Advanced Wearable Sensor Systems: Smart textiles, Energy Harvesting and Integration

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May 11, 2022

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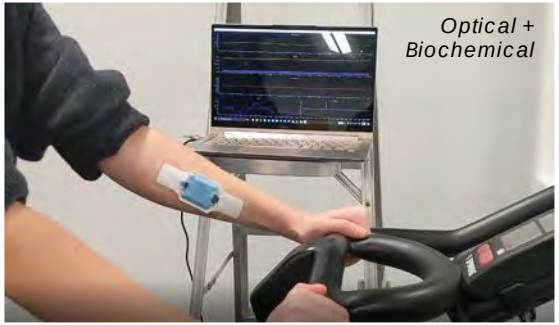
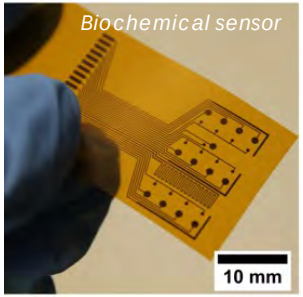
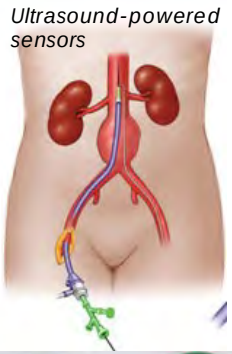
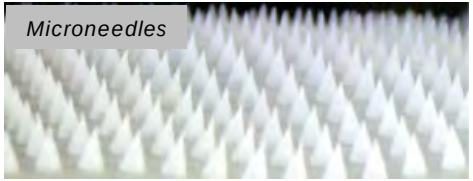
ASSIST Research Areas

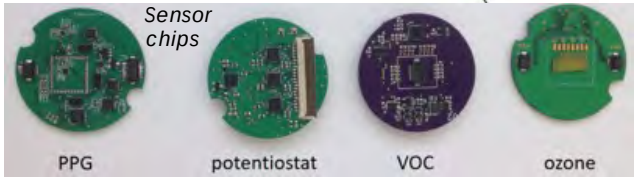
1. **Energy Harvesting & Storage**
2. **Low Power Sensing**
3. **Low Power Electronics**
4. **E-textiles**
5. **System Integration**





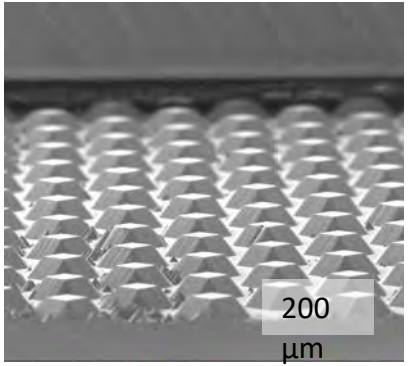




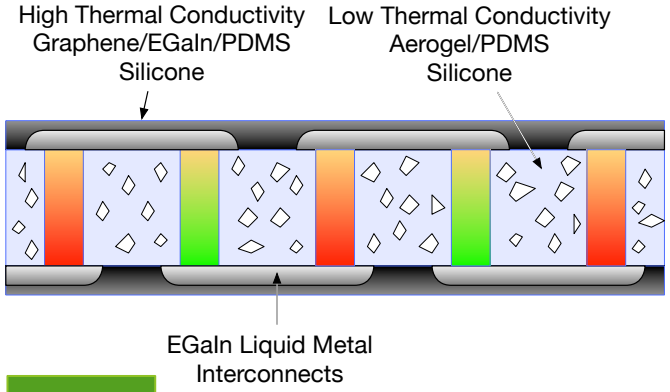


Energy Harvesting Technology

Body Heat	Body Motion	Ambient RF	Biofuels	Energy Storage
• Flexible thermoelectrics	• Piezoelectrics • Flexoelectrics • Liquid metal	• Ambient Wi-Fi • Novel antennas on textiles	• Passive sweat collection • Novel enzymes for lactate and glucose conversion	• Li ion capacitors • High Energy Density • Low leakage

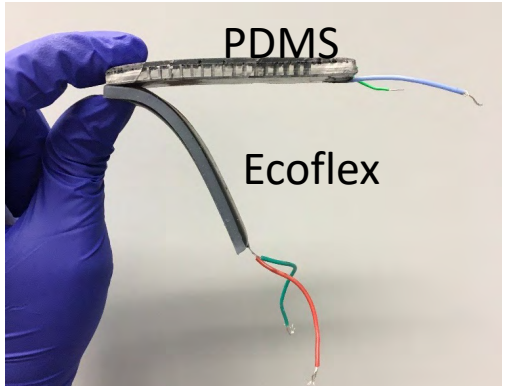


Wearable TEGs with Enhanced Flexibility

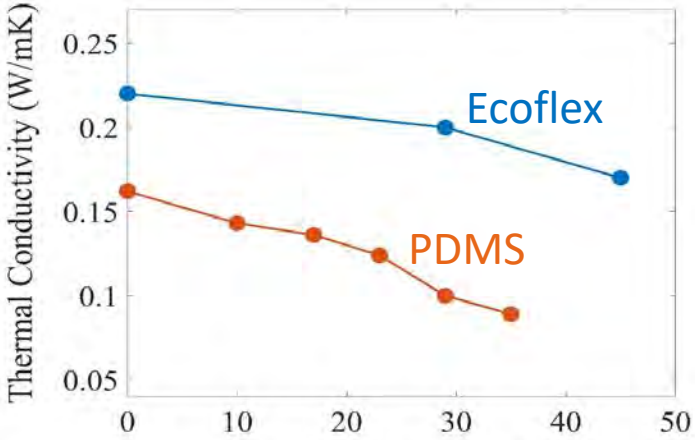


2019

NPJ Flexible Electronics 2021



2020



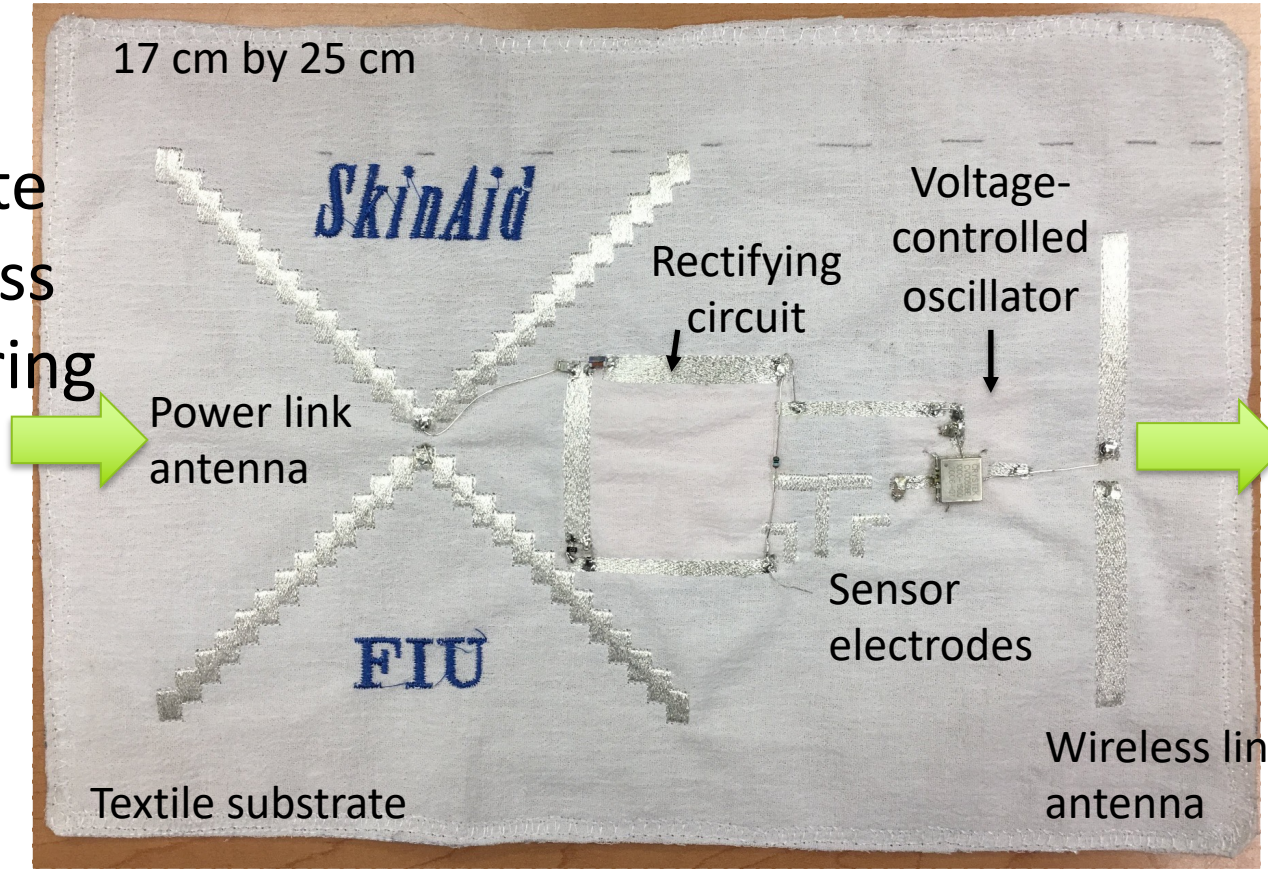
Challenge:

- Ecoflex Thermal Conductivity higher
- Aerogel Inclusion proved ineffective
- Reduced Device Performance

Ozturk/Dickey

Battery Free Wireless Sensing Patch

Remote wireless powering



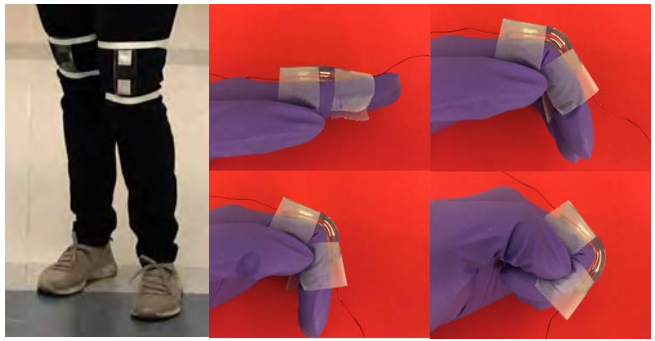
Modulated signal with pH/Uric Acid sensor data (to external Kiosk)

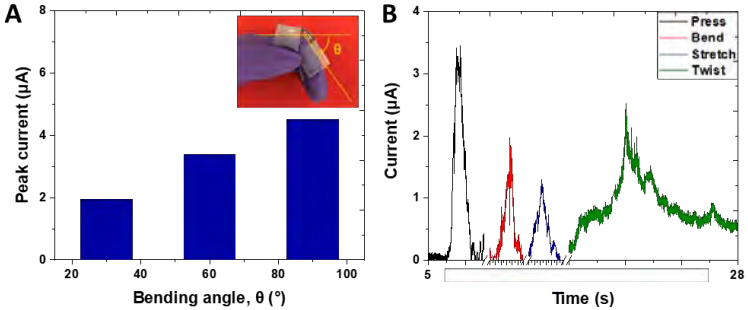
Soft Materials for Energy Harvesting

- **Problem**
  Energy sources that can convert mechanical energy to electrical energy can enable self-powered, tetherless, and sustainable wearable electronics, implantables, e-skins, sensors.
  - Inadequacy of existing solutions - e.g., compliance with human skin, deformability, need for additional power source, moisture intolerant etc.

- **Proposed solution**
  - Fabricate variable area liquid metal capacitors
  - Develop high surface area electrodes to enhance power output

- **Relevant applications**
  Energy harvester and self-powered sensors

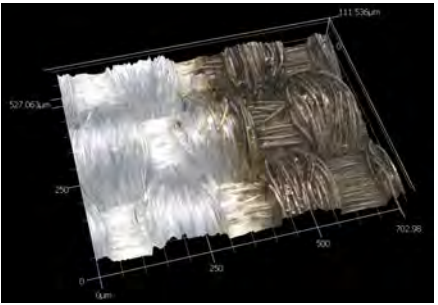




E-Textiles

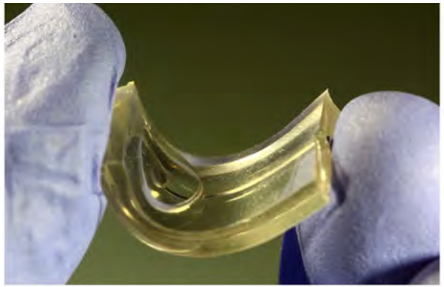
Smart textiles

- Printed electrodes
- Smart textile designs



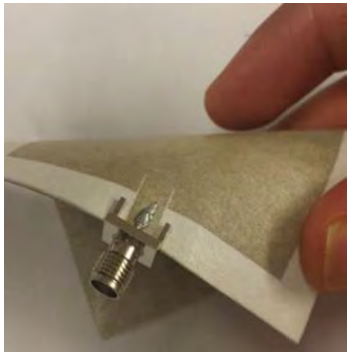
Liquid metals

- Stretchable conductors
- TEGs, antenna, and energy harvesting



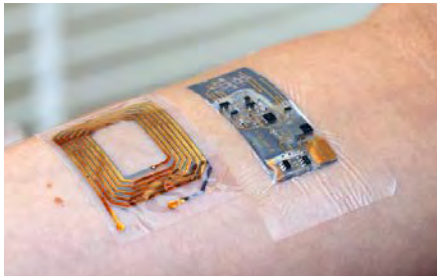
Fabric antennas

- Wearable and high efficiency



Flexible PCBs

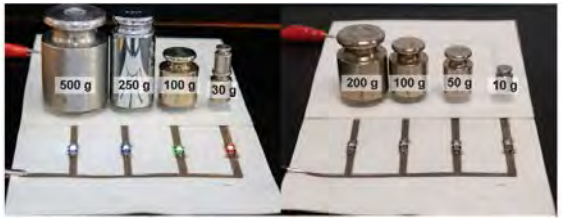
- Thin profile providing comfort and flexibility

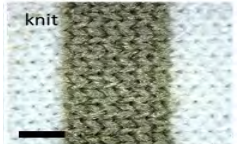


2-layer circuit board (< 25µm)

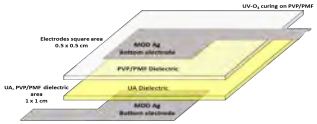
Ink-Jet Printing on Textiles

Metal Organic Decomposition (MOD) Ag Ink

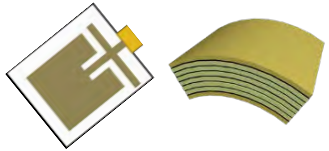




Polymer Dielectric Ink



Ceramic Dielectric Ink

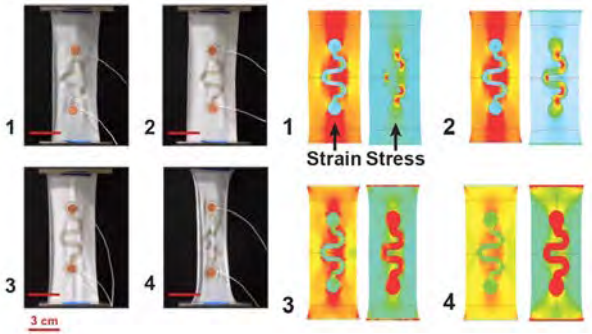


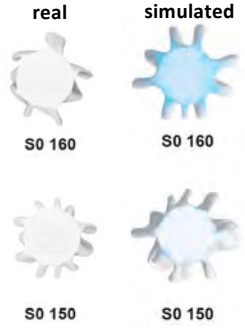
Inkjet printed flexible antenna design

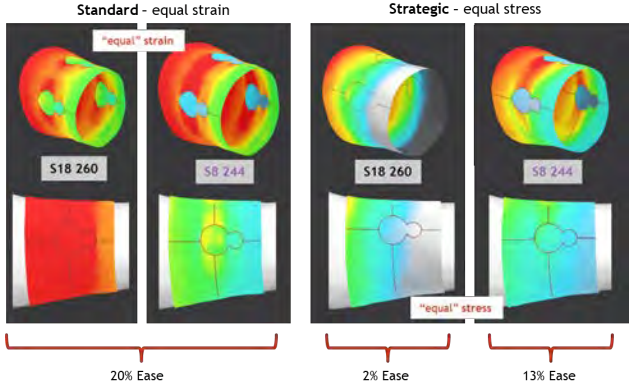
Screen Printed Magnetic Ink

Fabric Simulation

Assessing dissimilar material effects

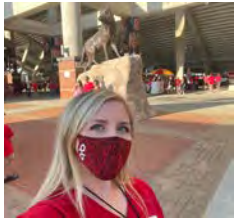




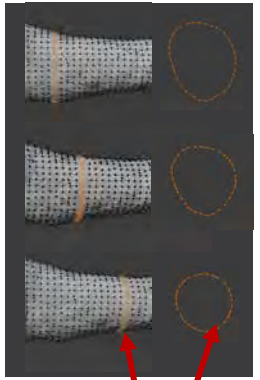


Strategic: determine pattern size based on CLO stress from **prediction curves**

PI - Dr. Jess Jur



Dr. Amanda Mills



Non-uniform cross sections

Andre West

Electrically Conductive Seamless Knitting

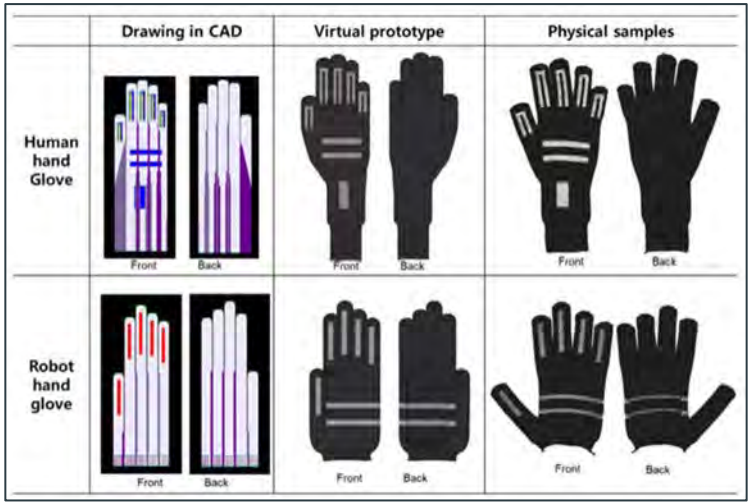
Benefits of Seamless Knitting

- Reduced waste compared to traditional cut-and-sew
- Improved comfort from lack of bulky seams
- Shorter production times from minimal post-processing
- Virtual and rapid prototyping with integrated CAD software system that directly connects with the knitting machines

Potential Applications

- Incontinence monitoring with improved comfort undergarments
- Strain sensor for breath monitoring
- Capacitive touch sensors with efficient space utilization and uninterrupted yarn traces

Pressure sensing sock (Luo et al, 2021)

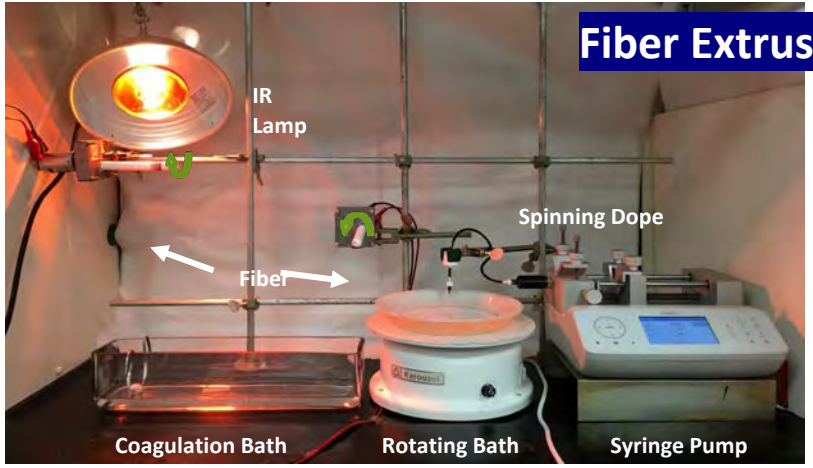


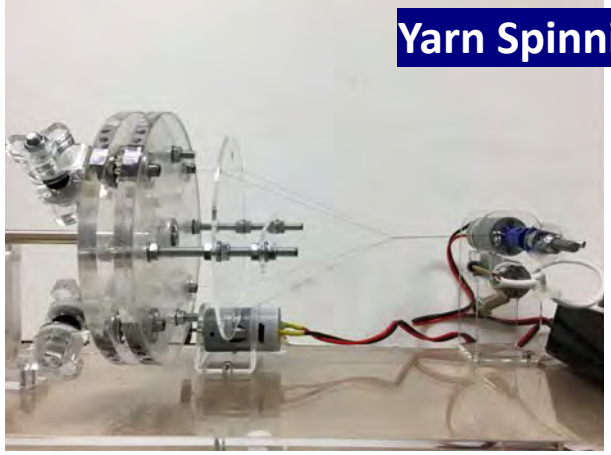
Design process for conductive glove to control a robotic hand from knit programming to virtual prototype simulation and final knit product (Song *et al*, 2021)

Seamless glove knit at ZTE Knitting Lab in Wilson College of Textiles with conductive thumb and pointer finger

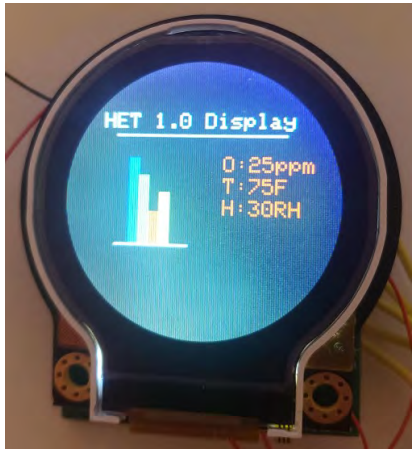
Song, Y., Lee, S., Choi, Y., Han, S., Won, H., Sung, T. H., ... & Bae, J. (2021). Design framework for a seamless smart glove using a digital knitting system. *Fashion and Textiles*, *8*(1), 1-13.
Luo, Y., Wu, K., Palacios, T., & Matusik, W. (2021, May). KnitUI: Fabricating interactive and sensing textiles with machine knitting. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (pp. 1-12)

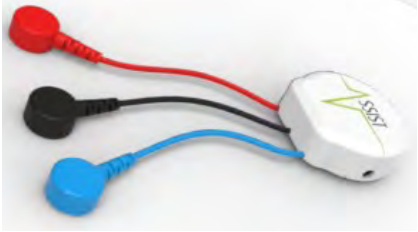
Gao Group Capabilities – Extrusion, Spinning, Sizing, Weaving, and Knitting of Electronic Yarns

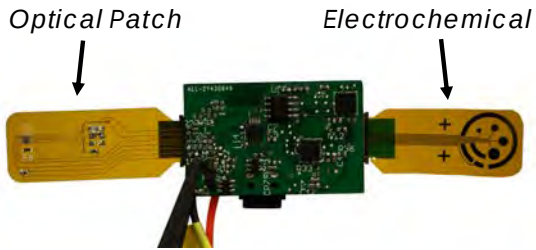




System Integration and Validation

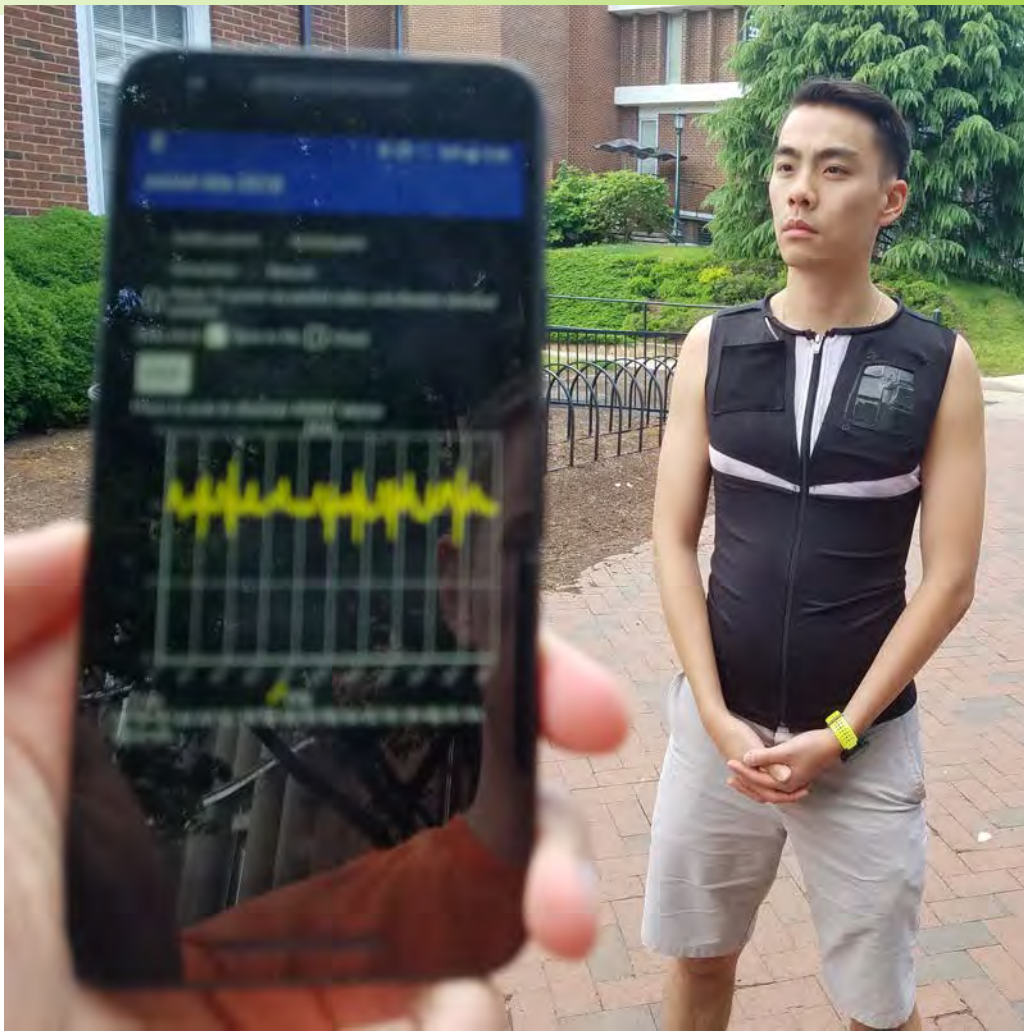




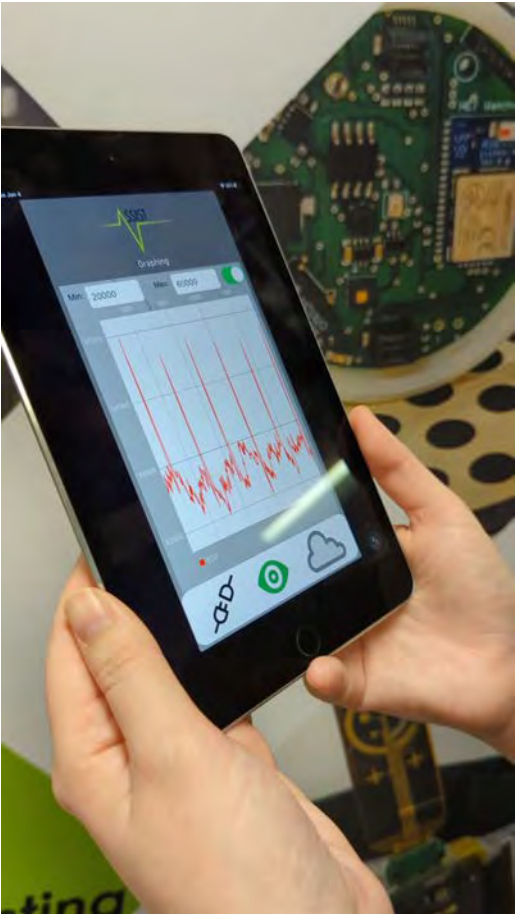


Vigilant ECG Shirt

- End-to-end functional
- Wearable
- Self-powered



ECG Monitoring Armband



- Textile-integrated dry electrodes
- Comfortable, arm-based system

Misra/Mills/Lee

Rapid Prototyping Group

Increasing the TRL level of our technologies and systems to drive engagement with industry and clinical partners

Circuit Population and Assembly

Circuit Debugging and Testing

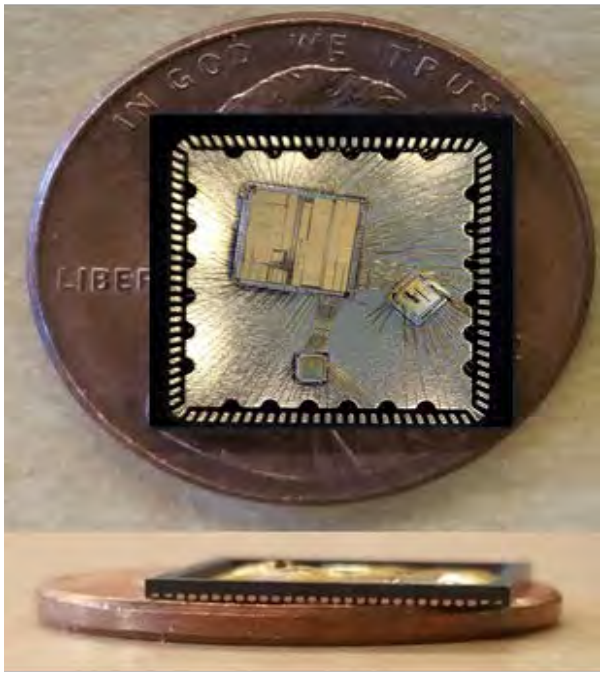
Physical Enclosure Manufacturing

RPG aims to deliver the lowest power biometric hardware platforms for research & commercial benchmarking

- Open-source development
- RPG Capabilities
  - PCB Layout
  - Arduino firmware
  - Sensor dashboarding

Dr. Dieffenderfer

Low-Power Electronics: Multi-Chip Solution



Ben Calhoun (UVA)

System on Chip

- 566 nW total power
- RISC-V

Analog Front End Chip

- ECG, PPG, RR, Ozone
- Respiration and ECG always on
- RR triggers PPG/Ozone

Energy Management Chip

- Multi-modal: TEG/PV/Piezo
- Four custom voltages outputs

Custom Radio Chip

- BLE 4.0 Compliant
- 300 uW total power
- -69dBm sensitivity and 500Kb/s

Low Power Multi-Modal Sensors

Eric Topol
http://t.co/m4yNon7vA3?amp=1

Bioelectric	Biophotonic	Inertial	Biochemical	Environmental
• **Low power ECG** • **Low power EDA** • **Dry electrodes**	• Low power PPG • Multi-wavelength LEDs • Heart rate, respiratory rate, blood oxygen, sleep, blood pressure	• **Activity** • Coughing • **Speech**	• New enzymes for lactate, glucose, and uric acid • Passive sweat/ interstitial fluid collection	• **Gases for air quality and breath** • VOCs for air quality and breath • Particulate matter

Multimodal sensors and their correlation

Industry Membership Program

Full

sas

Medtronic

Associate

HANES Brands Inc

muRata INNOVATOR IN ELECTRONICS

ANALOG DEVICES

BIOSERENITY Smart Healthcare Solutions

AstraZeneca

Affiliate

VitalFlo

VALENCELL

WAVESCIENCES

BIOSTRAP

DeviceSolutions

VADUM

DERMISENSE

TRIAD SEMICONDUCTOR

NEXT SYSTEMS RESEARCH & DEVELOPMENT

ONDA VISION TECHNOLOGIES, LLC. Seeing Beyond The Surface

OlfTech Solutions Sensor Company

Acknowledgements

assistcenter.org

- Mehmet Ozturk
- Michael Dickey
- Ben Calhoun
- Jess Jur
- John Lach
- Doug Werner
- Dave Wentzloff
- Susan Trolier-McKinstry
- Shad Roundy
- Mehdi Kiani

- Alper Bozkurt
- Omer Oralkan
- Bongmook Lee
- Veena Misra
- James Dieffenderfer
- Edgar Lobaton
- Michelle Hernandez, MD
- Michael Lim

- Michael Daniele
- Orlin Velev
- Michael Dickey
- Shekhar Bhansali
- Shubhendu Bhardwaj

NSF EEC-1160483

THANK YOU