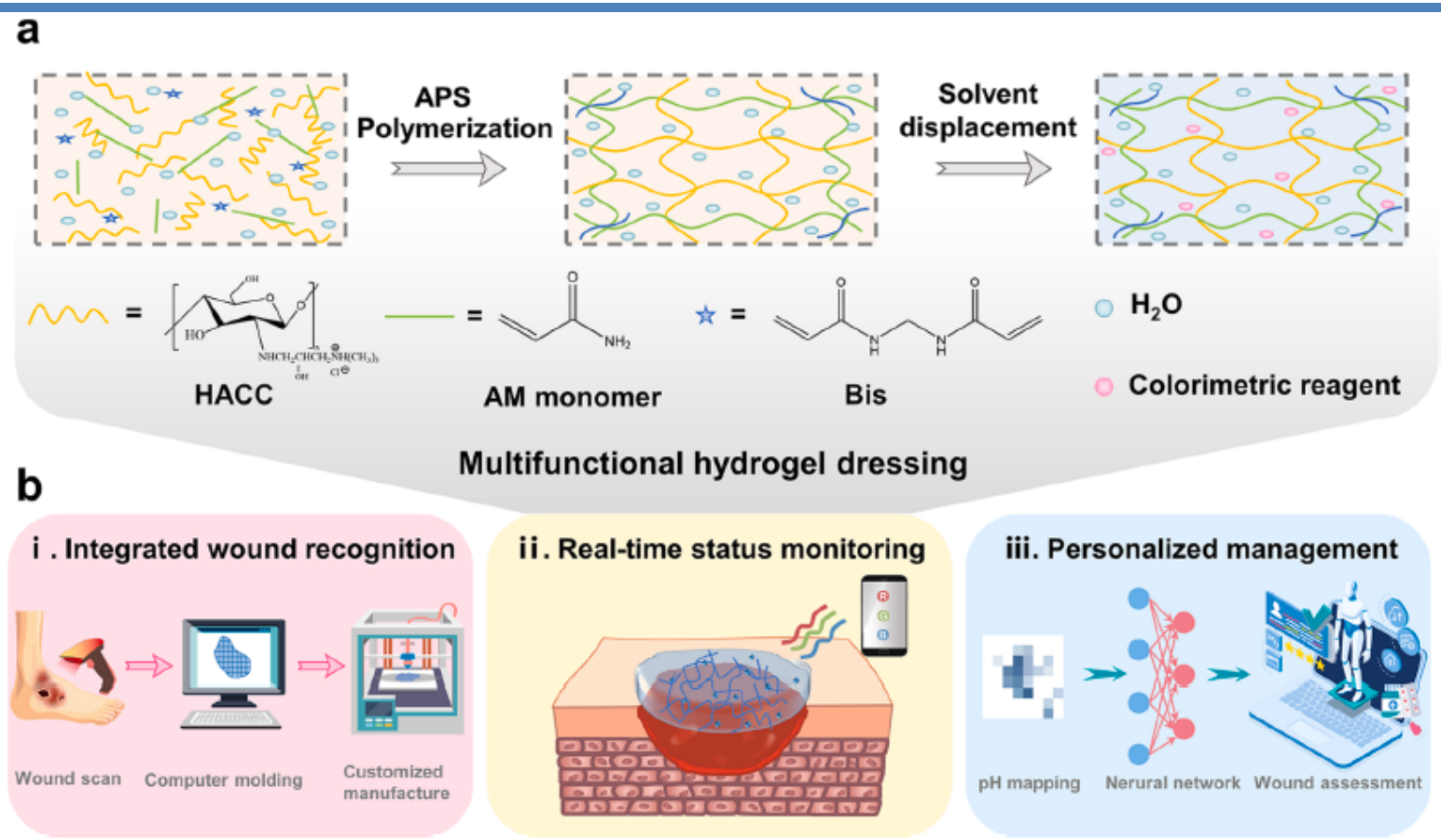
Adv. Healthc. Mater. **2020**, 9, e2000941

Intelligent bandage



Wound images undergo vectorization by generating “point clouds” data based on the chromatic aberration between the pixel of wound edges and normal skin by using a customized computer-assisted design software.

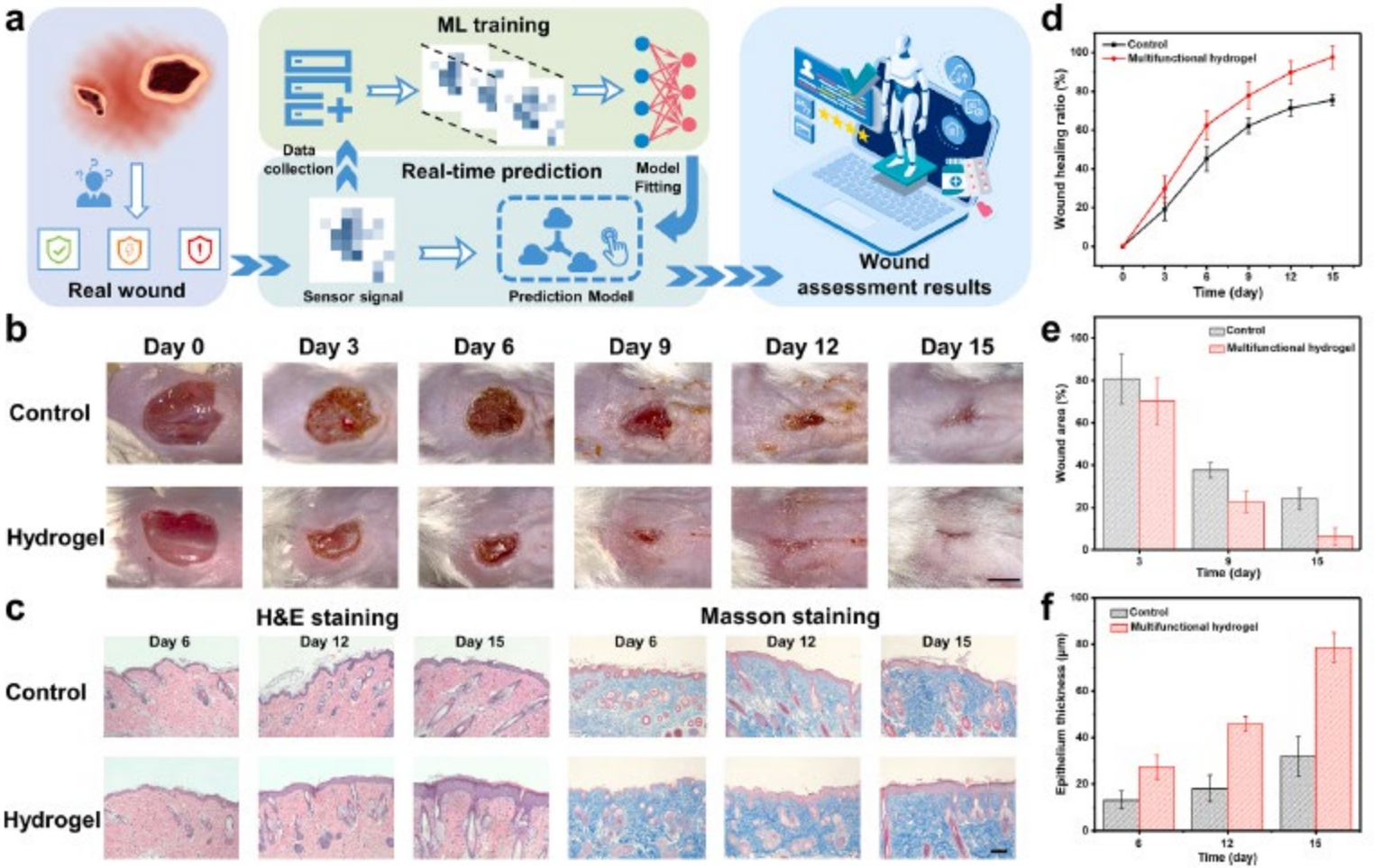
Multifunctional hydrogel as wound dressing for intelligent wound monitoring



A multifunctional hydrogel is employed as wound dressing for intelligent wound monitoring, which not only have the functions of antibacterial, hemostatic and adhesive properties for effectively promoting wound healing, but also can realize real-time wound status monitoring (e.g., pH). The whole intelligent wound monitoring process mainly includes three parts: wound recognition, real-time status monitoring and personalized wound management.

Chem. Eng. J , 2022, 433,134625.

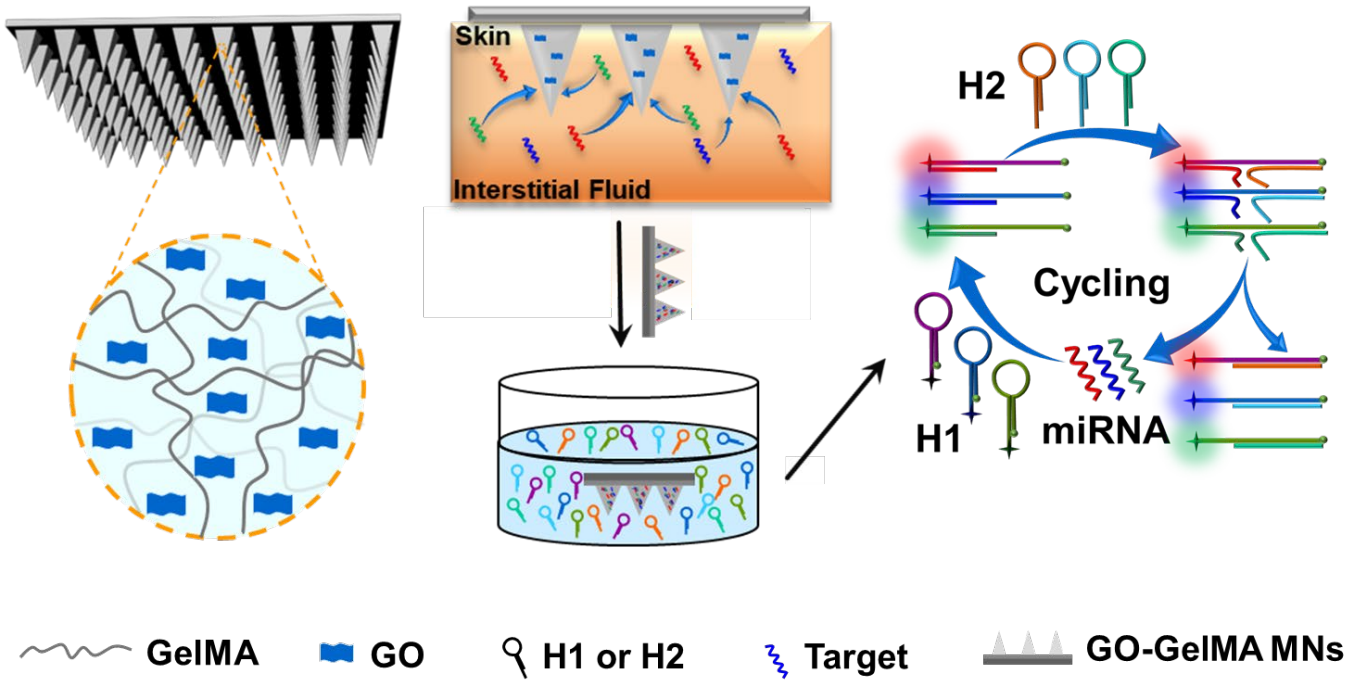
In vivo wound healing



Multifunctional hydrogel can be used as wound dressing for wound healing in vivo under intelligent wound monitoring. It mainly includes personalized wound management process from sensor signal collection to machine learning training and real-time prediction. From the first day to the 15th day, the healing process of wound treated with multi-functional hydrogel dressing can be observed significantly.

Chem. Eng. J , 2022, 433,134625.

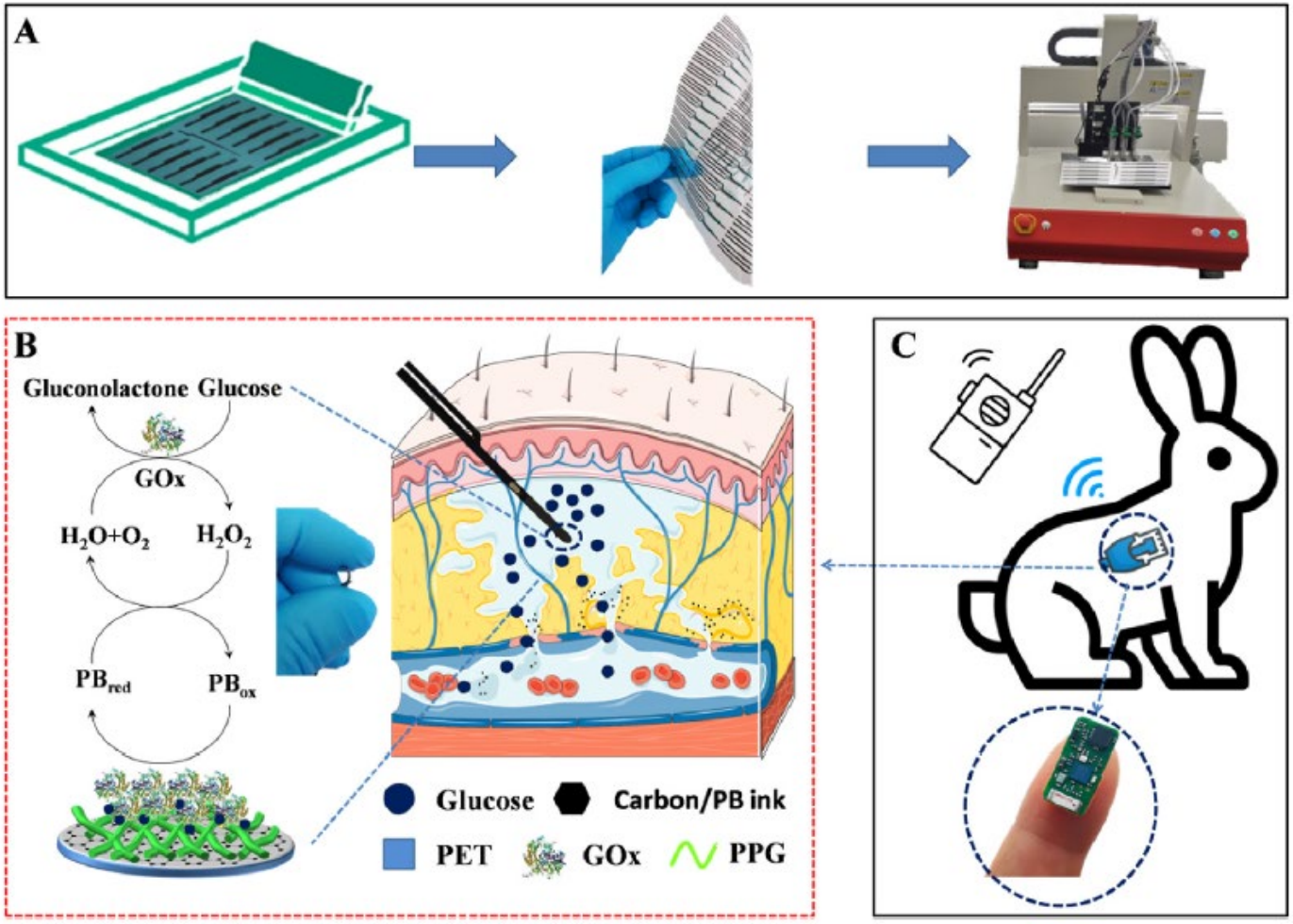
A Sample and Detection Microneedle Patch for Psoriasis MicroRNA Biomarker Analysis in Interstitial Fluid



We developed microneedles (MNs) that consist of gelatin methacryloyl (GelMA) and graphene oxide (GO) for the enrichment and sensitive detection of multiple microRNA (miRNA) biomarkers from skin ISF.

Anal. Chem., 2022, 94, 5538−5545

Fully integrated flexible biosensor for wearable continuous glucose monitoring

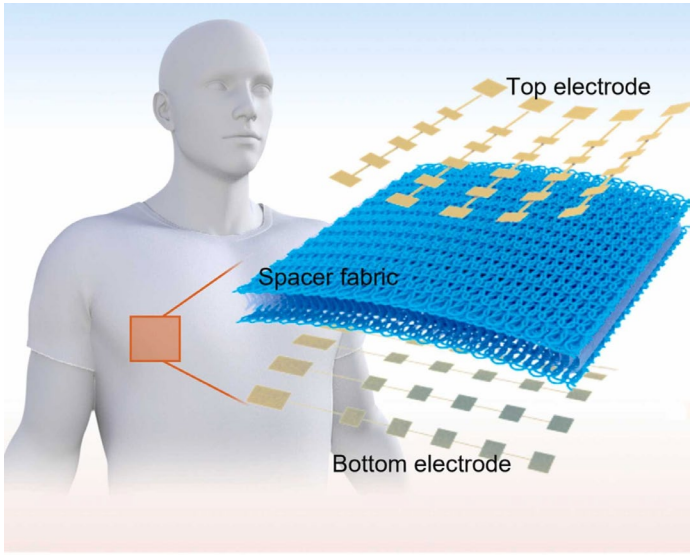


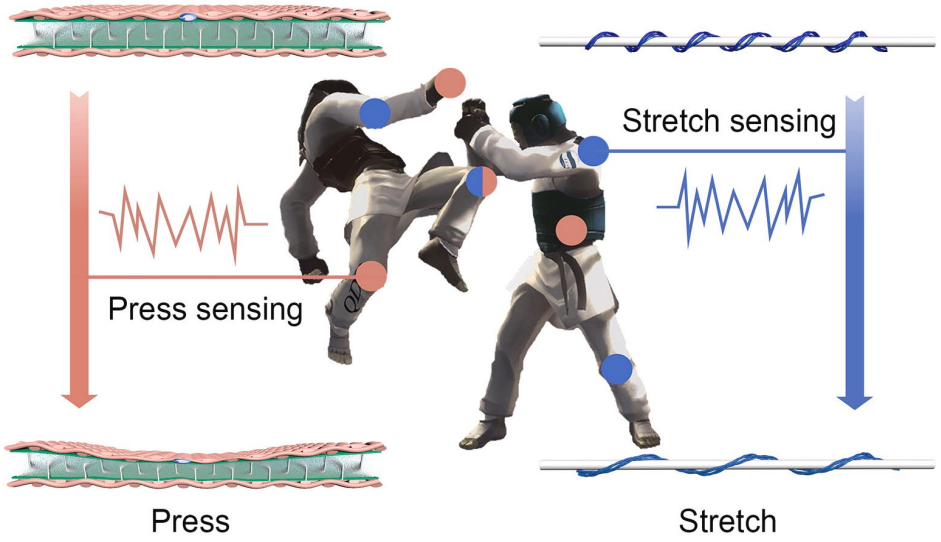
A flexible glucose sensor was designed with long-term stability up to 30 days. The entire system design is very small (0.8 × 1.8 cm) and mainly consists of a signal conditioning section, a programmable electrochemical chip, and a wireless connection to a smartphone using Bluetooth low energy.

Biosensors and Bioelectronics 2022, 196, 113760.

Intelligent textile-based sensors

- **We designed and fabricated two-dimensional intelligent textile sensing fabric;**
- **The fabric can achieve multi-mode sensing including limb movement, life signal monitoring.**



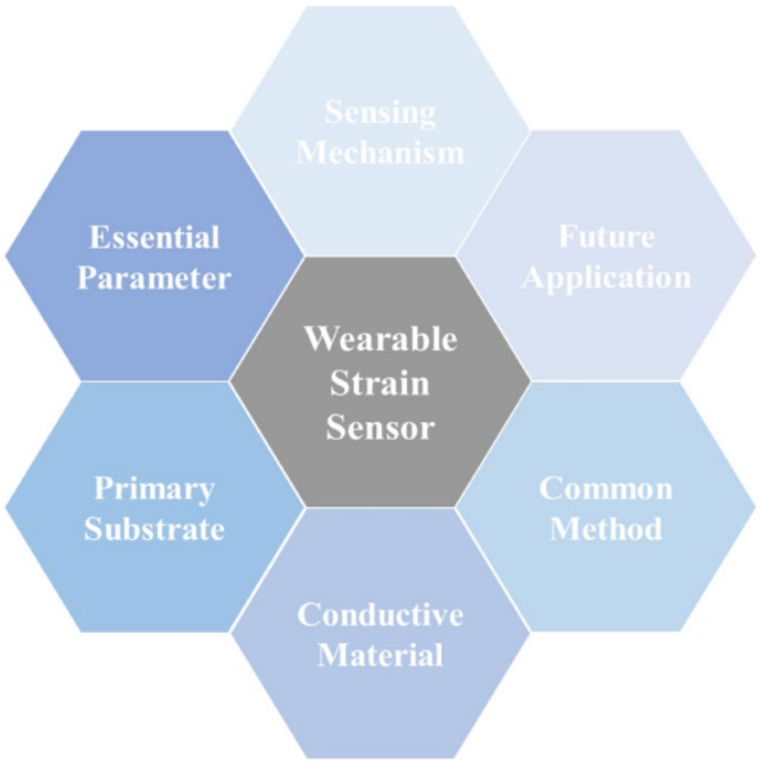


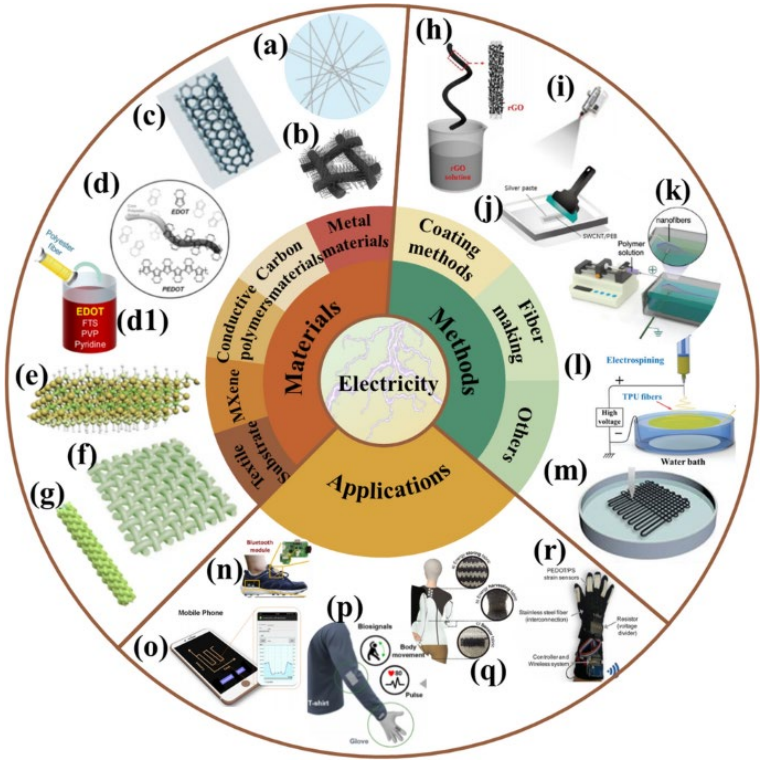
Chem. Eng. J. 2023, 451, 138321.
Chem.Eng.J 2022, 430, 1, 132605
Chem.Eng.J , 2022, 433,134625
Nano Lett., 2022, 22, 2, 740

Nano-micro letters, 2022, 14, 1
Nano Energy, 2021, 85, 105941
Nano Letters, 2021, 21,19, 8126
Adv. Mater. 2021, 33, 48,2105174

Nano Energy, 2020, 76, 104926
ACS AMI, 2020, 12,50, 55876
ACS nano, 2019, 14, 1, 559
Nano Lett. 2019, 19, 9, 6592.

Recent Progress on Smart Fiber and Textile Based Wearable Strain Sensors: Materials, Fabrications and Applications

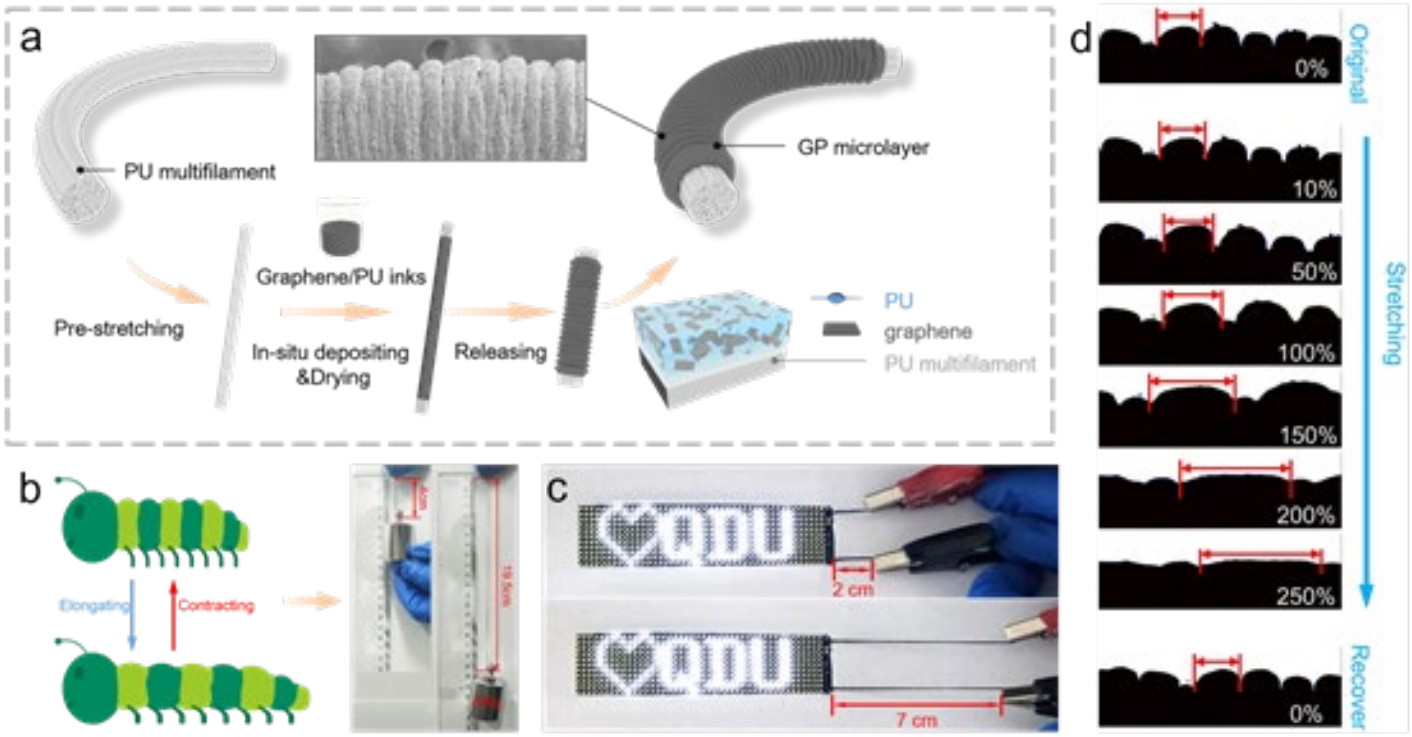




The research progress of flexible strain sensors in recent years are reviewed, which mainly introducing the sensing principles and key parameters of strain sensors, commonly used conductive materials and flexible substrates and common preparation methods, and finally proposes the future application and prospects of strain sensors.

Adv. Fiber Mater. 2022, 4:361–389

Stretchable Conductive Fibers of Ultra-high Tensile Strain Sensors

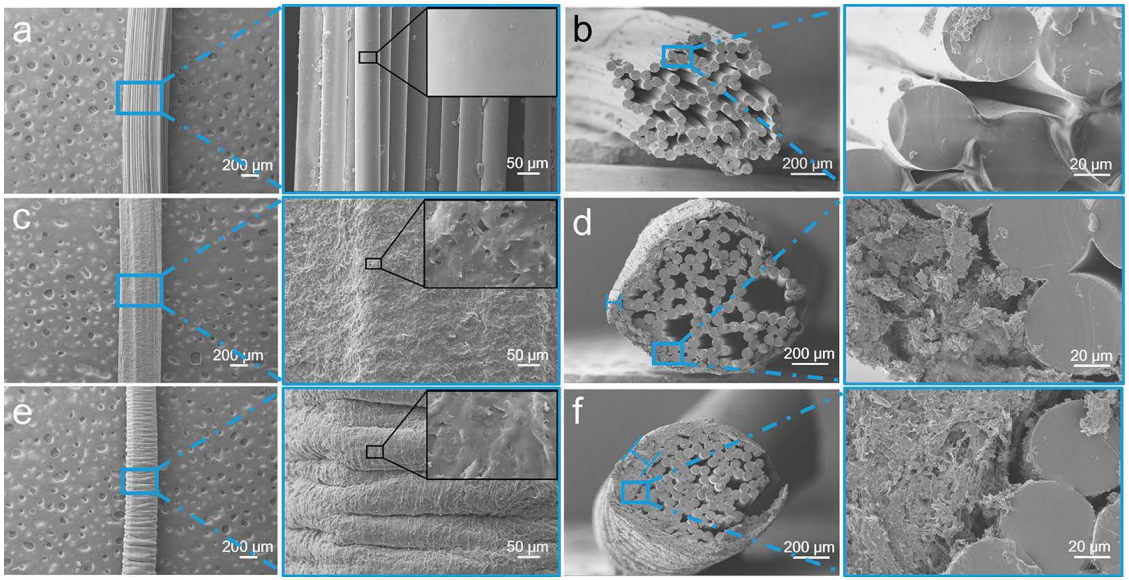


Bionic superelastic conductive polyurethane filaments with worm-shape graphene microlayer. The worm-shaped graphene structure aims to compensate strain deformation.

Nano Lett. **2019**, *19 (9), 6592-6599.*

Stretchable Conductive Fibers of Ultra-high Tensile Strain Sensors

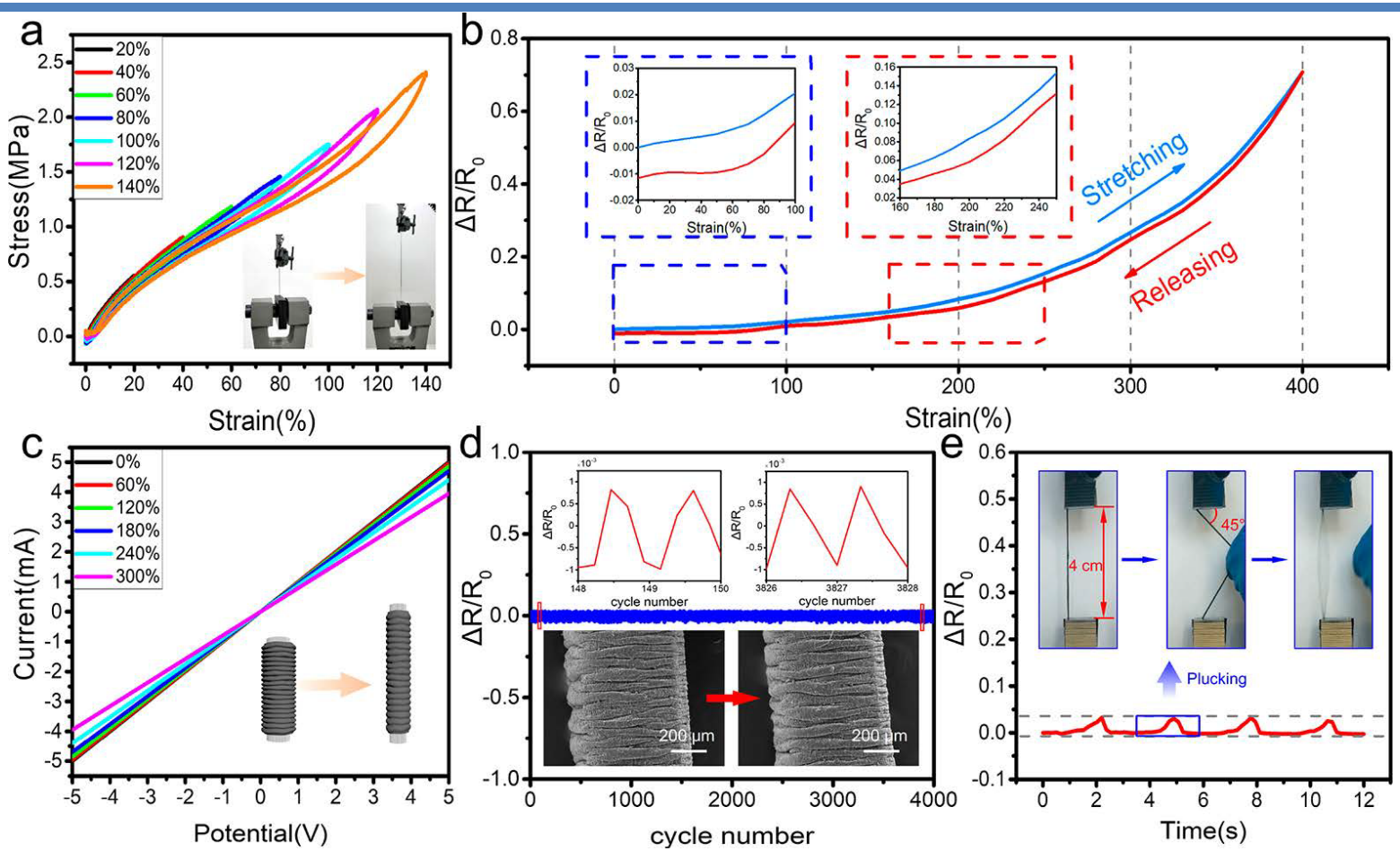
Front view Cross-section view



The graphene/PU microlayer is entirely deposited on the surface of the PU filament without an obvious gap or pore, indicating the well interface interaction between the microlayer and PU substrate.

Nano Lett. **2019**, *19 (9), 6592-6599.*

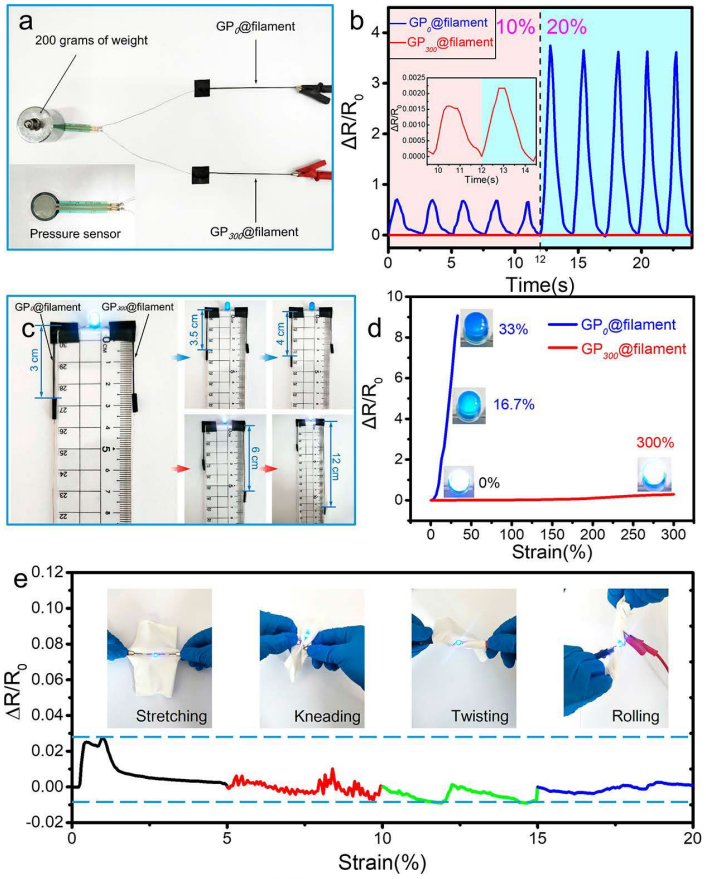
Stretchable Conductive Fibers of Ultra-high Tensile Strain Sensors



Strain-insensitive performance of stretchy electronics. $\Delta R/R_0$ of the filament is still under 0.8 and can even be elongated to 400%, 4000 cycles with only a 0.4% increase of electrical resistance compared with the initial value.

Nano Lett. **2019**, *19 (9), 6592-6599.*

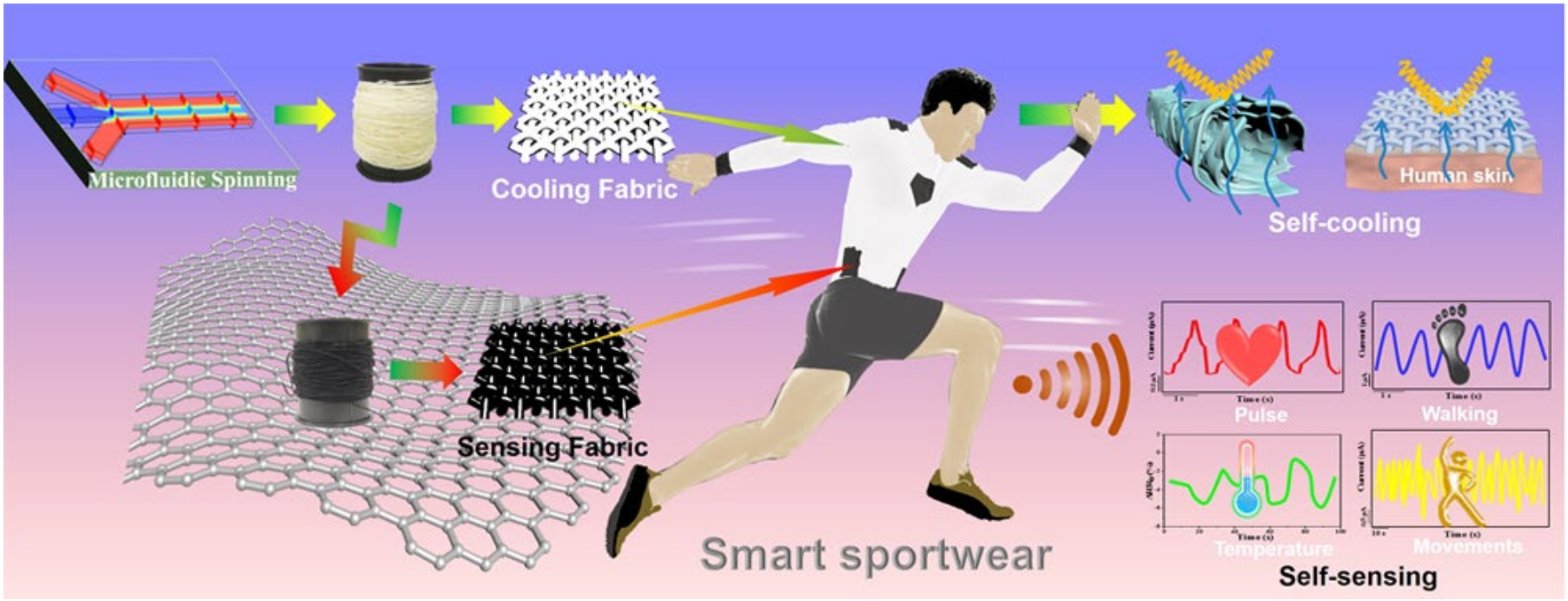
Stretchable Conductive Fibers of Ultra-high Tensile Strain Sensors



Typical applications example: stretchable and strain-insensitive electronic circuits

Nano Lett. **2019**, *19 (9), 6592-6599.*

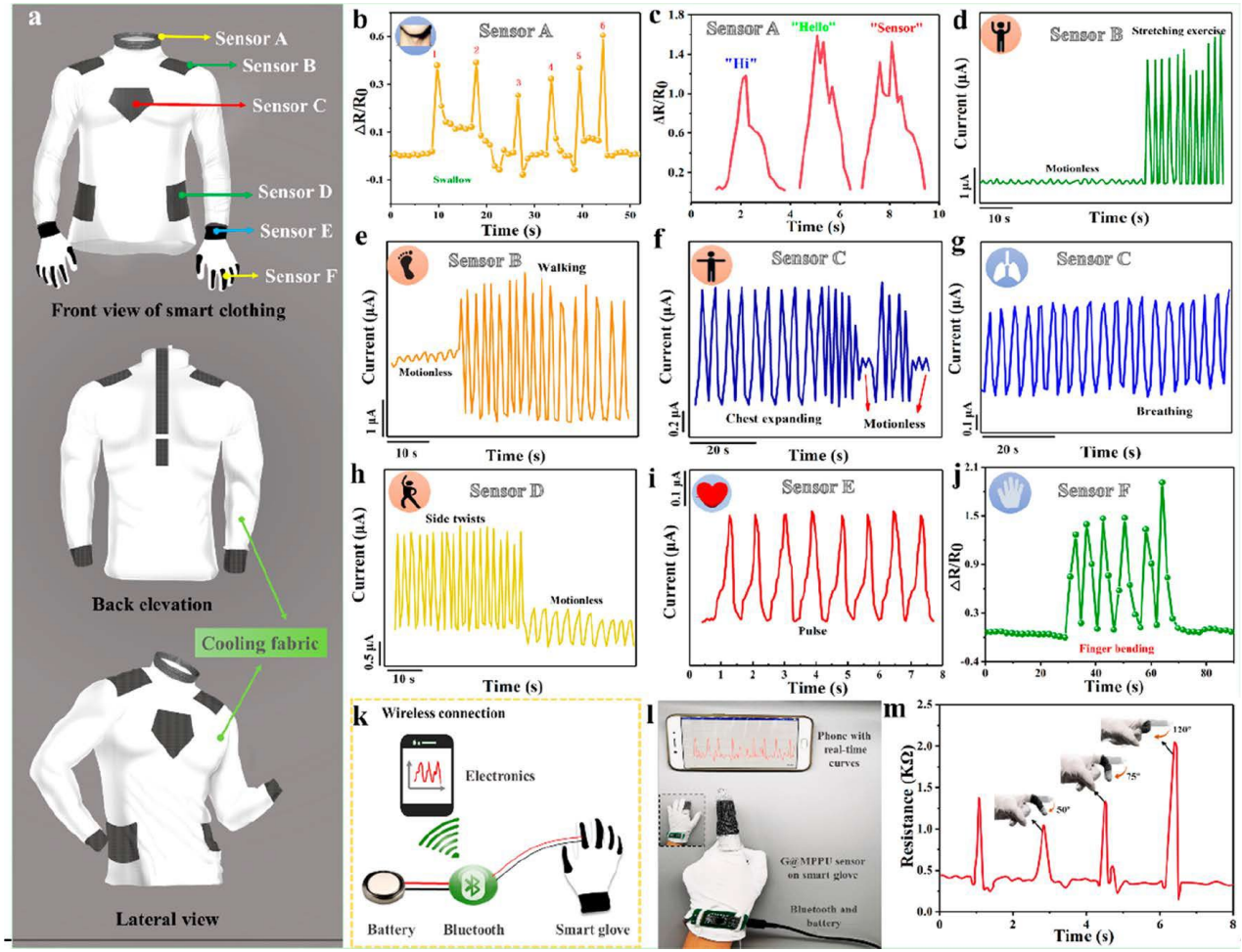
Self-Cooling Integrated Smart Sportswear



It has realized body temperature measurement, large-scale movement tracking of limbs, collection of human body's subtle physiological signals, and self-cooling ability.

ACS Nano 2020, 14 (1), 559-567.

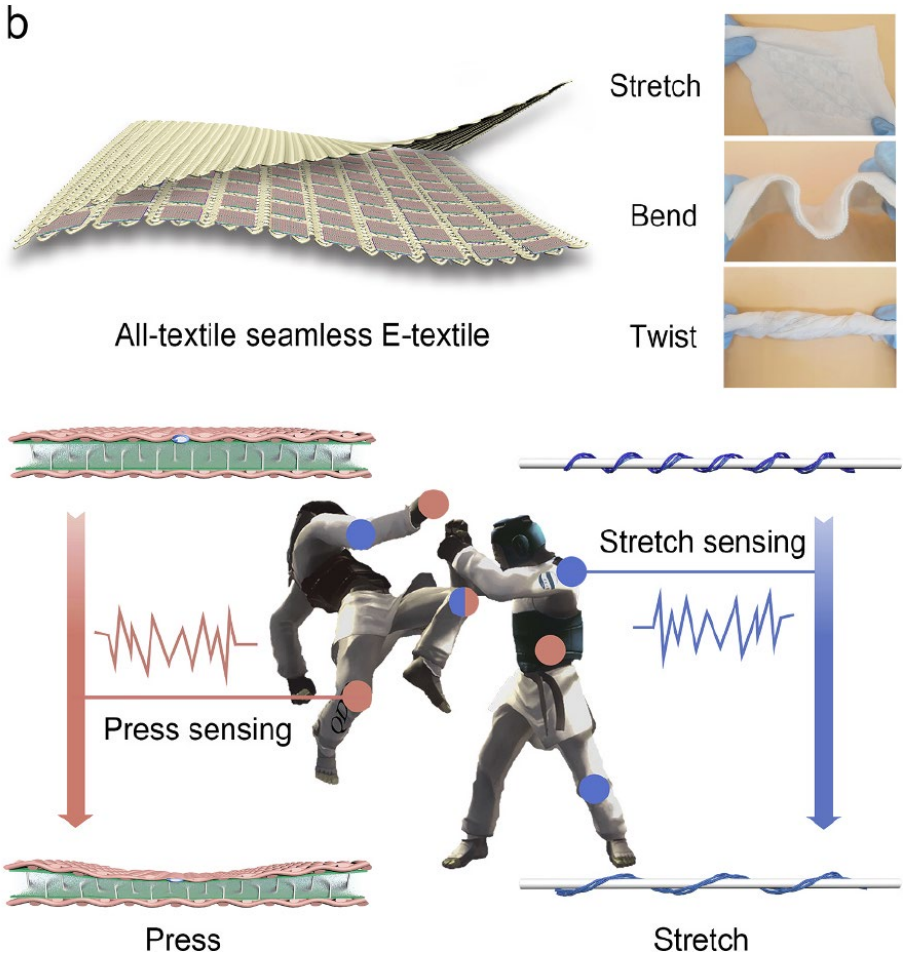
Self-Cooling Integrated Smart Sportswear



Smart clothing and applications on movements and vital signals' monitoring. (b) swallowing, (c) speaking, (d) stretching exercise, (e) walking, (f) chest expanding, (g) breathing, (h) side twist, (i) pulse, and (j) finger bending.

ACS Nano 2020, 14 (1), 559-567.

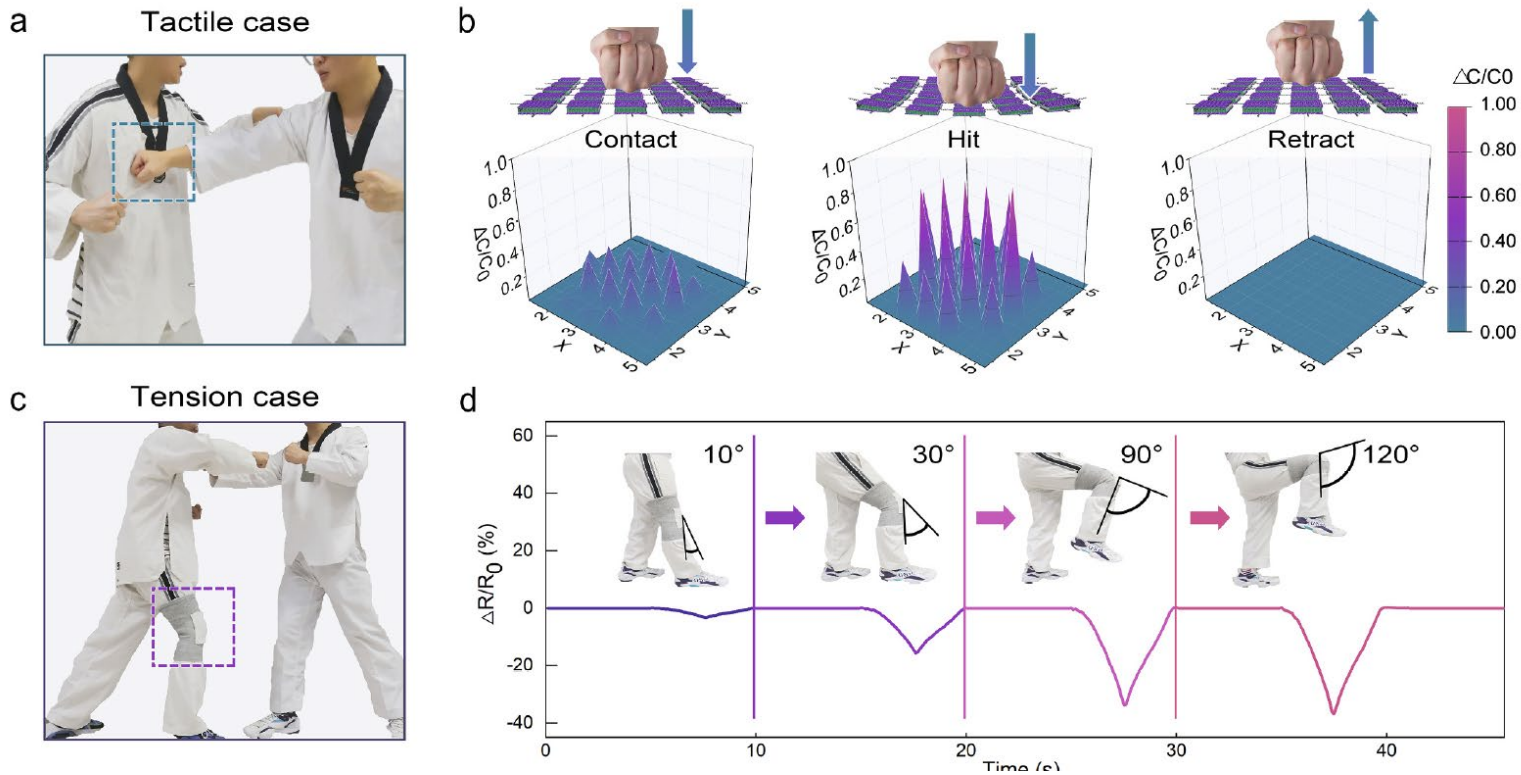
All-textile dual tactile-tension sensors



All in one textile Integrating stretch and press sensors for monitoring athletic motion during taekwondo .

Nano Energy **2021,** *85,* 105941.

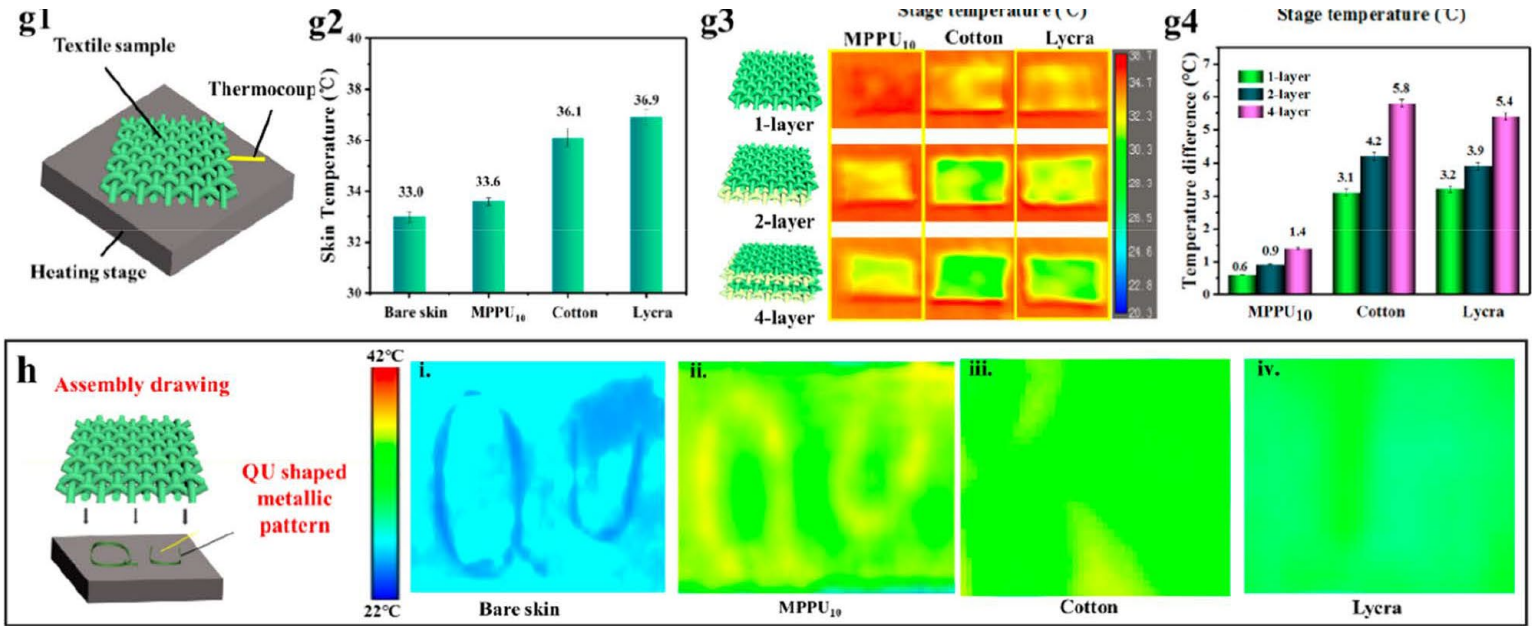
All-textile dual tactile-tension sensors



Application of the seamless E-textile to taekwondo suits. Tactile sensing response of the E-textile upon being hit in the chest being struck with a fist. And tension sensing response of the E-textile during joint bending.

Nano Energy **2021,** *85,* 105941.

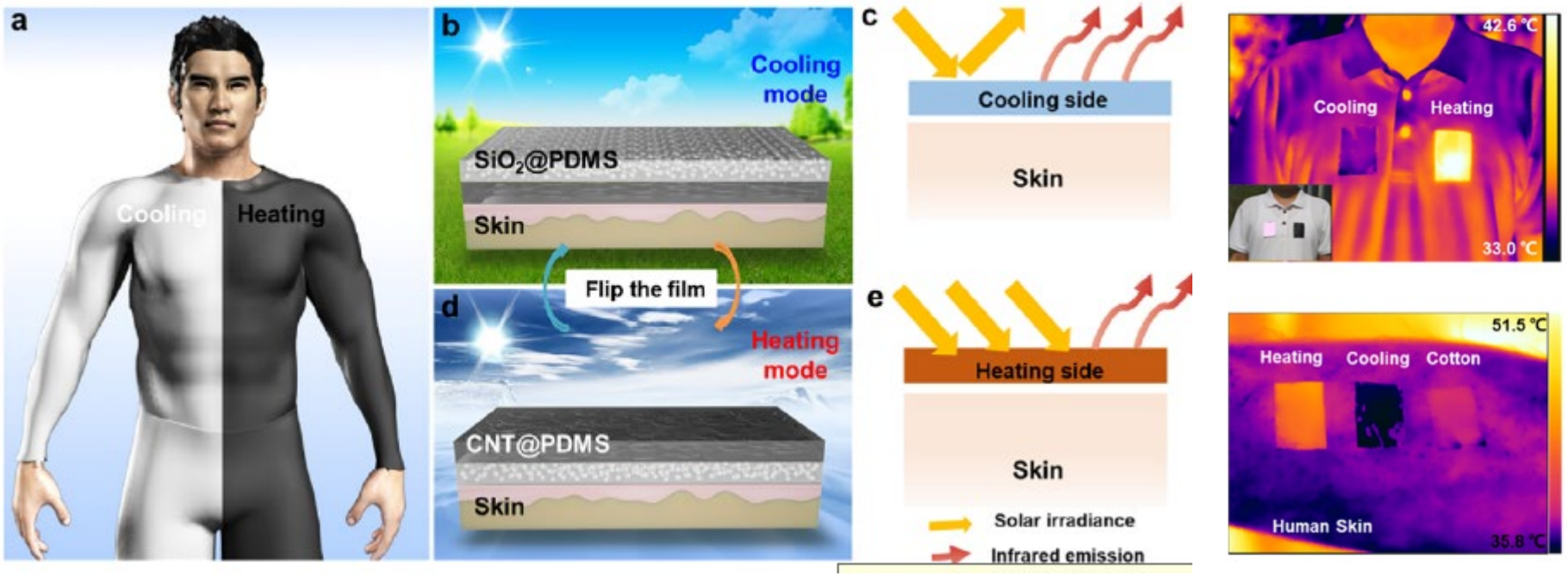
Self-Cooling Integrated Smart Sportswear



Thermal IR images of bare skin and the MPPU10, cotton, and commercial Lycra, Such a temperature difference indicates MPPU10 fabrics possess an excellent heat dissipation property.

ACS Nano 2020, 14 (1), 559-567.

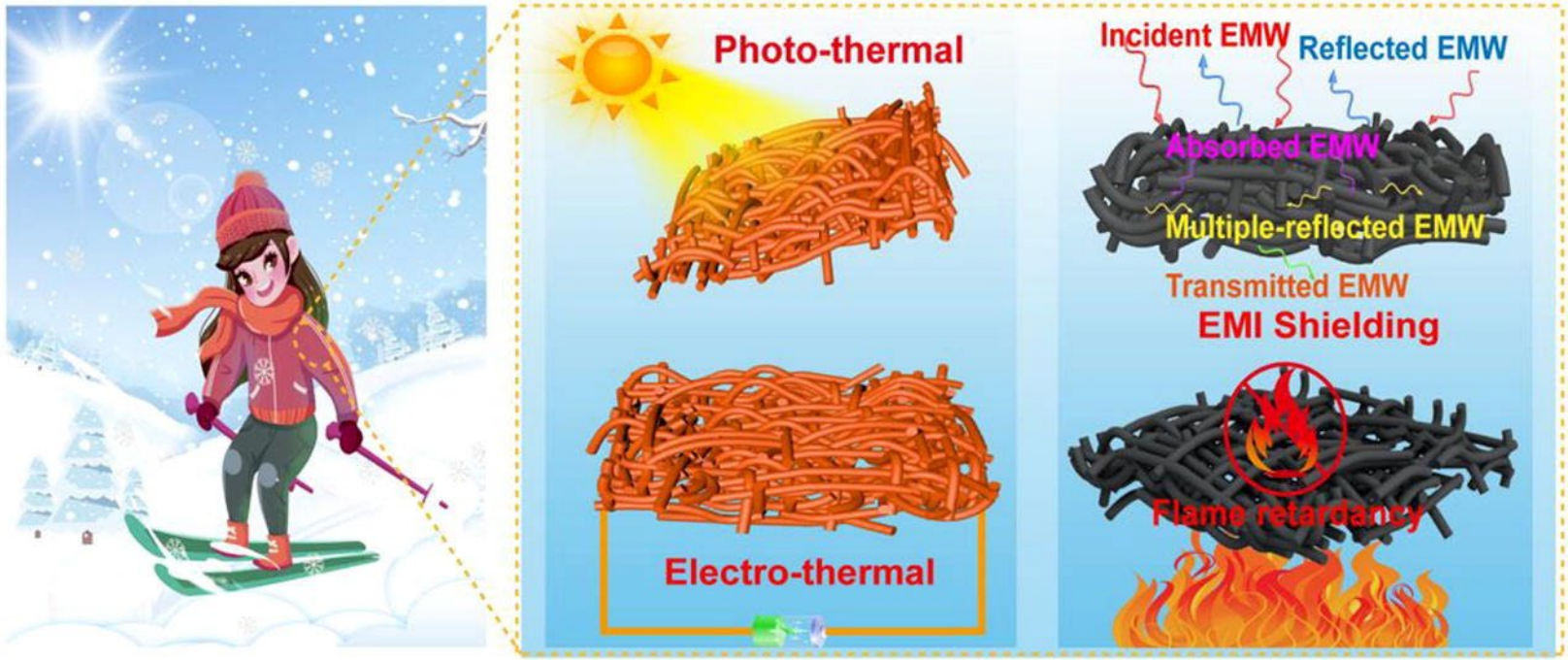
Radiative Cooling and Solar Heating Janus Films for Personal Thermal Management



a Janus film that integrates the two opposite requirements of heating and cooling into one functional dual-mode film is fabricated. In cooling mode, the backing and embedded silicon dioxide (SiO2) microparticle can achieve a high solar reflectivity (~0.85) and high IR emissivity (~0.95) to induce a temperature drop of ~2 ° C. In contrast, the embedded carbon nanotubes (CNTs) can improve solar absorption (~0.95) and induce a temperature increase of ~7 ° C.

B. Dai, X. Li, T. Xu, X. Zhang, ACS Appl. Mater. Interfaces 2022, 14, 18877-18883

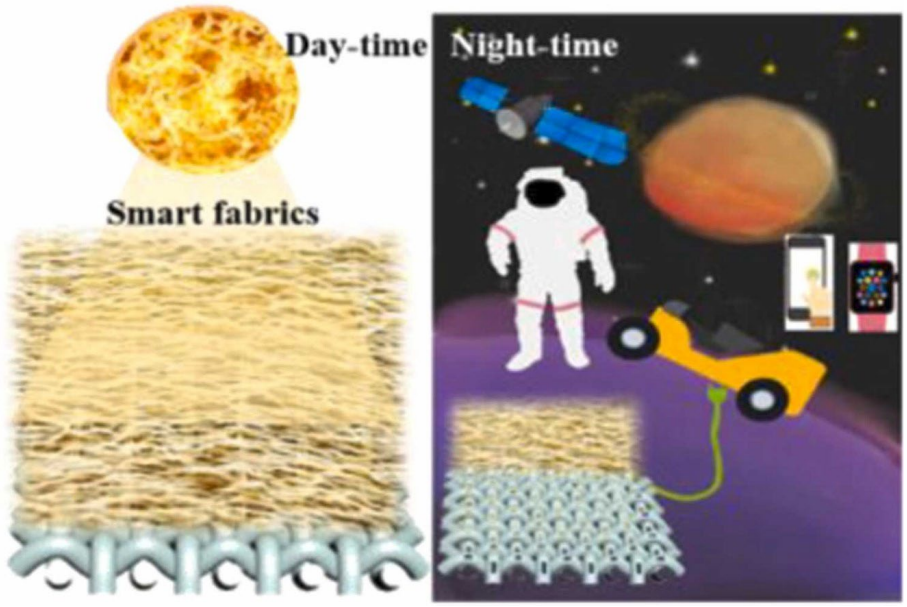
A lightweight MXene-Coated nonwoven fabric for wearable heater



The integration of Joule heating and solar photothermal conversion into a wearable heating system demonstrates an energy-saving method for all-day thermal management, allowing the flame retardant MXene fabric to precisely heat the body in a variety of scenarios including indoor/outdoor, day/night, sunny/cloudy.

Chem. Eng. J , 2022, 430,132605.

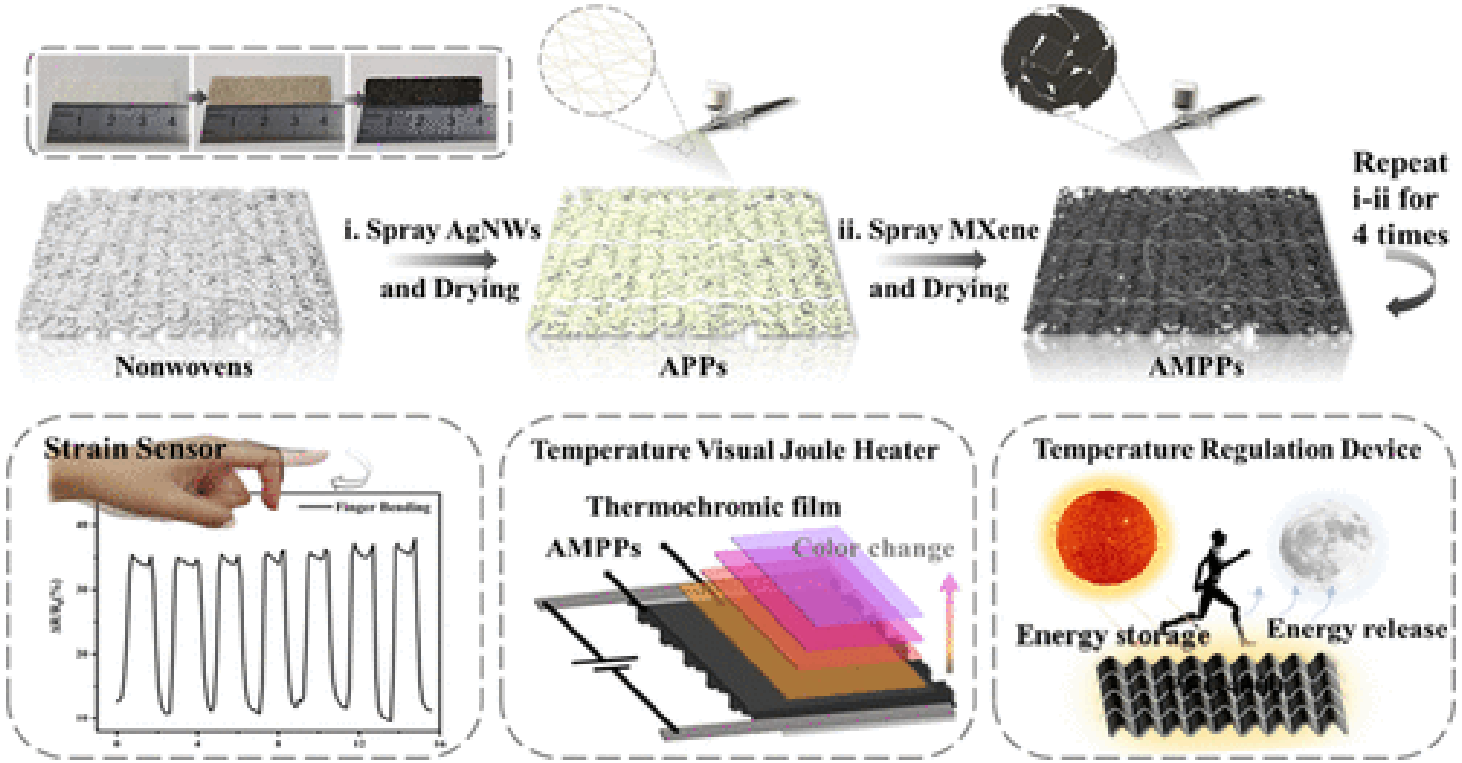
Smart multi-responsive aramid aerogel fiber enabled self-powered fabrics



Smart multi-response (light, electrical, heat, temperature, stress) fiber was successfully developed via wet-spinning porous ANFs aerogel while utilized as 3D hierarchically percolating skeleton for silver nanowires (AgNWs) interwoven transition metal carbide/nitride (MXene) interconnected conductive network, followed by impregnating organic polyethylene glycol (PEG) and encapsulated with transparent fluorosilicone (FSi) resin.

Nano Energy, 2022, 101,107559.

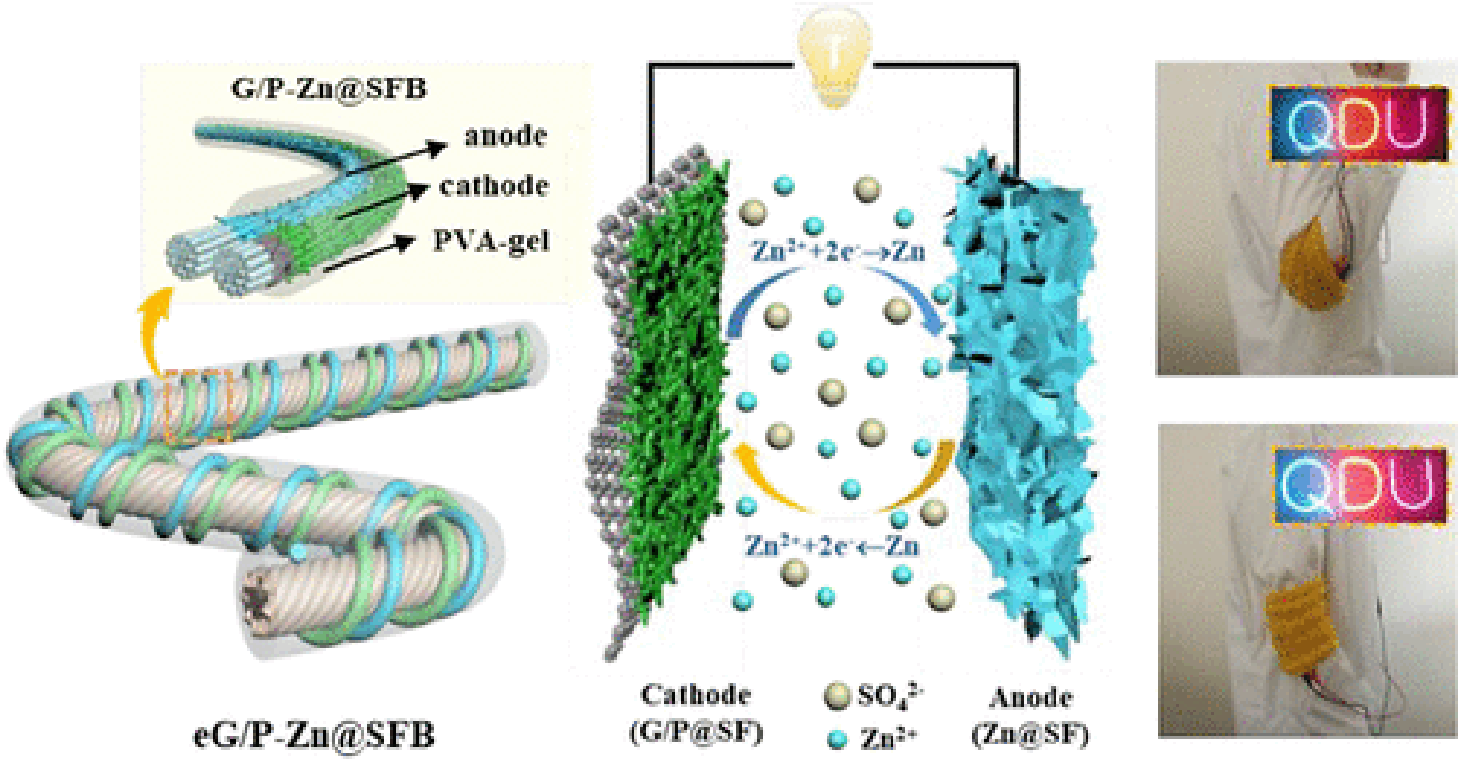
Smart Textile Based on 3D Stretchable Silver Nanowires/MXene Conductive Networks for Personal Healthcare and Thermal Management



We proposed a personal healthcare and thermal management smart textile with a three-dimensional (3D) interconnected conductive network, formed by silver nanowires (AgNWs) bridging lamellar structured transition-metal carbide/carbonitride (MXene) nanosheets deposited on nonwoven fabrics.

ACS Appl. Mater. Interfaces 2021, 13, 47, 56607–56619

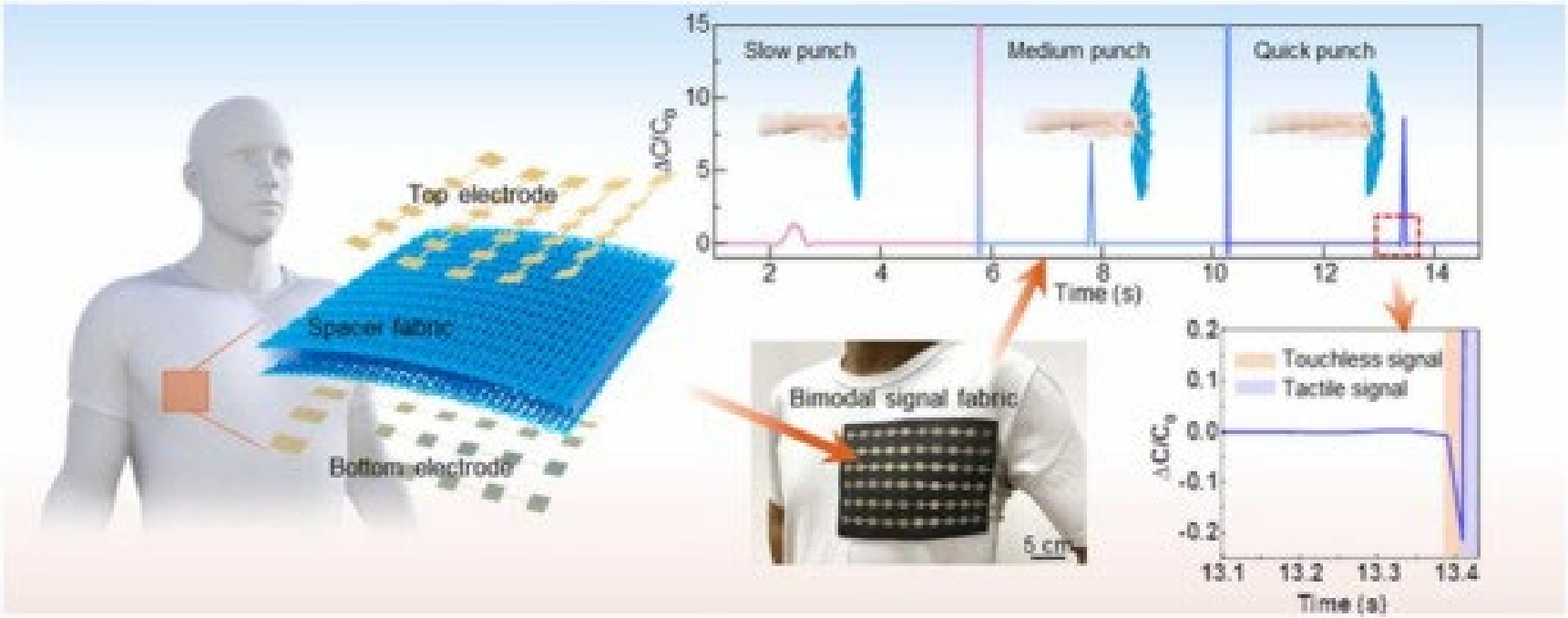
Tendril-inspired 900% ultrastretching fiber-based zn-ion batteries for wearable energy textiles



An elastic graphene/polyaniline-Zn@silver fiber-based battery (eG/P-Zn@SFB) with a helical structure inspired by the biological structure of luffa tendril is reported.

ACS Appl. Mater. Interfaces 2021, 13, 14, 17110–17117

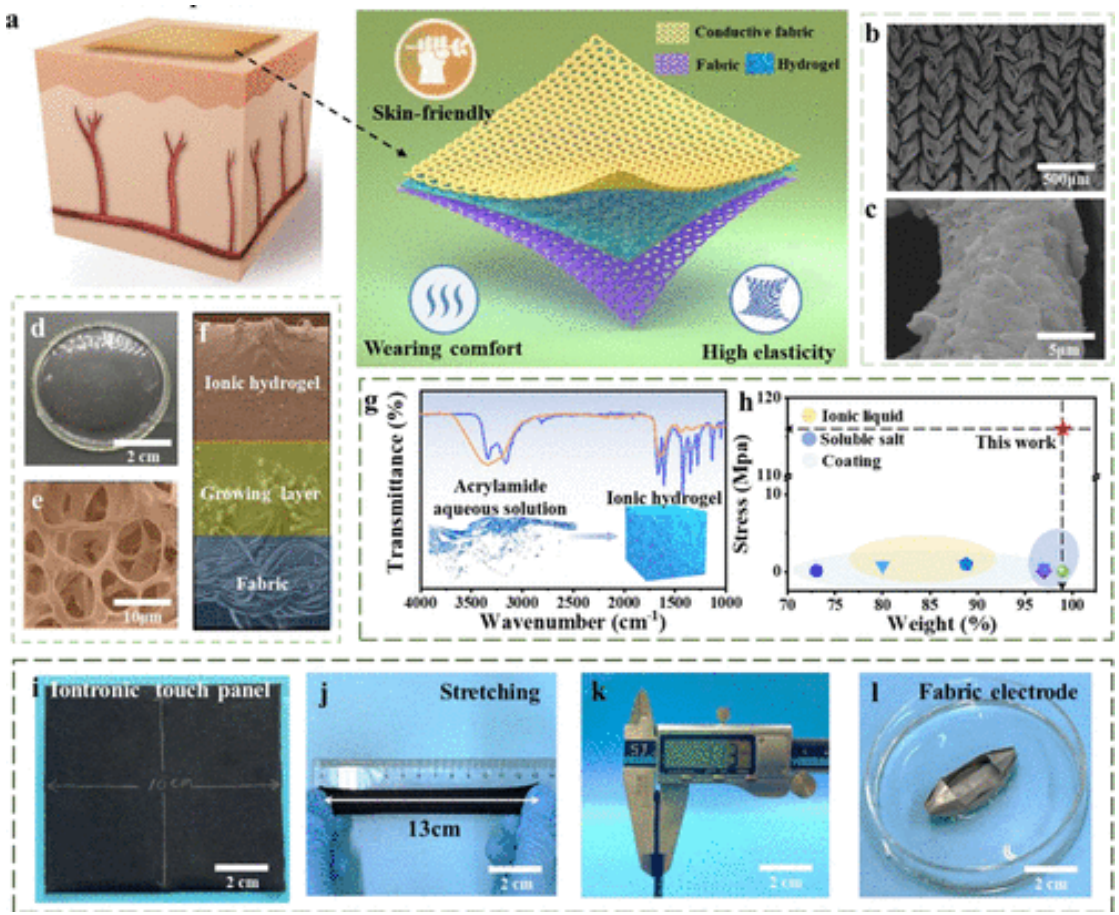
All-textile sensors for boxing punch force and velocity detection



We develop a new design of wearable and stretchable tactile and touchless sensor, called the Bimodal All-Textile (BAT) sensor, which presents high sensitivity, long-term stability, and good wearability for monitoring motion in sports.

Nano Energy, 2022, 97,107114.

Skin-Friendly and Wearable Iontronic Touch Panel for Virtual-Real Handwriting Interaction

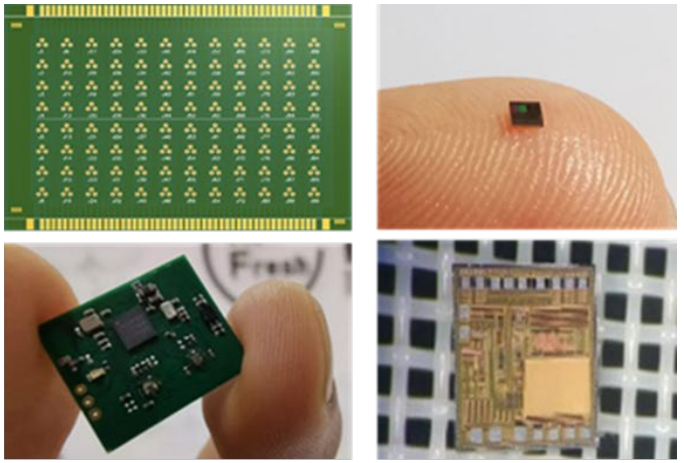


a skin-friendly and wearable iontronic textile-based touch panel with highly touch-sensing resolution and deformation insensitivity is designed based on an in-suit growing strategy. The developed touch panel enables handwriting interaction with good mechanical capacity (114 MPa), nearly 4145 times higher than pure hydrogel. More importantly, our touch panel possesses intrinsic insensitivity to wide external loading from the silver fiber (<0.003 g) to even heavy metal block (>10 kg).

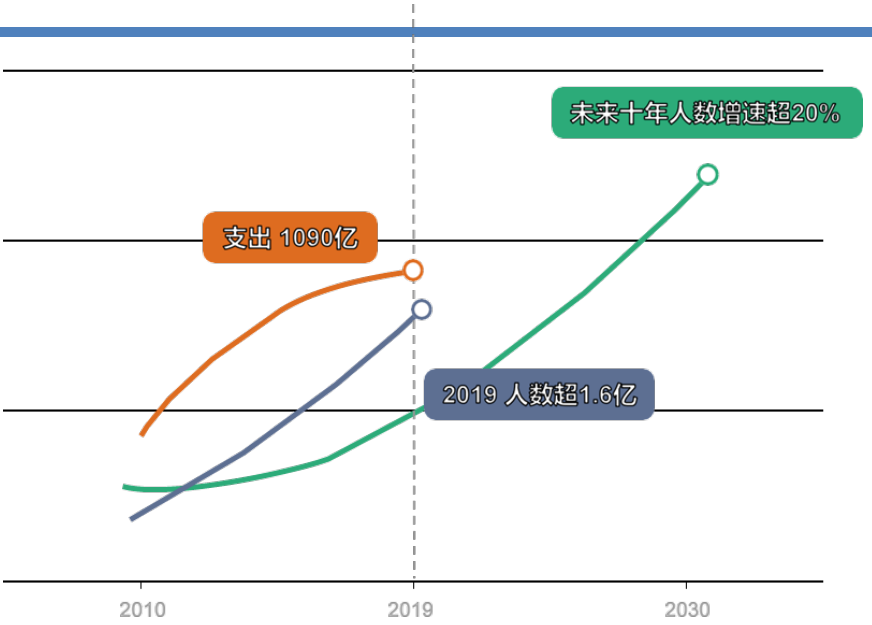
ACS Nano 2023, 17, 9, 8293–8302

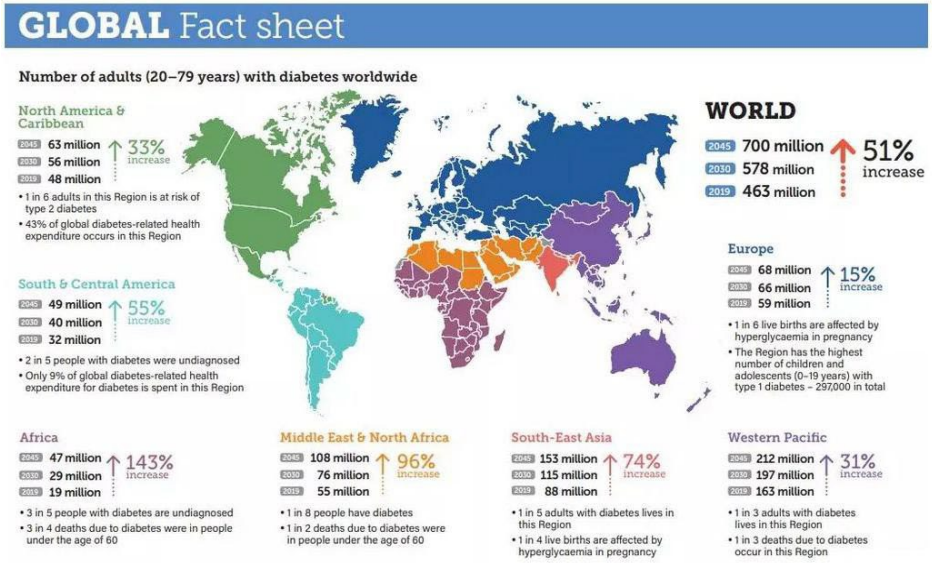
From Campus to Commercialization

Commercialization



Survey of diabetes population





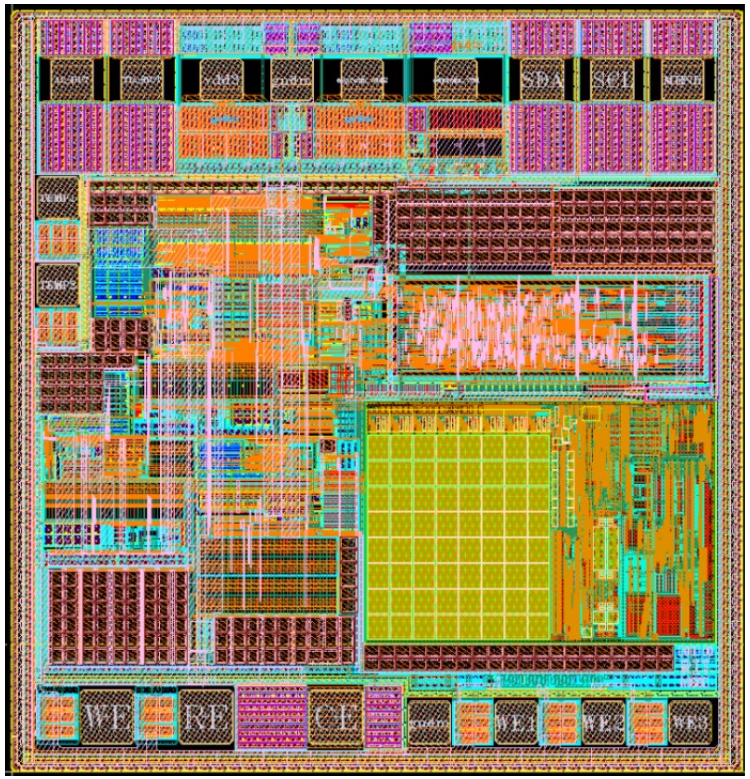
Large scale

In 2023, the global total of diabetes was about 563 million, with an average growth rate of 51% on all continents.

There are 148 million people with impaired glucose tolerance in early China and 116.4 million people with diabetes. One in 10 people has impaired glucose tolerance. And eight out of every 100 people are diabetic.

Rank	2019		2030		2045	
	Country or territory	No. of people w diabetes (millions)	Country or territory	No. of people w diabetes (millions)	Country or territory	No. of people w diabetes (millions)
1	China	116.4	China	140.5	China	147.2
2	India	77.0	India	101.0	India	134.2
3	United States of America	31.0	United States of America	34.4	Pakistan	37.1
4	Pakistan	19.4	Pakistan	26.2	United States of America	36.0
5	Brazil	16.8	Brazil	21.5	Brazil	26.0
6	Mexico	12.8	Mexico	17.2	Mexico	22.3
7	Indonesia	10.7	Indonesia	13.7	Egypt	16.9
8	Germany	9.5	Egypt	11.9	Indonesia	16.6
9	Egypt	8.9	Bangladesh	11.4	Bangladesh	15.0
10	Bangladesh	8.4	Germany	10.1	Turkey	10.4

Refresh®Biochip-MS02



http://home.refresh.cc/

Technical Parameters

- The accuracy is 10pA, and the measurement range is 10pA~100uA;
- The bias voltage output range is wider and the accuracy is higher; 8-bit DAC;
- Support 3-electrode and two-electrode system;I2C bus communication

System function (micro electrochemical workstation)

- Cyclic voltammetry
- Chronoamperometry
- Differential pulse voltammetry
- Anodic stripping

Application scenario

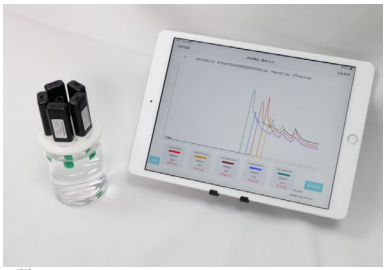
- Heavy metal detection
- Gas/liquid detection based on electrochemical principles, such as formaldehyde, hydrogen, etc.;
- Support sensor array

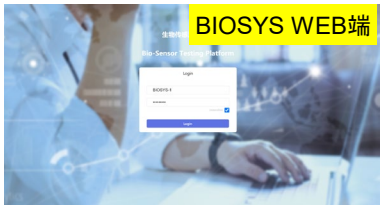
1.1 Intelligent Biosensor System-BIOSYS

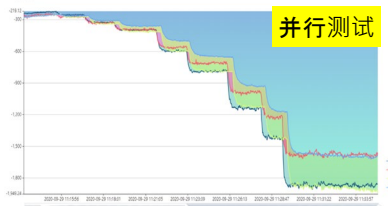
Features

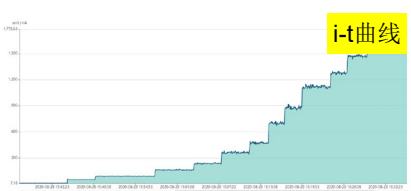
BIOSYS is a biosensing system developed by Shenzhen Refresh Intelligent Electronics Co., Ltd. based on the self-developed biochip MS02. It can be used for the development of electrochemical enzyme sensors, microbial sensors, DNA sensors, nucleic acid sensors and immunosensors. It is also suitable for studying membrane interfaces. Electron transfer, as well as the development and industrialization of electrochemical gas sensors, heavy metal detection sensors, ion sensors and pH sensors;

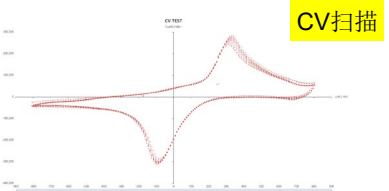
BIOSYS has the characteristics of high integration, easy operation, real-time observation of experimental process and results, automatic analysis of experimental data and parallel transplantation, and its system software can realize OTA remote upgrade.







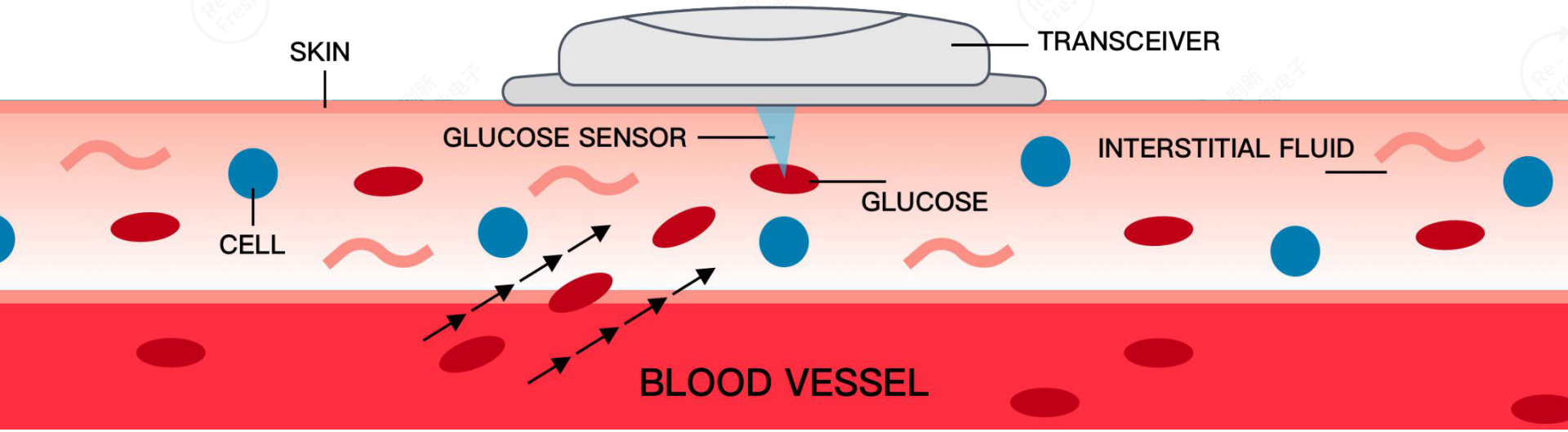




Refresh®CGM Continuous Glucose Meter

Continuous Glucose Monitoring

affordable for all diabetics

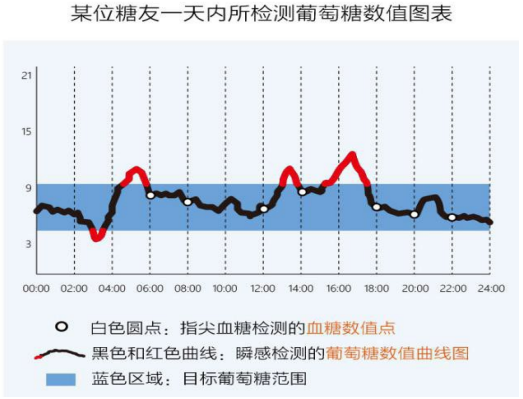


Dynamic glucose monitoring is the main way of blood glucose management

SMBG and HbA1c monitoring

SMBG is cheap and affordable, but it is not real-time and continuous, and it is very painful. It can not reflect the whole day blood glucose map.

HbA1c reflects the average blood glucose level of the past 2-3 months and has a delayed effect on treatment evaluation, and does not reflect the risk of hypoglycemia or the characteristics of blood glucose changes



CGM

CGM is a Must Have product for patients with type I diabetes and a Nice to Have product for patients with type II diabetes who receive intensive insulin- therapy

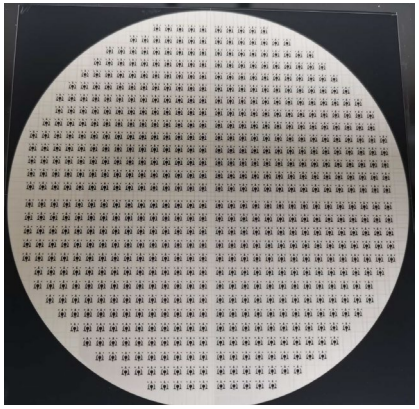
1.3 Intelligent Biosensor System-BIOSYS

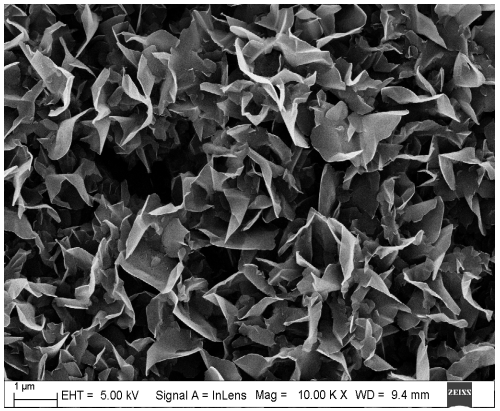
- **Application:**
- Portable equipment: environmental monitoring, food testing, drug and drug testing, urine testing;
- Wearable devices: sweat analysis, smart bracelet, smart clothing, glucose monitoring
- Electronic skin: testing and industrialization of flexible stress-strain materials
- Swallowable equipment: electronic biological capsule (9*12mm)
- **Benefits:** parallel porting of software algorithms, saving development time
- **Services:** Prototype customization, algorithm development, Development of batch test system and process customization, project cooperation

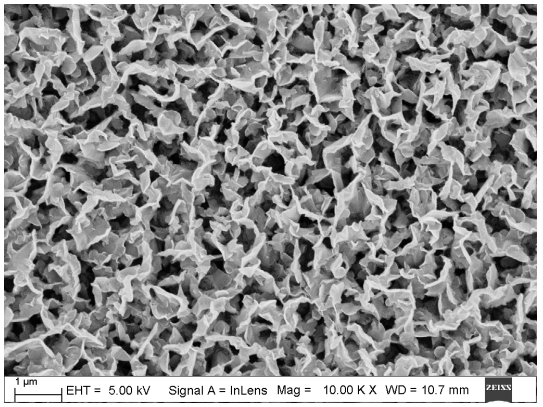



Microelectrode fabrication

- **Base material**:PET,Ceramic,silicon
- Electrode material:carbon,Au,Pt,Graphene
- **shape:**Disposable printed , needle , integrated, assembled, customized electrodes;







1.6 BIOSYS Packing List

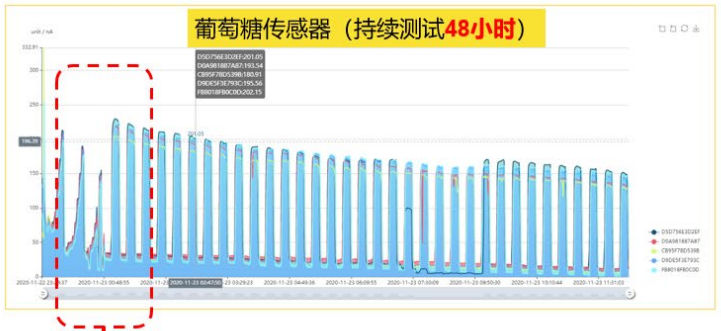
In the Box			
Number	Module	Modle P15E MAX	Modle P15E
①	BIOSYS Host	2	2
②	Electrode adapter unit	2 Current Type Adaptation Units 2 Potential Type Adapter Units 5 Alligator clip wires	2 Current Type Adaptation Units 5 Alligator clip wires
③	Calibration unit	C01-1M，C01-1K	C01-1M，C01-1K
④	Testing electrode	2 Printed electrodes	2 Printed electrodes
⑤	Electrolysis cell	1	1
⑥	Application	Android photo/Pad APP	Android photo/Pad APP
⑦	Web-side data platform	✓	✓
⑧	User Manual	✓	✓
⑨	Factory inspection report	✓	✓
⑩	Anti-static box	1	1
⑪	Android display terminal	1 Original system Pad	×

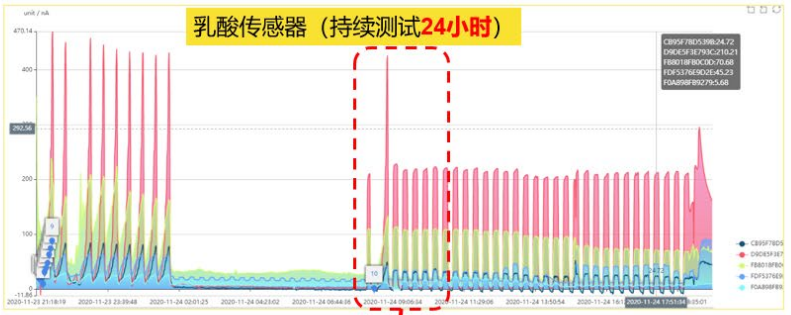
Application case:

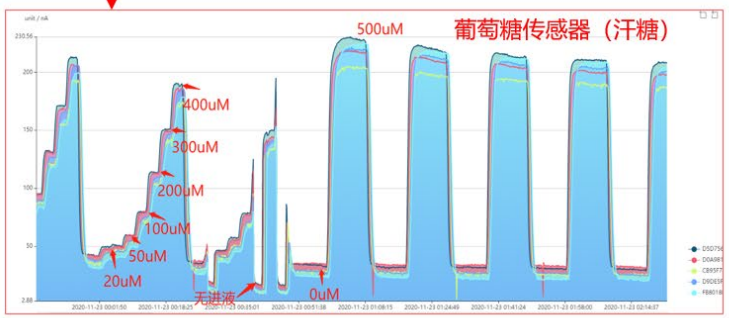
glucose sensor and lactate sensor

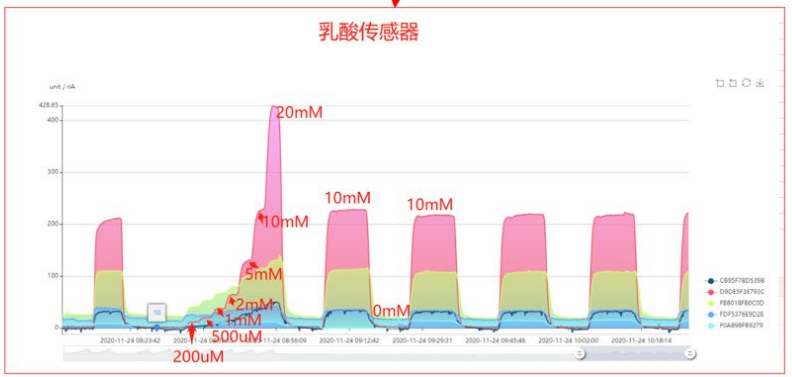
MORE THAN REFRESH 不止于刷新

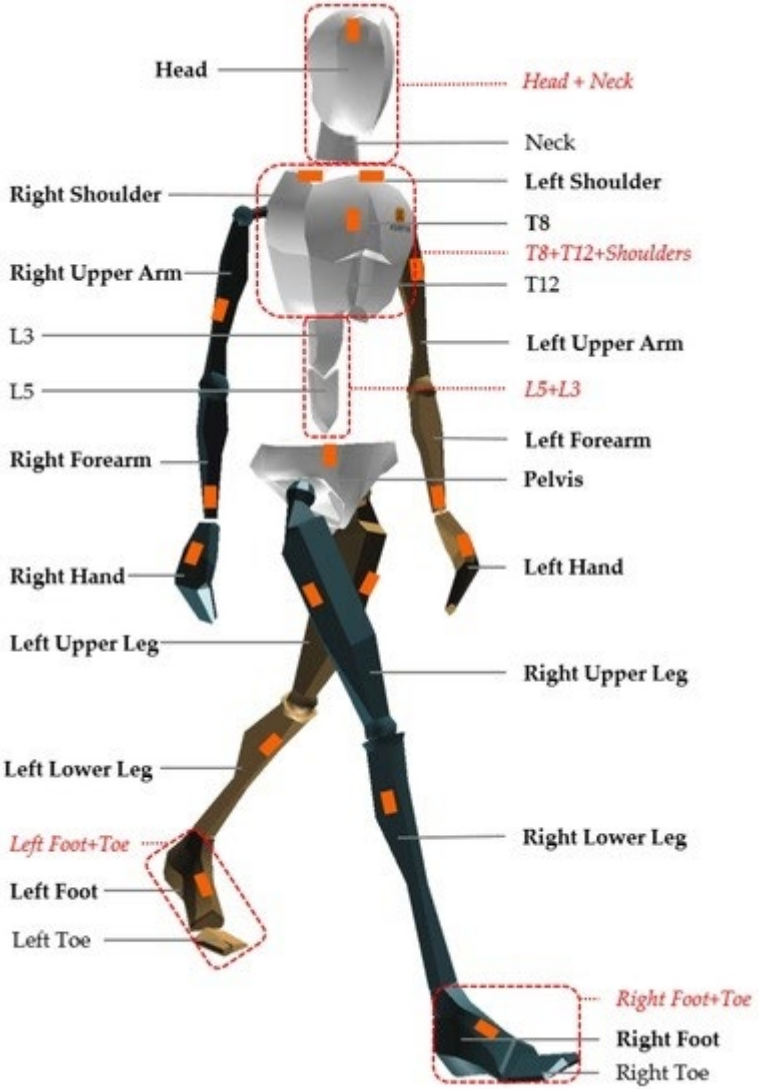
Application: glucuse sensor,lactate sensor

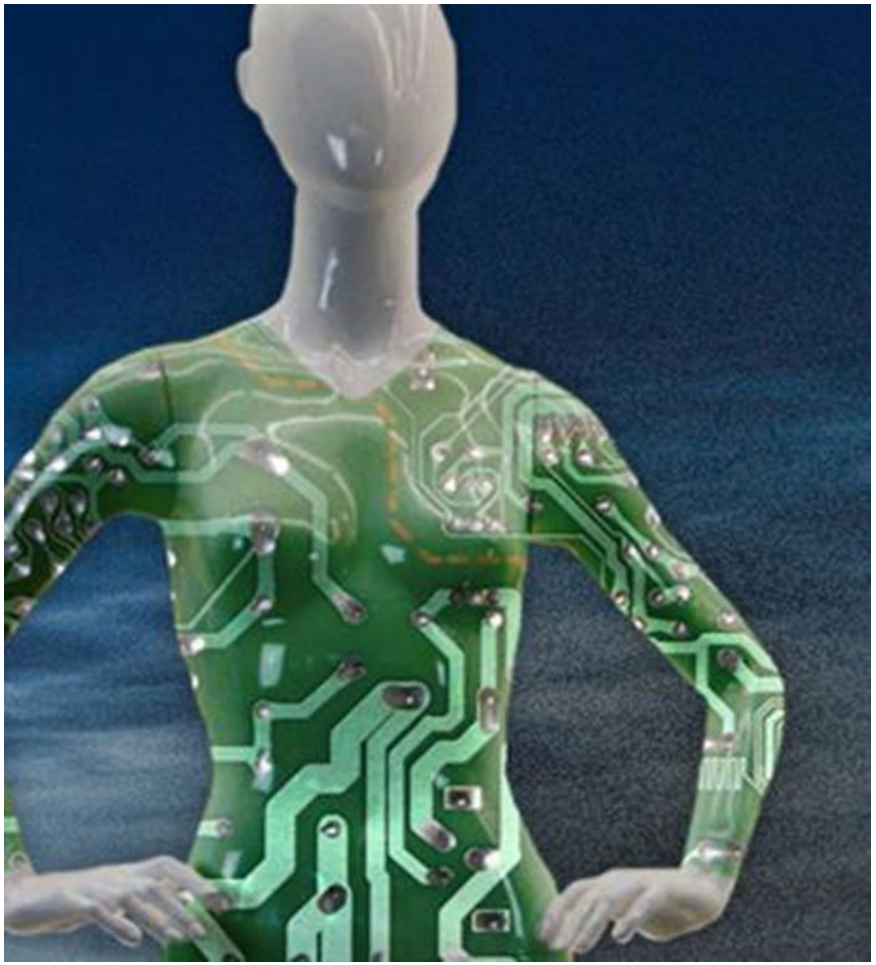












Towards “lab-on-Skin”

其它产品

智能多功能衣服

- 脑电
- 眼动
- 眼电
- 鼾声
- 体动
- 海拔
- 气压
- 杀菌
- 血压
- 血氧
- 脉率
- 心电
- 呼吸
- 心率

- 血糖
- 体温
- 体脂
- 肌电
- 轨迹
- 加热
- 制冷
- 防弹
- 防刺
- 压力分布
- 地理位置
- 电子围栏
- 身体姿态
- 无线传输
- ...

AIBio Sensing智能传感

Digital Human数字人生

Deaf can hear聋子能听见

Blind can see瞎子能看见

Numb can speak 哑巴能说话

Paralytic can run 瘫子跑起来

Intelligent + Diligent 智慧+勤奋

Eternal Life --Fact OR Fiction人类永生 ---事实还是幻想！

致 谢

国家自然科学基金委员会
National Natural Science Foundation of China

中华人民共和国科学技术部
Ministry of Science and Technology of the People's Republic of China

◆ 2022 科技部智能传感器重大专项（90M），2023 孔雀团队（15M）

◆ 2016YFC0106600 科技部 微流控芯片-核酸质谱集成装备研制及在肿瘤精准医学中

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