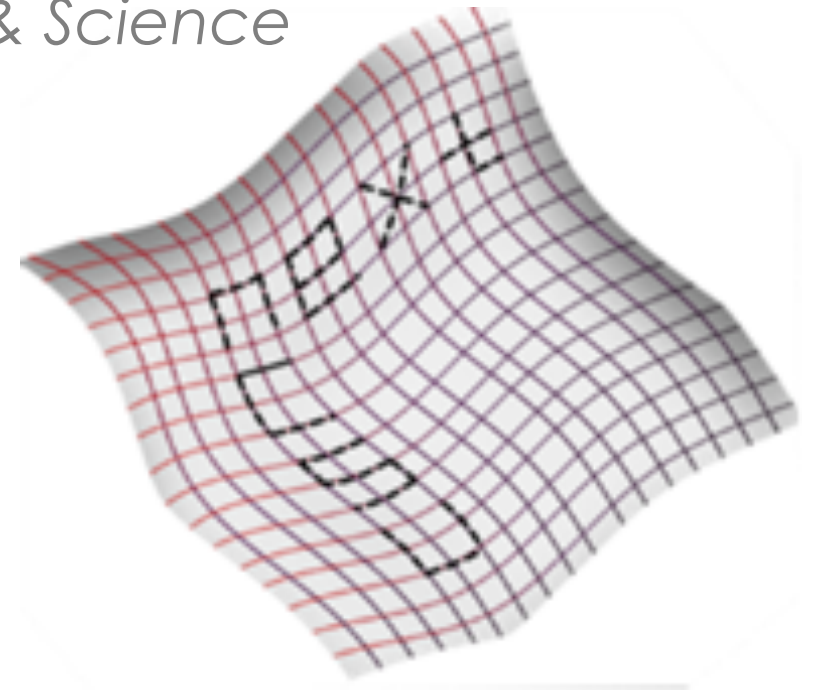


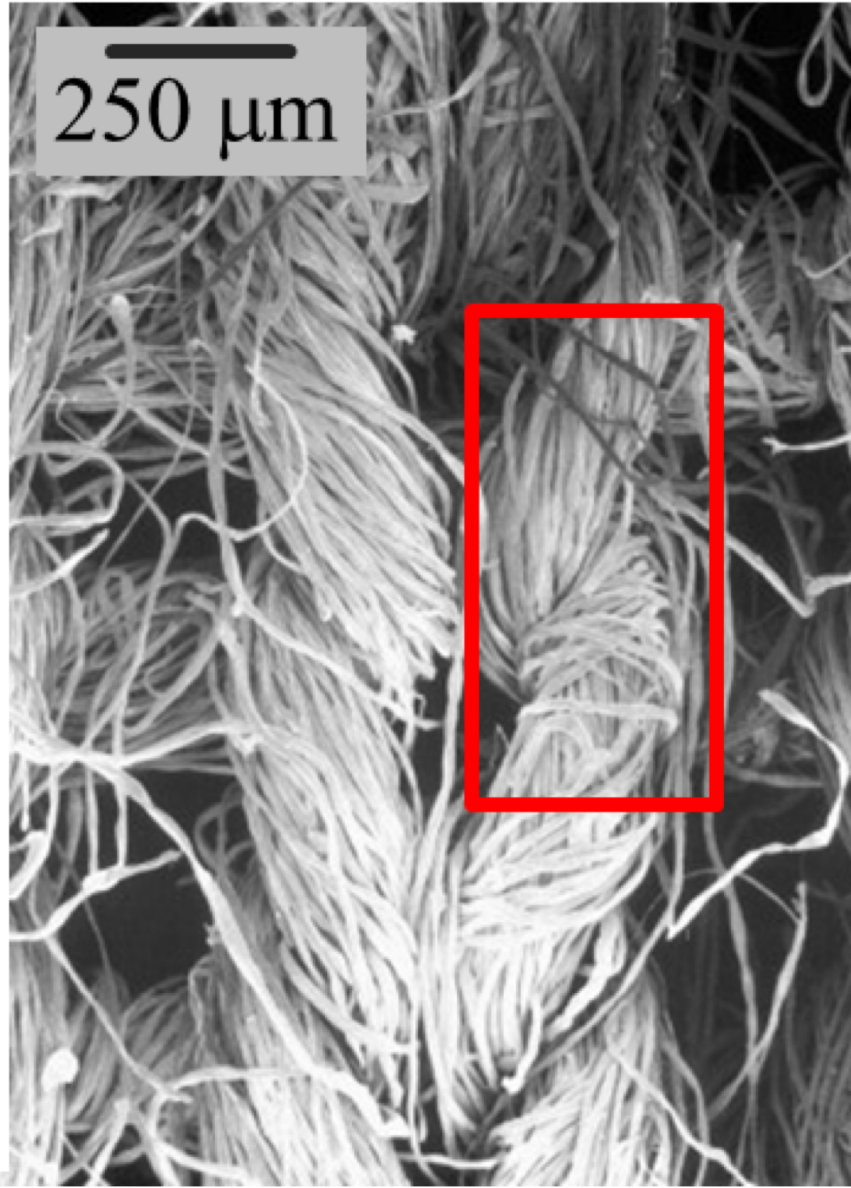
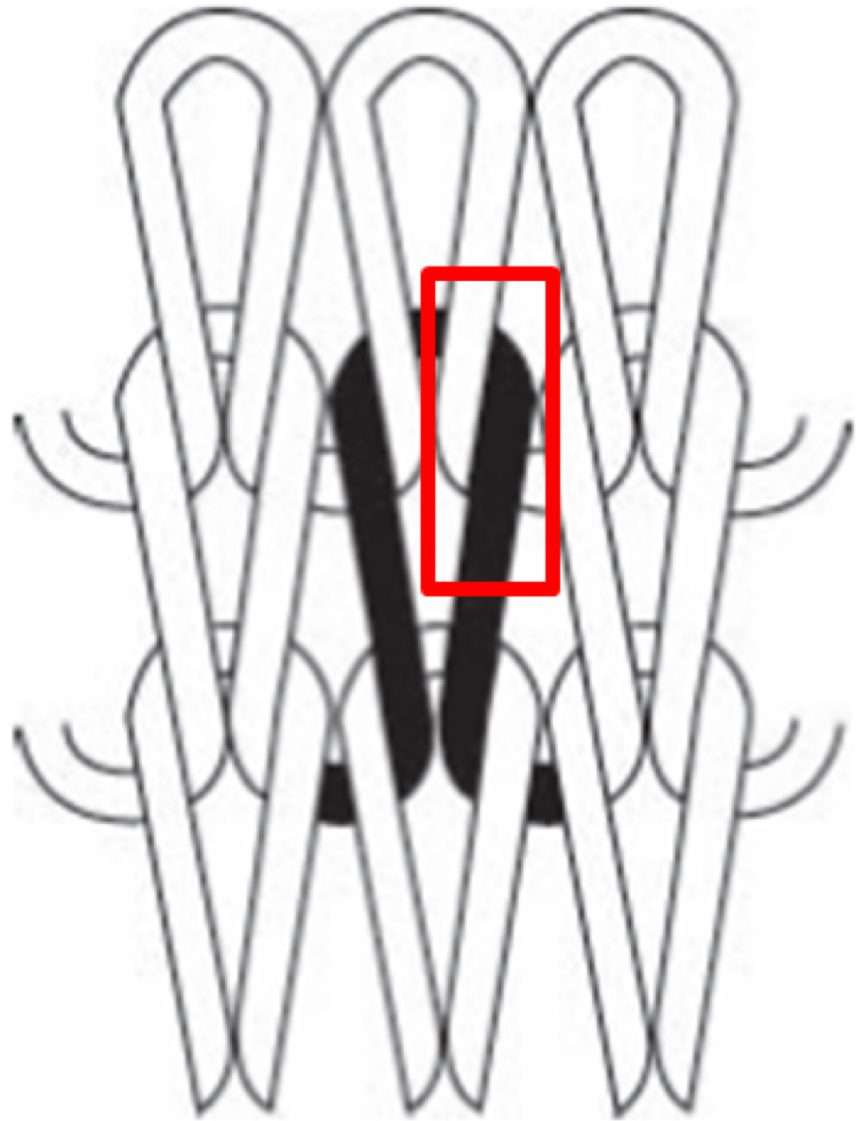
New Methods in Textile Wearable Electronic Materials Development

Jesse S. Jur

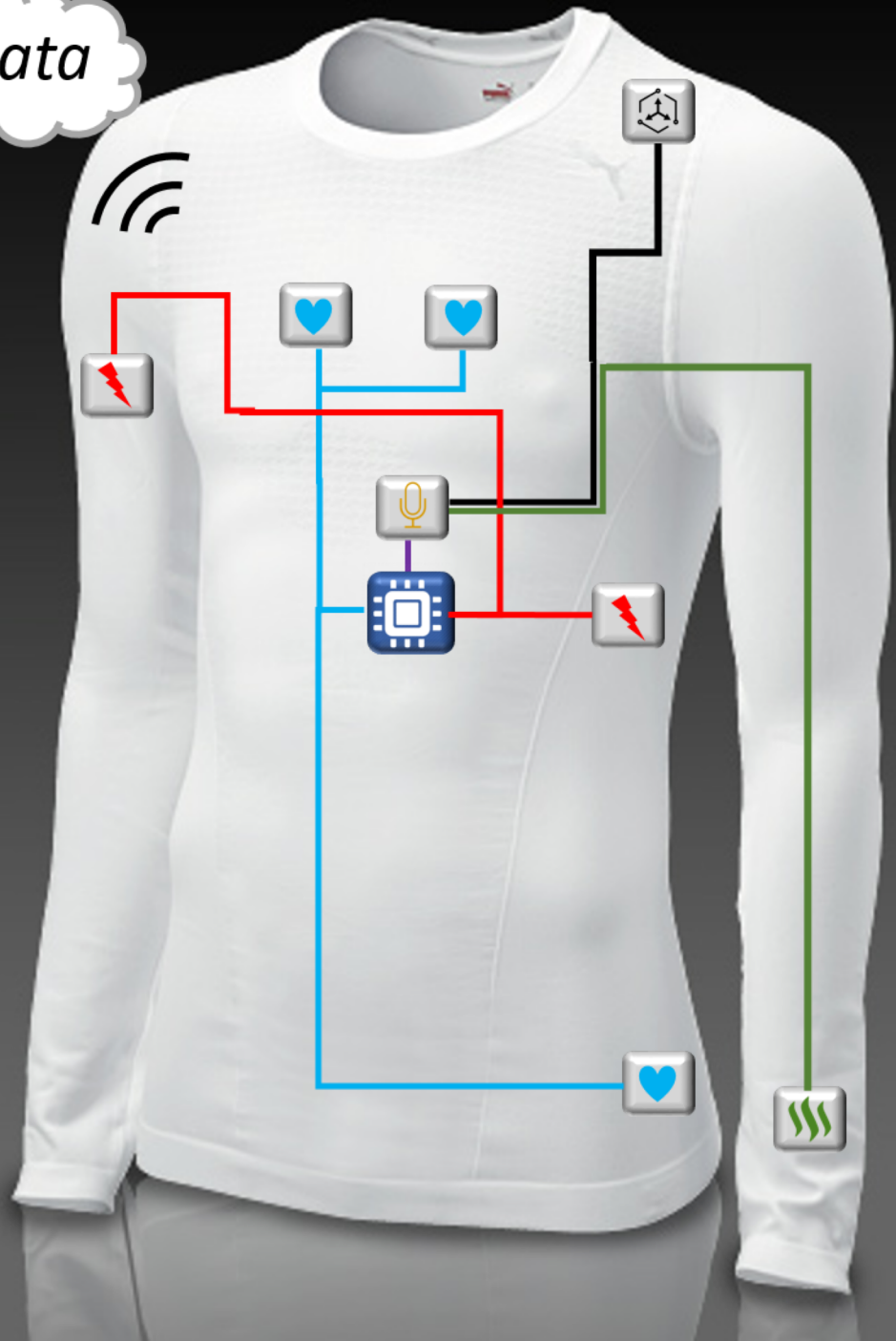
Department of Textile Engineering, Chemistry & Science

NC STATE UNIVERSITY

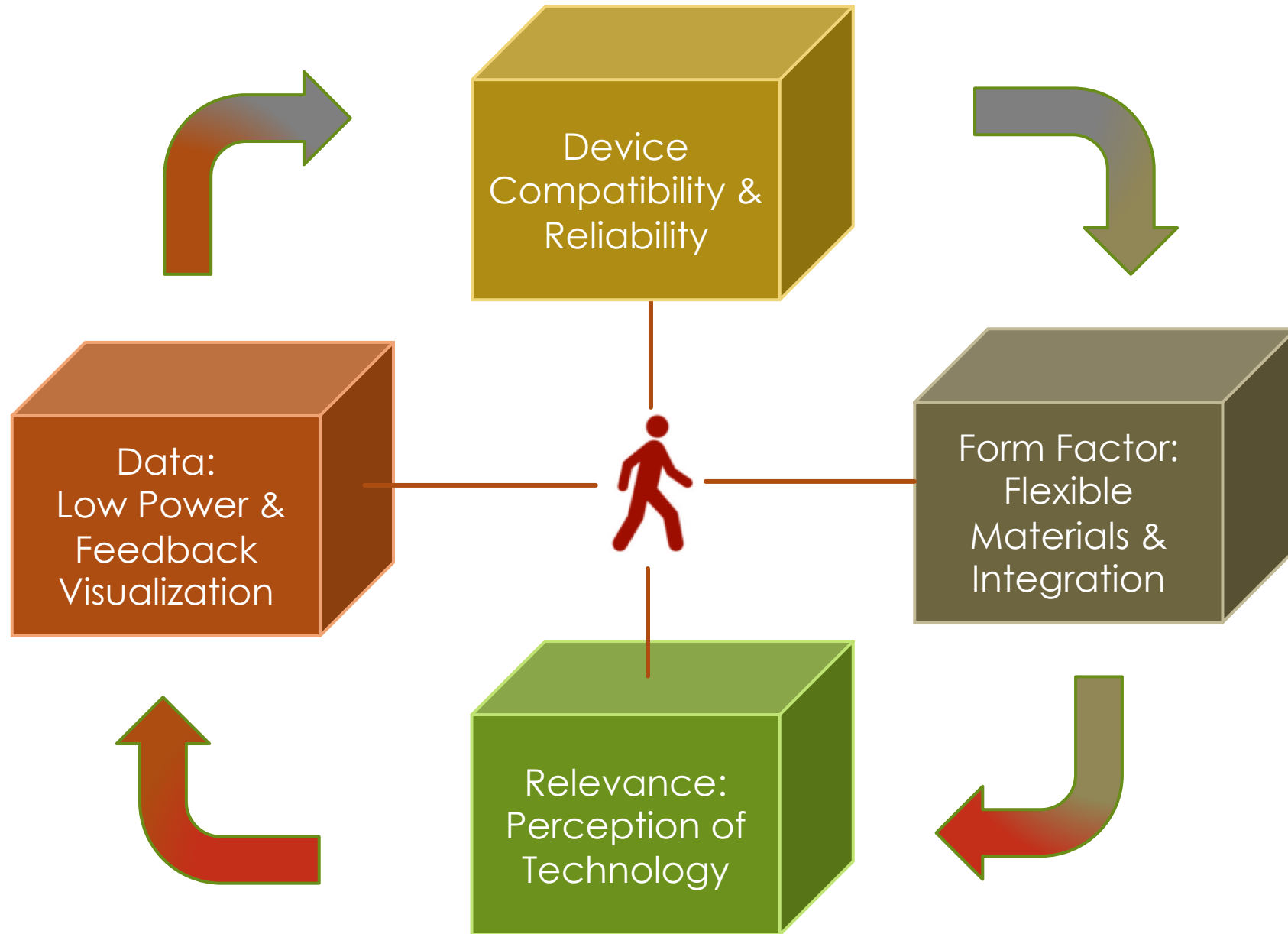




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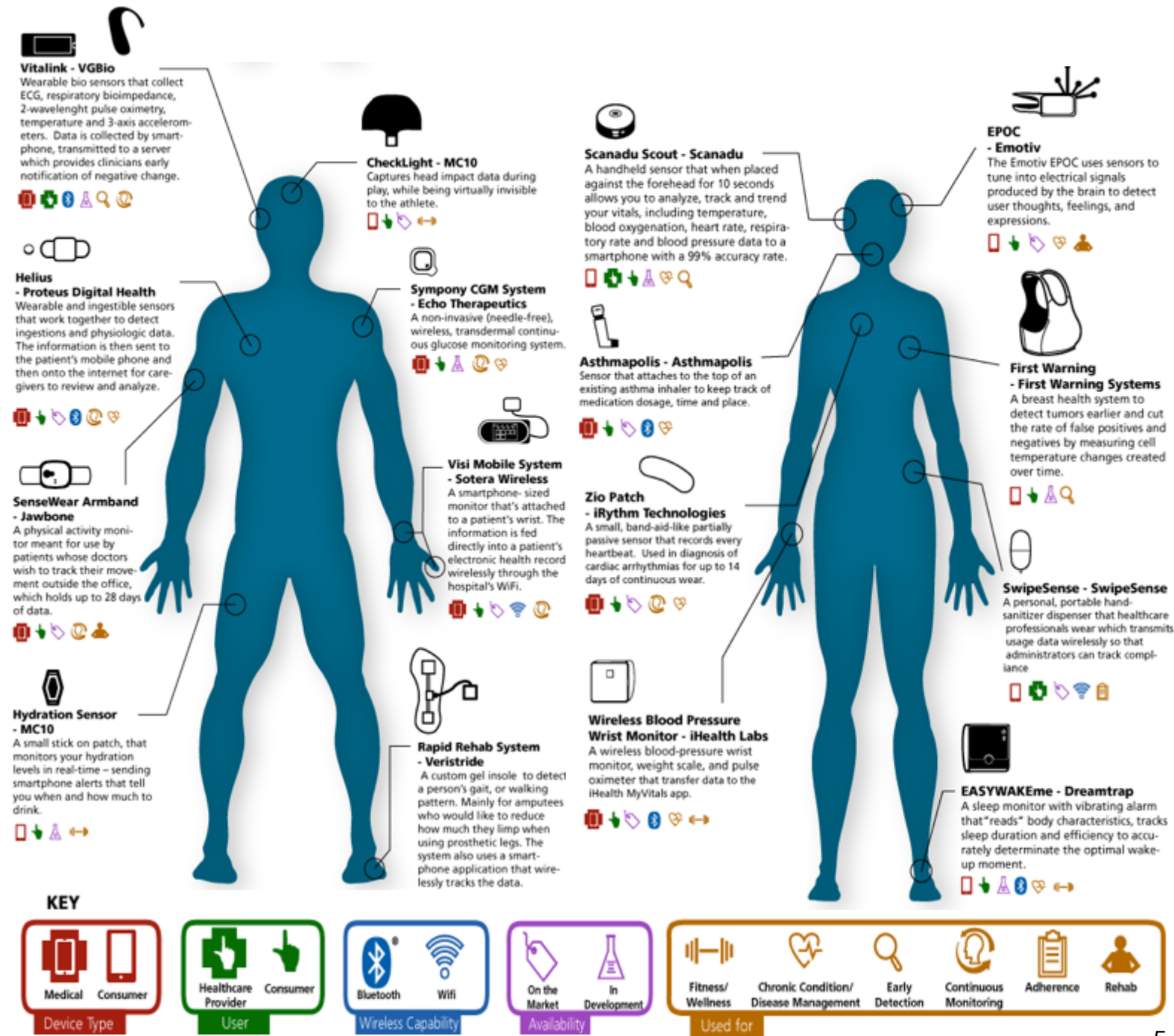


Wearable Design Considerations

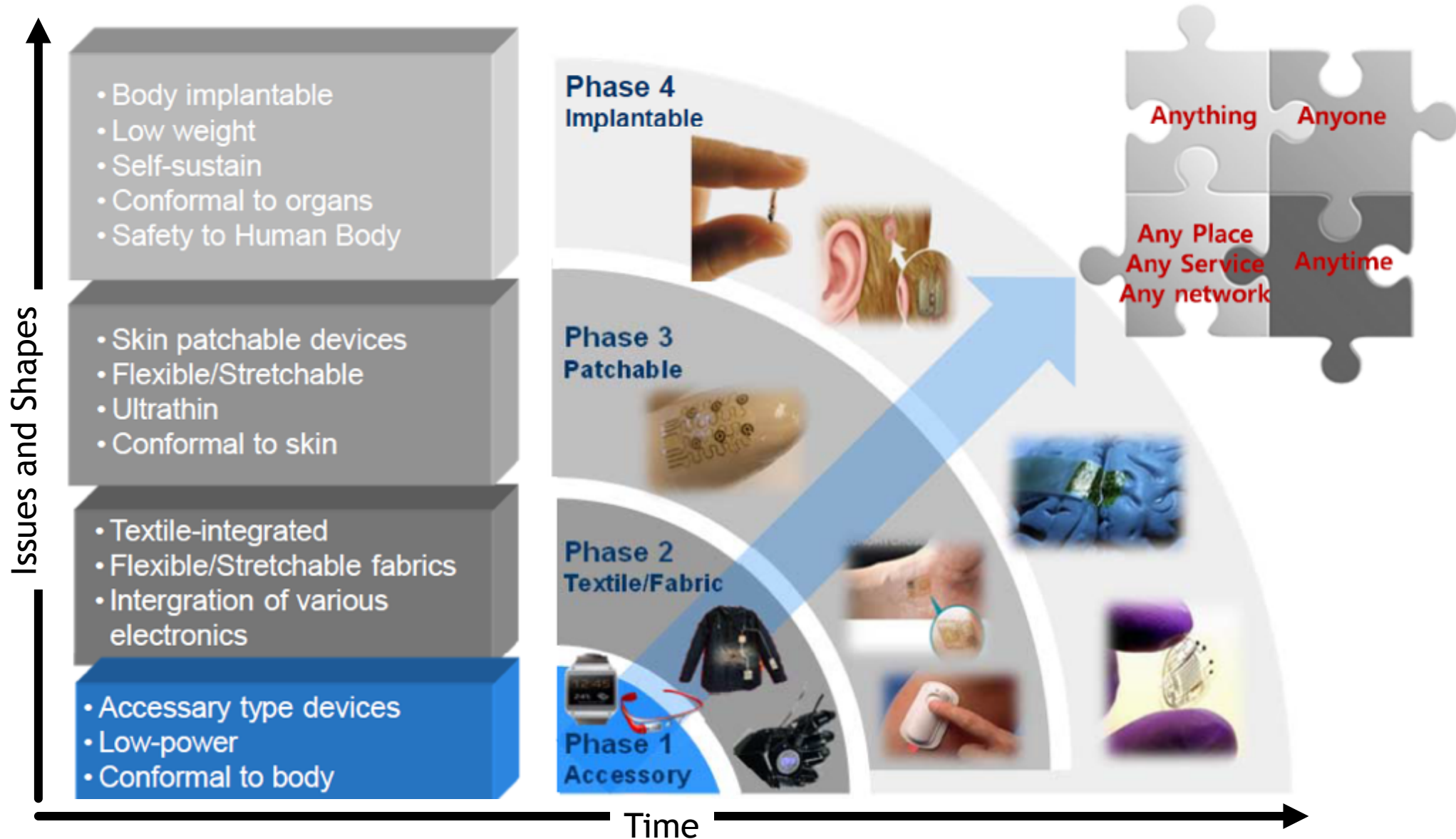


Wearables 5 years ago...

- Product Development Focus Areas:**
- Reduce system power
 - Reduce size of form factor
 - Lower hassle and improve adoption
 - Increase number of available sensor modalities at low power
 - Increase configurability

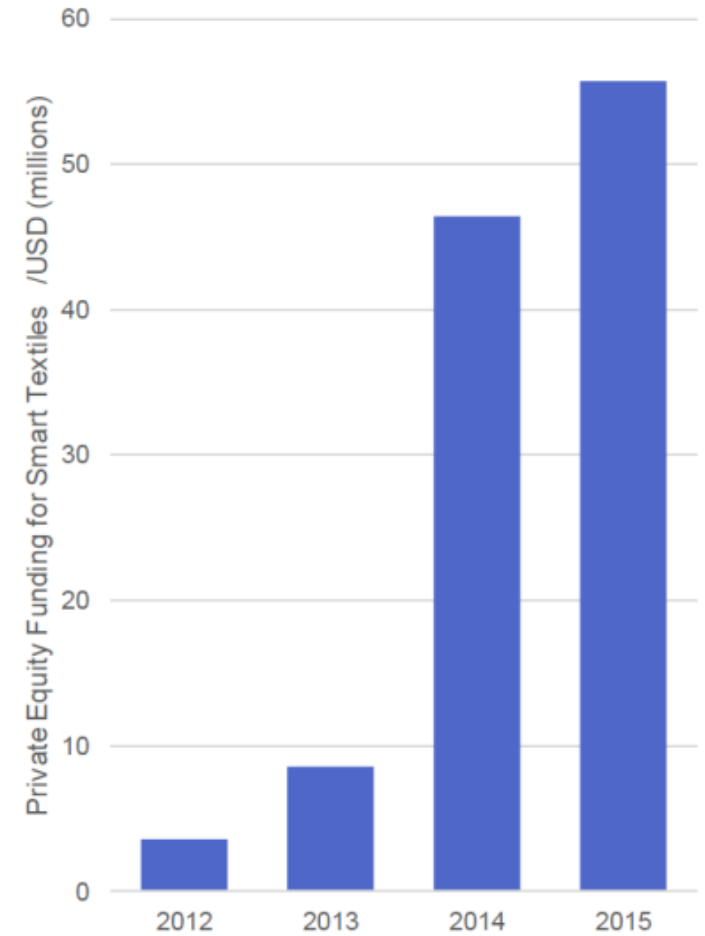
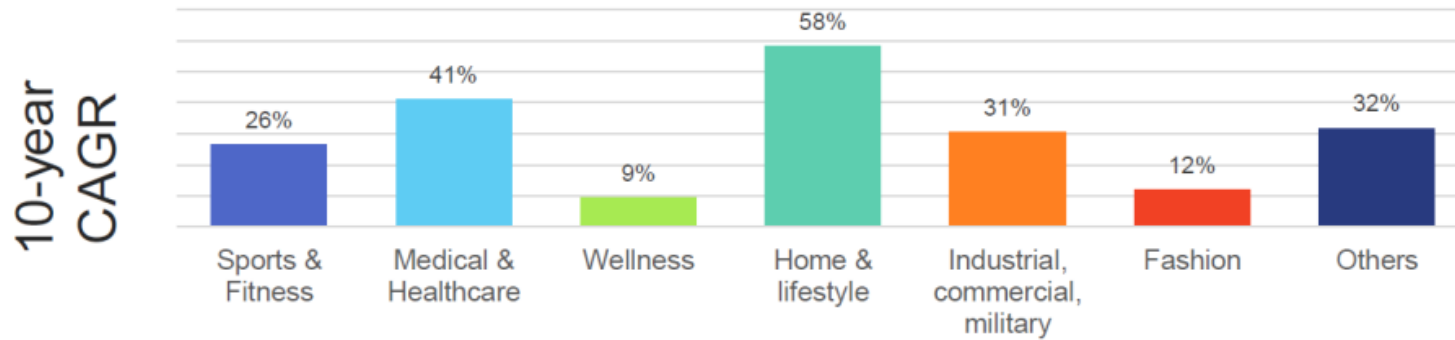
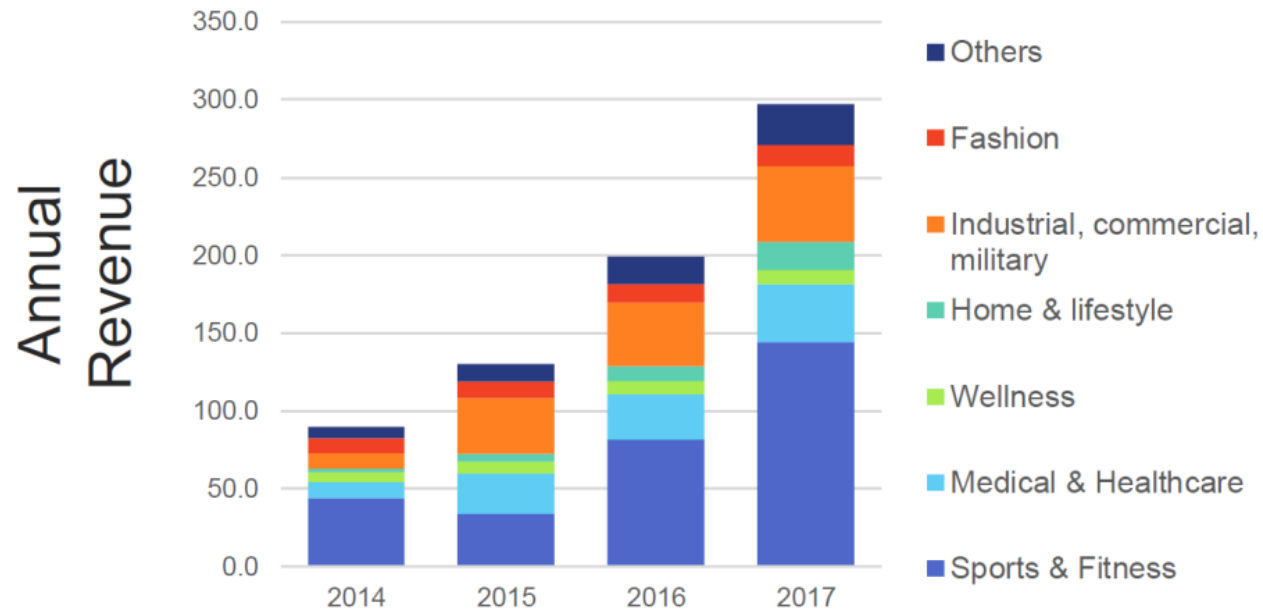


Wearable Technology Roadmap



Textile Electronics (or e-textiles)

IDTechEx



Wearable Product Platforms

Sports & Fitness

Product	Image	Biometrics Measured & System Notes	Laundryability	Price
OM Smart Shirt (Omsignal)		Heart Rate, Breathing Rate, Push Score, Steps, Calorie Count, and Heart Rate Zone Up to 30 hour lifetime.	Remove OM smartbox and the shirt is launderable	\$249
Ombra (Omsignal)		Same as OM Smart Shirt Advertised to last 10 workouts.	Remove OM smartbox and the bra is launderable and splashproof.	\$150
Athos (Athos)		Muscle Activity, Heart Rate, Breathing Rate Real time feedback.	Remove 'Athos Core' Bluetooth and the shirt is machine washable.	\$398
Hexoskin (Hexoskin)		Heart Rate/Heart Rate Variability, Breathing Rate & Volume, Steps, Cadence & Calories, Sleep Logs past readings.	Remove Hexoskin Bluetooth Device, Material is machine washable	\$399
PoloTech (Polo Ralph Lauren)		Steps, Heart Rate, Breathing Rate, Activity Duration Log past readings and provides real time feedback.	Remove Bluetooth connected box and shirt is machine washable	\$295
D-Shirt (Cityzen Sciences)		Body temperature, Heart beat & Heart rate, Speed & Intensity of Workouts Logs past readings as well as gives real time feedback.	Transmitter must be detached and shirt is machine washable	N/A
Sensoria Sports Bra & HRM (Sensoria)		Heart Rate Monitor Logs past readings. Compatible with Polar H7 and Garmin devices.	Remove box and the bra is machine washable	\$139
Nadi (We:eX)		Form an Posture monitoring APP provides realtime feedback through the use of vibrations to inform use.	Electronics are embedded in the pants. Laundryability details unavailable	NA



WE-EX FAN JERSEY USA

The 4th dimension of entertainment / FANDOM. This Fan Jersey leverages today's technology to transport a fan into the actual positive actions of their favorite team on the field.

A depth camera is used for gesture and environment tracking, and can see others as they approach.

Shadow displays the wearer's eyes when in MR mode.

Shadow features an external screen that displays to others what its wearer is experiencing in VR.

Entertainment & Virtual Reality

A neuromuscular force feedback sleeve along the elbow allows for tactile interactions with virtual objects.

EMG (electromyographic) sensors allow precise small finger movement recognition.



The headset comes with a hoodie that isolates Shadow's wearer from the surroundings.

A smart fabric inside my VR headset or an external camera system recognize facial expressions and mood which can be mapped to the user's VR avatar.

The headset is attached to a wearable computer that allows the wearer to get a tangle-free VR experience.

A sound vibration pack provides tactile feedback from within games.

Music and Sound



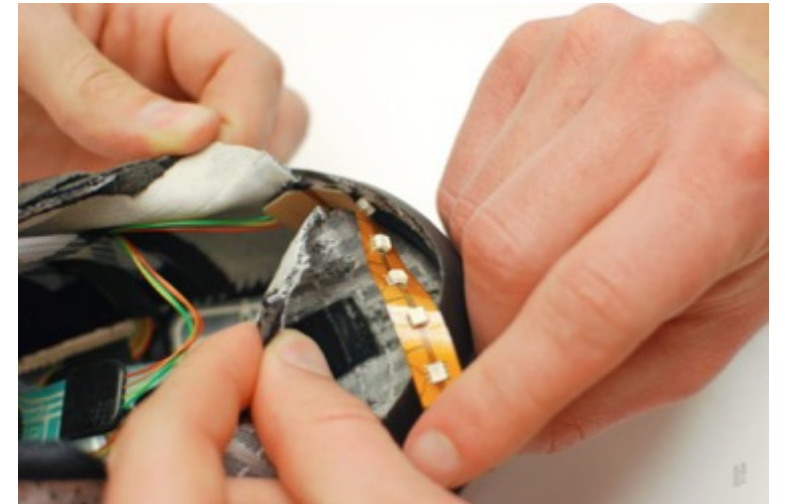
Machina MIDI:
Synthesizer Jacket

The MJ v1.0 | MIDI controller jacket allows a musician to create music through body movements and body sensors. It includes: an accelerometer, a gyroscope, with two push buttons and one piezo electric. Use your arms to raise the volume and tempo of your music, tap your chest to make sound, configure it however you like. It's a different type of instrument.

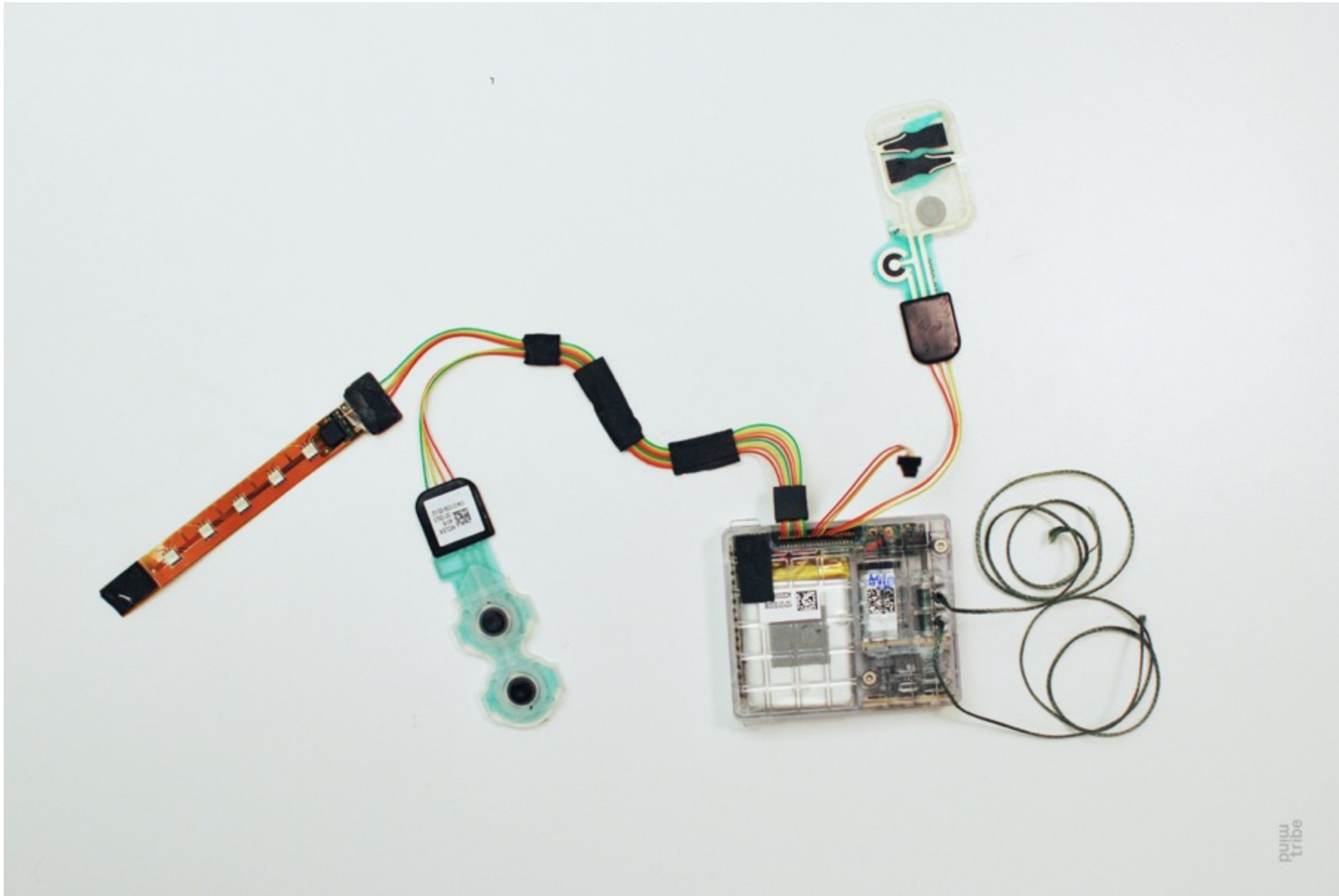




Nike HyperAdapt

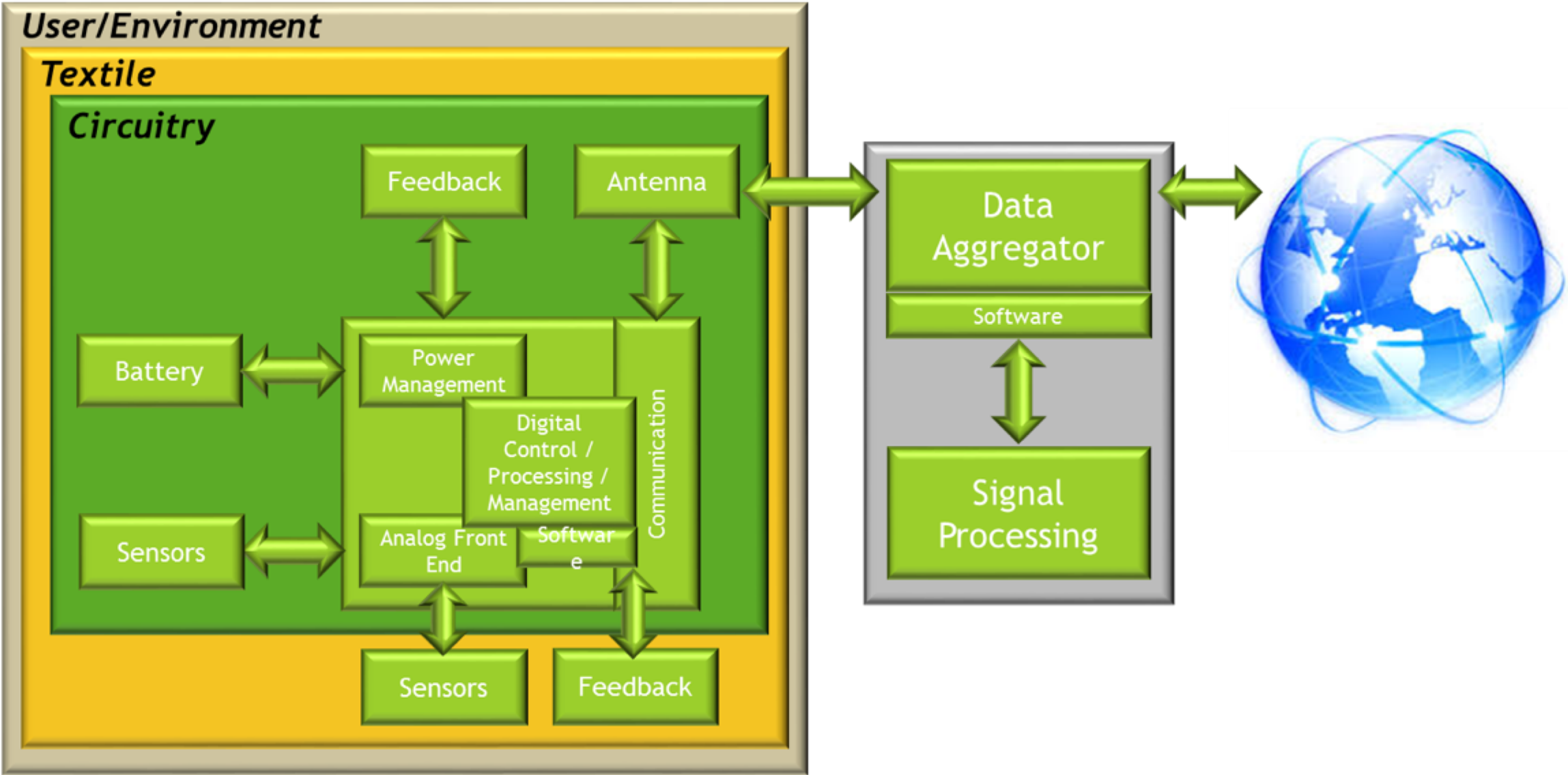


Teardown at: <http://mindtribe.com/2017/02/nike-hyperadapt-teardown/>



Teardown at: <http://mindtribe.com/2017/02/nike-hyperadapt-teardown/>

Textile Electronic System Design

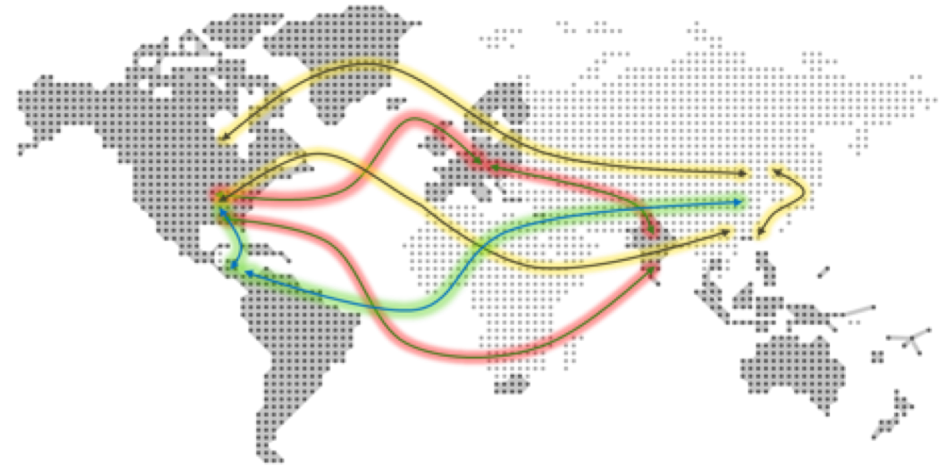


Market Challenges

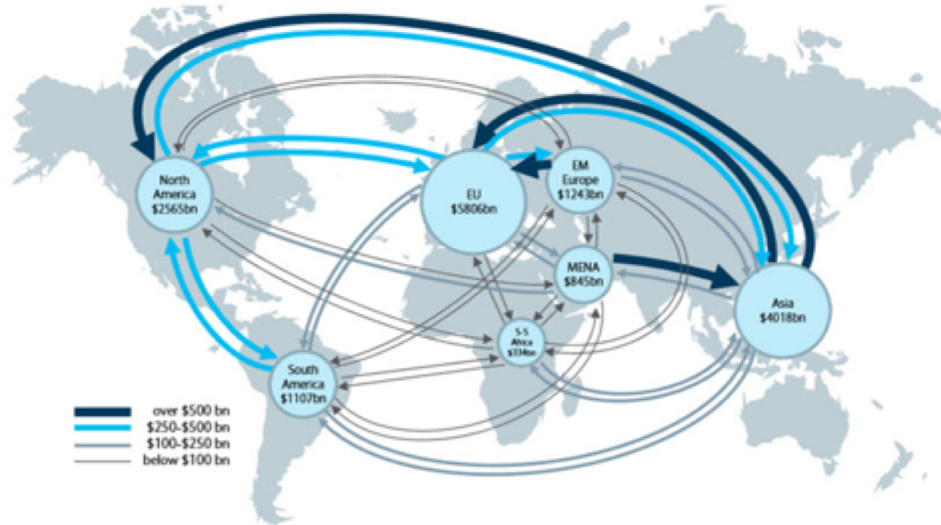
Conflicting Industry Goals



Supply Chain Timing



Standards



<http://www.zerohedge.com>

Manufacturing

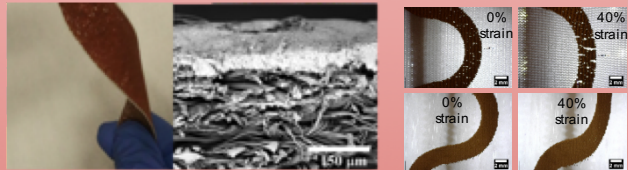


Research/Education Structure

Technology Innovation Through Engineering Design

Materials Innovation

Materials Design for 'Today' Technologies

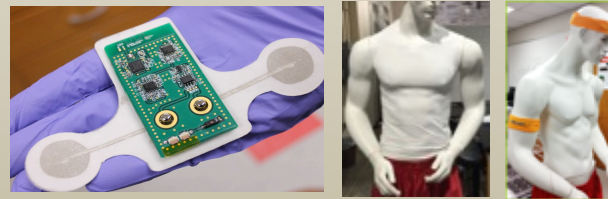


Next-Gen Materials for 'Tomorrow'

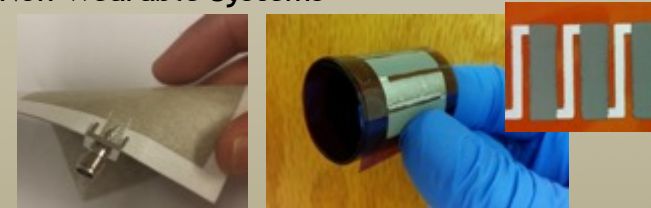


Textile Electronic Systems

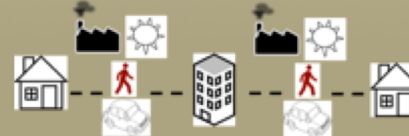
Wearable Systems



Non-Wearable Systems



System Standards & Human Scenario Testing



Project-based Education

Industry-Inspired Projects (Undergraduate)



E-Textile Systems (Graduate Education)



Wearables for Animals (K-12 Curriculum)



next (nano-extended textiles) research group

...Expanding the Influence of Nanotechnology in Textiles

Industry Cross-Over

Textiles

- Well established industry
- Already LOW price
- Inexpensive materials
- High throughput processing
- Resurgence in Local-for-Local
- Everyone wears them

Printed
Electronics

- Rapidly developing industry
- Driving force for price reduction
- Materials development
- Roll-to-roll a necessity
- US, Japan, Korea growing leaders

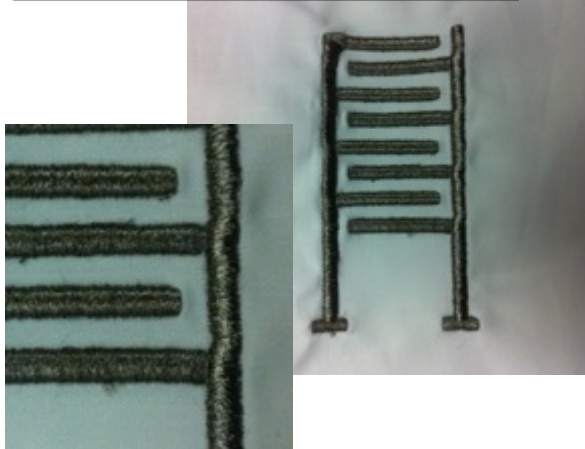
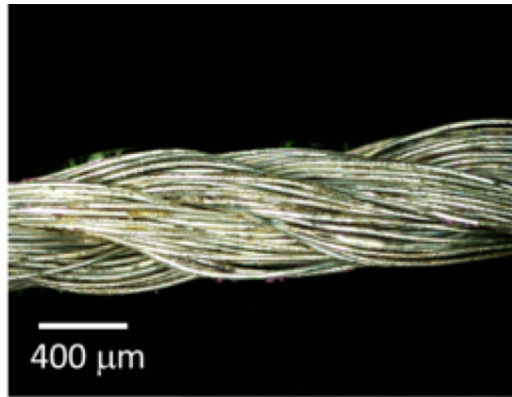
E-Textiles



Materials

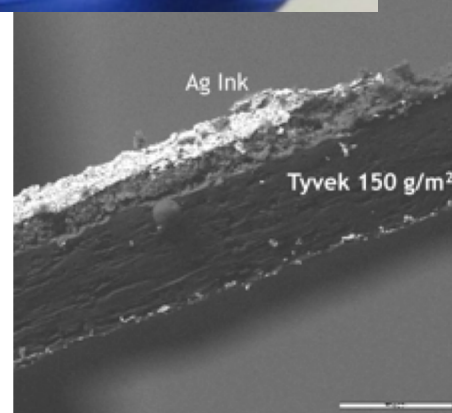
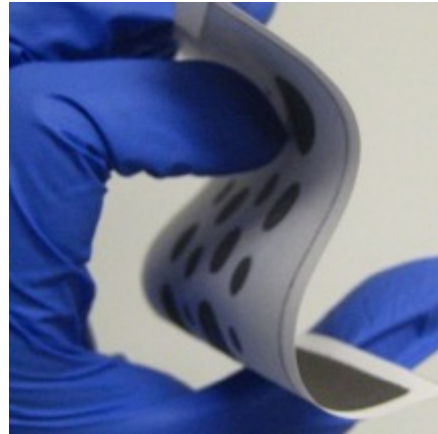
Conductive Yarns

good availability; textile-like; complacent in materials innovation (no market need); challenging retrofit application



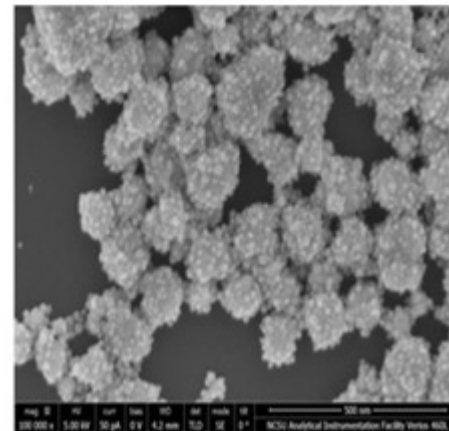
Conductive Pastes

high materials & process innovation (flexible electronic markets); polyurethane & PVA growth; Retro-fit application



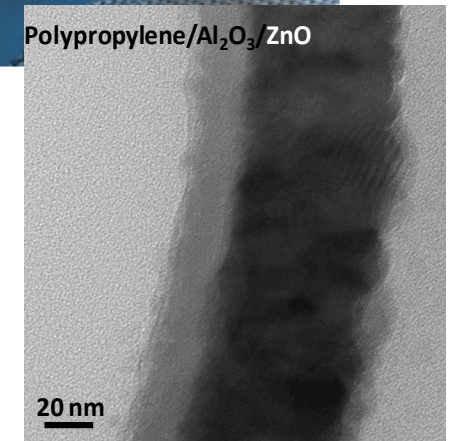
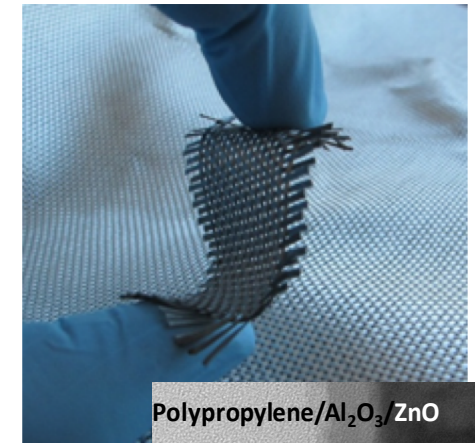
Conductive Inks (ink-jet)

Improved materials/performance cost vs. screen print; back to fiber-level integration; multi-layer device design capable

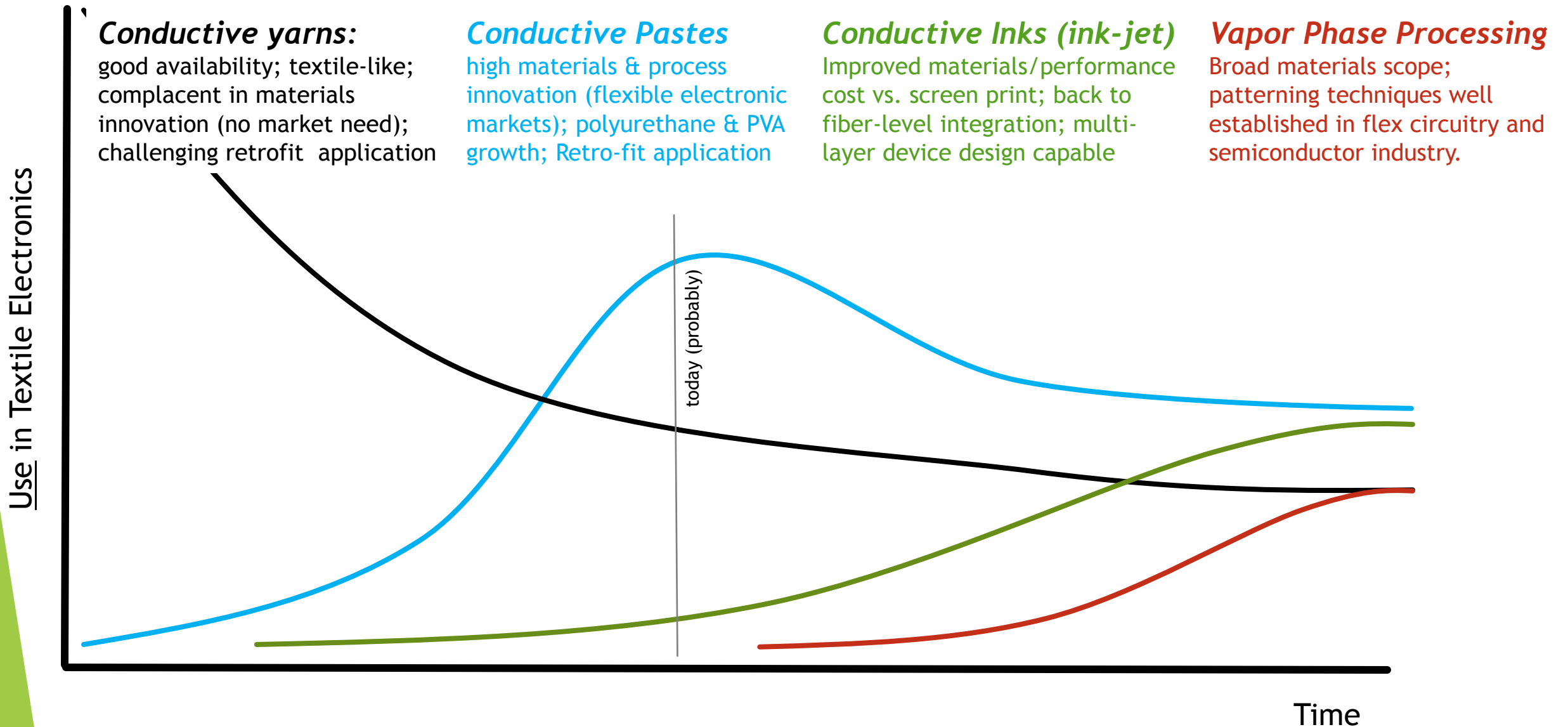


Vapor Phase Processing

Broad materials scope; patterning techniques well established in flex circuitry and semiconductor industry.



Evolution of Materials: Textile Electronics



Screen-Printing

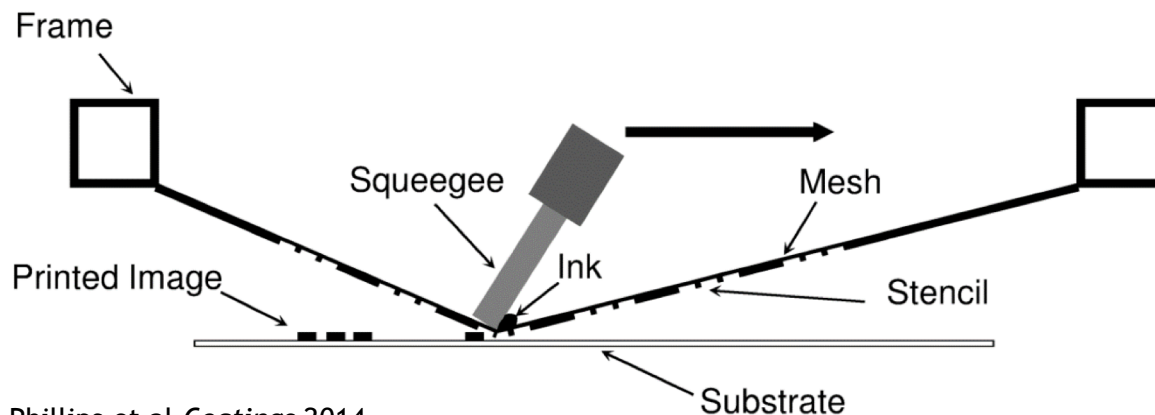


Benefits

- Low cost (material and process)
- Industry scalable
- Less process complexity
- Level of integration

Challenges

- Ink waste
- Post-process cleanup
- Sample-to-sample variability
- Rapid customization of designs
- Batch-style processing



Phillips et al *Coatings* 2014

Direct-Write Printing



Benefits:

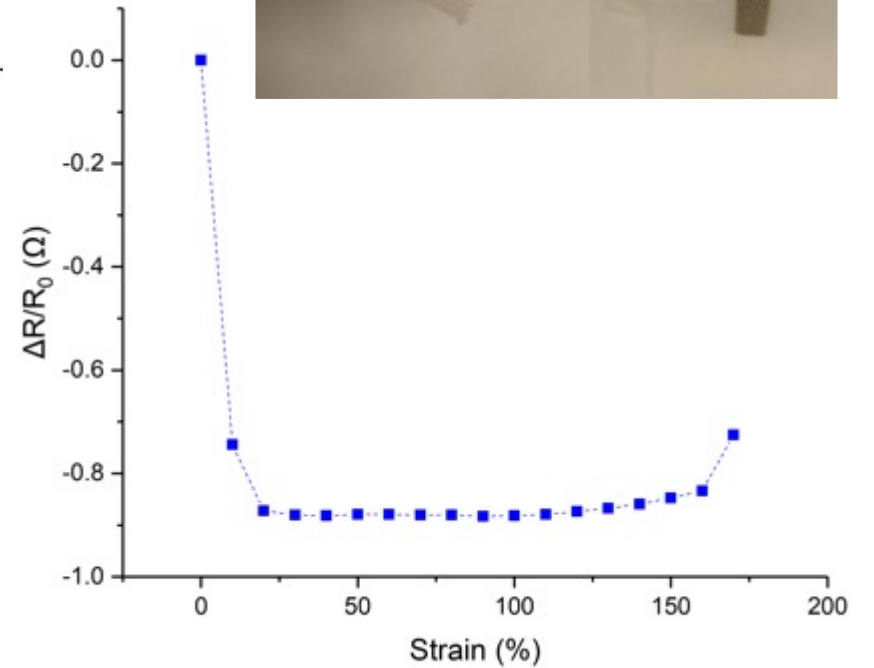
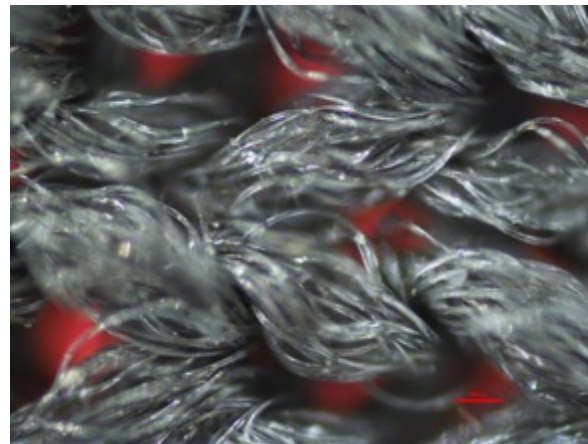
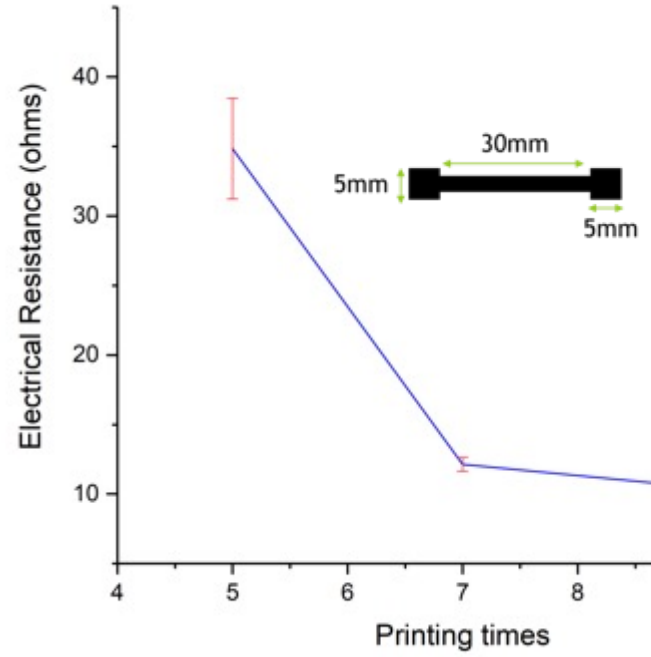
- Dispense velocity is 80x what's in literature
- Minimal ink waste and minimal post-process cleanup
- One-step materials deposition process
- 4x lower resistivity than screen printed interconnects
- Interconnects cost < \$1 (for 12cm)
- Integrate hard electronics -> resistors, LEDs, etc. using pick and place



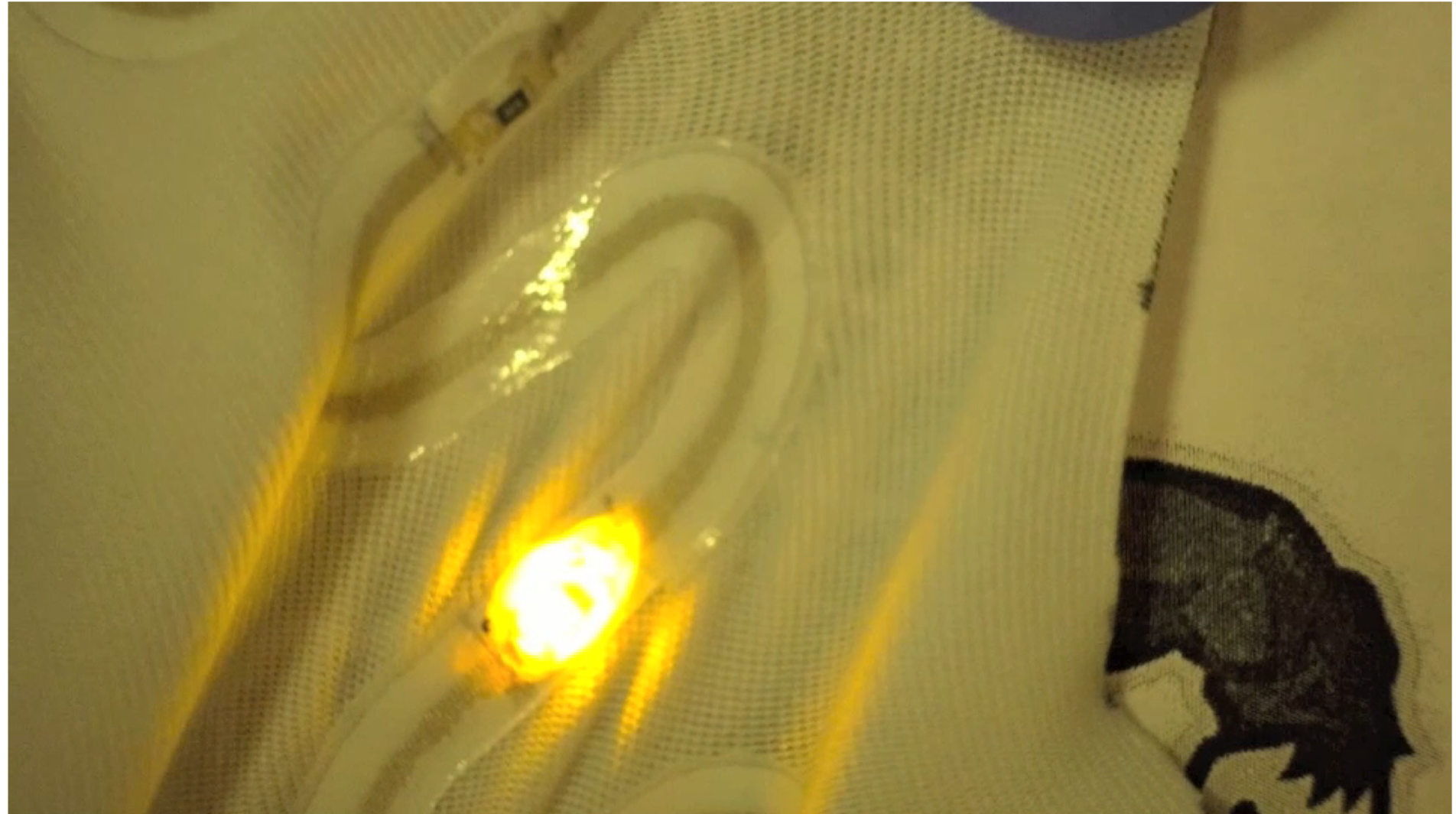
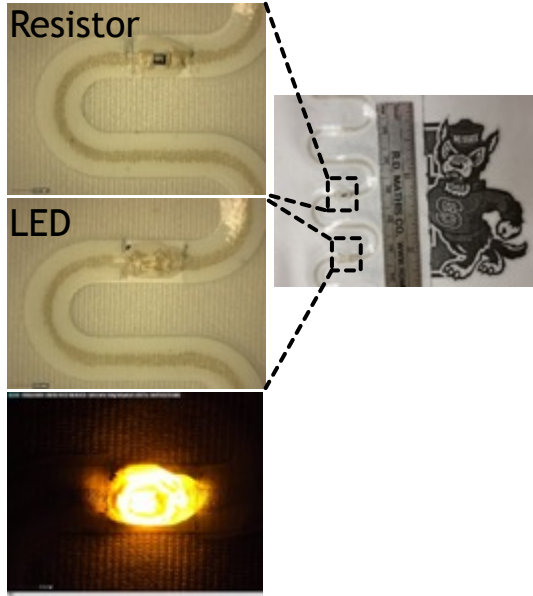
Challenges:

- Equipment costs
- Line resolution
- Penetration into textile

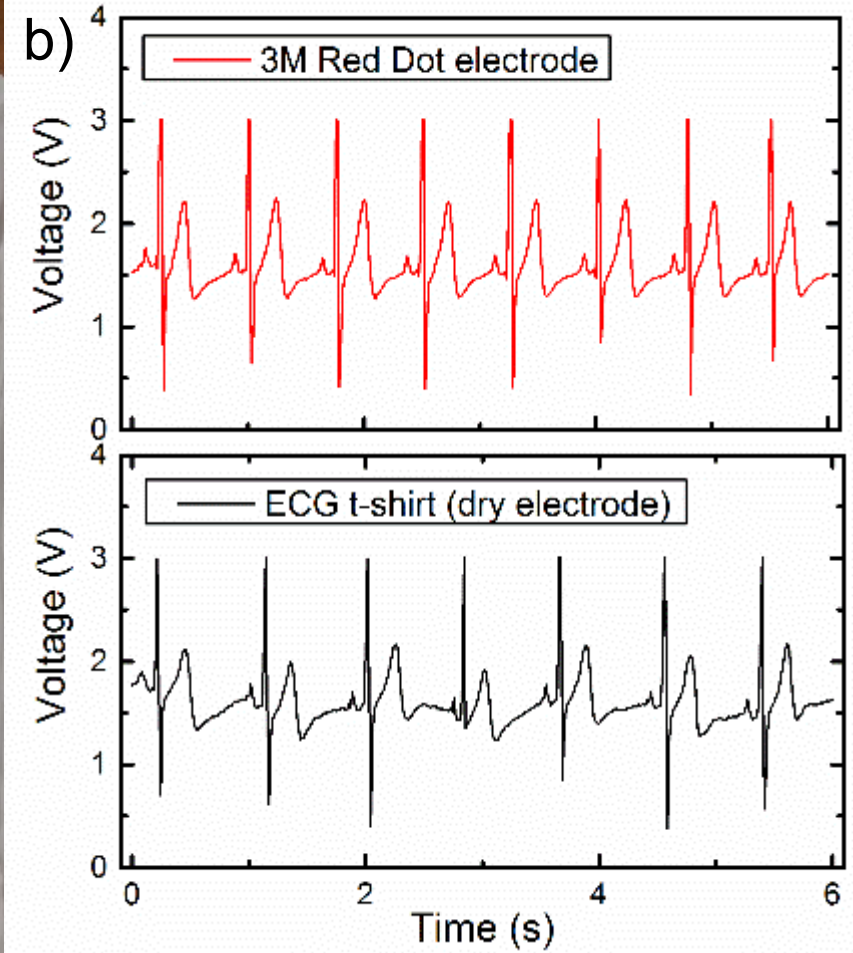
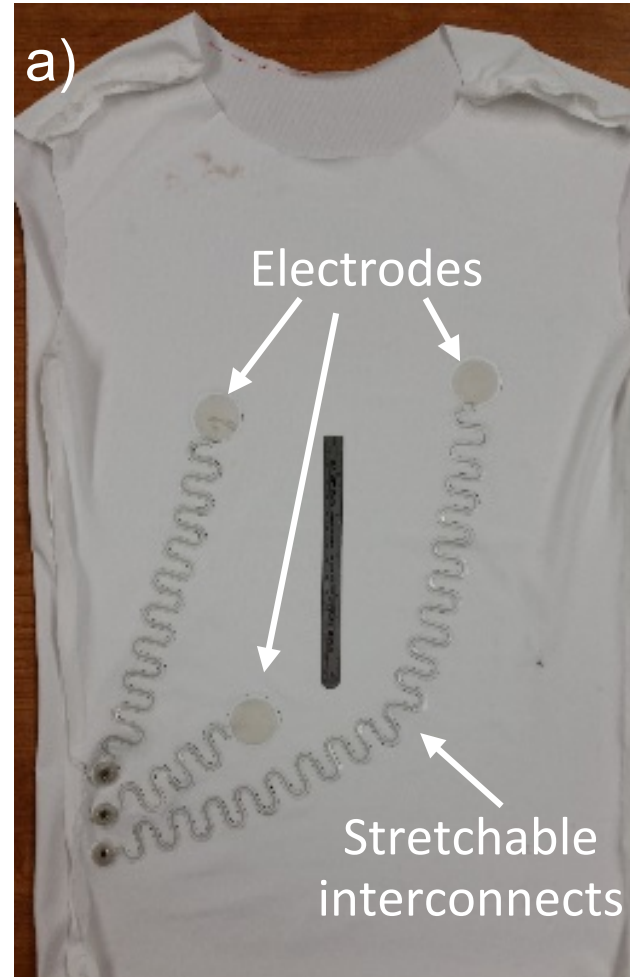
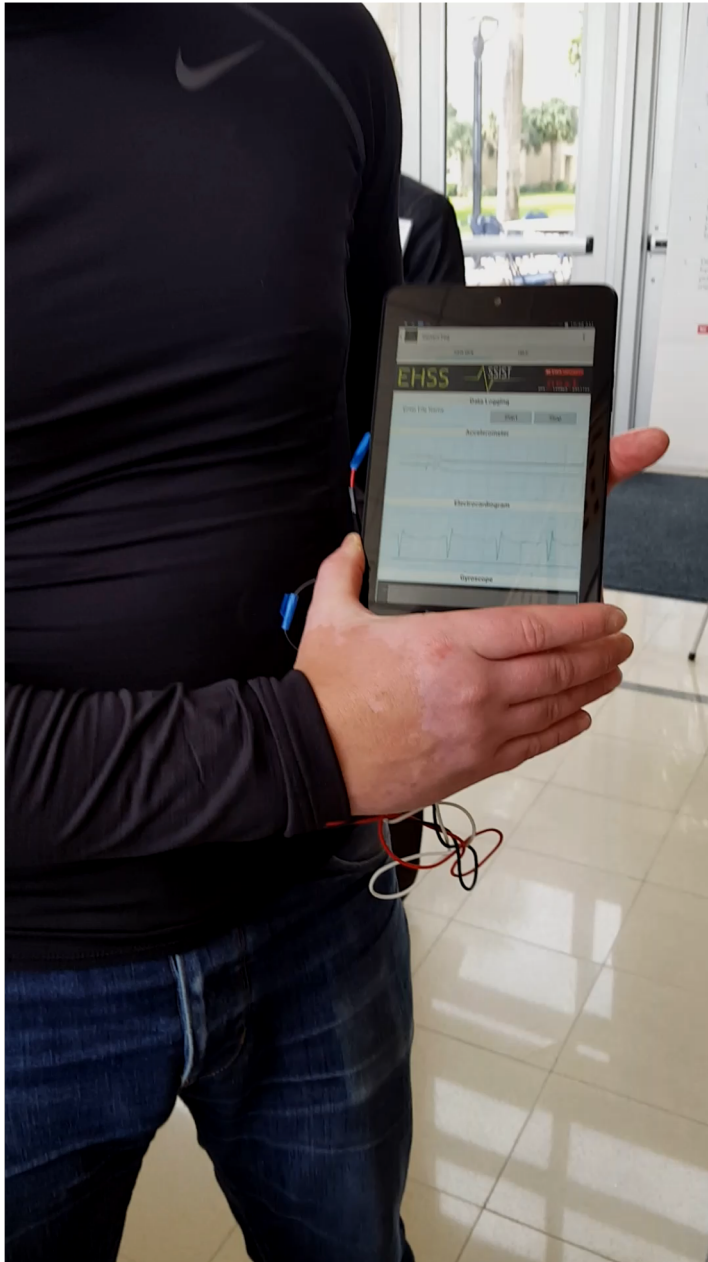
Ink-Jet Printing



Hard Component Integration



Biometric Monitoring Garments



Barrier: Manufacturing

- Needs to be less expensive & customizable!



Customization via Whole Garment Knitting

- ▶ '3D Printing' of garments
- ▶ Knit entire garment in one operation, including finishing
- ▶ Yarn (including conductive yarns) can be selectively added/designed.
- ▶ Localized compression can be added based on knit structure.



MACH2X Specialized WHOLEGARMENT® machine with 4 needle beds

your choice
SHIMA SEIKI

STOLL
KNIT AHEAD