Welcome to

EMERGING TECHNOLOGIES CONFERENCE

at Advanced Textiles EXPO®

Vertical Flexible Interconnects for Electronic Textiles

*Prateeti Ugale, Dr. Amanda Mills**

NC STATE UNIVERSITY
Wilson College of Textiles

SHIFT
Smart Holistically Integrated Functional Textiles

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Background

Bachelor of Technology (B.Tech.) from Institute of Chemical Technology, Mumbai, India (2012-2016)

PhD Internship (2024 - Ongoing)

Process Development Engineer II (2020-2021)

Research Associate I (2018-2020)

NC STATE UNIVERSITY

Wilson College of Textiles

- *MS in Textile Engineering (2016-2018)*
- *Research and Development Assistant (2018)*
- **PhD in Fiber and Polymer Science (2021 - Ongoing)**

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Agenda

01
Introduction to E-Textiles

02
Interconnects in E-Textiles

03
Vertical Interconnects

04
Connectors in E-Textiles

05
Conclusion – Research Gaps

Agenda

01
Introduction to E-Textiles

02
Interconnects in E-Textiles

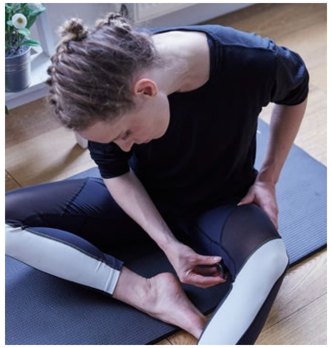
03
Vertical Interconnects

04
Connectors in E-Textiles

05
Conclusion – Research Gaps

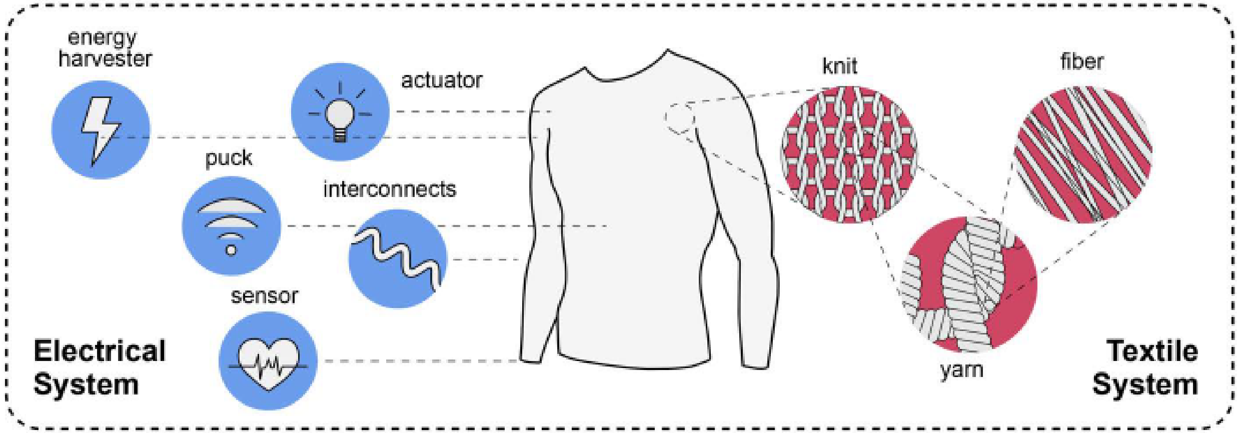
E-Textiles

Hexoskin Smart Shirts



Nadi X Smart Yoga Pants

Jacquard by Google X Levis



Knowles, C. G. (2023). Digital Strategies for E-Textile Design and Manufacturing.

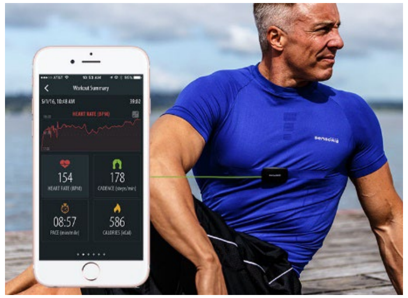
"Electronic Textile, n – a fiber, yarn, fabric or end product comprising elements that result in an electrical or electronic circuit, with or without processing capability, or the components thereof."

- ASTM D8248-20

Advantages

Textiles → Flexible, Breathable, Comfortable, lightweight
E-Textiles enable health monitoring

Images from Google



Sensoria® T-Shirt

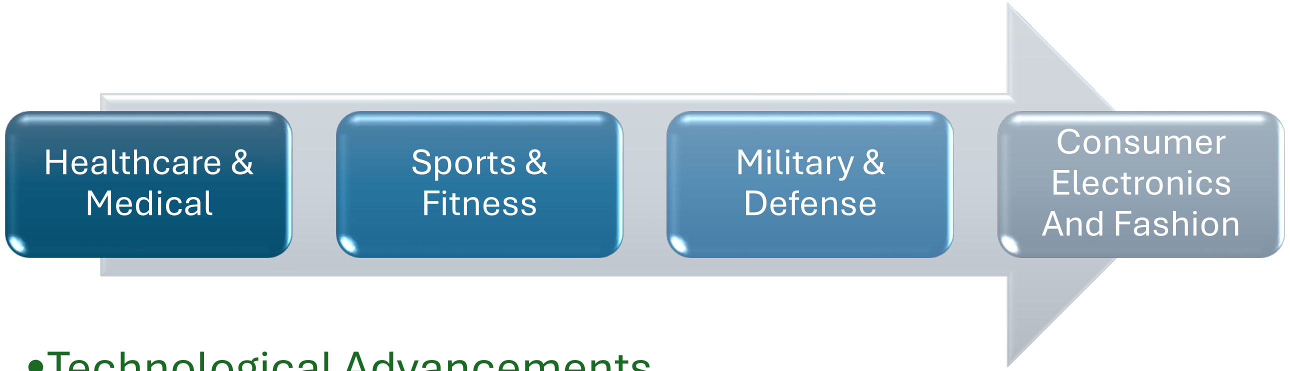
OMsignal Smart Shirts

Muse™ headband

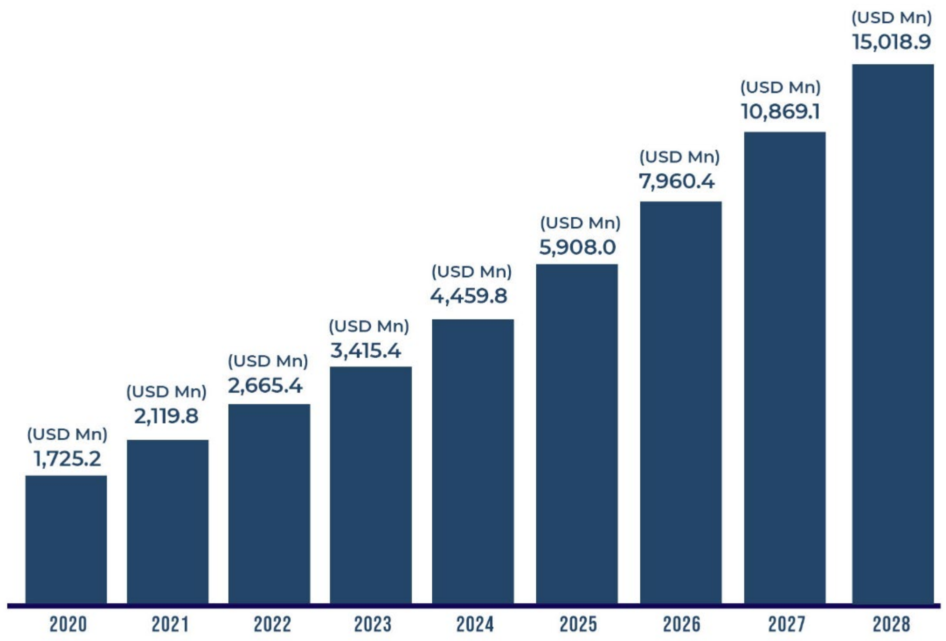
Sensoria® Socks

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

E-Textiles are Growing!



- Technological Advancements
- Internet Of Things (IoT) Integration
- Lightweight and durable materials
- Growing Research And Development (R&D)



Source: www.acumenresearchandconsulting.com

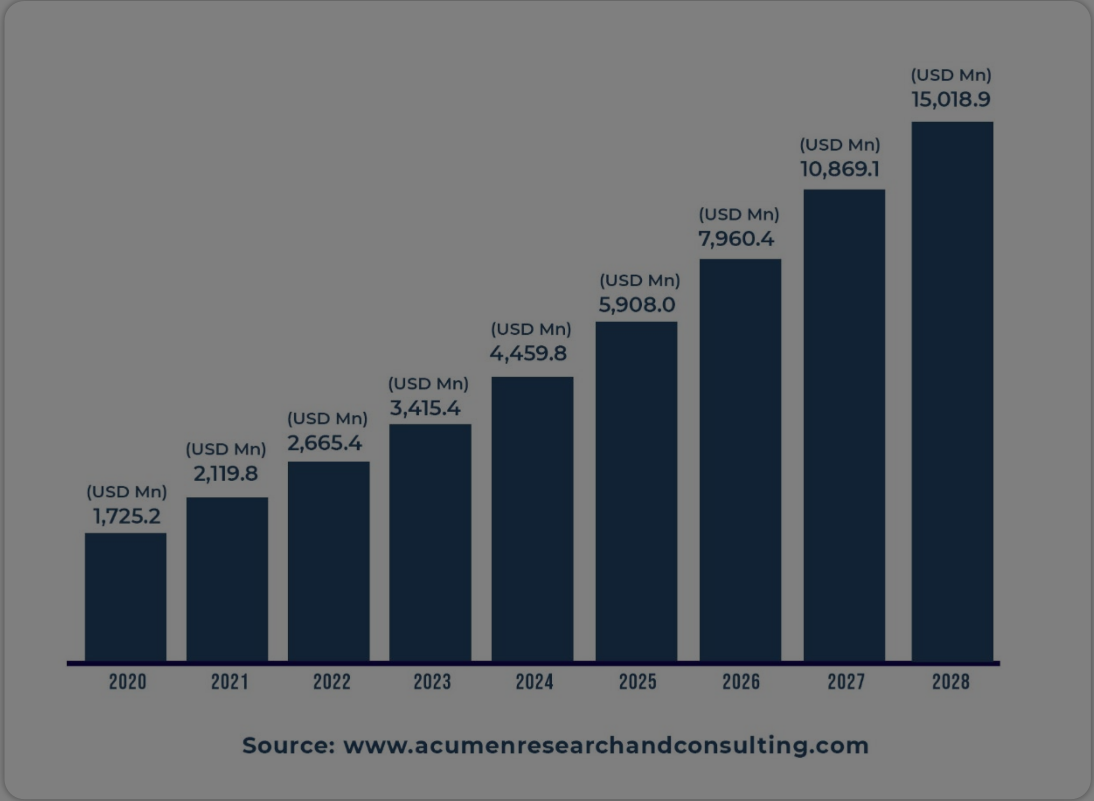
- **Technical Difficulties**
- High Production Prices
- Complex Supply Chain
- Regulatory And Standards Issue
- **Limited Durability And Longevity**
- Market Acceptance And Awareness
- Ethical And Environmental Concerns
- Costs Of Intellectual Property And R&D

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

E-Textiles are Growing!

Healthcare & Medical → Sports & Fitness → Military & Defense → Consumer Electronics And Fashion

- Technological Advancements
- Internet Of Things (IoT) Integration
- Lightweight and durable materials
- Growing Research And Development (R&D)

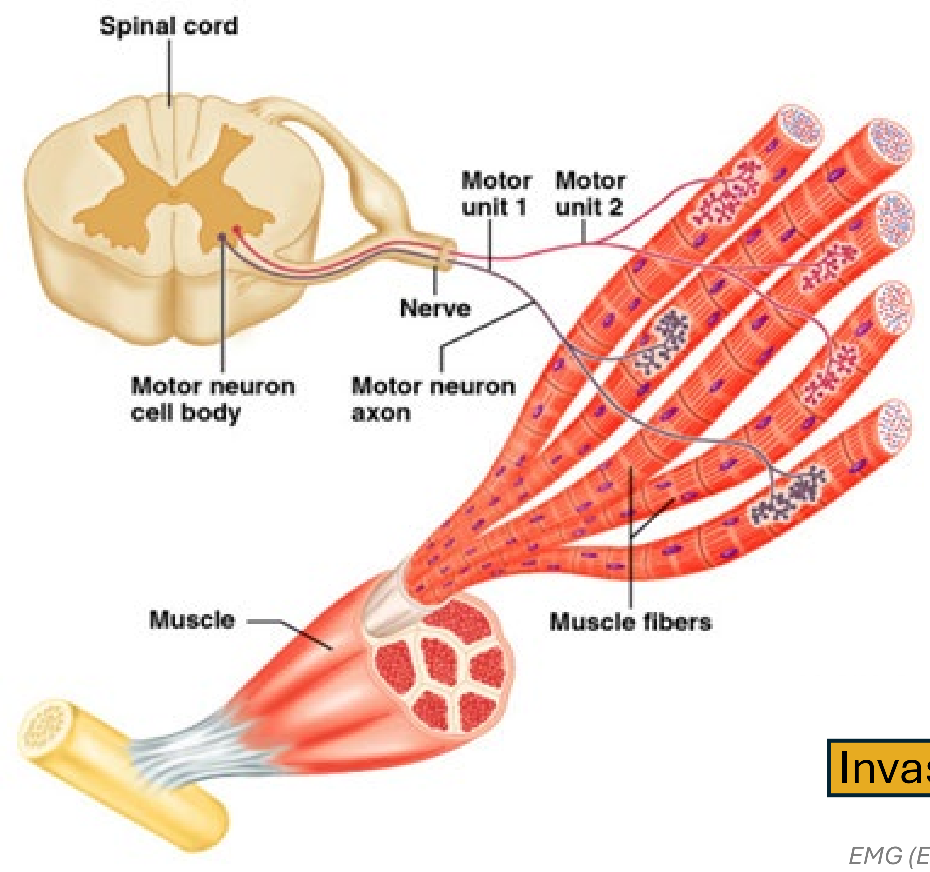


- **Technical Difficulties**
- High Production Prices
- Complex Supply Chain
- Regulatory And Standards Issues
- **Limited Durability And Longevity**
- Market Acceptance And Awareness
- Ethical And Environmental Concerns
- Costs Of Intellectual Property And R&D

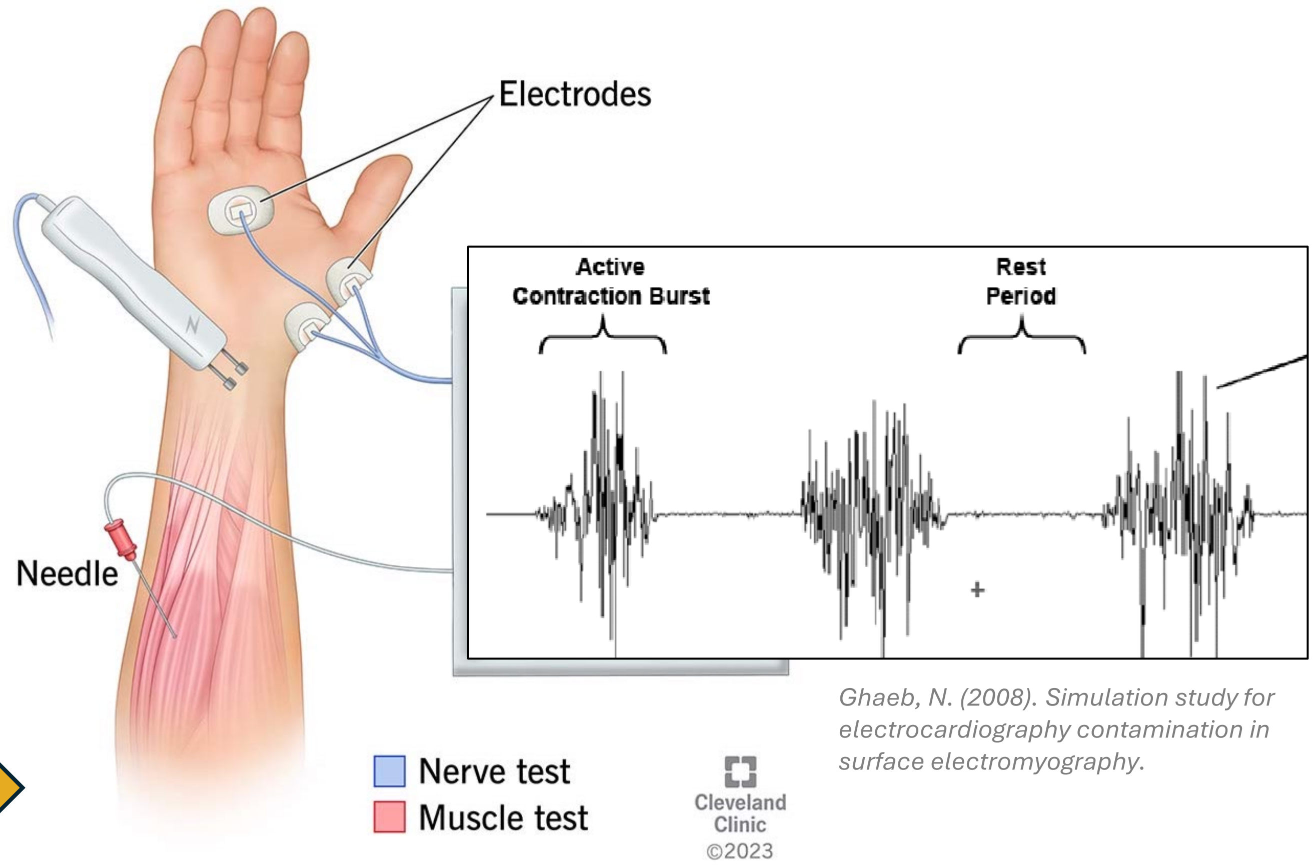
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Electromyography (EMG)

- A diagnostic test that measures the electrical activity of muscles in response to nerve stimulation.



Invasive



Ghaeb, N. (2008). Simulation study for electrocardiography contamination in surface electromyography.

EMG (Electromyography): What It Is, Purpose, Procedure & Results, n.d.

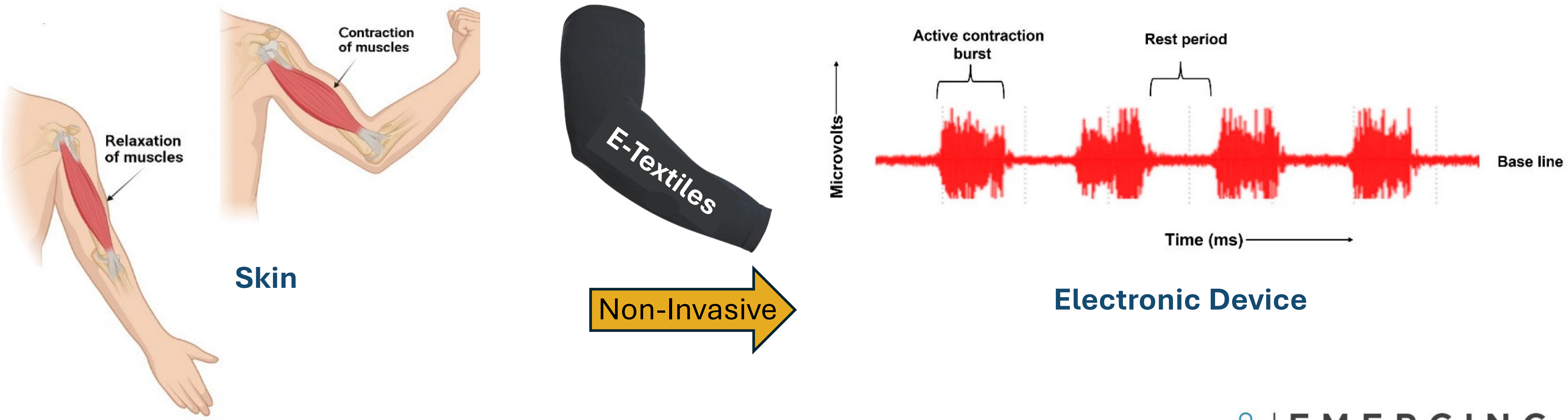
- Invasive methods measure EMG directly inside or near the muscle by inserting an electrode

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

E-Textiles for Monitoring EMG

- E-Textiles offer a unique combination of convenience, real-time data analysis, and personalization of medical treatments, thereby revolutionizing patient care and disease management

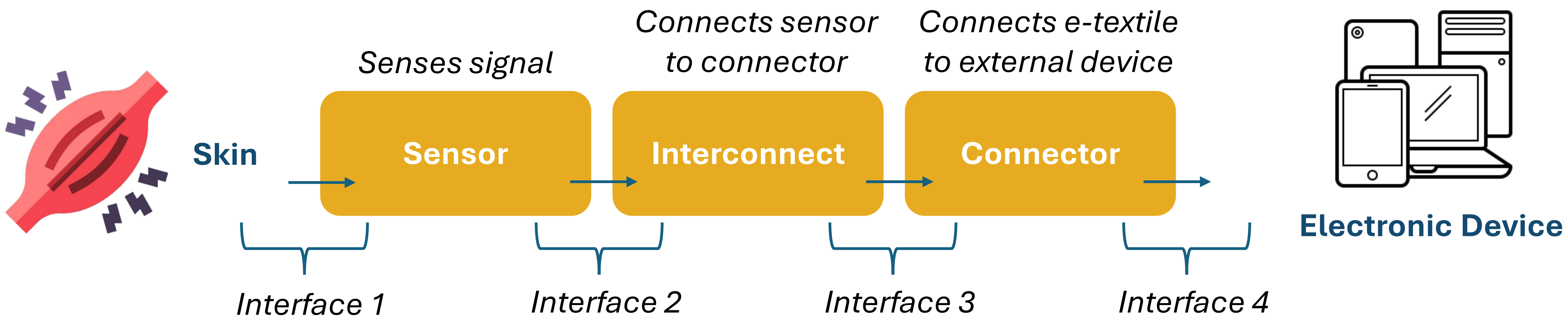
- E-Textiles offer – Comfort, lightweight, easier-to-use, and more cost-effective self-health management systems

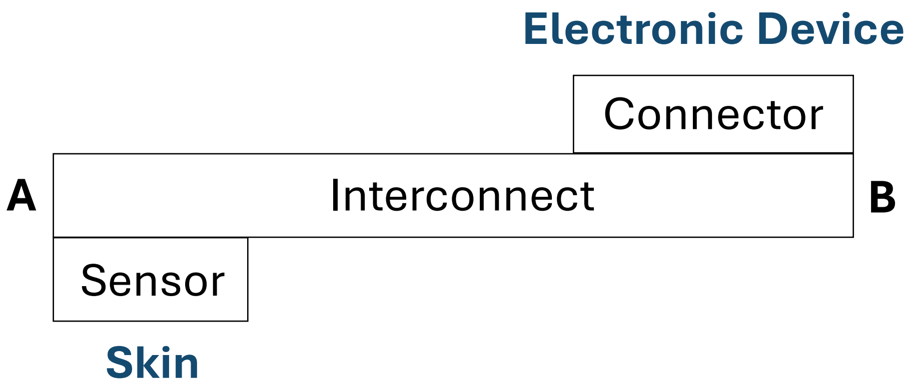


- Non-invasive methods measure EMG on the skin surface

Vidhya, C. M., Maithani, Y., & Singh, J. P. (2023). Recent Advances and Challenges in Textile Electrodes for Wearable Biopotential Signal Monitoring: A Comprehensive Review.

Components of E-Textiles for Monitoring EMG

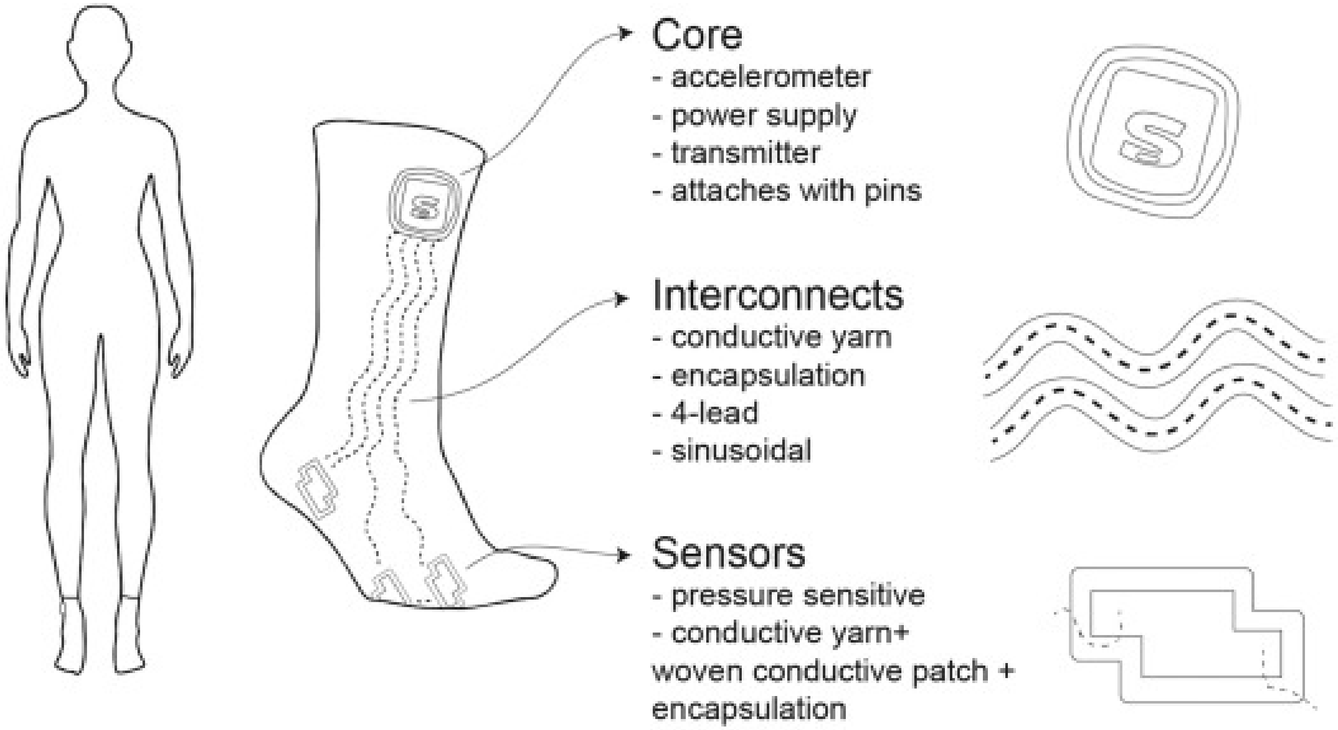




EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Example – Sensoria® Socks V2

Sensoria® Socks

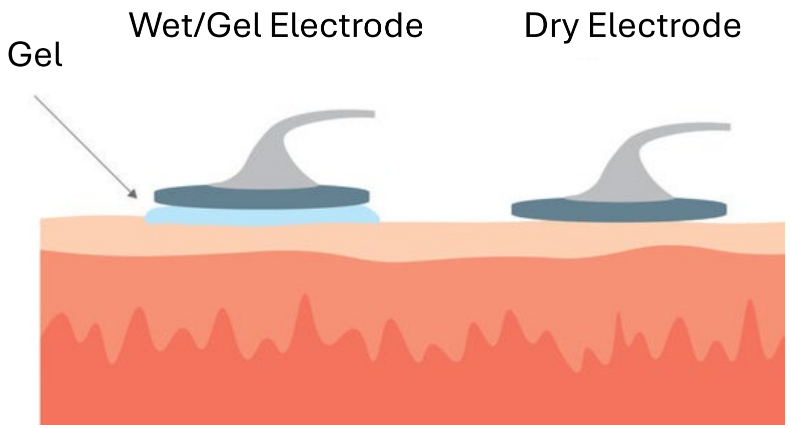


Sensoria Sock V2 electronic components and integration

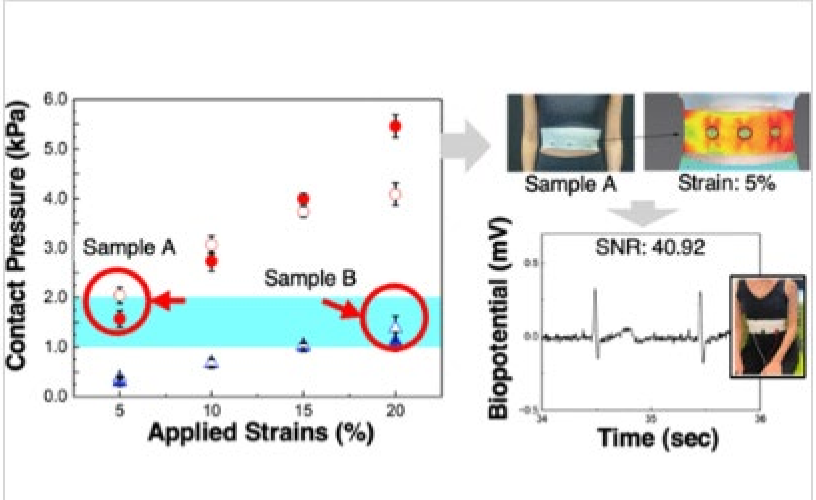
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Rosenberg, Z. B., Knowles, C. G., Mills, A. C., & Jur, J. S. (2022). Design strategies for e-textile manufacturing.

Sensors/ Electrodes

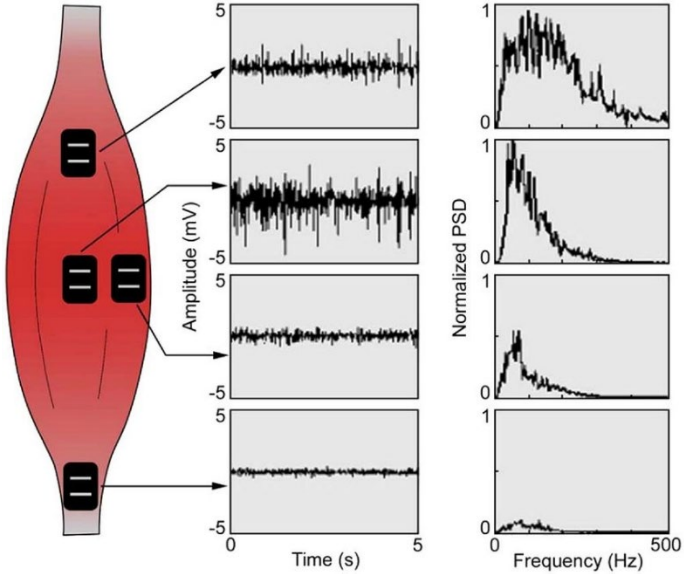


Type of electrode – Wet and Dry



ACS Appl. Eng. Mater. 2024, 2, 6, 1640–1653

Contact Pressure between electrode and skin



Position of electrode

1	2	3

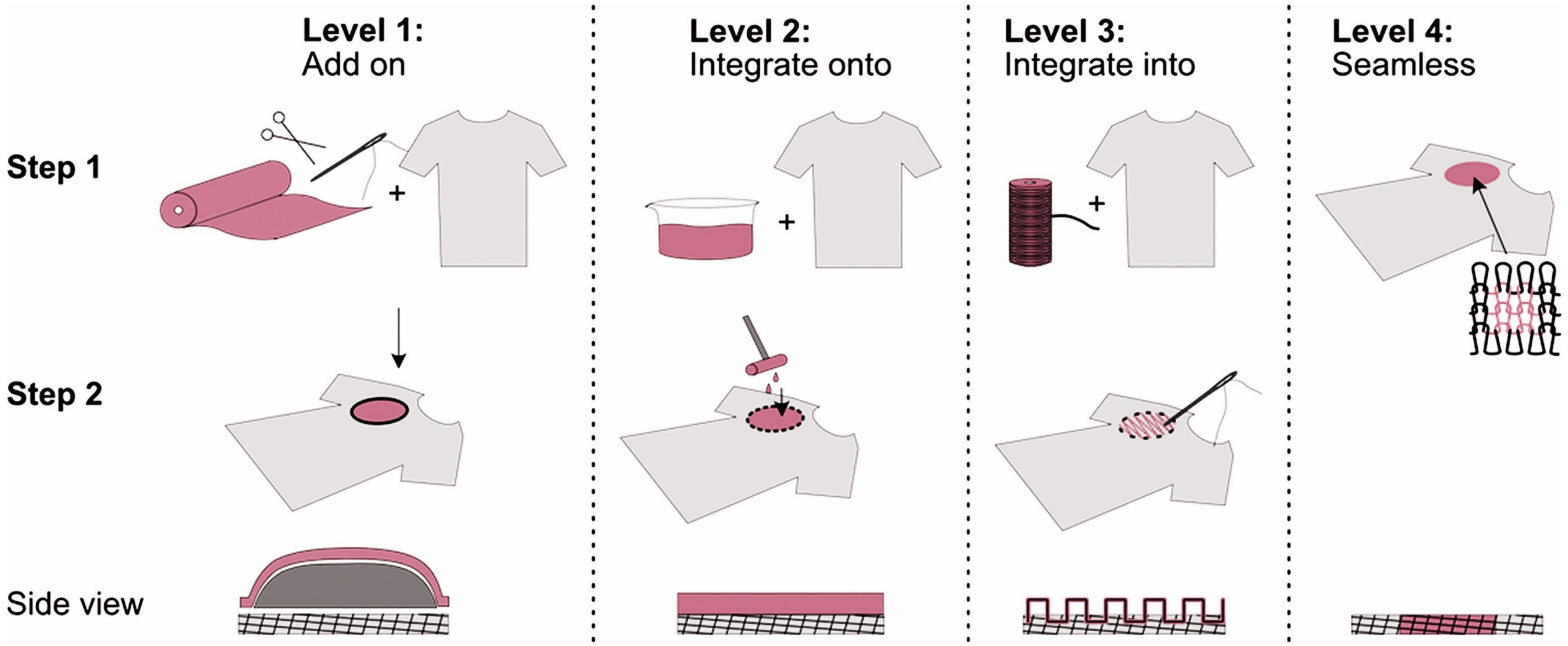
- Gel electrodes perform better than dry – Often used as standards
- Optimal contact pressure between the dry electrode and the skin can enhance signal quality
- Electrodes placed on the belly of a muscle gives better signal quality

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Diference from Wet and Gel electrode and a Dry electrode for monitoring. EEG and ECG monitoring electrodes By JFontan

Micera, Silvestro & Carpaneto, Jacopo & Raspopovic, Stanisa. (2010). Control of hand prostheses using peripheral information

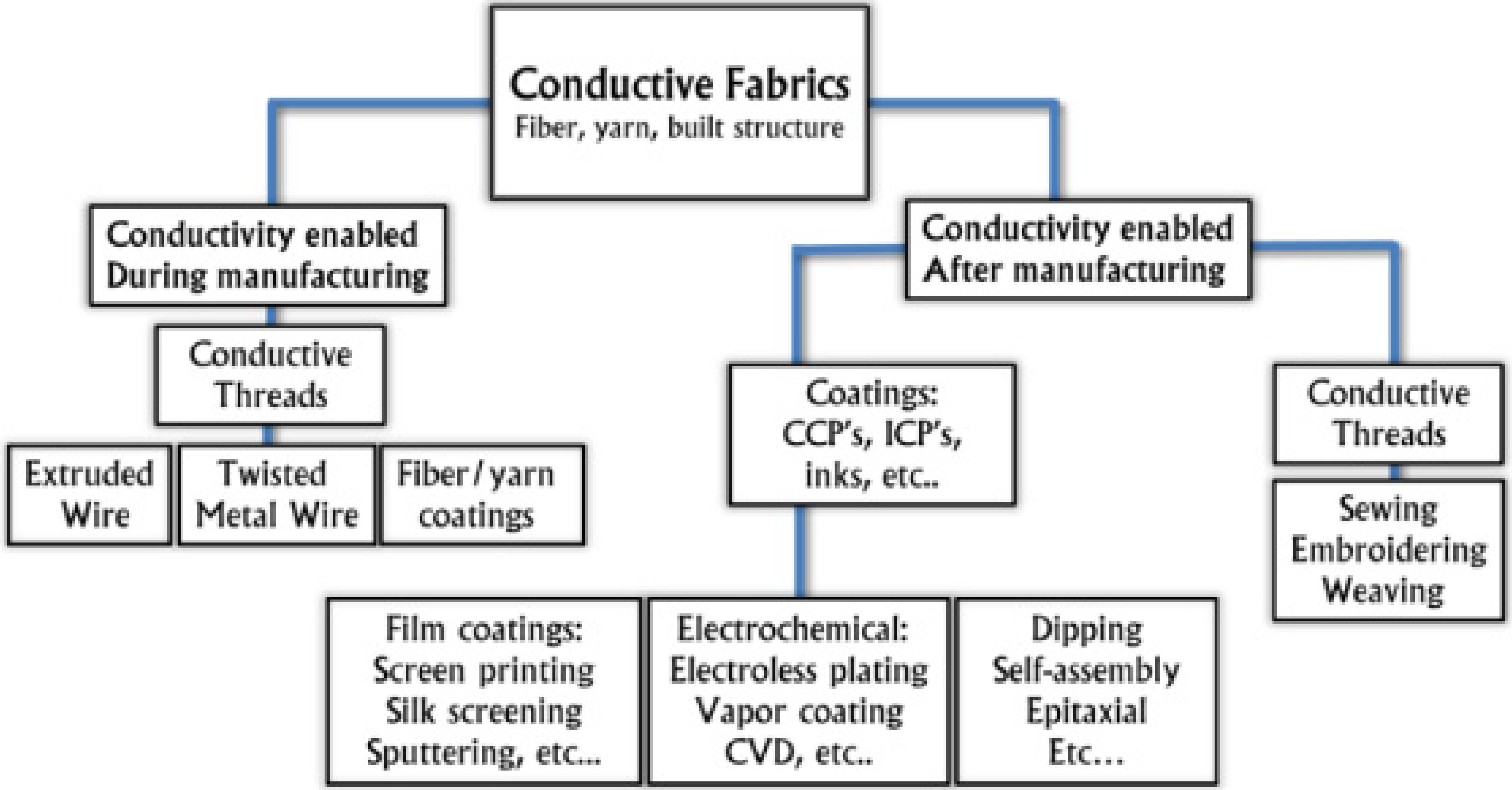
Integration of E-Textiles



Schematic drawing of integration Levels 1–4 for wearable systems. Conductive elements are marked in pink

Euler L, Guo L, Persson N-K. A review of textile-based electrodes developed for electrostimulation.

Conductive Materials for Integration

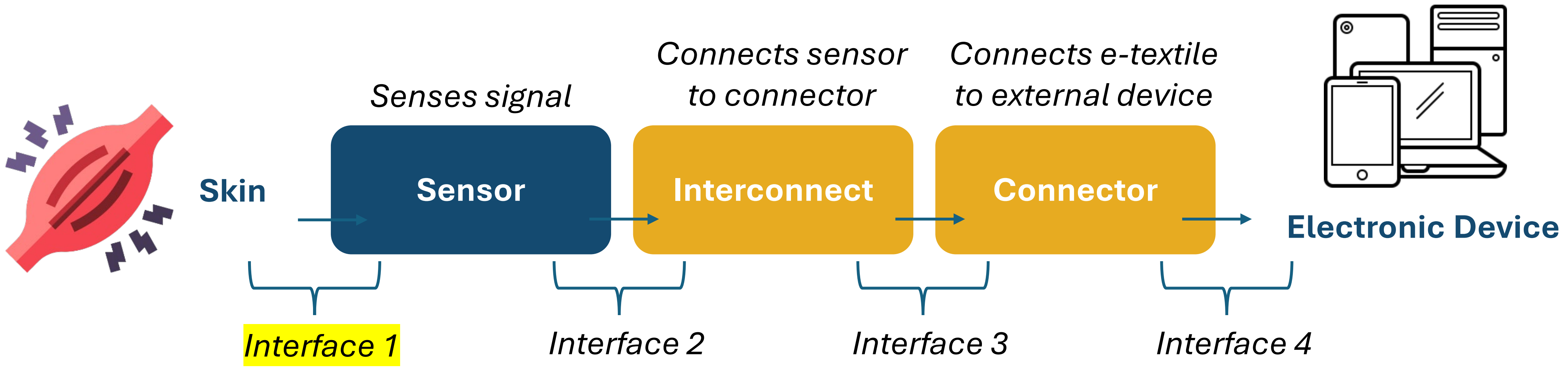


Techniques to enable conductivity in fabrics

Castano, L. M., & Flatau, A. B. (2014). Smart fabric sensors and e-textile technologies: a review.

How are sensors electrically integrated?

USING INTERCONNECTS!



- ***Type of electrode***
- ***Contact pressure***
- ***Electrode Position***
- ***Integration techniques***
- ***Conductive materials***

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Agenda

01

Introduction to E-Textiles

02

Interconnects in E-Textiles

03

Vertical Interconnects

04

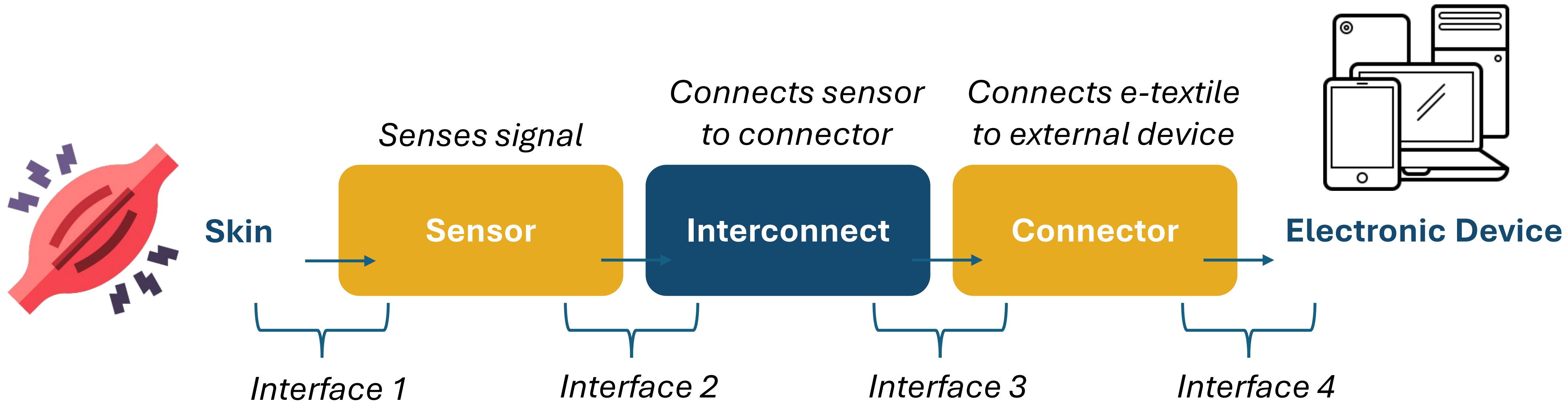
Connectors in E-Textiles

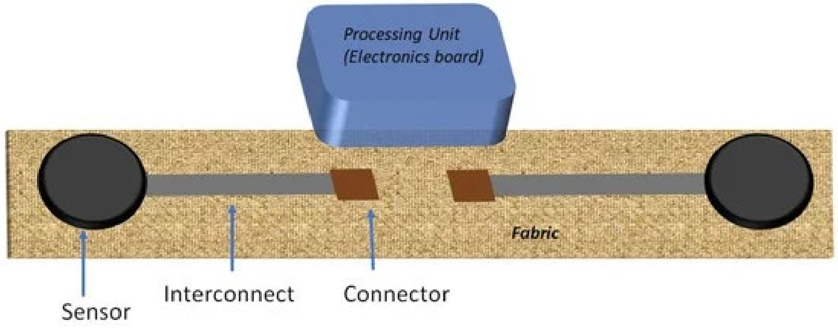
05

Conclusion – Research Gaps

E-Textile Interconnects

E-textile interconnects are **conductive paths** or **connections** integrated into textile materials**, enabling the transmission of electrical signals or power** within fabric-based systems.





EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Muhammad Sayem, Abu Sadat & Teay, Siew & Shahariar, Hasan & Fink, Paula & Albarbar, A.. (2020). Review on Smart Electro-Clothing Systems (SeCSs).

Properties of E-Textile Interconnects

An Ideal Interconnect Must Possess

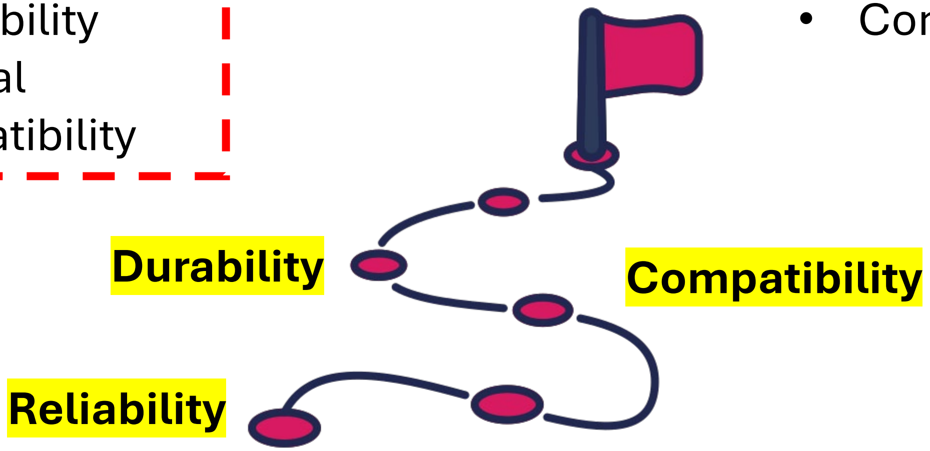
Electrical Reliability
- Electrical Connectivity
- Signal Integrity

Mechanical Durability
- Flexibility
- Stretchability
- Washability
- Material Compatibility

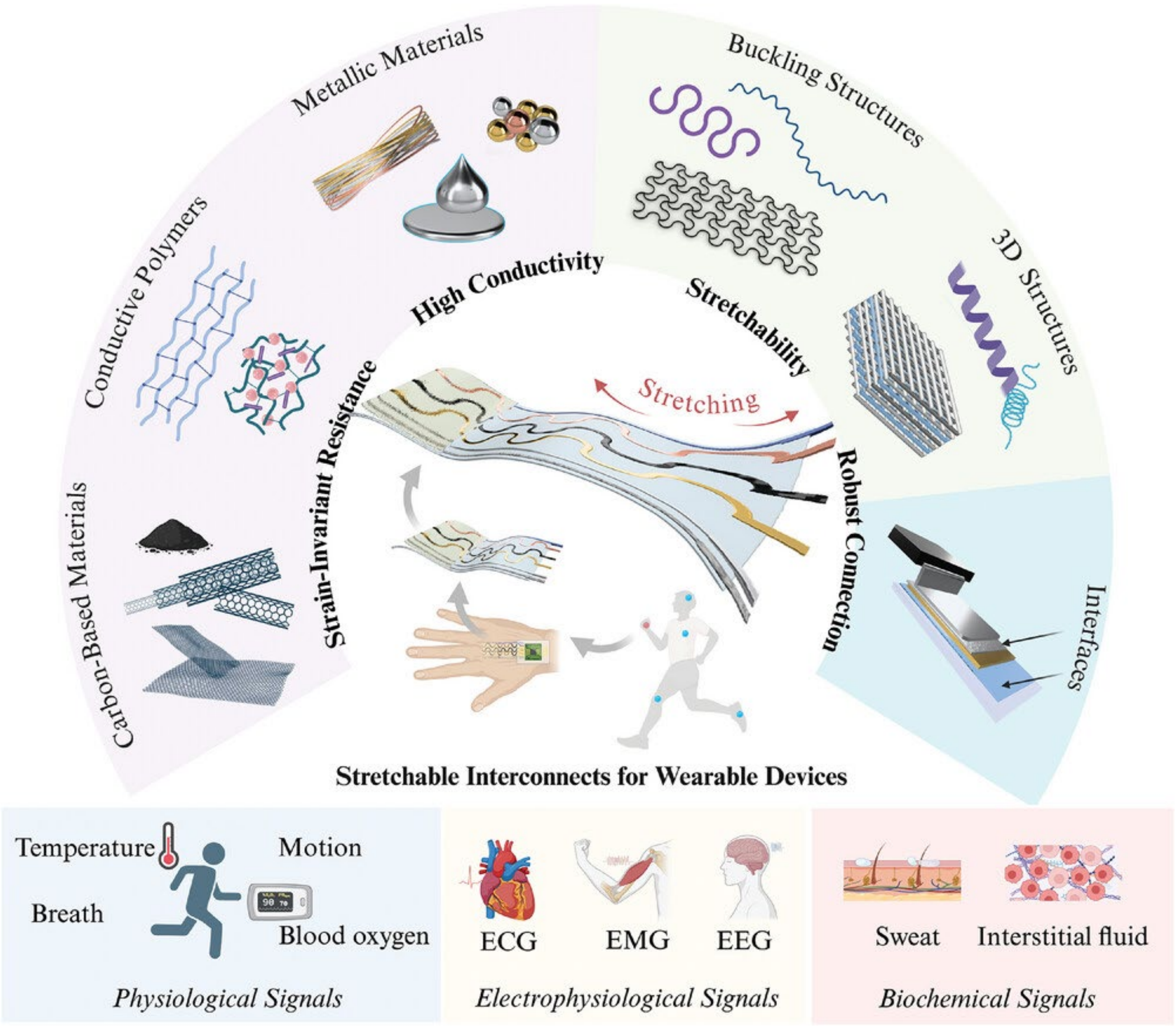
Manufacturability
- Scalable
- Cheap

Wearer Comfort
- Aesthetically Pleasing
- Comfortable

Safety
- Breathability
- Non-toxic
- Avoid Skin Irritation

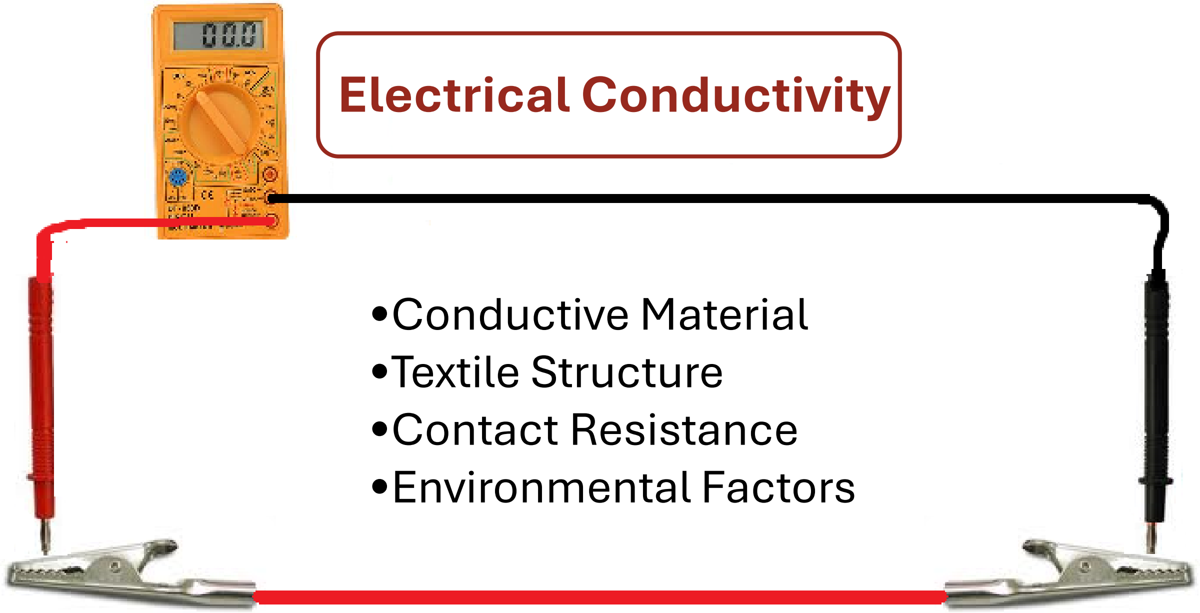


Interdependency of E-Textile Interconnects



EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Electrical Reliability of E-Textile Interconnects



Electrical Conductivity

- Conductive Material
- Textile Structure
- Contact Resistance
- Environmental Factors

Signal Integrity

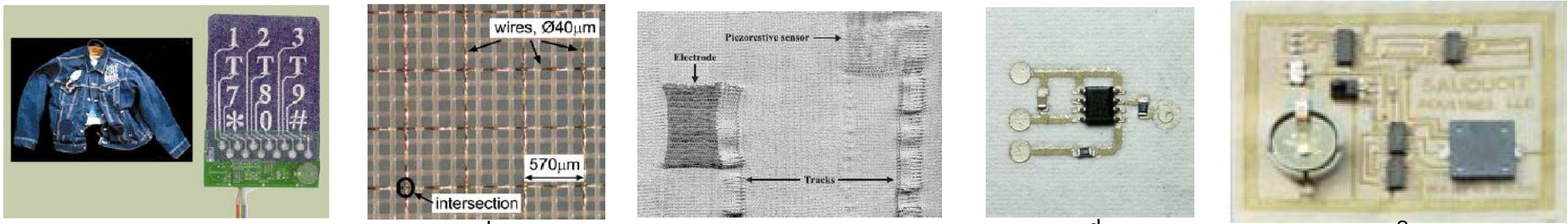
- Signal Loss
- Electromagnetic Interference (EMI)
- Mechanical Stress
- Signal Reflection
- Frequency Dependence

To enhance electrical conductivity and signal integrity in textile interconnects

- **Material Selection**
- **Design Optimization**
- **Protective Coatings**
- **Shielding and Grounding**
- **Signal Conditioning**

Conductive Materials for E-Textile Interconnects

Type	Material	Integration Methods
Wire	Copper etc.	Sewing, Weaving
Yarn	Stainless steel, silver coated etc.	Sewing, Embroidery, Weaving, Knitting
Fabric	Copper and Silver	Stitching, Sewing, Weaving, Fabric Etching
Polymer	Polypyrole, Polyaniline etc.	Stenciling
Rubber	Carbon filled silicone rubber	Stenciling
Ink	Copper, Silver, Gold, Carbon etc.	Screen Printing, Ink-Jet Printing, Stenciling



a b c d e

(a) examples of embroidery using conductive yarns showing controllable patterns: MIDI Jacket with e-broidery (b) woven fabric with insulated copper wire (c) knitted conductive tracks and sensors from WEALTHY project (d) screen printed circuit on nonwoven fabric (e) conductive fabric etched printed circuit

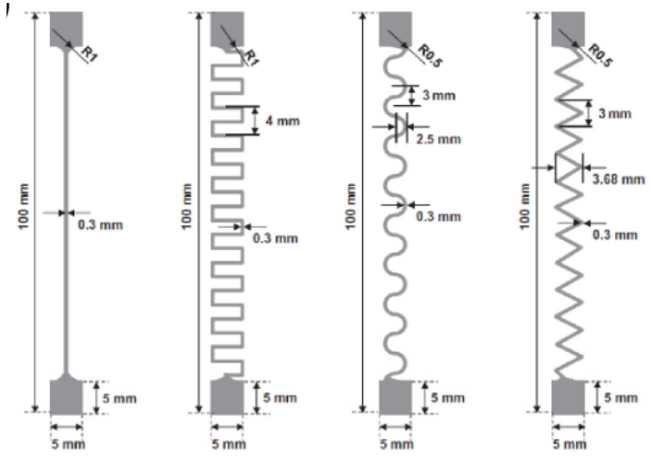
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

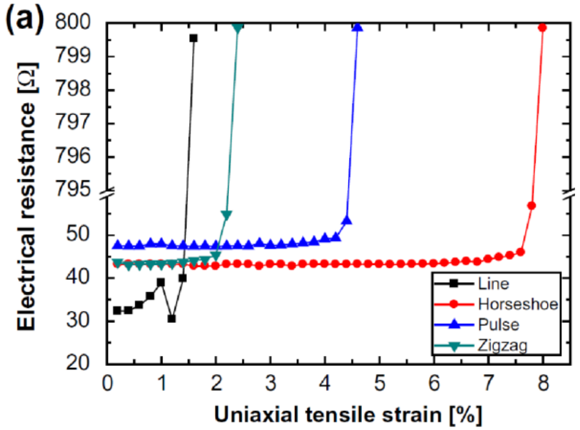
Merritt, C. R. (2008). Electronic textile-based sensors and systems for long-term health monitoring.

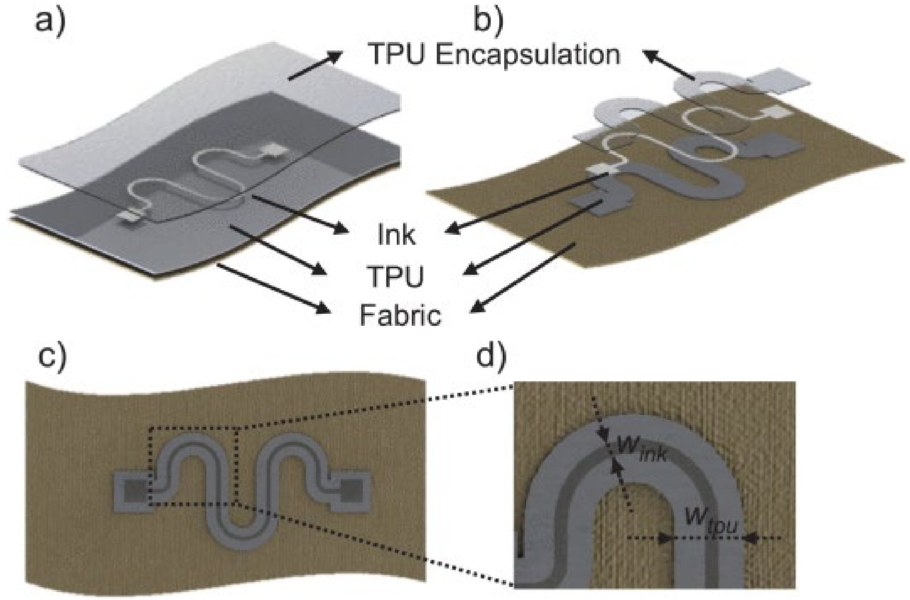
Mechanical Durability of E-Textiles

Geometry and Design of the Interconnect

Properties of Base Material & Encapsulation







- Usually, conventional metals can impede the flexible or stretchable performance
- Serpentine, arc-shaped, horseshoe, kirigami, self-similar, 2D spiral, and 3D helical forms

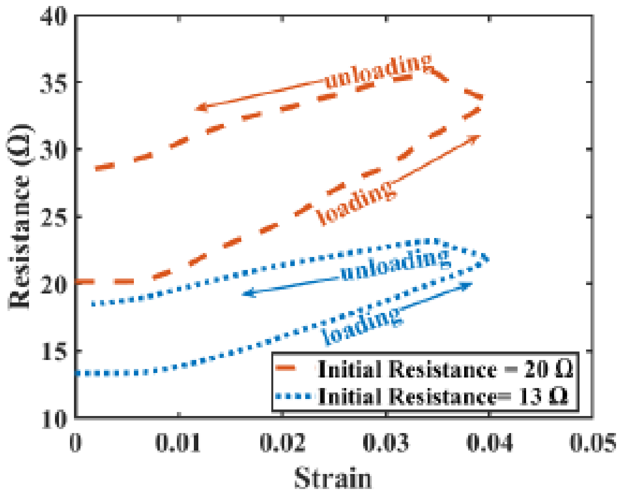
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

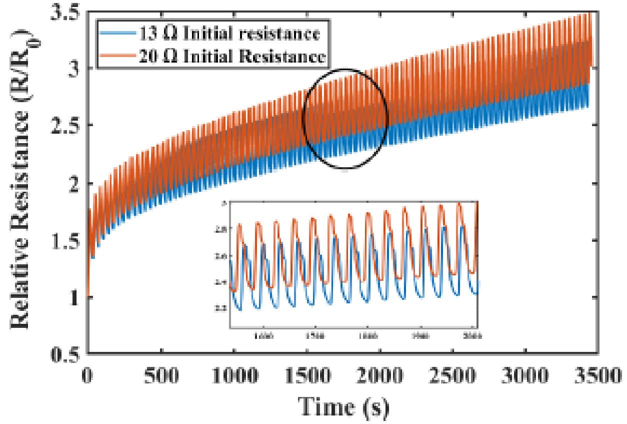
Yokus, M.A., Foote, R., & Jur, J.S. (2016). Printed Stretchable Interconnects for Smart Garments: Design, Fabrication, and Characterization.
Garakani, B. (2022). Fabrication, Characterization, and Electromechanical Reliability of Printed Stretchable and Wearable Electronics (Doctoral dissertation, State University of New York at Binghamton).

Evaluation of E-Textile Interconnects

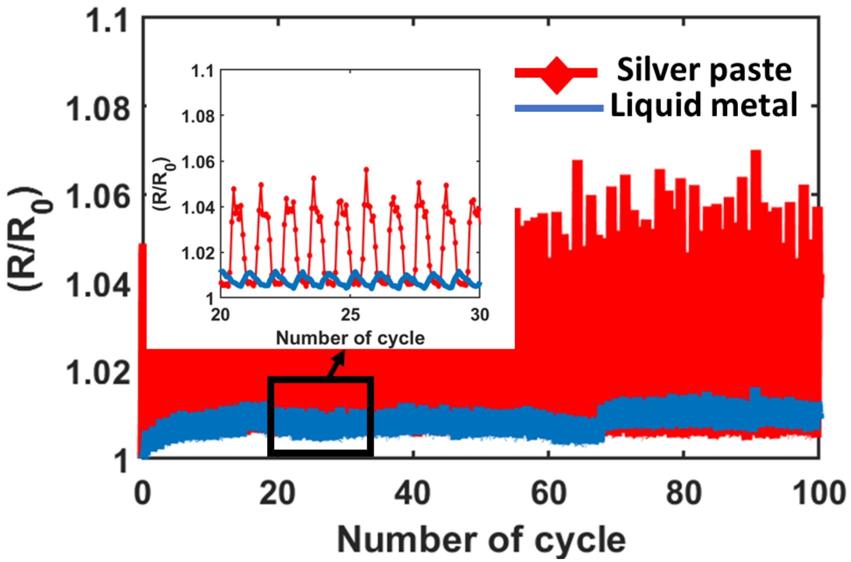
- Monitoring for changes in electrical resistance and mechanical integrity under continuous or intermittent use

Stretchability



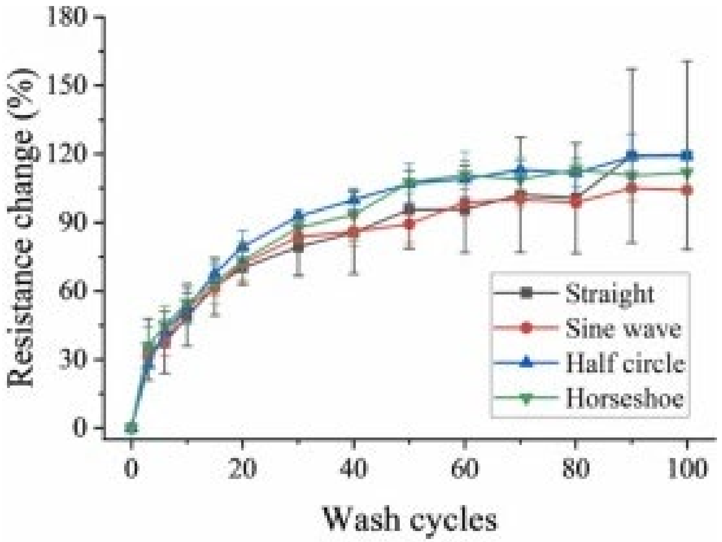


Flexibility



The change in electrical resistance during cyclic bend fatigue for 1000 bend cycles and a rate of 1 Hz at a bending radius of 2.5 mm

Washability



Liu, M., Lake-Thompson, G., Wescott, A., Beeby, S., Tudor, J., & Yang, K. (2024). Design and development of a stretchable electronic textile and its application in a knee sleeve targeting wearable pain management.

Garakani, B. (2022). Fabrication, Characterization, and Electromechanical Reliability of Printed Stretchable and Wearable Electronics (Doctoral dissertation, State University of New York at Binghamton).

Agenda

01
Introduction to E-Textiles

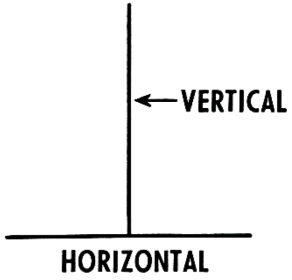
02
Interconnects in E-Textiles

03
Vertical Interconnects

04
Connectors in E-Textiles

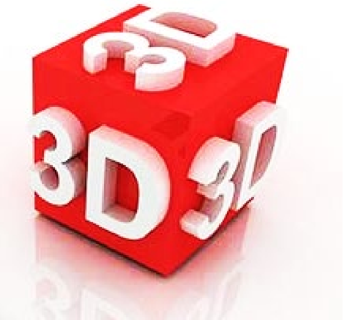
05
Conclusion – Research Gaps

Interconnect Geometries



Horizontal

Vertical

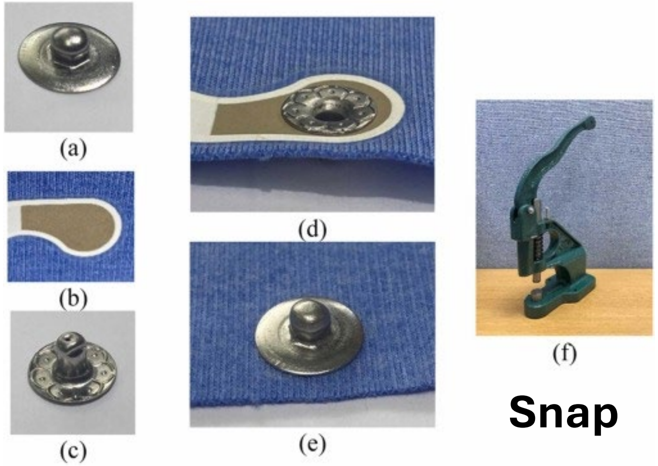


1. **2D integration** (same plane)
2. Electronic **components side by side**
3. **Connect** multiple components **across a larger area**
4. **Prone to damage from bending and stretching** if not flexible enough
5. Preferred Applications: Fitness trackers and LED-embedded clothing etc.

1. **3D integration** (different plane, multilayer)
2. Electronic **components on front and back**
3. Allow for more **compact and integrated designs**
4. **May affect the flexibility and comfort of the fabric**, depending on the materials and methods used
5. Preferred Application: Smart textiles for healthcare monitoring, military uniforms with integrated communication systems, and garments with complex sensor arrays

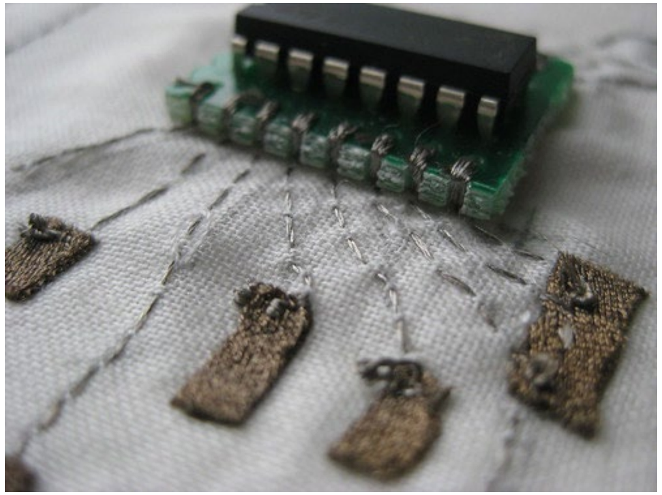
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Current Vertical Interconnects in E-Textile



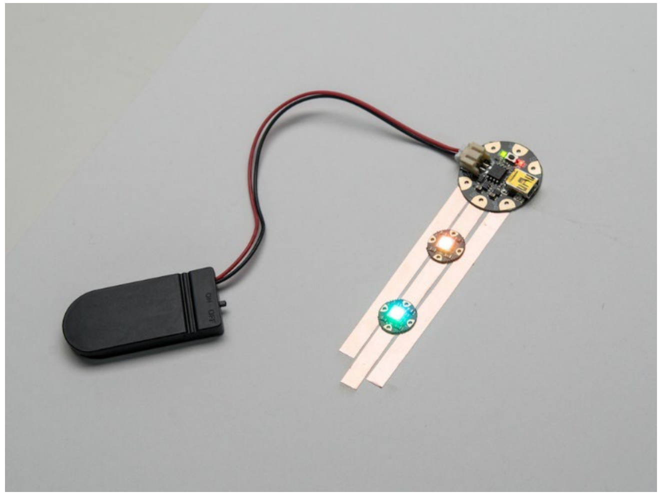
Snap

Solder

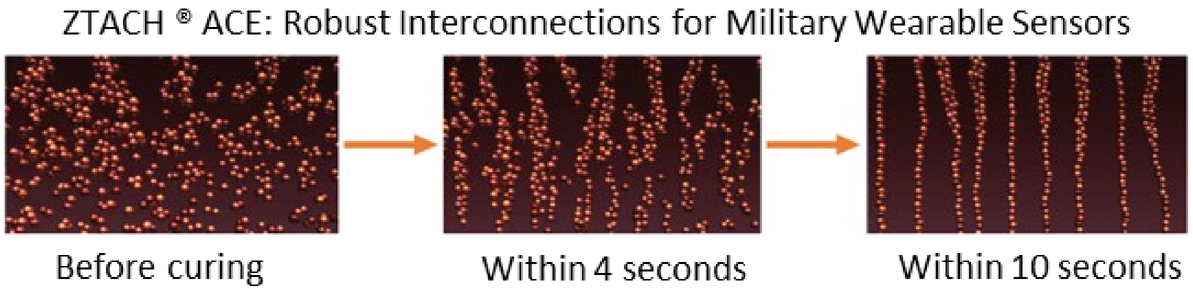


Sewing/Embroidery

HOW TO GET WHAT YOU WANT. (n.d.).



Adafruit's Z-Tape

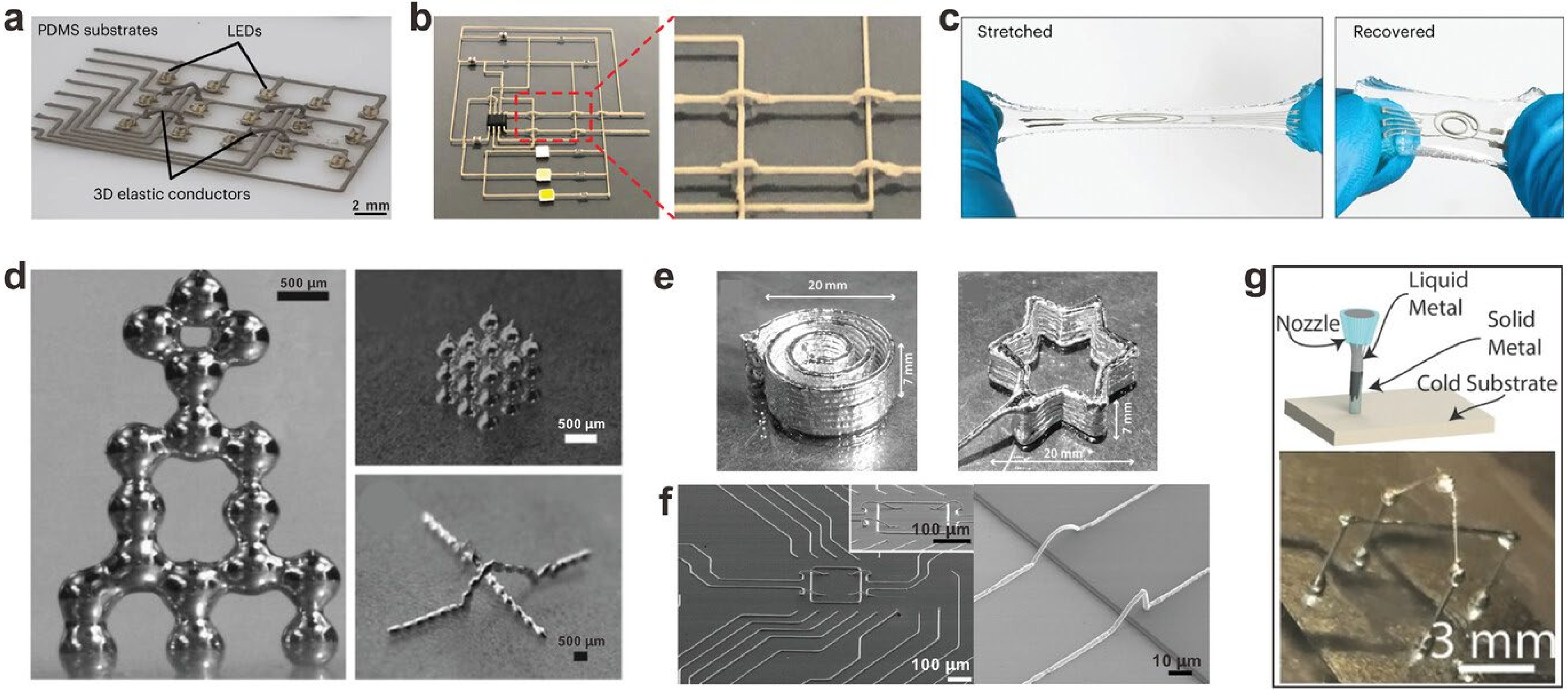


Sunray Scientific's Epoxy

Agcayazi, T., Chatterjee, K., Bozkurt, A., & Ghosh, T. K. (2018). Flexible interconnects for electronic textiles.

Liu, M., Lake-Thompson, G., Wescott, A., Beeby, S., Tudor, J., & Yang, K. (2024). Design and development of a stretchable electronic textile and its application in a knee sleeve targeting wearable pain management.

3D Printed Interconnects



a) Omnidirectional printed 3D elastic conductors using polymer/Ag particle/MWCNT composite ink, (b) 3D circuit printed using elastic silver ink, c) Printing 3D interconnects in hydrogel, d) 3D printing of free-standing LM microstructures, e) LM conductive lines with modified rheology, f) High-resolution LM with 3D structures g) Freeze-printing of LM alloys for 3D conductive networks

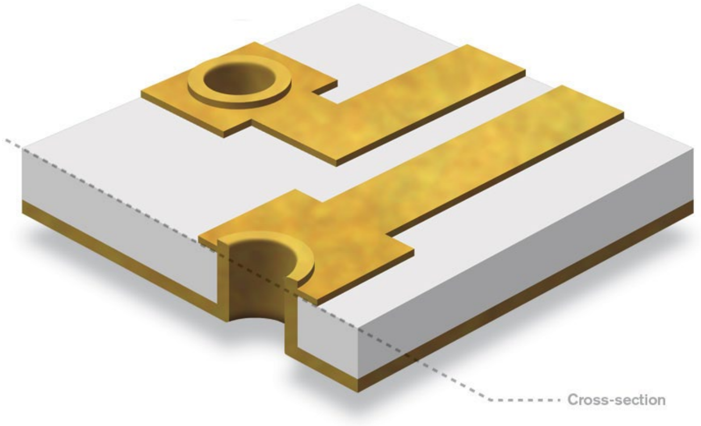
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Li, Y., Veronica, A., Ma, J., & Nyein, H. Y. Y. (2024). Materials, Structure, and Interface of Stretchable Interconnects for Wearable Bioelectronics.

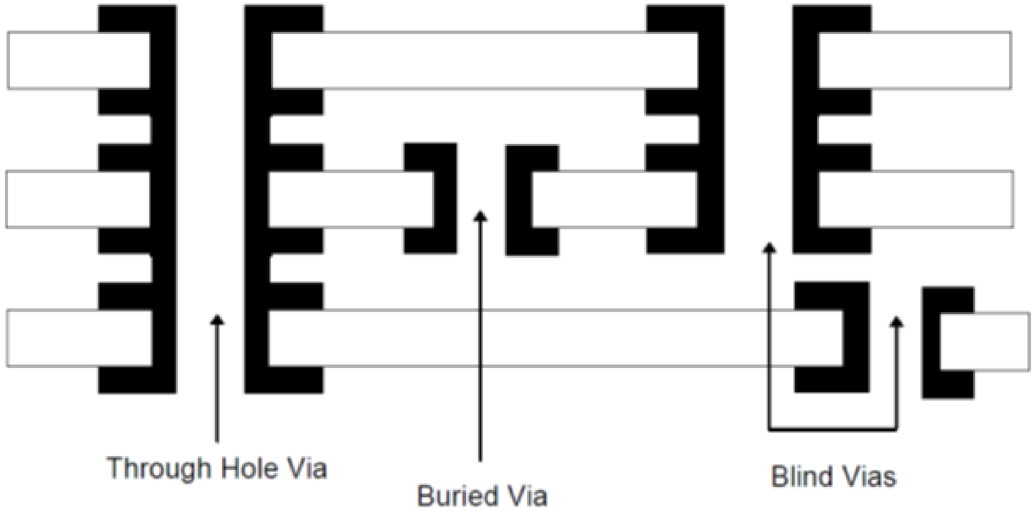
Vertical Interconnect Access (VIA) in Electronics

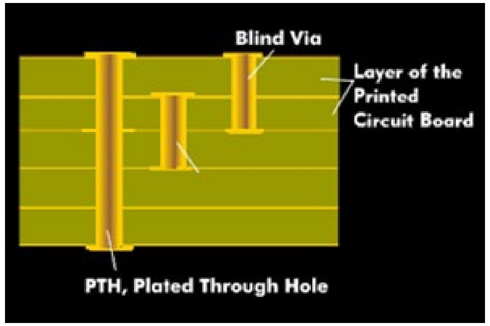
- VIA is a layered connection in form of a metallized (drilled) hole in a printed circuit board (PCB). The connection hole is for the electrical connection of the various layers of the circuit board

- Used in semiconductor manufacturing to create high-density vertical interconnects & printed circuit boards (PCBs) for high wire density

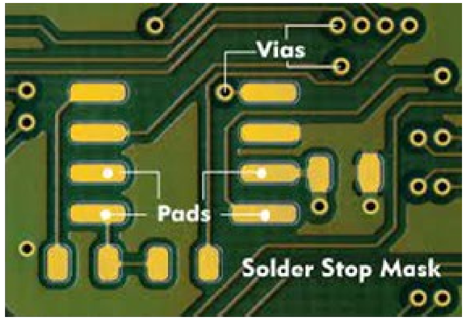


ATP - Vias: Plated Through, n.d.





VIA Top View



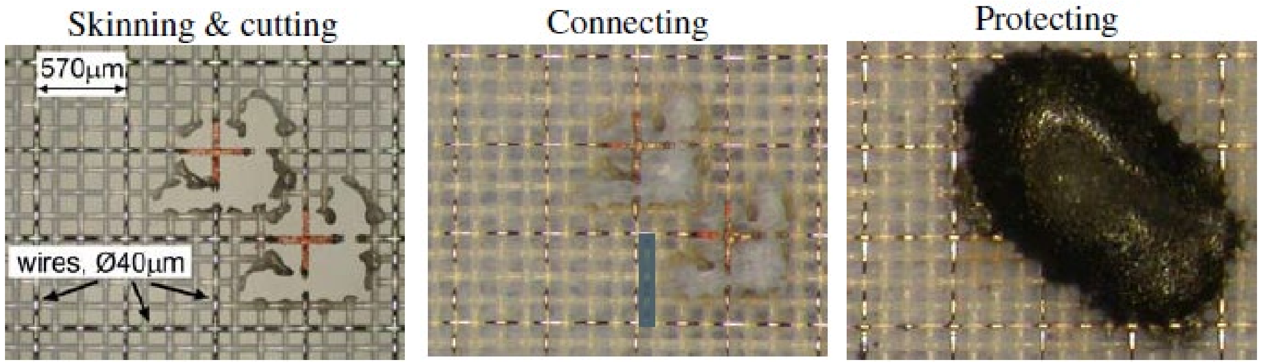
VIA Cross-Sectional View

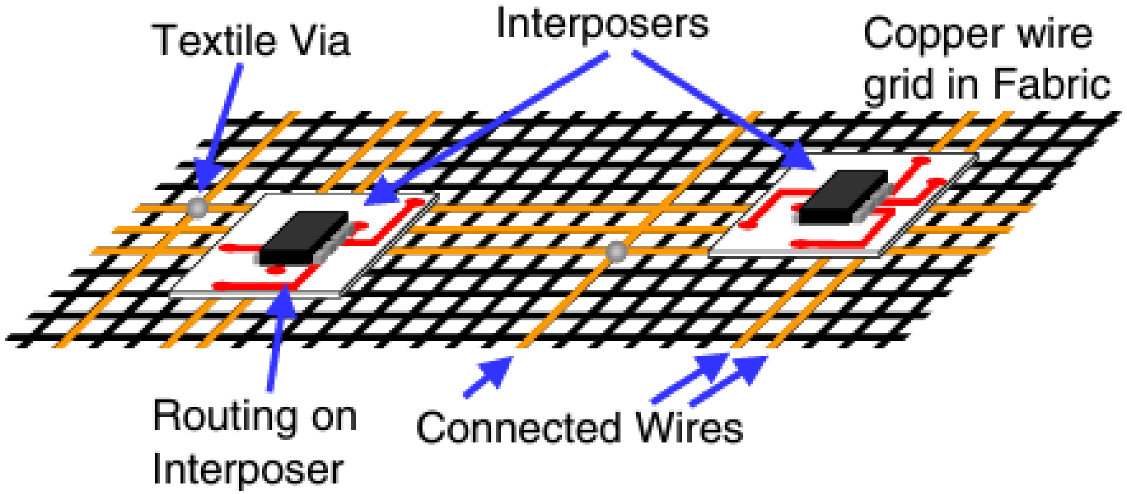
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

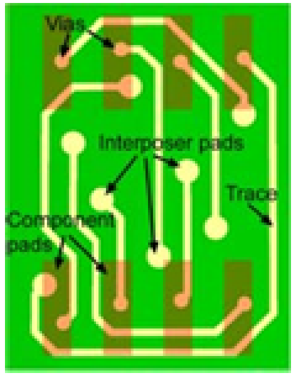
(Micro-VIA & Vertical Interconnect Access (VIA) on HDI PCBs - Bittele, n.d.)

Images from Google *https://www.itwissen.info/en/vertical-interconnect-access-PCB-via-120480.html*

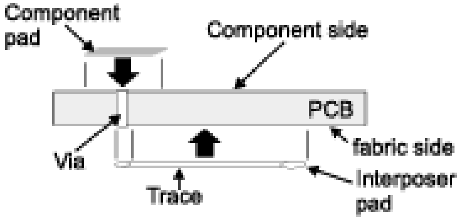
Textile VIAs







(a) Top view (component side is translucent)

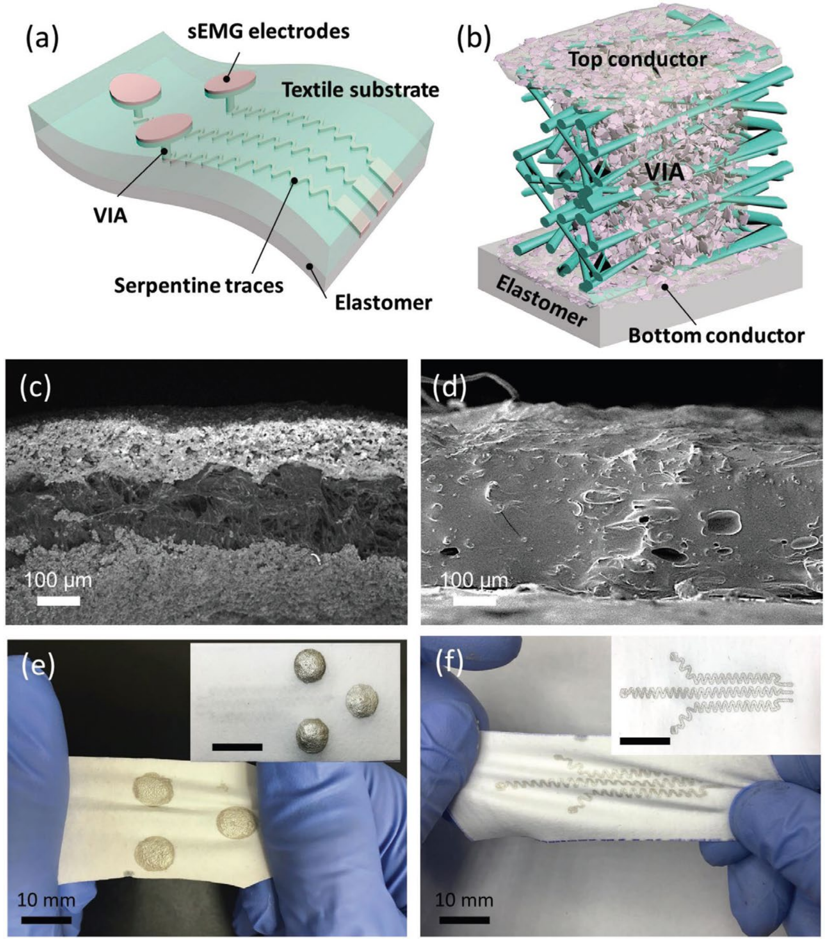


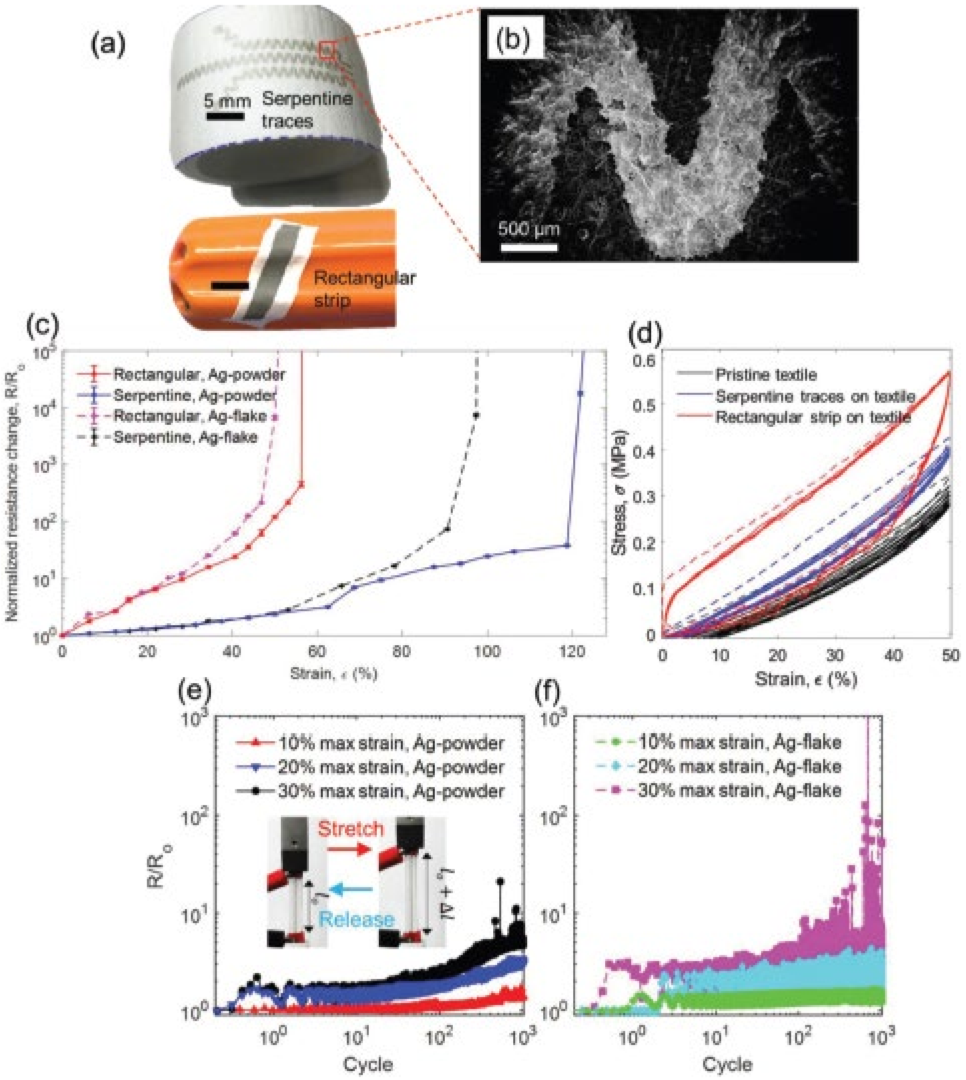
(b) Cross-section sketch

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Locher, I. (2006). Technologies for system-on-textile integration (Doctoral dissertation, ETH Zurich).

Textile VIAs

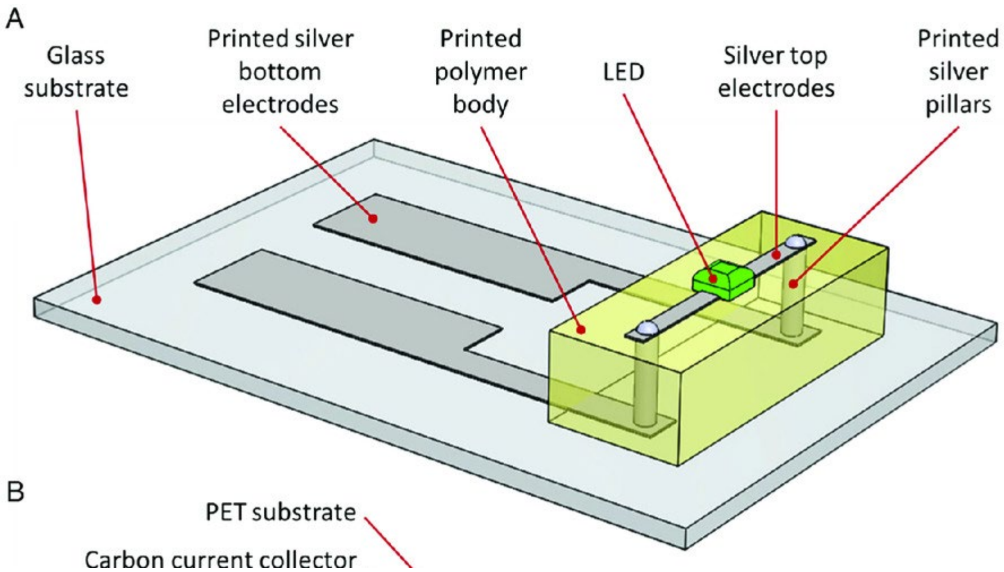




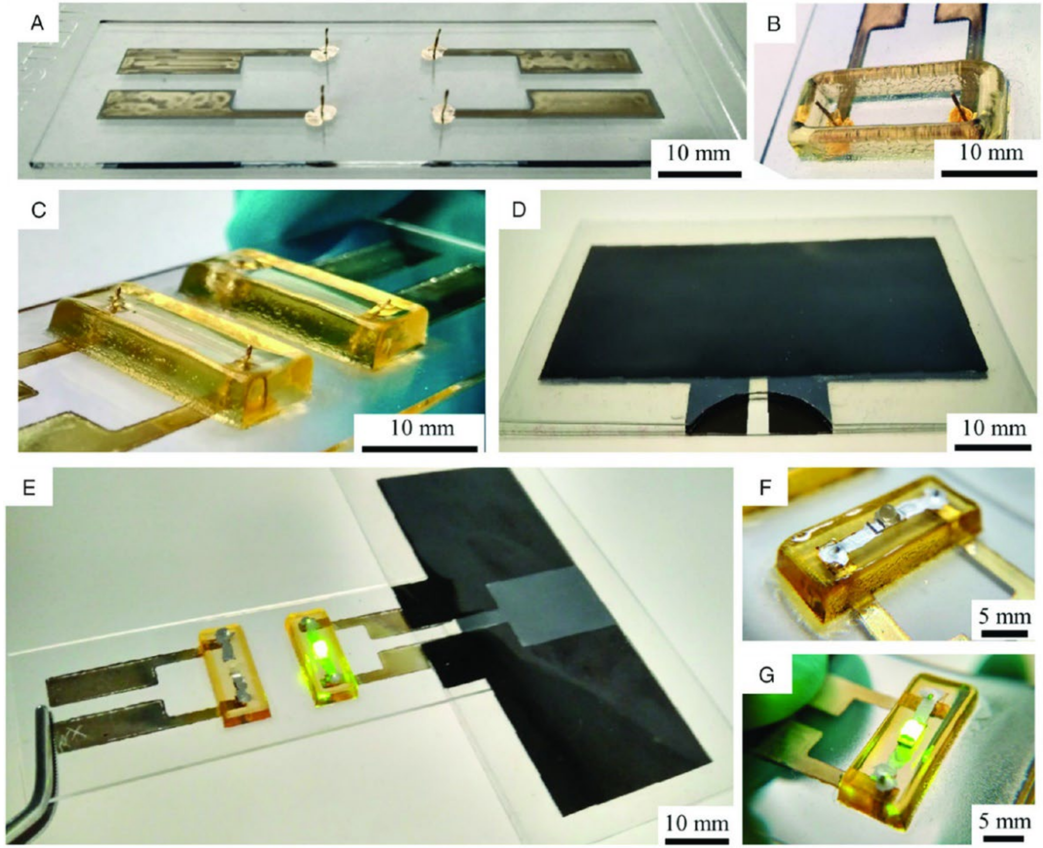
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

La, T. G., Qiu, S., Scott, D. K., Bakhtiari, R., Kuziek, J. W., Mathewson, K. E., ... & Chung, H. J. (2018). Two-layered and stretchable e-textile patches for wearable healthcare electronics.

Textile VIAs



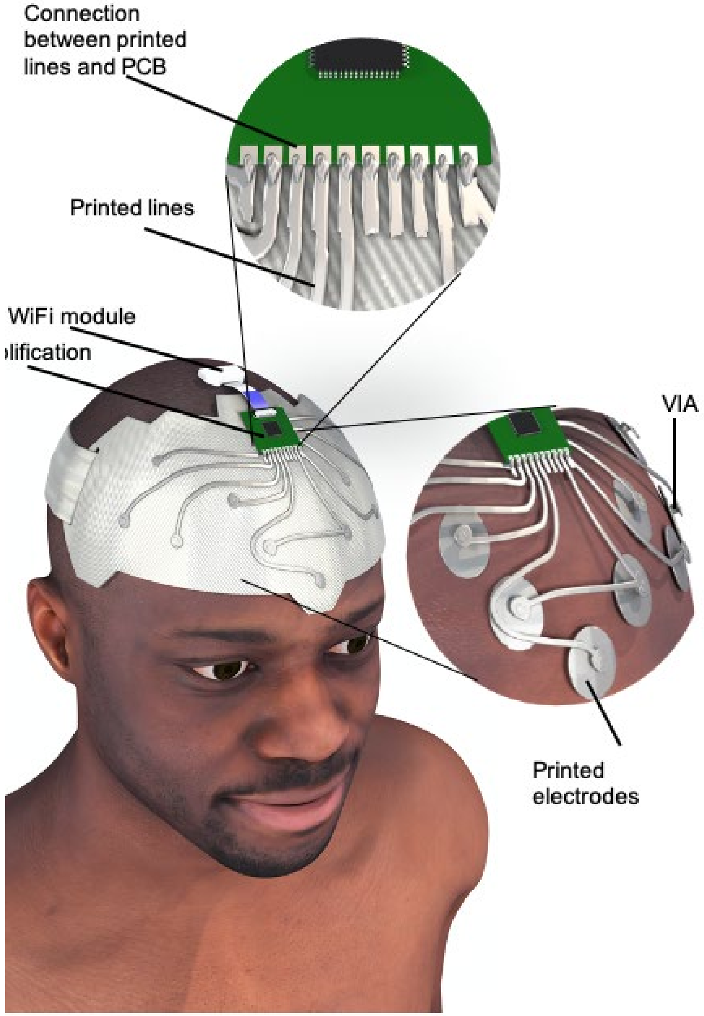
Inkjet-printed demonstrator device with a solid-state LED

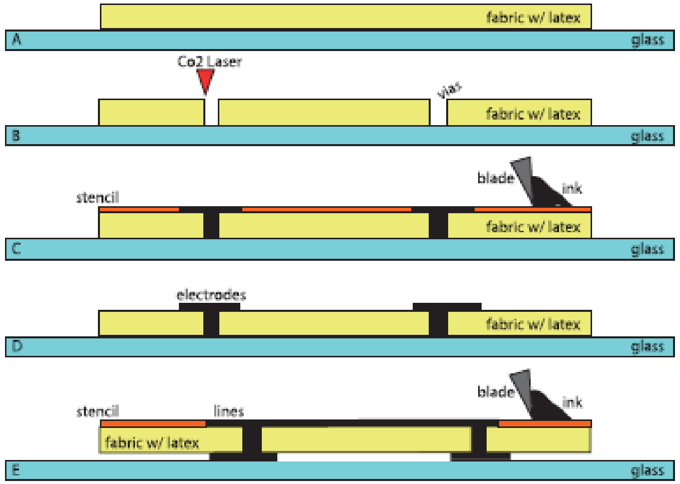


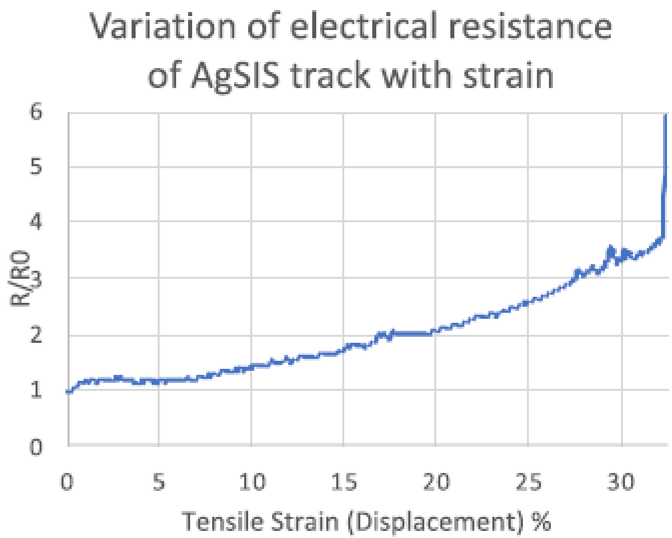
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

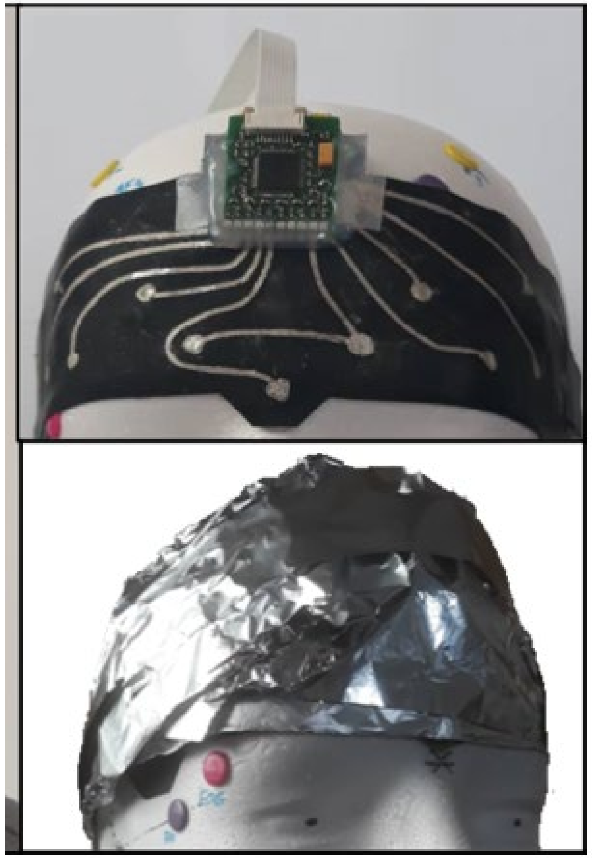
Sowade, E., Polomoshnov, M., Willert, A., & Baumann, R. R. (2019). Toward 3D-printed electronics: inkjet-printed vertical metal wire interconnects and screen-printed batteries.

Textile VIAs



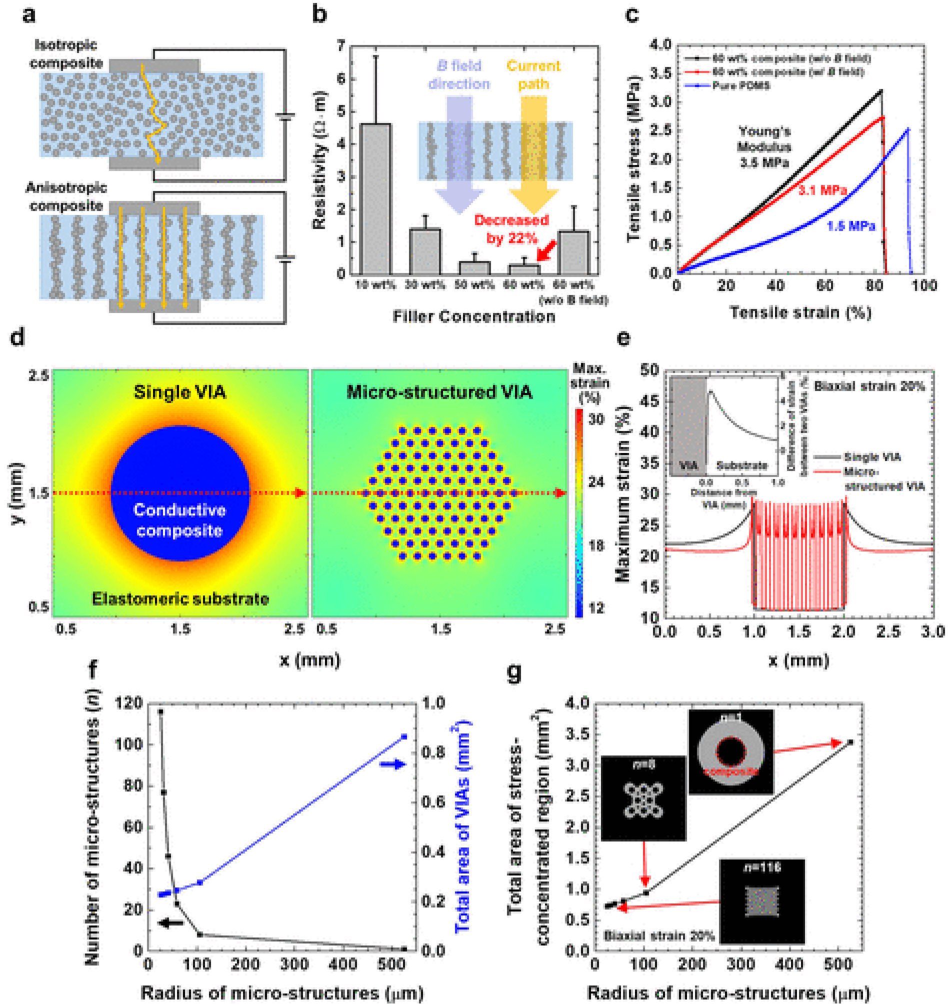


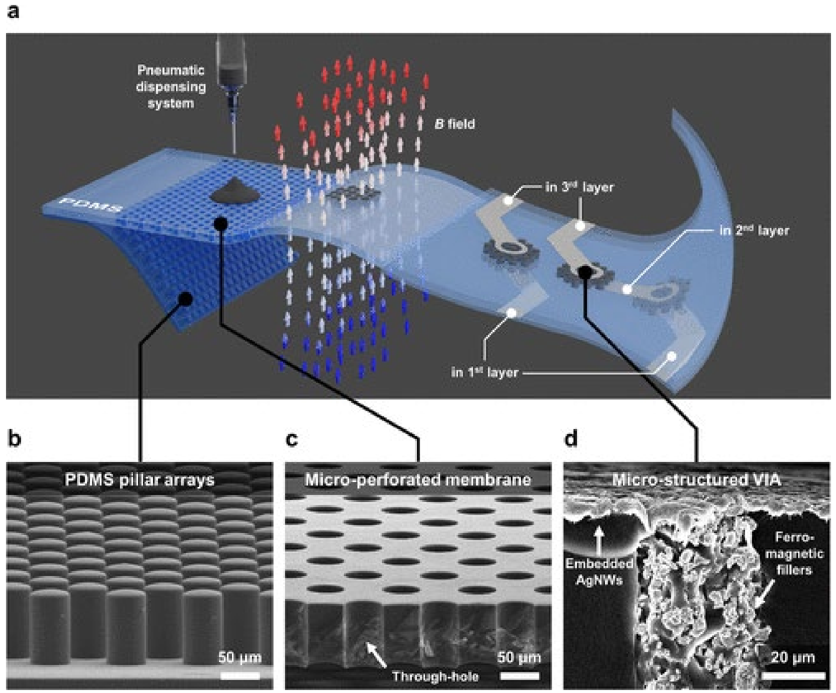




Carneiro, M. R., de Almeida, A. T., & Tavakoli, M. (2020). Wearable and comfortable e-textile headband for long-term acquisition of forehead EEG signals.

Textile VIAs

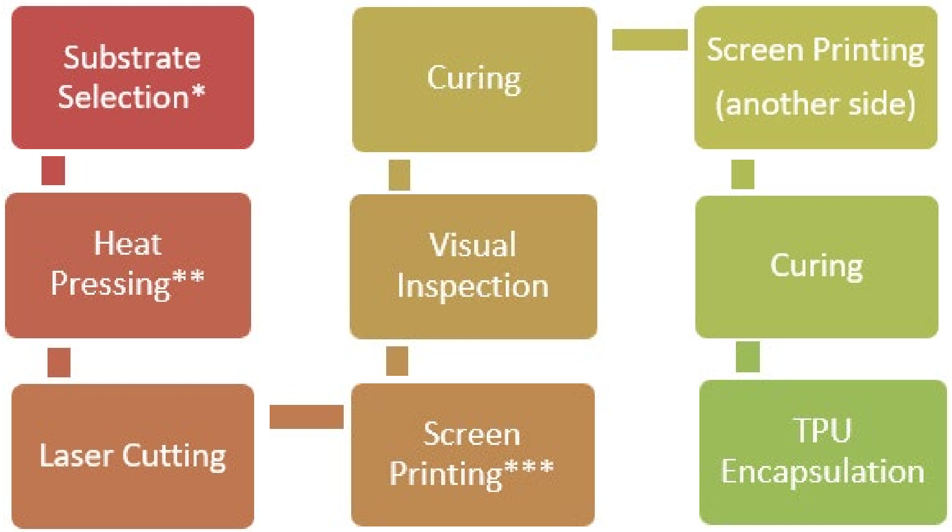




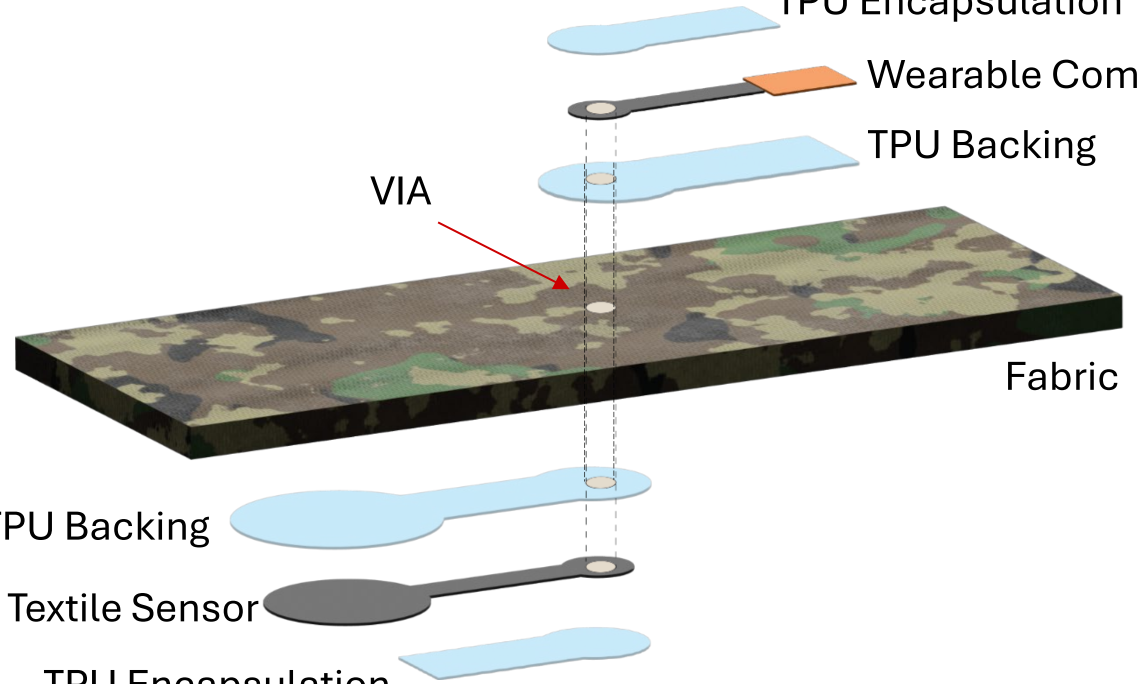
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Seo, J., Yoon, J., Kim, G., Cho, H., Jang, D., Yoon, H., ... & Hong, Y. (2023). Microstructured Anisotropic Elastomer Composite-Based Vertical Interconnect Access (VIA) for Multilayered Stretchable Electronics.

My Research – VIA in E-Textiles



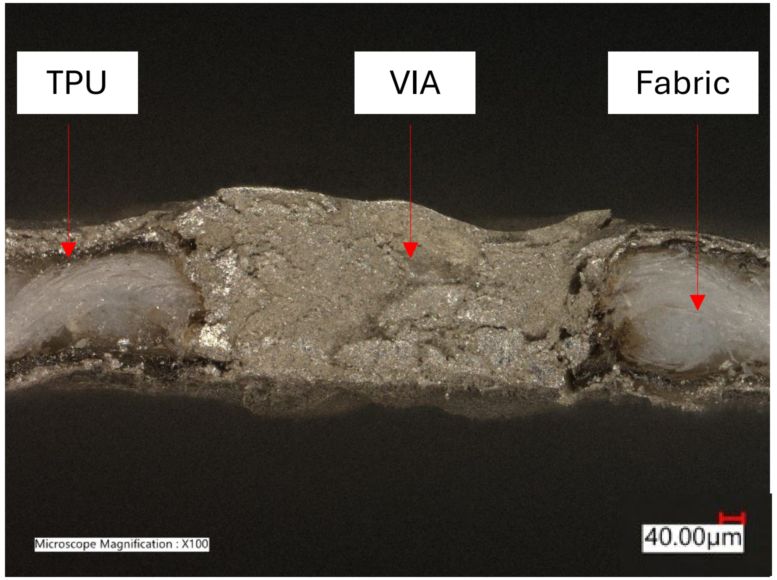
*Fabric substrate: Woven or Knit
**Thermoplastic Polyurethane (TPU) film
***Conductive Filling Materials: Conductive Ink or Epoxy



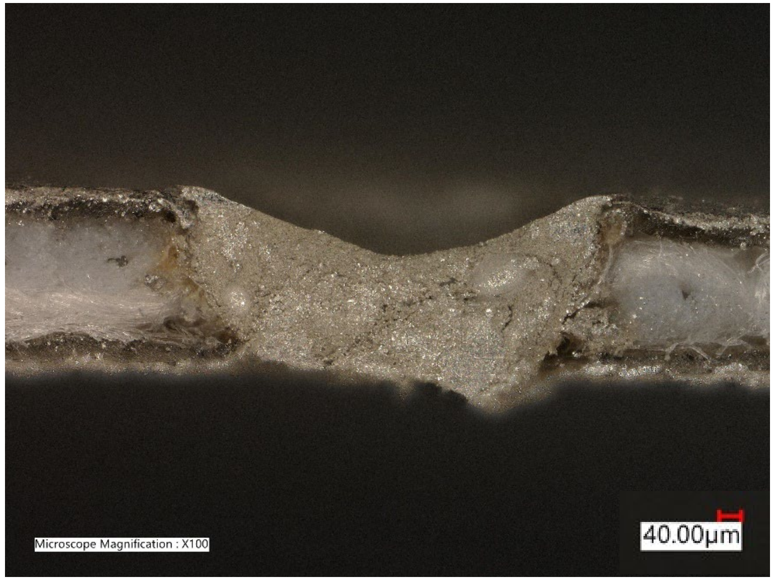
Schematic of Vertical Interconnect Access (VIA) through multiple layers of printed e-textiles

Vertical interconnect from fabric back to fabric front

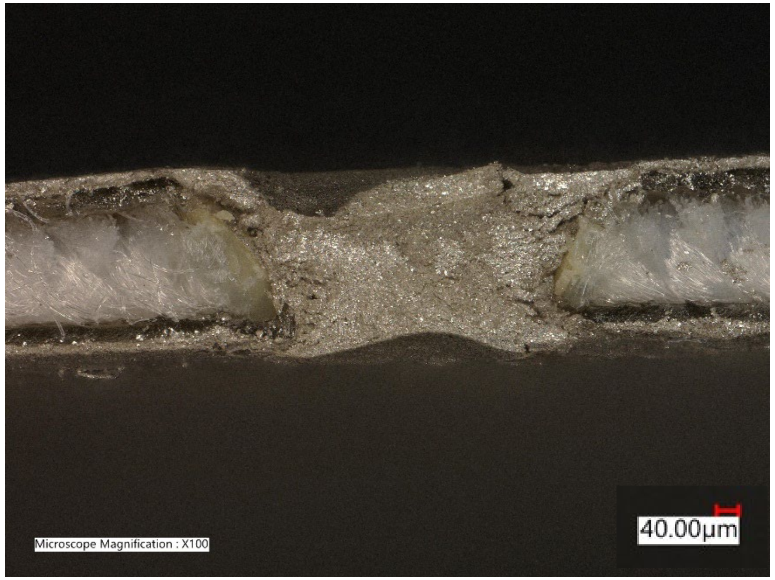
Digital Microscopy Images



Non-Stretchy Woven



Stretchy Woven



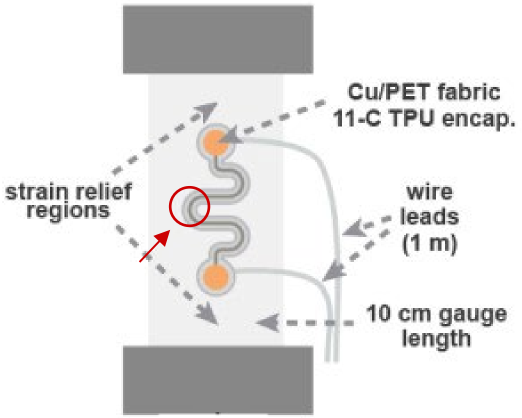
Knit

Magnification: x100
Scale: 40 micrometer
TPU – Thermoplastic Polyurethane
VIA – Vertical Interconnect Access
Ag/AgCl Conductive Ink Filling

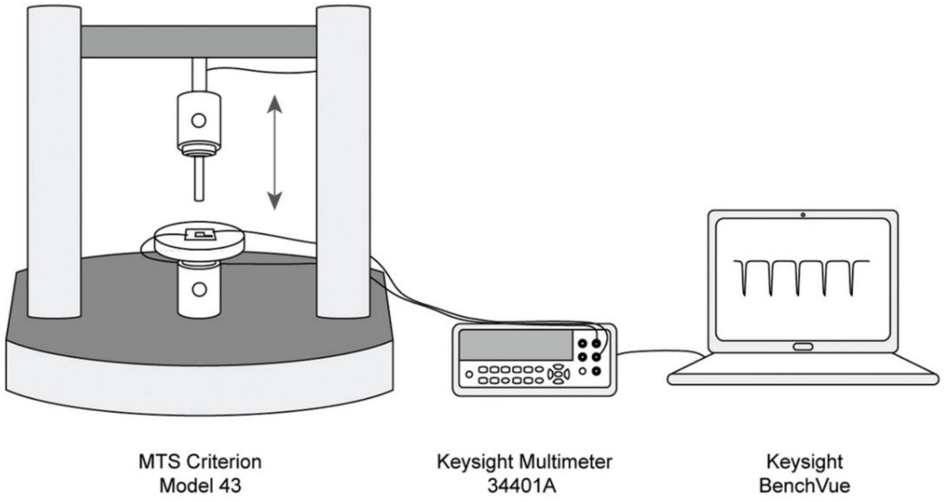
- 3 Fabrics – Non-stretchy and stretchy twill woven fabric, and single jersey knit
- Conductive filling material – Conductive silver/silver chloride ink
- VIA diameter: 1mm

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

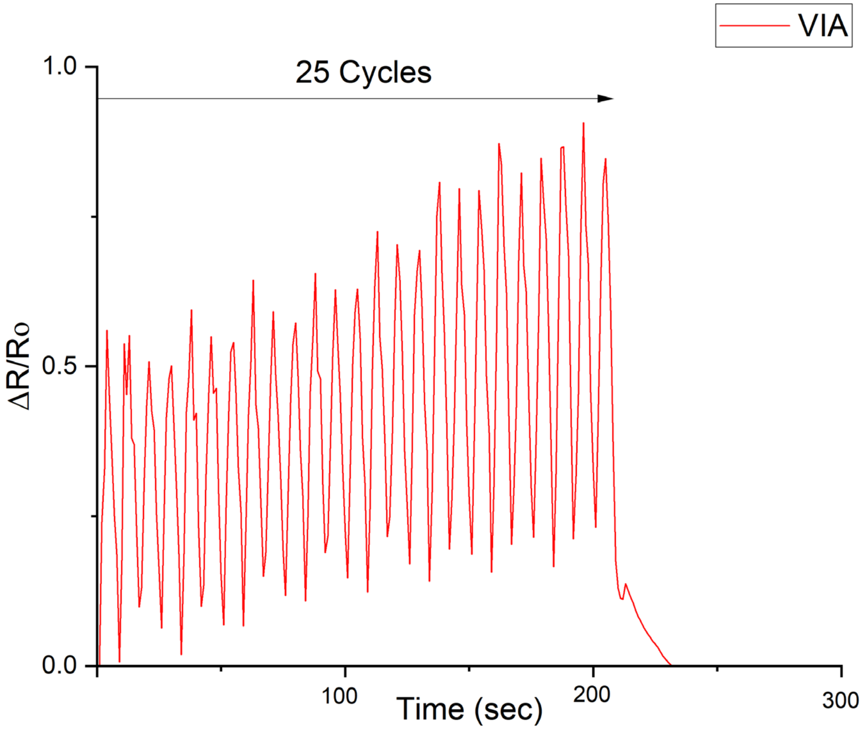
Electromechanical Test



VIA in Knit Sample



Test Setup



25 Cyclic Stretch and Release Cycles (2% strain)

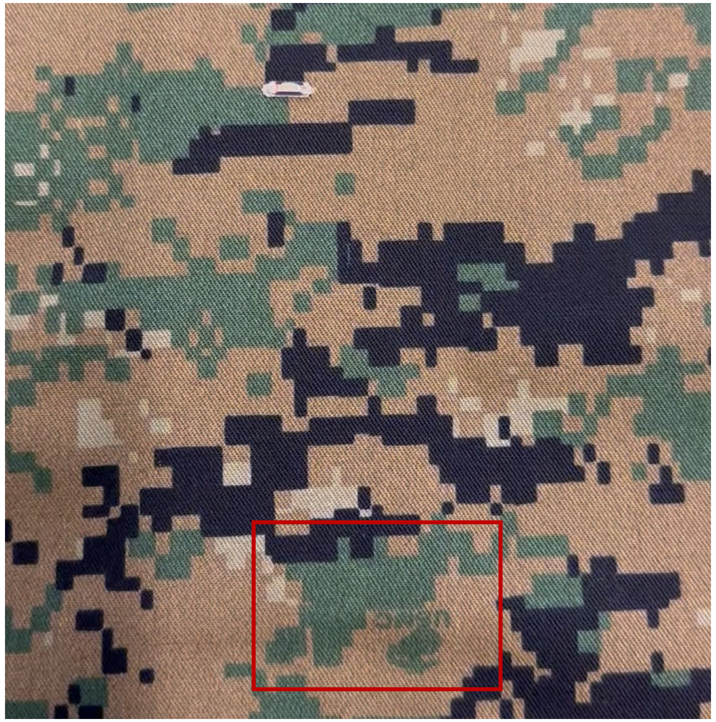
<u>Preliminary Results</u>

- Number of cycles increased – Change in resistance of VIA increased
- After 25 stretch and release cycles – Resistance of VIA goes back down
- Further testing – Knit and woven fabrics, with metal snap, conductive ink, and conductive epoxy VIA interconnect (100 cycles)

Knowles, C.G., 2023. Digital Strategies for E-Textile Design and Manufacturing. North Carolina State University.

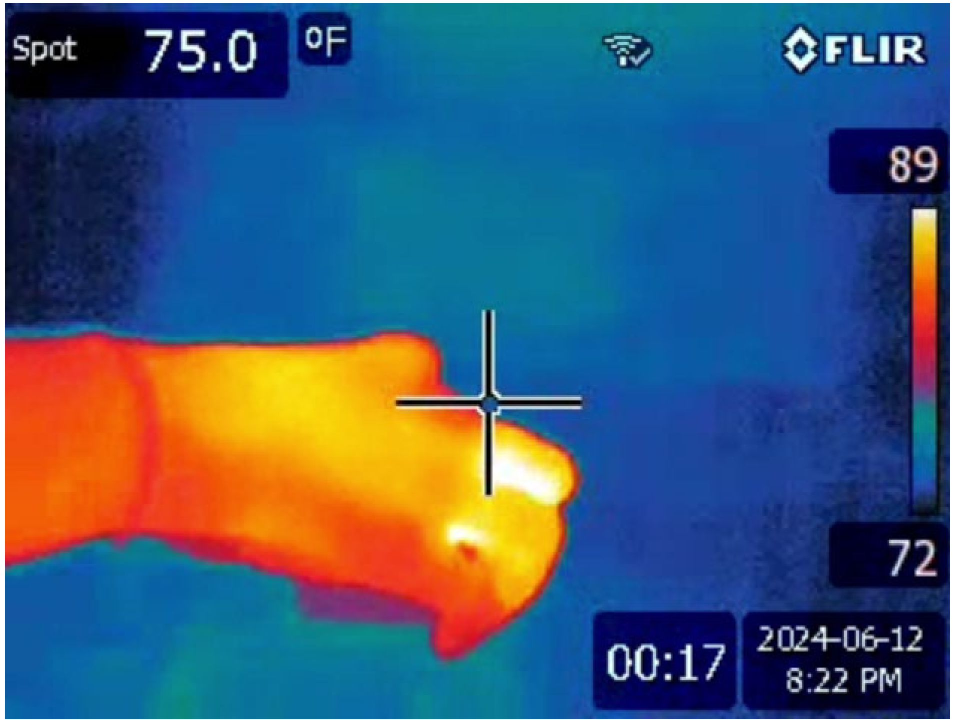
Military Application of VIA

1

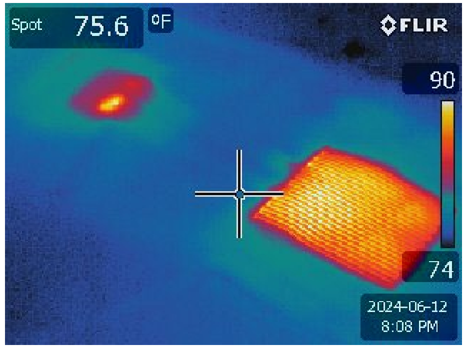


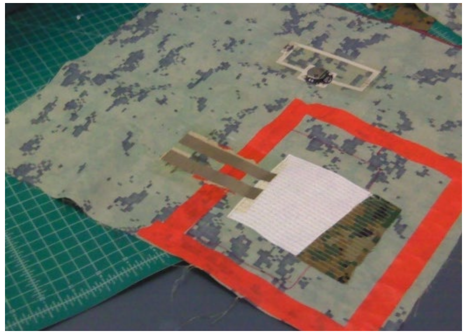
Strategic Application (using Switches)

2



Thermal Comfort Application





Fabric Heating through VIA

Concept and Fabrication by	Dr. Amanda Mills acmyers3@ncsu.edu	Ethan Hill ewhill3@ncsu.edu	Carson Jenkins csjenki4@ncsu.edu	Prateeti Ugale pmugale@ncsu.edu

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Benefits of VIA for E-Textiles

Vertical Connection

- Provides vertical and short connection from fabric back to fabric front and vice versa

Design Features

- Low and soft form factor
- Avoids the requirement of longer interconnect paths
- Manufacturable and scalable

Reliability Durability

- TPU provides protection against dirt, water, and other impurities
- Provides heat dissipation from high power components
- Mechanical durability

Enhanced Performance

- Allows complex circuitry to be packed into a smaller footprint
- Offers secure communication systems

Seamless Integration

- Avoids soft to hard connection stresses
- Avoids using rigid components like snaps, rivets etc.

Agenda

01 Introduction to E-Textiles

02 Interconnects in E-Textiles

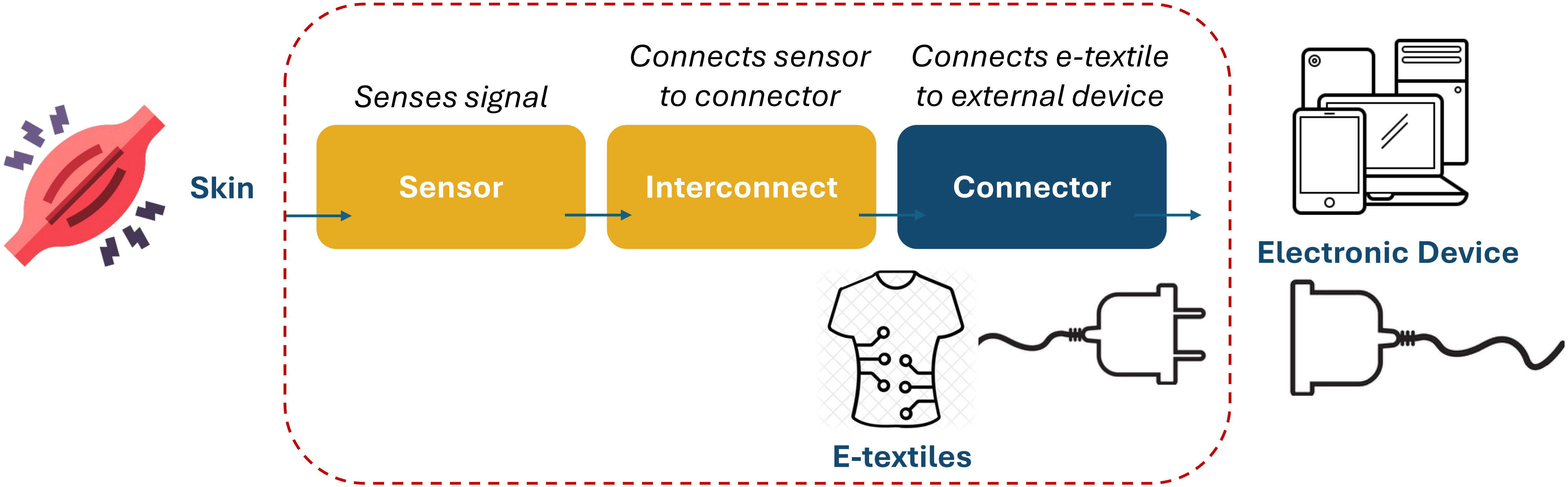
03 Vertical Interconnects

04 Connectors in E-Textiles

05 Conclusion – Research Gaps

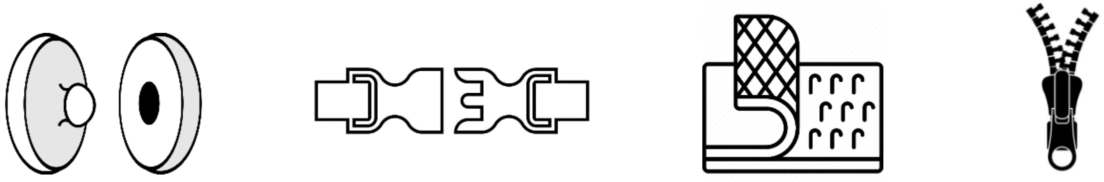
Wearable E-Textile Connectors

These are specialized components that allow for the connection of electronic components to e-textiles



- Wearable functionalities are plugged into computers using bulky electronics – hinders natural feeling of textiles
- Withstand the repeated mating-un-mating cycles to maintain robust electrical conductivity
- Expected to merge contrasting conditions (flexible and rigid)

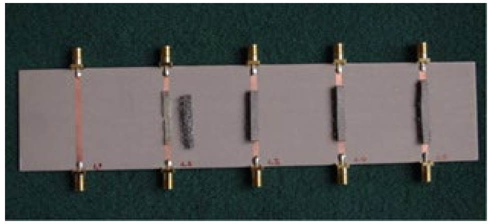
Wearable Connectors



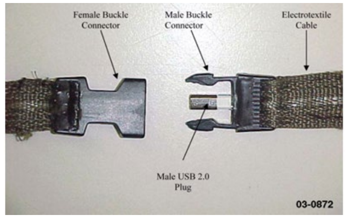
Snap Buckle Hook & Loop Zipper

Examples

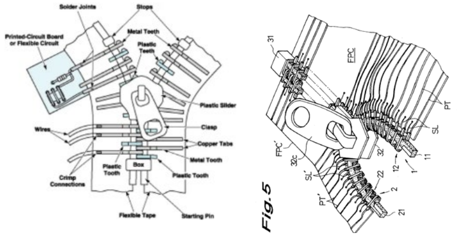
Snap



Hook & Loop



Buckle



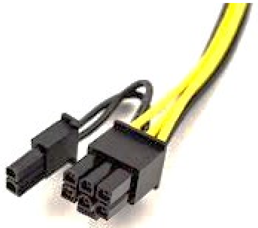
Zipper

- CONNECTION - Need to make physical connection (mechanical or magnetic) as well as electrical connections (pogo pins are commonly used)

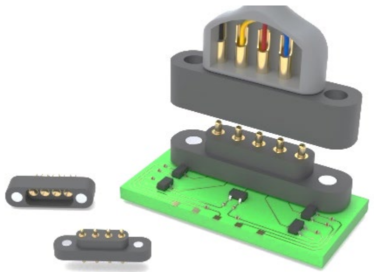
- SIZE - Number of connection points can increase the size of the connector

- COMMUNICATION - Various communication protocol can be used such as – 1 Wire, I2C, SPI, CAN Bus, USB etc.

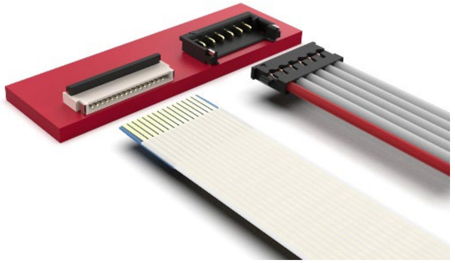
- PERFORMANCE - Evaluation includes tests like – Mating-unmaking cycles, contact resistance etc.



Connector Housing



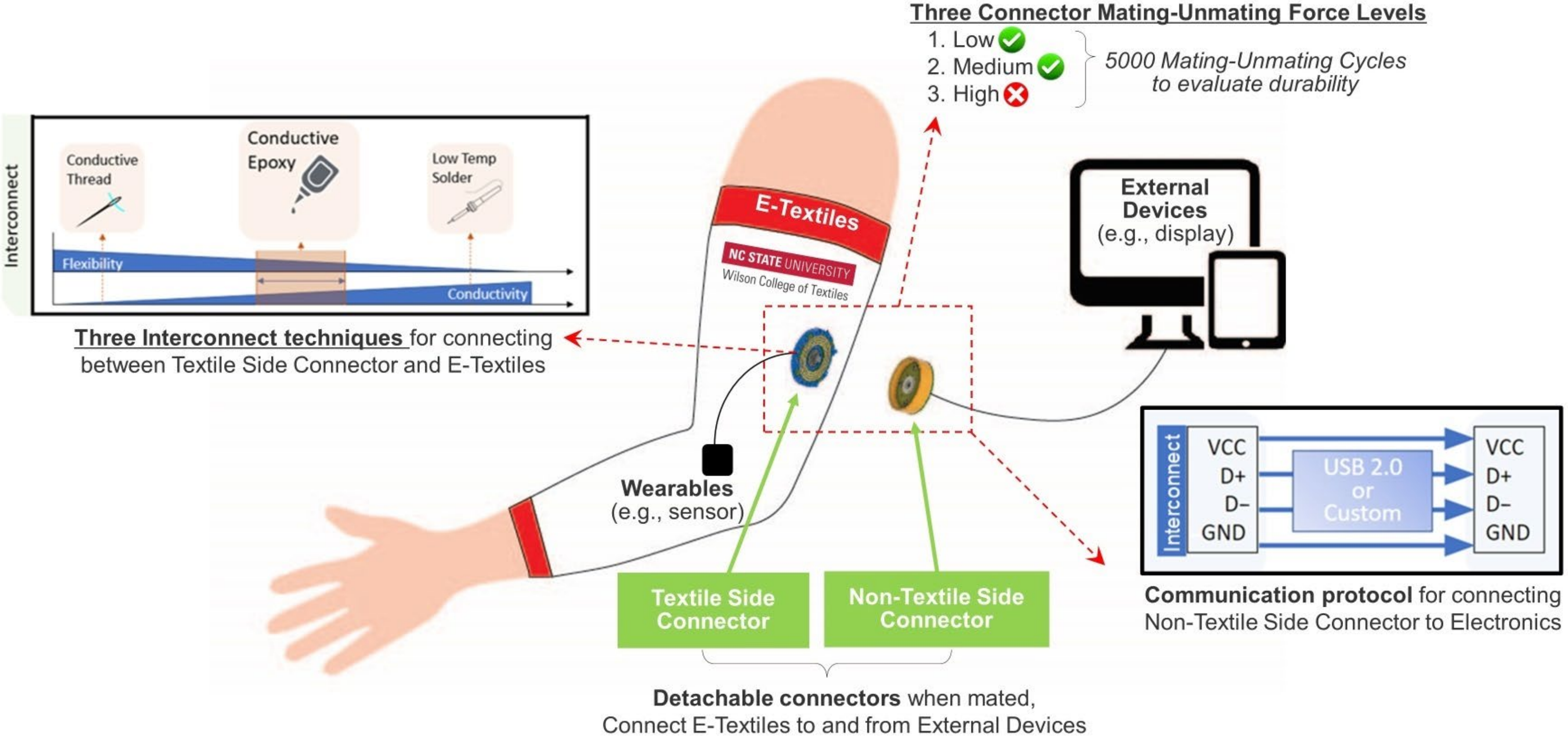
Magnetic Connector with Pogo Pins



Flexible Ribbon Cable with Connector

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Wearable Solutions: Design, Durability, and Electrical Performance of Snap Connectors and Integrating Them into Textiles Using Interconnects

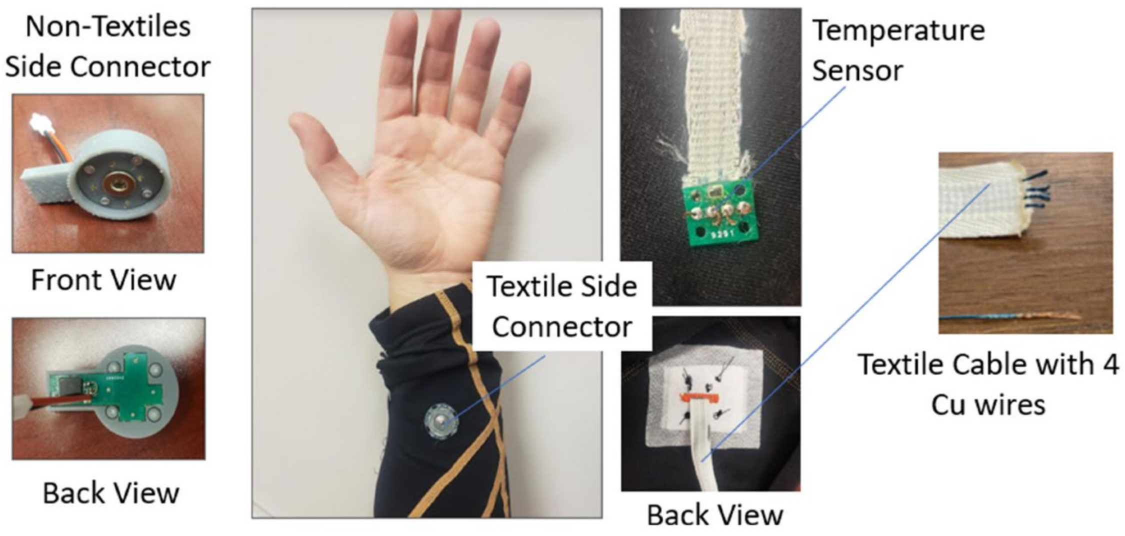


Graphical Abstract

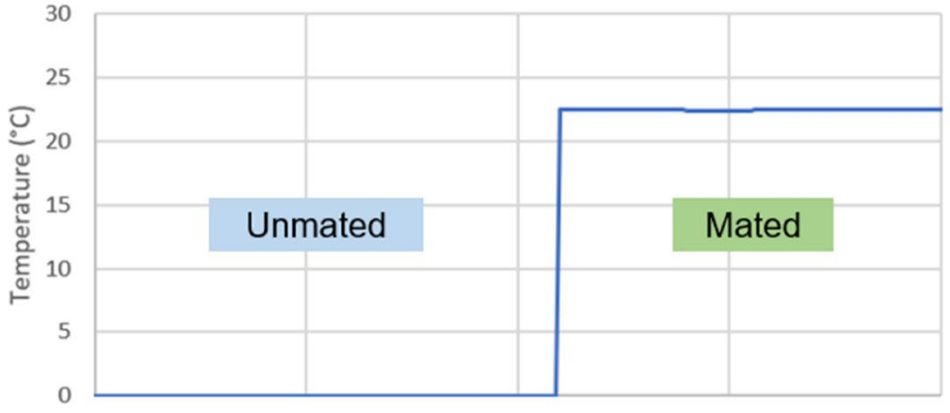
EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Ugale, P., Lingampally, S., Dieffenderfer, J., & Suh, M. (2024). Wearable Solutions: Design, Durability, and Electrical Performance of Snap Connectors and Integrating Them into Textiles Using Interconnects.

Working Prototype

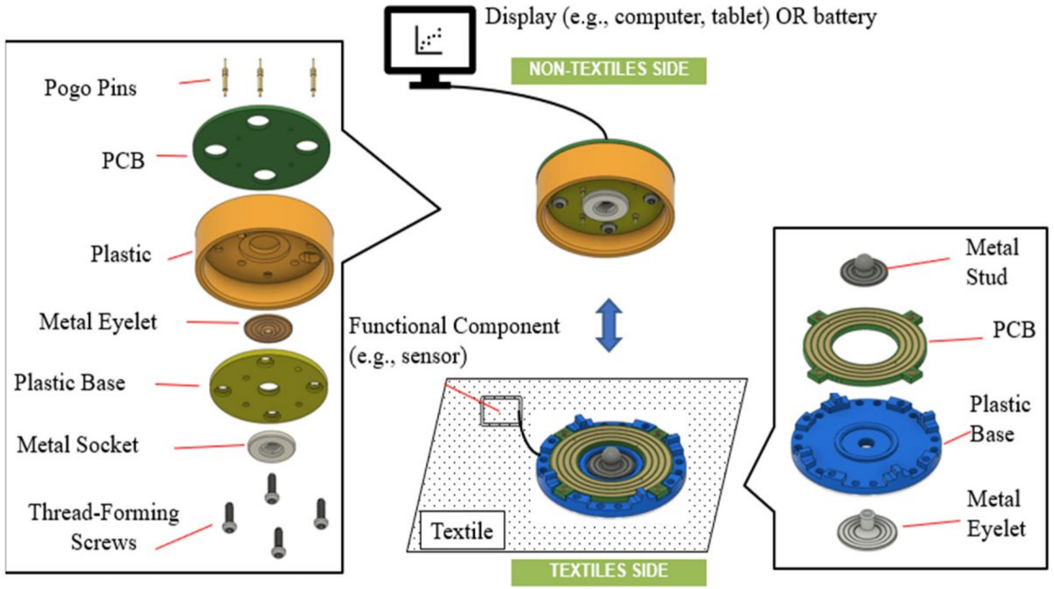


(a)

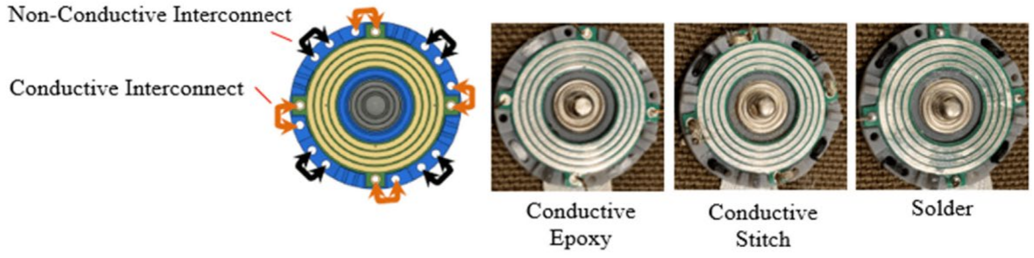


(b)

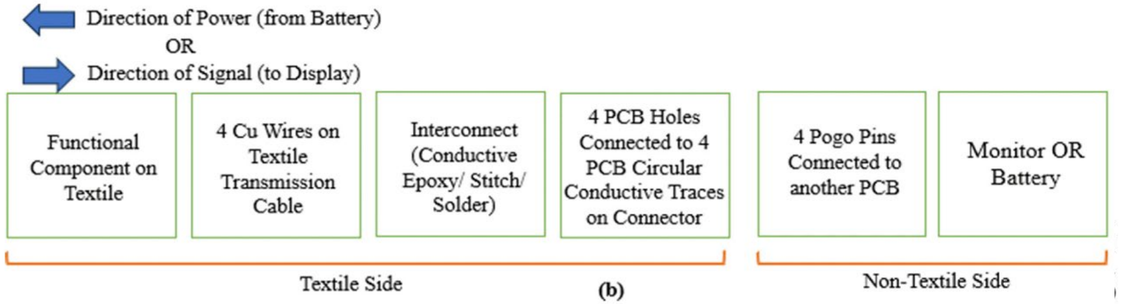
(**a**) The working concept of detachable wearable snap connector to monitor skin temperature using temperature sensor when mated, (**b**) Graph demonstrating the temperature reading when connectors are mated.



Snap connector schematic.



(a)



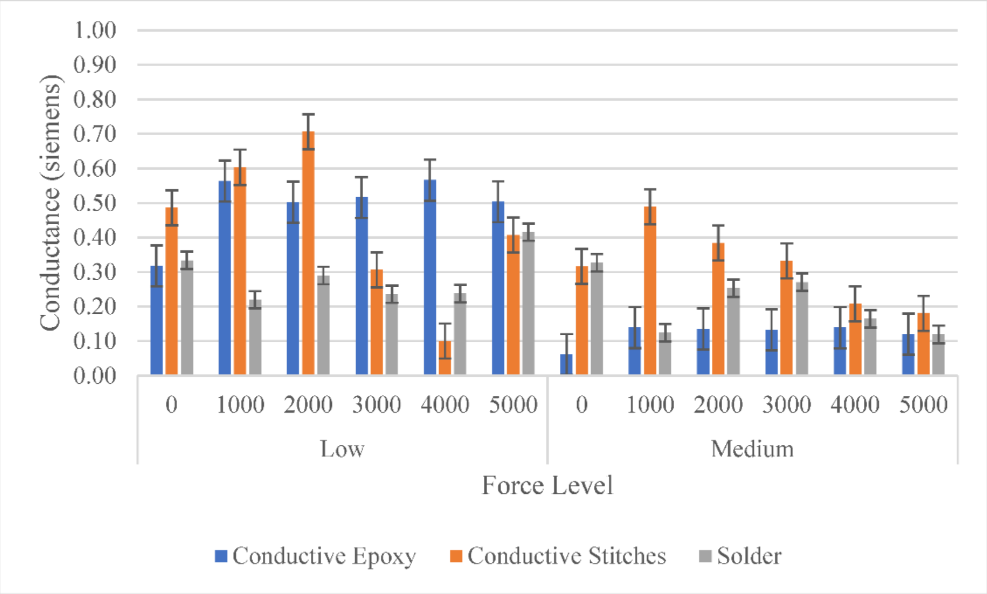
(b)

(a) Interconnect sides for textile side snap connectors.
(b) Flow through the different components.

Results

(a) Conductive Epoxy | (b) Conductive Stitches | (c) Solder

Failure Modes for high force level:
- (a) Metal socket disassembled from the non-textile side of connector body
- (b) Metal stud disassembled from the textile side of connector body
- (c) Textile side of the connector plastic broken, non-conductive stitches broken too



Conductance in the snap connector from two force levels (low and medium) across the three interconnect methods (conductive epoxy, conductive sewing, and solder) at every 1000 mating–unmating cycles starting from 0 to 5000.

Source	DF	Sum of Squares	F Ratio	Prob > F
Force Level	1	0.9900	16.0728	0.0001 **
Interconnect Method	2	0.6009	4.8782	0.0094 **
Force Level × Interconnect Method	2	0.9644	7.8288	0.0007 **
Mating–Unmating Cycles	5	0.3935	1.2778	0.2788
Force Level × Mating–Unmating Cycles	5	0.0110	0.0357	0.9993
Interconnect Method × Mating–Unmating Cycles	10	0.5099	0.8279	0.6027
Force Level × Interconnect Method × Mating–Unmating Cycles	10	0.0740	0.1202	0.9995

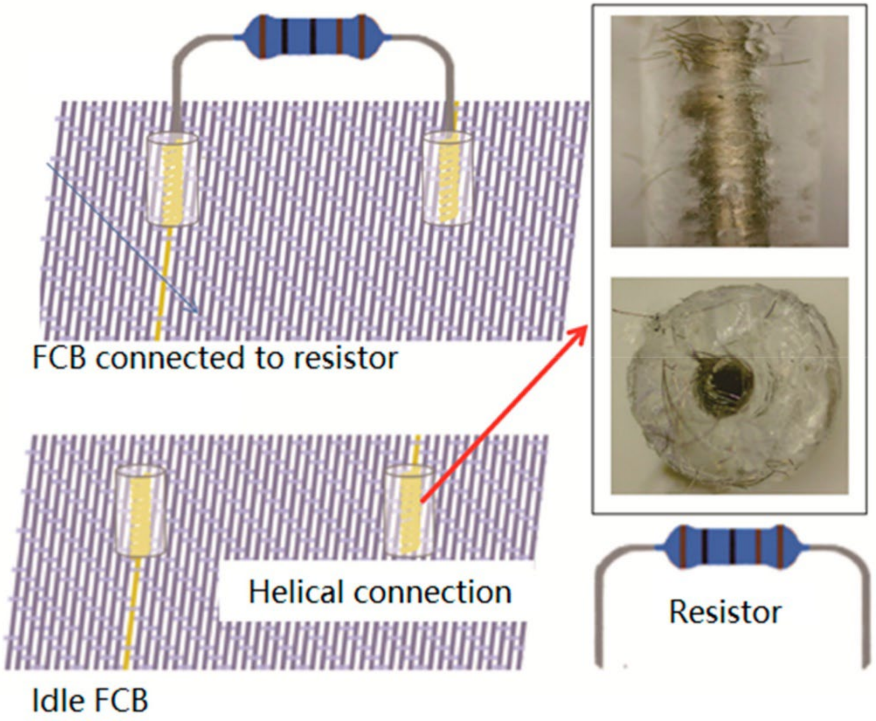
** indicateds statistical significance.

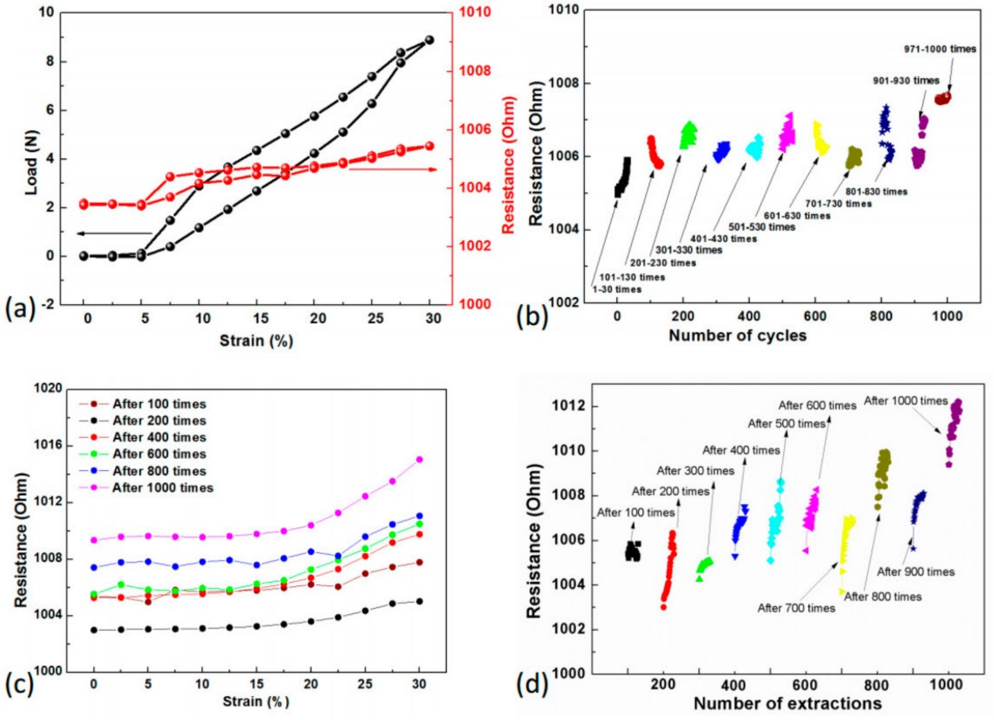
Effect tests for snap connector conductance.

Level				Least Sq Mean
Low, Conductive Epoxy	A			0.5225
Low, Conductive Sewing	A	B		0.4337
Medium, Conductive Sewing	A	B	C	0.3333
Low, Solder		B	C	0.2304
Medium, Solder			C	0.2241
Medium, Conductive Epoxy			C	0.1316

Tukey's HSD connecting letter report of Force Level x Interconnect Method.

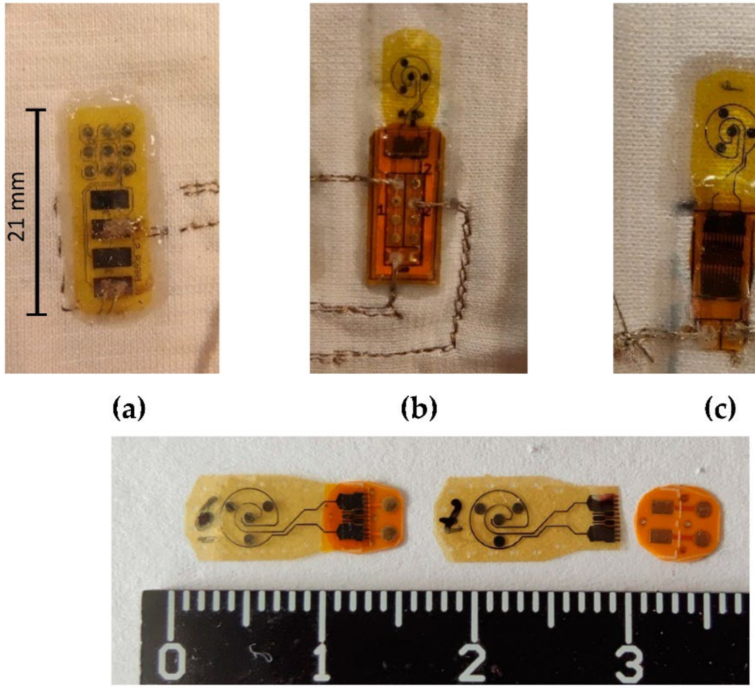
Vertical Connectors





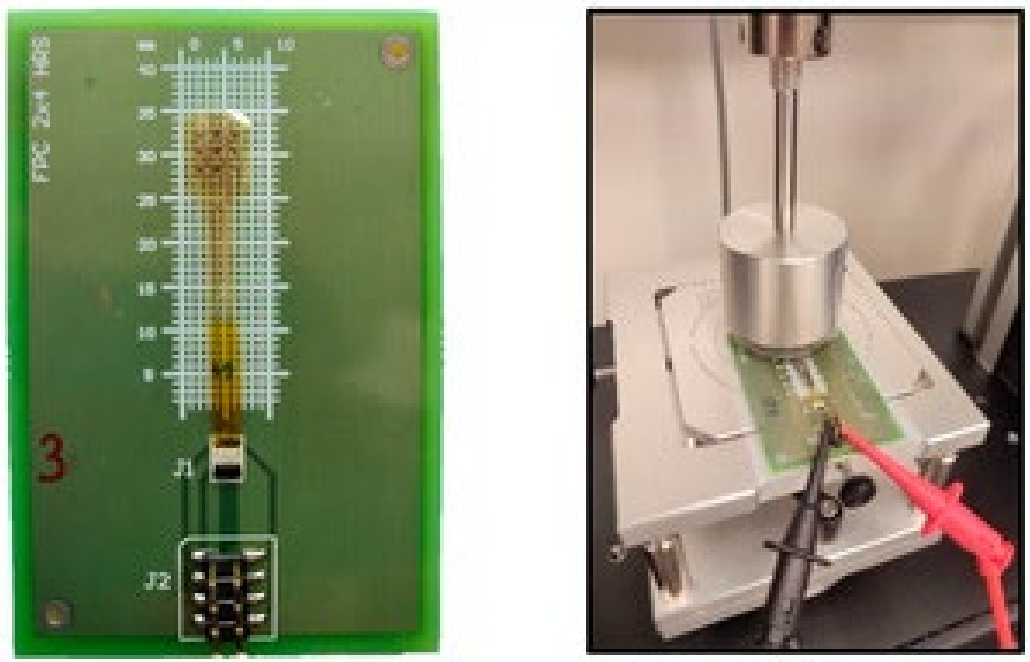
Li, Q., Ran, Z., Ding, X., & Wang, X. (2019). Fabric circuit board connecting to flexible sensors or rigid components for wearable applications

Vertical Connectors



(a) (b) (c)

(d)



(a) (b)

dos Santos, D. E., José, B. Q., Garcia, I. S., Vieira, J., Fernandes, J., Sotgiu, E., Minas, G., Bouçanova, M., Luisa, M. A., Fangueiro, R., Salgueiro-Oliveira, A., Ainla, A., Filipe, S. A., & Rosana, A. D. (2024). Flexible Pressure and Temperature Microsensors for Textile-Integrated Wearables.

Agenda

01
Introduction to E-Textiles

02
Interconnects in E-Textiles

03
Vertical Interconnects

04
Connectors in E-Textiles

05
Conclusion – Research Gaps

Research Focus

3

Compatible connector for the VIA interconnect

2

Optimization of VIA interconnect

1

Performance of VIA as compared to other interconnects

Conclusion

- **Vertical interconnects and connectors** for wearable e-textiles **is a crucial step towards fully integrated, flexible, and functional wearable electronics**
- Reliable **electrical connections, mechanical durability, and compatibility with textile substrates** ensure comfort and performance in wearable applications
- **Current research shows promising advancements** in materials and fabrication techniques that enhance the functionality and resilience of these components
- However, **challenges remain in ensuring long-term reliability, scalability, and compatibility with various textile forms**
- **My work focuses on developing and optimizing vertical interconnects and compatible interconnects to enhance their integration into EMG monitoring wearables**
- By addressing this work, we can move closer to widespread adoption of e-textiles in various applications, from healthcare monitoring to smart clothing and beyond

Accomplishments

Publications

Ugale, Prateeti, et al. *"Wearable Solutions: Design, Durability, and Electrical Performance of Snap Connectors and Integrating Them into Textiles Using Interconnects." Textiles 4.3 (2024): 328-343.*

Ugale, Prateeti. *"Composites: Innovation in Machinery for ITMA 2023 Milan, Italy." Journal of Textile and Apparel, Technology and Management (2023). Also published in AATCC Review*

Awards/Funding

- *University funding to attend International Textile Machinery Association (ITMA) exhibition 2023 – Milan, Italy*
- *AuxDefense 2024 Innovation Award – Braga, Portugal*
- *AATCC Foundation Scholar (2024-2025) – Kanti and Hansa Jasani Family Scholarship – Raleigh, USA*

Presentations/ Conferences/Exhibits

- *Advanced Functional Fabrics of America (AFFOA) Membership Summit (2022) – Boston, USA*
- *NC State University – Research Open House (2023 & 2024) – Raleigh, USA*
- *International Textile Machinery Association exhibition (ITMA) (2023) – Milan, Italy*
- *Auxdefense 2024 – Braga, Portugal*
- *IEEE Engineering in Medicine and Biology Society 2024 Conference (EMBC) – Orlando, USA*
- *Techtextil North America (Multiple - Raleigh)*
- **Emerging Technologies Conference 2024 – California, USA**
- AATCC Discovery Summit – Savanna, USA

Acknowledgement

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Project Sponsored by

NIDILRR
National Institute on Disability, Independent Living, and Rehabilitation Research

Impulse Wellness

This work is supported under the project "Bluetooth Electromyography-based Stroke Therapeutic (BEST): Shifting the Paradigm with Biofeedback-Driven Home Therapy" funded by Impulse Wellness and the US Dept. of Health & Human Services (DHHS).

NC STATE UNIVERSITY
Wilson College of Textiles

SHIFT
Smart Holistically Integrated Functional Textiles

Dr. Amanda Mills
PhD Advisor

Dr. Faisal Abedin, Dr. Beomjun Ju, Dr. Seonyoung Youn, Erin Parker, Ayesha Siddika, Ethan Hill, Carson Jenkins, Sophia Thompson & Crista Villasenor-Reyes

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

Thank you!

Prateeti Ugale

pmugale@ncsu.edu

NC STATE UNIVERSITY
Wilson College of Textiles

SHIFT
Smart Holistically Integrated Functional Textiles

Share your feedback on this session

Scan the QR code using your smart phone camera

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO

See you next year!

EMERGING TECHNOLOGIES CONFERENCE at Advanced Textiles EXPO®

Nov. 4–7, 2025 | Indianapolis, IN USA