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The Center for Education and Research in Information Assurance and Security

Nanomanufactured connected wearable sensors for human body digital twins

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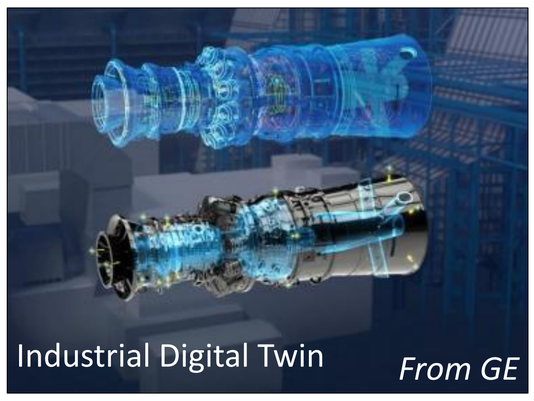
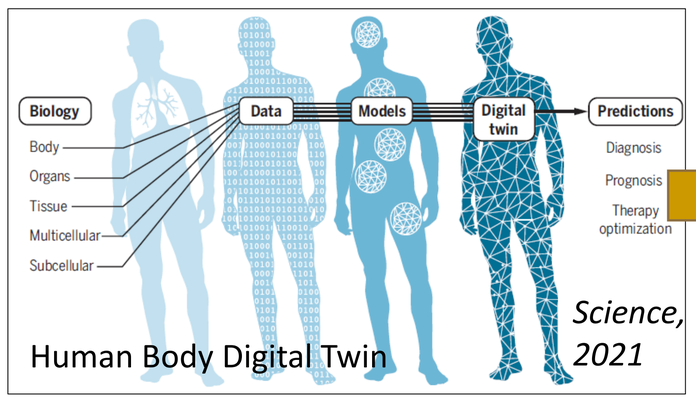
Our Mission:
Innovating unprecedented material technologies for next-generation products through nanomanufacturing across length scales.

Core Expertise:
Nanomanufacturing, semiconductor fabrication, data-driven design

Application Areas:
Wearable devices, ubiquitous sensors, robotics, quantum electronics, etc.

Personalized medical digital twins

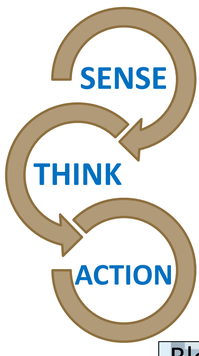




- Predictive model calibrated using regularly collected historical data aggregated from many devices
- Continuous forecasting and interventions
- Interaction between physical and digital domains

- Multi-scale clinical/sensor data to build computational biological/body models
- Predictions about diagnosis, prognosis, efficacy and optimization of therapeutic interventions.
- Enabled by multimodal sensors.

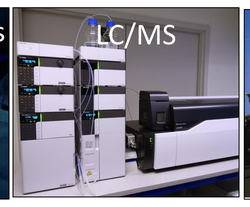
Wearable sensors for physiological & mental monitoring

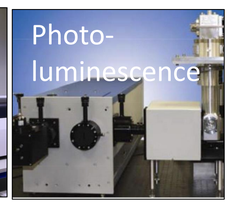


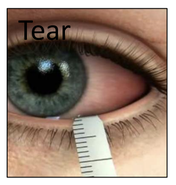
sense, learn

reason, optimize

inform, intervene

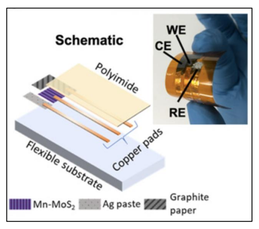


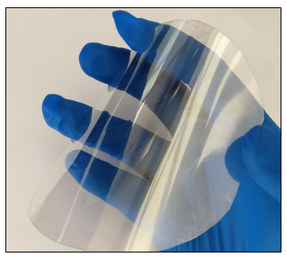




- Current tools are bulky, expensive; need lengthy preparation and analysis, invasive.
- Measure real-time longitudinal variations of biomarkers in sweat can enable **just-in-time diagnosis** and **early personalized intervention** with improved treatment outcomes for many physiological & psychiatric disorders.

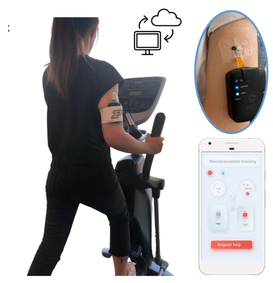
Challenges facing current wearable sweat sensors

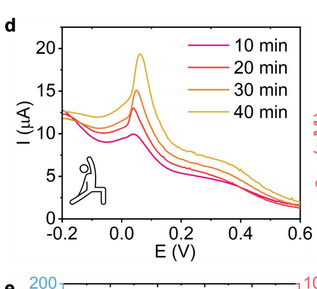


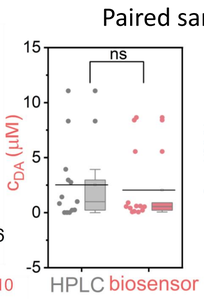


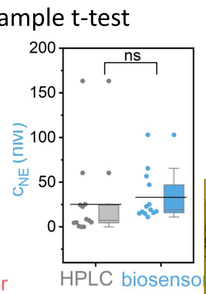
- Existing wearables fail to measure critical **neurodegenerative disease** (ND) specific markers in sweat due to poor sensitivity, selectivity, limit of detection (LoD).
- Widely-adopted multi-omics approaches only portray the average heterogeneous metabolic activities within brain or blood tissue, making it challenging to accurately predict and estimate the specific metabolite variations in sweat.

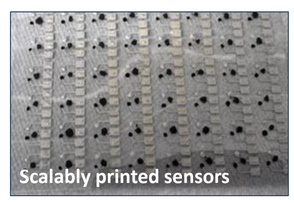
On-body characterization & validation

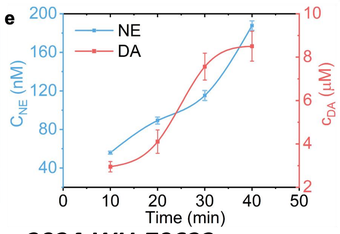


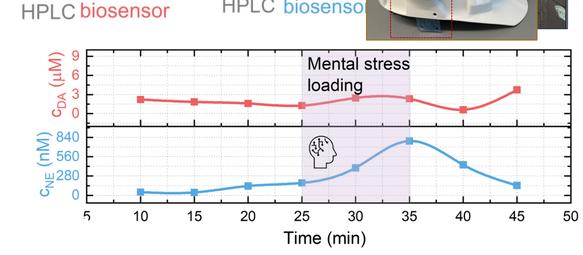






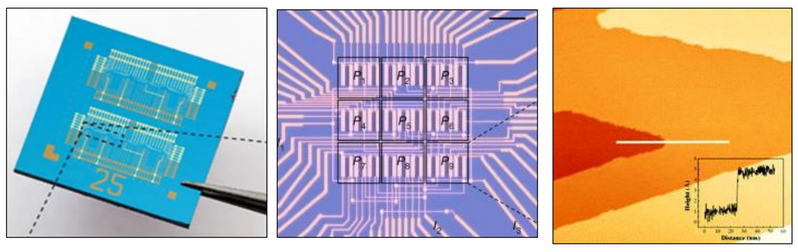






Submitted; PRF Disclosure 2024-WU-70623

2D semiconductors for wearable sensors?

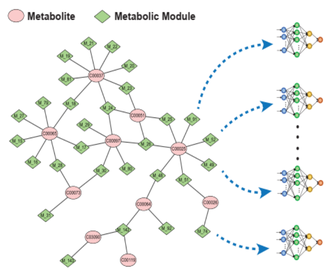


- 2D materials exhibit high sensitivity to physiology-relevant signals.
- However, few studies report 2D materials-based sweat sensors, due to the materials' intrinsic limitations that render them poor performance for sweat sensing. Ongoing efforts in 2D semiconductors also face difficulty scaling up due to restrictions on synthesis and stability.

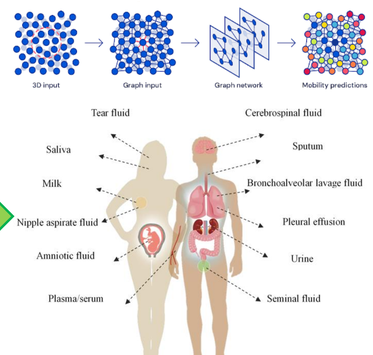
AI-powered prediction & learning of disease-specific biomarkers

Prediction of metabolic flux and abundance change

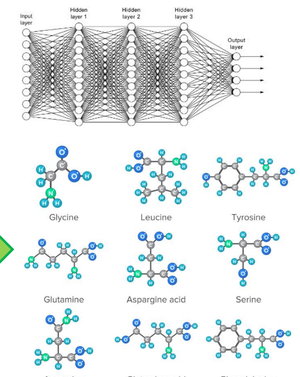
$$L = \sum_{\text{Cells}} \sum_{\text{Metabolize}} \text{Flux Balance Loss} + \sum_{\text{Modules}} \text{Non-Negative Loss}$$



Prediction of presence in body fluids

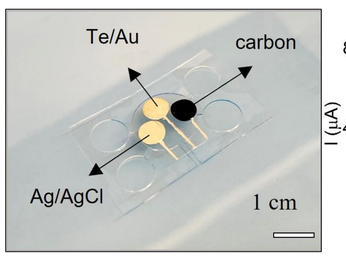


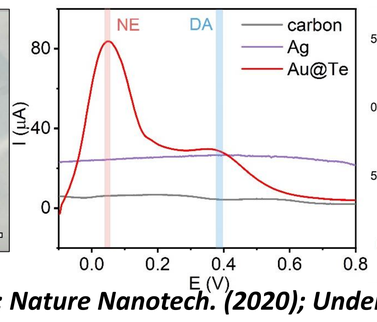
Refinement of sensors

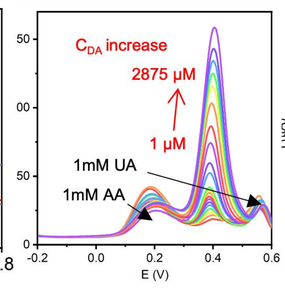


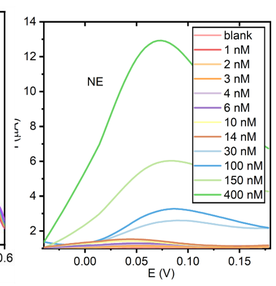
In collaboration with Prof. Chi Zhang at Indiana U. School of Medicine

2D semiconductors for wearable sweat sensors





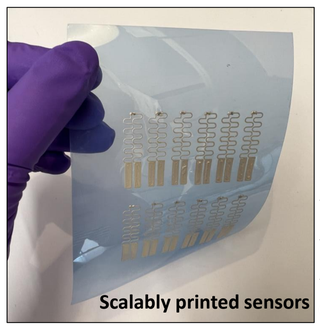


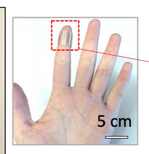


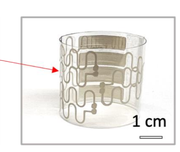
Nature Electronics (2018); Nature Nanotech. (2020); Under Review

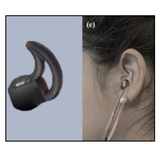
- We demonstrated **for the first time** wearable sensors that measure DA/NE in real human sweat in real time, leveraging nanomanufacturing of 2D semiconductors.

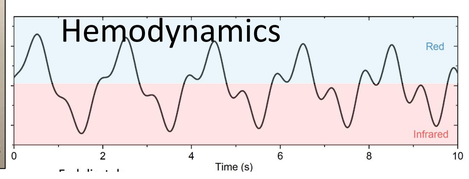
Opportunities & Prospects for 2D Semiconductor based Wearables

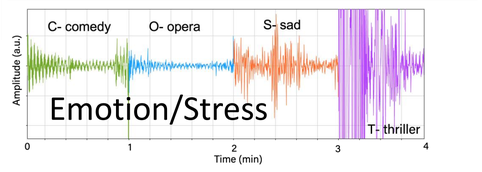












- Imperceptible continuous monitoring of human status

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