1

Exploring the World of Smart Textiles:
What We Learned Along the Way

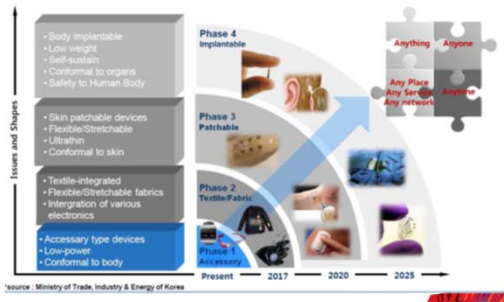
Amanda Mills (Myers)

2

A Connected World

3

A Connected Self



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Overlapping Needs

ELECTRONICS NEED…

- Power source
- Defined operating conditions
- Engineered integration (circuitry)
- Automated manufacturing

GARMENTS NEED…

- Pattern
- Defined fabric for environment
- Reusable and washable

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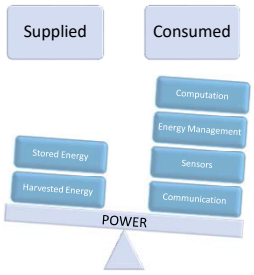
The Balancing Act



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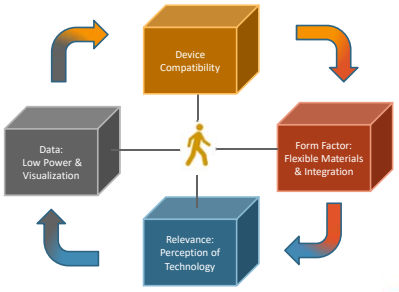
Wearable Factors



Amanda Mills| Exploring the World of Smart Textiles| Oct. 3, 2019

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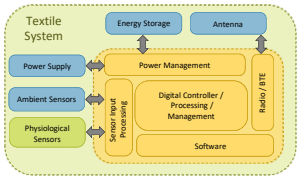
Electronic Concerns

1. Power
2. Motion artifact
3. Materials
4. Operating environment
5. Component location/Human interface



Data Flow

Sense → Process → Communicate

Power Flow

Generate → Store → Manage

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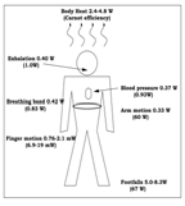
Power: The Human Generator



Average person (150lb 15% body fat) stores ~ 384 MJ of energy

ACTIVE	and	PASSIVE
o Piezoelectric • Arm/Leg Motion • Typing • Footfalls o Triboelectric		o Thermoelectric • Body Heat o Piezoelectric • Respiration

Starner and Paradiso, *Low-Power Elect Des.* (2004)

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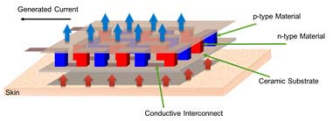
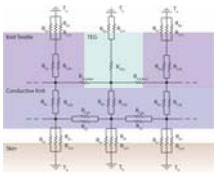
Power: Thermal Energy Harvesting

The conversion of a temperature difference to electric voltage via the Seebeck Effect.

Seebeck Effect $E_{emf} = -SVT$





Leonov and Vullers, *J Elect. Mat.* (2009)

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The Human Factor

Human – Environment Interactions

Human – Garment Interactions

Human – Garment - Environment

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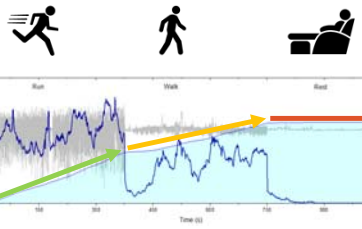
The Human Factor: Movement



Myers et. al. *Energy Conversion and Management* (2016)

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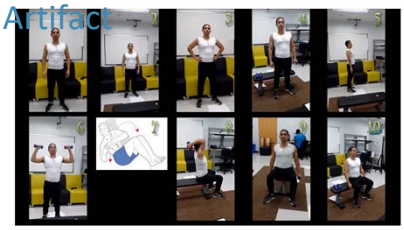
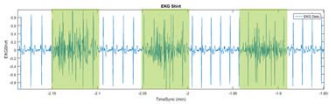
The Human Factor: Motion Artifact





Human movement can introduce noise into electrical signals

For wearable electronics, this poses a significant challenge

We need good skin contact

w/ E. Lobaton (NC State)

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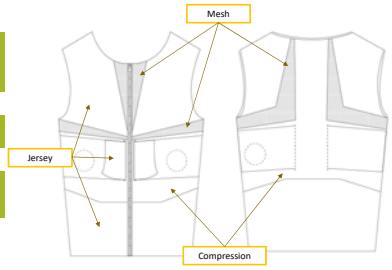
Motion Artifact Mitigation

Create garment regions with specific elastic moduli to 'absorb' displacement in areas of high motion

Isolate the sensing region to create a stable environment

Customized compression for a variety of body types and personal preferences



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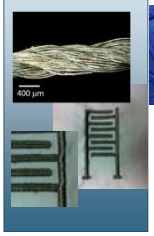
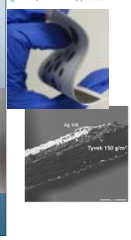
Conductive Materials for Textiles

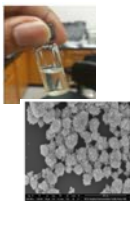
Conductive yarns:
good availability; textile-like; complacent in materials innovation (no market need); challenging retrofit application



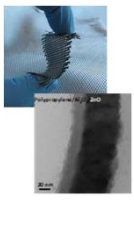
Conductive Pastes
high materials & process innovation (flexible electronic markets); polyurethane & PVA growth; Retro-fit application



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.



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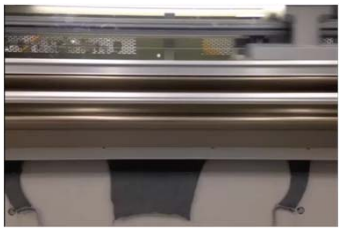
Automation: Knitting

Why a knit textile?

- Gives fabric large range of elasticity
- Create detailed knit structures
- Yarn (including conductive yarns) can be selectively added/designed.
- Localized compression can be added based on knit structure and stitch length



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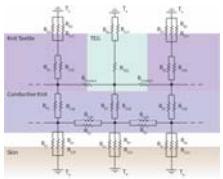
Knit Structures

Variations in knit structure and stitches…

…dictate the shape of the fabric



…define mechanical, thermal, and electrical properties of the textile

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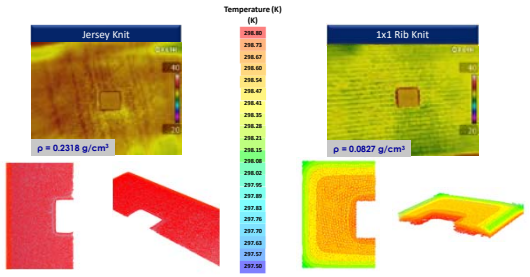
Knit Thermal Properties



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Applications

Cut & Sew Panels

Knit Structure Design

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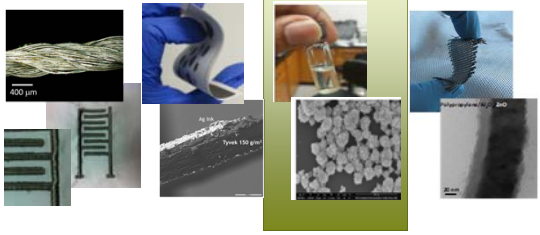

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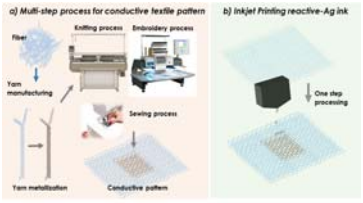
Automation: Printing



- Direct additive technique
- Non-contact
- Reduce material waste
- Uniform particle deposition
- High film homogeneity
- Cost effective

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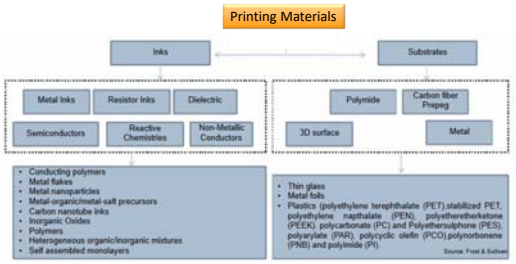
Conductive Printing Materials



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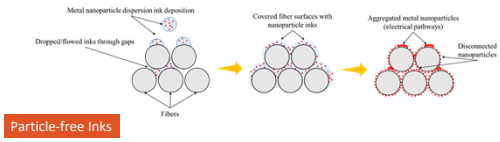
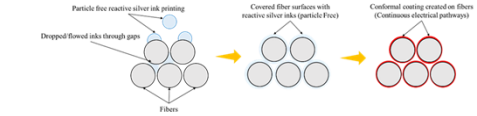
Ink Composition

Nanoparticle Inks



Particle-free Inks



I Kim, H Shahariar, W Ingram, Y Zhou, J Jur, *Advanced Functional Materials* 2018

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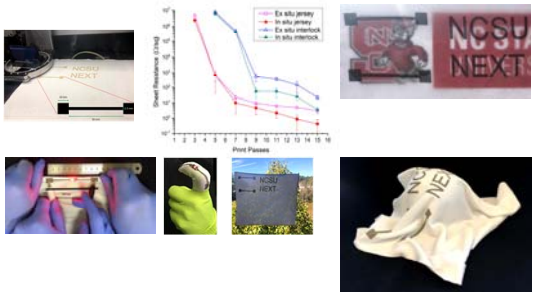
Inkjet Printing on Textiles



Kim, I., Shahariar, H., Ingram, W. F., Zhou, Y., & Jur, J. S. (2018). *Advanced Functional Materials*, 1807573.
Shahariar, H., Kim, I., Soewardiman, H., & Jur, J. S. (2019). *ACS Applied Materials & Interfaces*.

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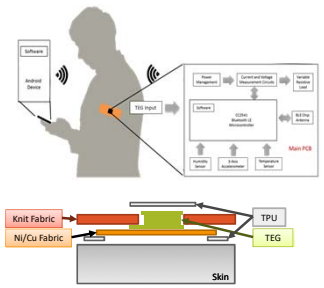
Integrated Systems



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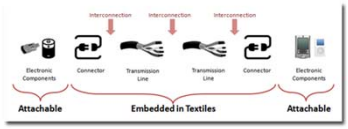
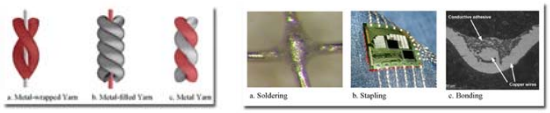
Making Connections





Suh, Textile World 2010

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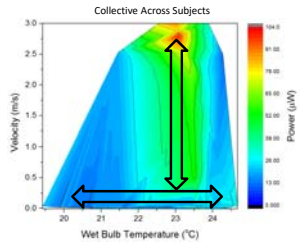
Environmental Effects



Minor power variations across the range of temperatures.

Low power generation even at low ambient temperature

Significant increase in power with more movement/convection

Onset of sweating increases the heat flux away from the body which increases the power generated

Myers et. al. *Energy Conversion and Management* (2016)

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Analyzing the Human Scenario

- Volunteers performed 3 activities for approximately 15 min each:
  - Running Outdoors
  - Walking Outdoors
  - Resting/Working Indoors
- Recorded data
  - Accelerometer
  - Gyroscope
  - External Temperature and Humidity
  - TEG Voltage

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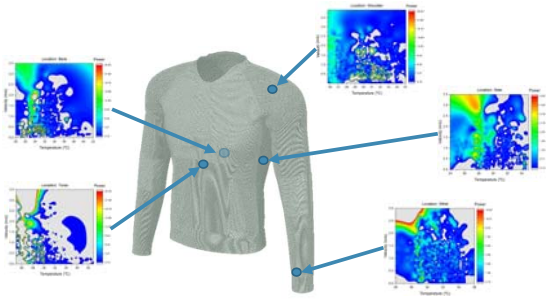
Mapping Thermal Power



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What is Next?

- Continued functionalization of textiles
- Improved electronics integration enabled by automation
- Layer by layer techniques applied to fabrics
- User-driven design

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Thank You

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NEXT Research Group

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Linkedin: www.linkedin.com/in/jessejur

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