Rapid Iron-On User Interfaces:
Hands-on Fabrication of Interactive Textile Prototypes

Konstantin Klamka[1], Raimund Dachselt[1,2], Jürgen Steimle[3]

[1] *Interactive Media Lab Dresden, Technische Universität Dresden, Germany*

[2] *Centre for Tactile Internet with Human-in-the-Loop (CeTI), Technische Universität Dresden, Germany*

[3] *Human Computer Interaction Lab, Saarland University, Saarland Informatics Campus, Saarbrücken, Germany*

CHI 2020

TECHNISCHE UNIVERSITÄT DRESDEN

INTERACTIVE MEDIA LAB DRESDEN

CeTI Centre for Tactile Internet with Human-in-the-Loop

Saarland Informatics Campus SIC

HCI Human Computer Interaction Lab Saarland University

Emerging E-Textiles

Recent advances are bringing a new generation of wearable user interfaces that are deeply integrated.

Fashion

Workwear

Medical

Sports

Accessories

Everyday Life

Maker & Innovators

- Great technical skills
- Capabilities to innovate and prototype

Fab Lab Vestmannaeyjar Iceland © by Frosti Gíslason / Saethor Vido

E-Textile Prototyping

- quite time-consuming
- cumbersome when done manually

Fashion Designer

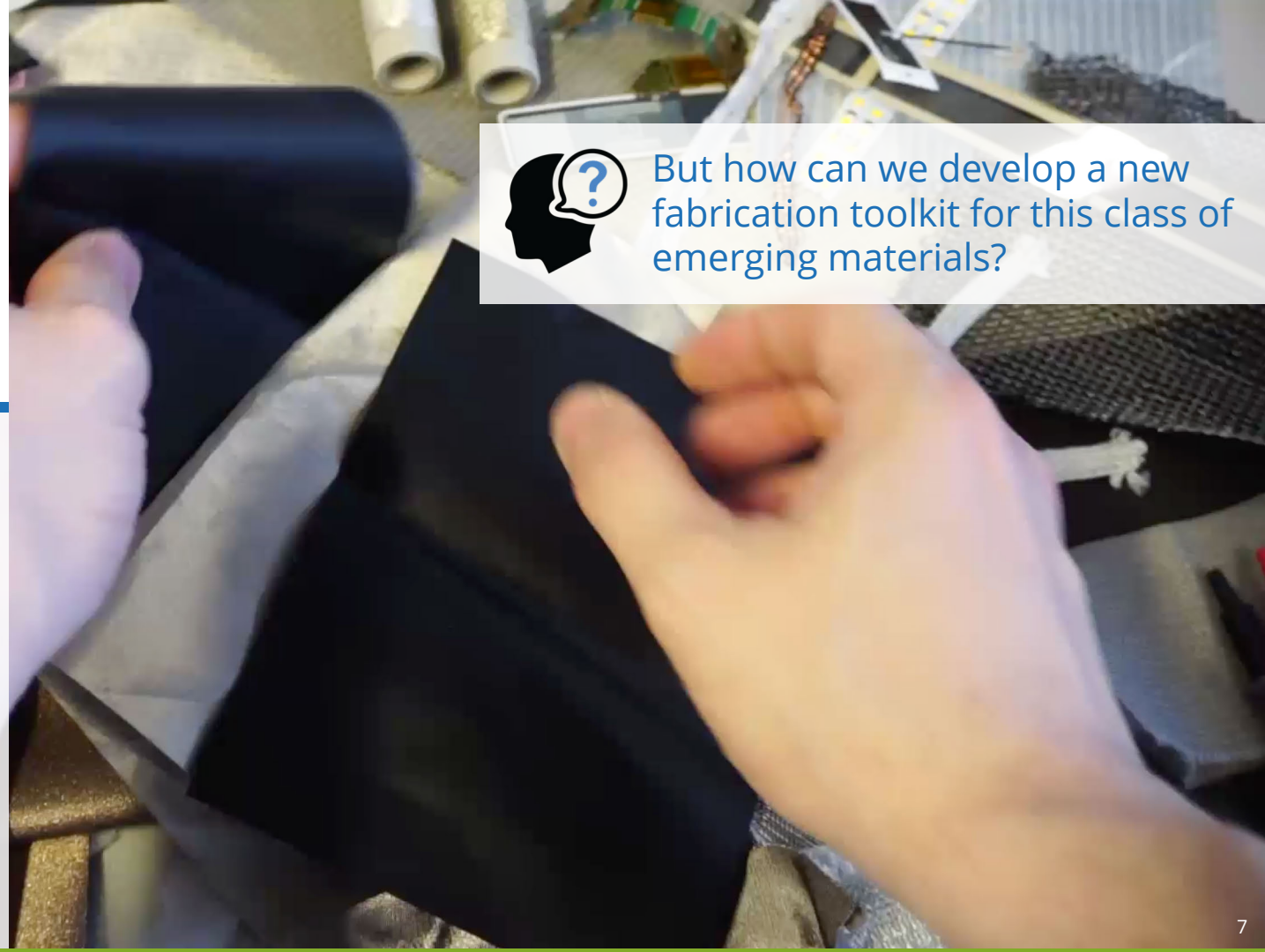
- Require toolkits at early design stages
- Did not have access to textile expert machinery and knowledge

E-Textile Prototyping

- Automation requires expert machinery and knowledge
- Typically outside the realm of a prototyping space.

Smart Materials & Printed Electronics

- Conductive or (piezo-)resistive textiles & fabrics
- An emerging variety of (semi-) flexible printed electronics

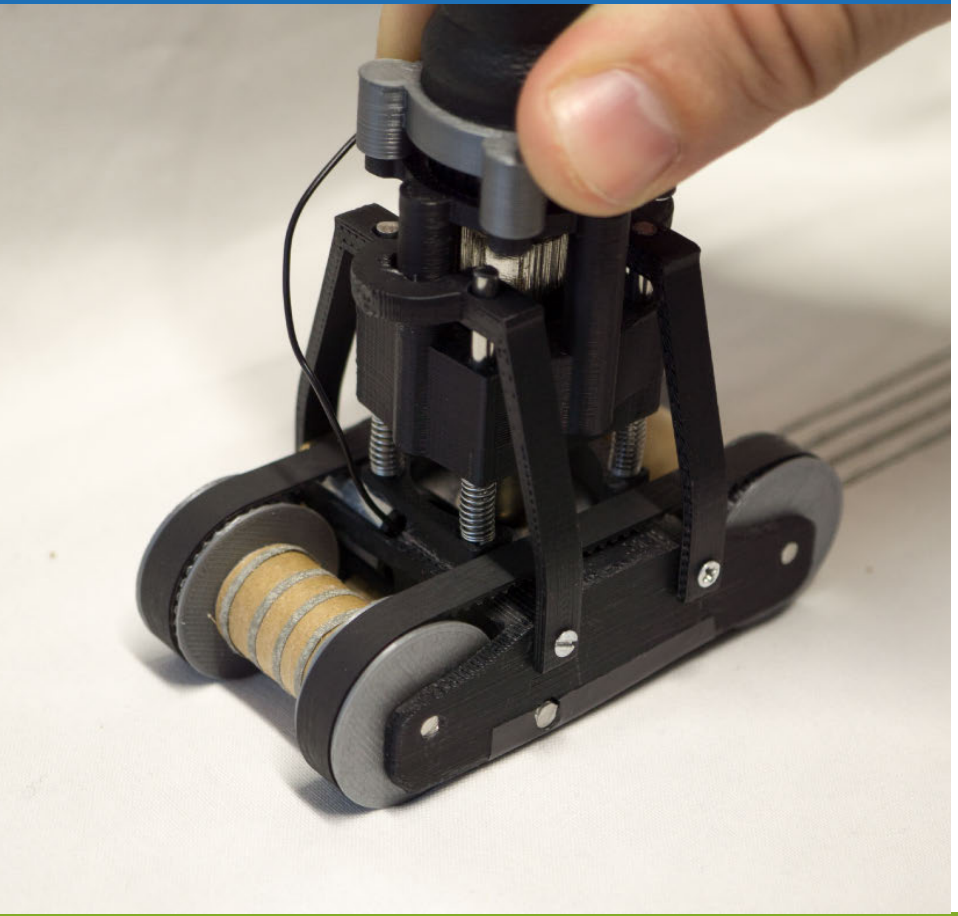


But how can we develop a new fabrication toolkit for this class of emerging materials?

Tape Dispenser

- Sketching-like interaction
- Transfers a pre-manufactured film onto another surface

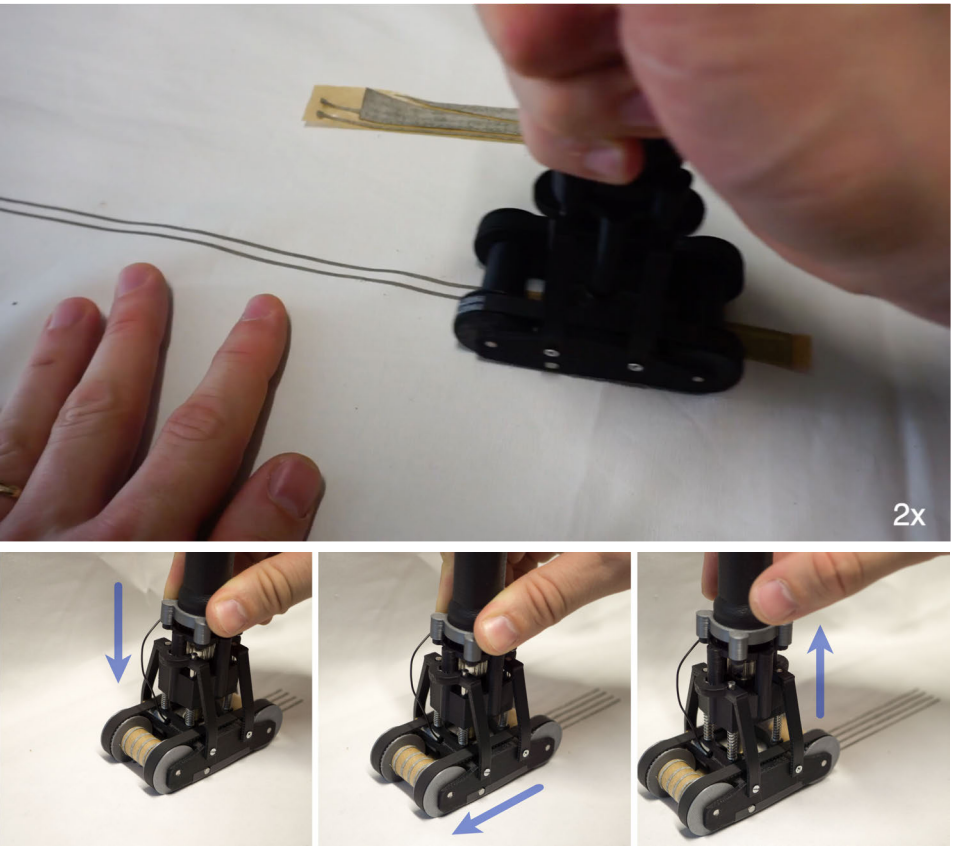
Rapid Iron-On User Interfaces



Our Main Contributions

- **Novel Fabrication Technique**
  combines design and fabrication into a single process

Rapid Iron-On User Interfaces



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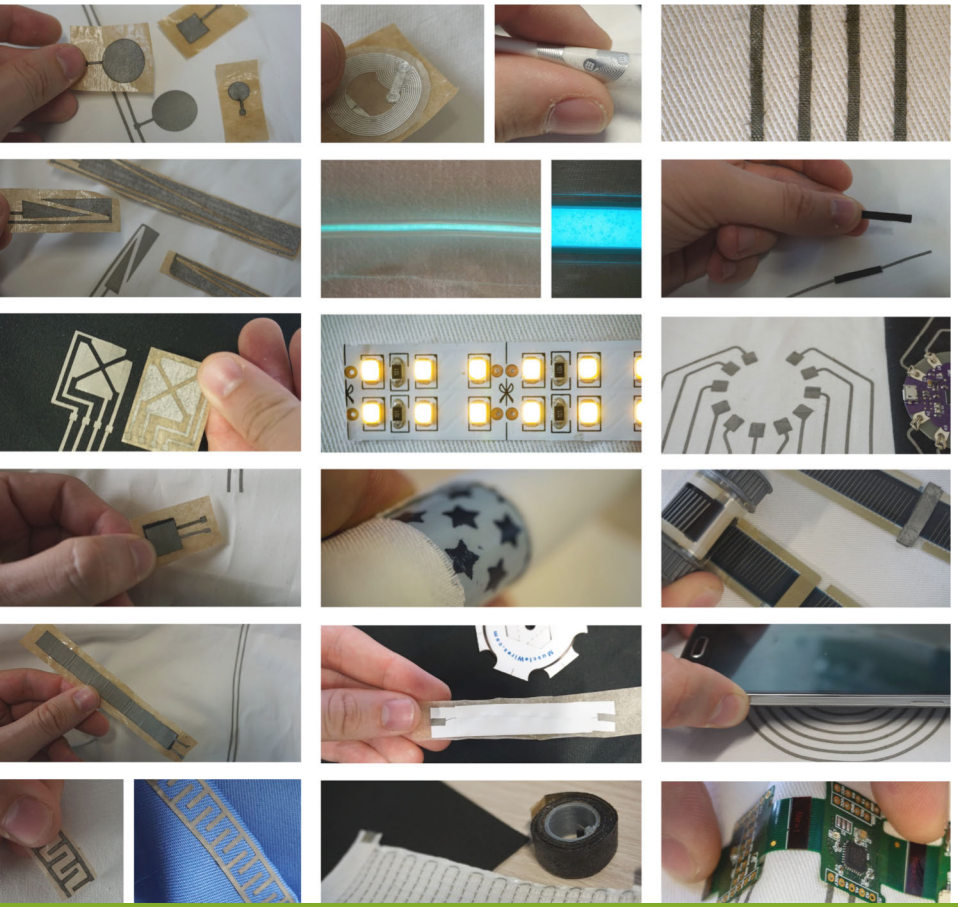

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  consisting of tapes and patches

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- **Application Examples**

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- **Library of Components**
  consisting of tapes and patches
- **Application Examples**
- **Technical Experiments & Expert Reviews**

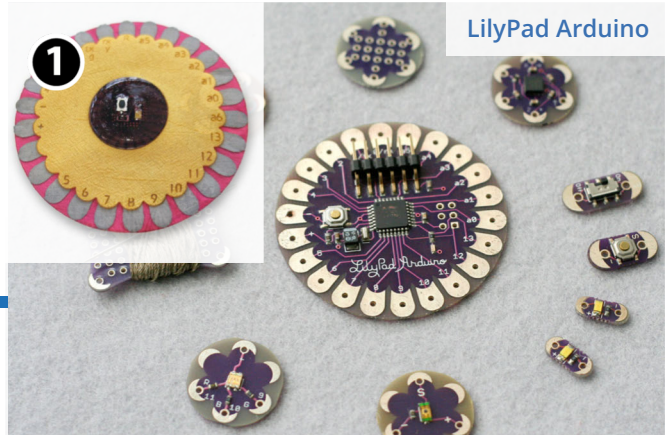
Related Work

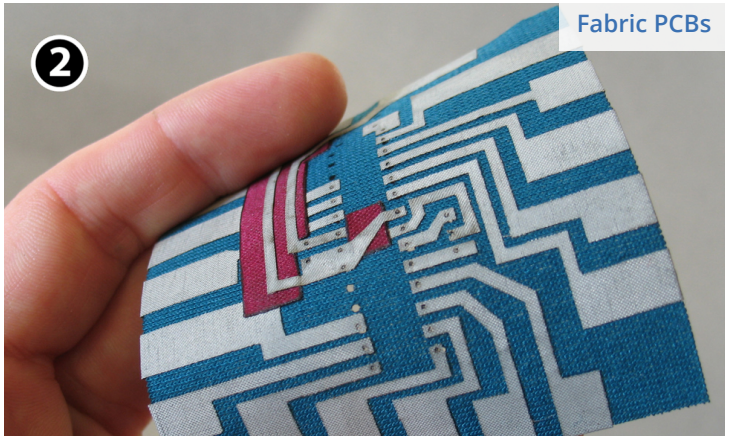
1 LilyPad Arduino
Buechley et al.,
ACM CHI '08

2 Fabric PCBs
Buechley & Eisenberg,
Personal and Ubiquitous Computing '09

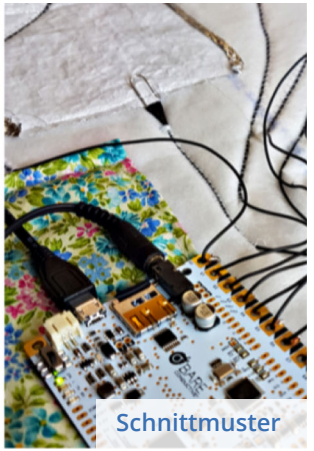
3 Kit-of-no-parts
Perner-Wilson et al.,
ACM TEI '11

4 Schnittmuster
Meissner et al.,
ACM CHI '18





Crafting E-Textiles



Related Work

1 i*Catch
Ngai et al.
ACM CHI '10

2 MakerWear
Kazemitabaar et al.,
ACM CHI '17

3 zPatch
Strohmeier et al.,
ACM TEI '18

4 BodyHub
Peetz et al.
ACM UIST EA '19

Modular Wearable Toolkits

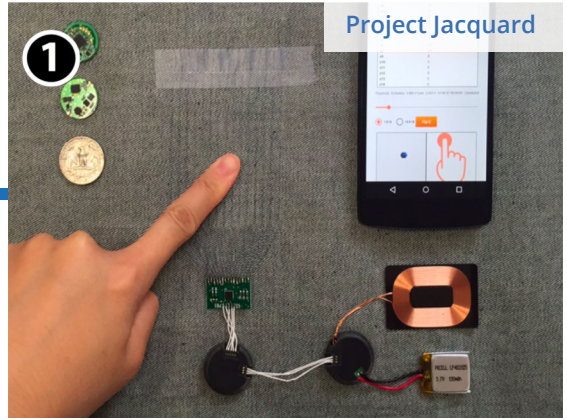
Related Work

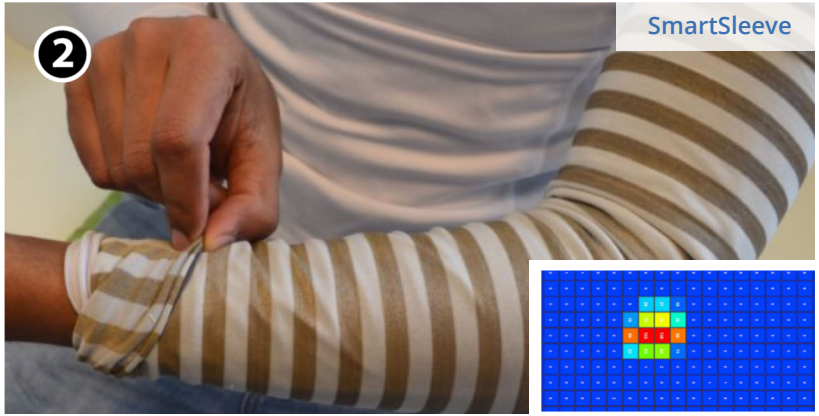
1 Project Jacquard
Poupyrev et al.,
ACM CHI '16

2 SmartSleeve
Parzer et al.,
ACM UIST '17

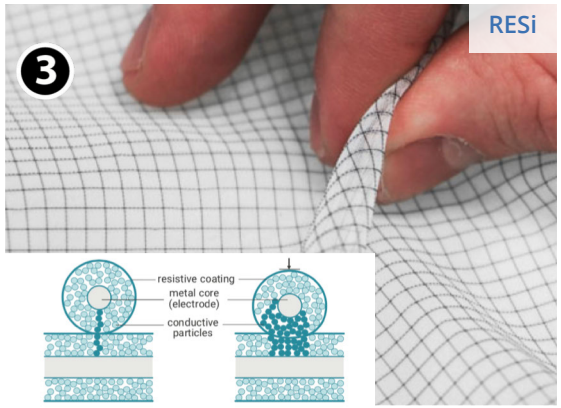
3 RESi
Parzer et al.,
ACM UIST '18

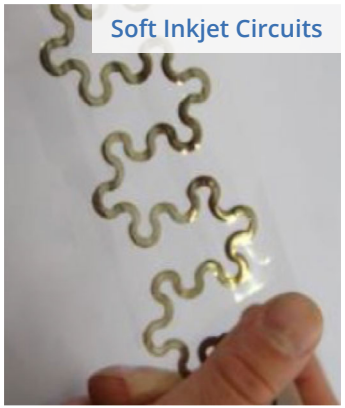
4 Soft Inkjet Circuits
Khan et al.,
ACM UIST '19





Advanced Fabrication & Sensing





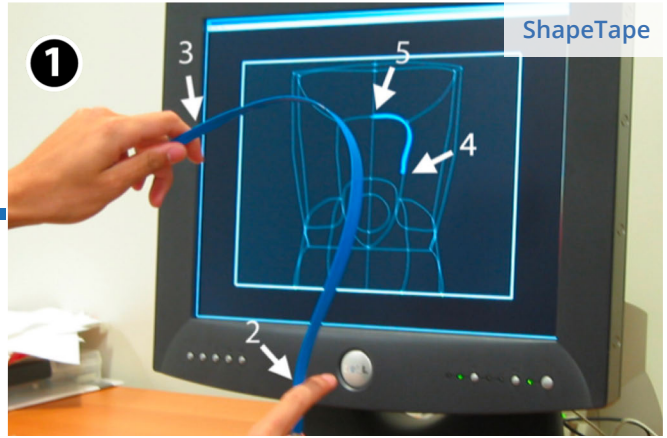
Related Work

❶ ShapeTape
Grossman et al.
ACM CHI '03

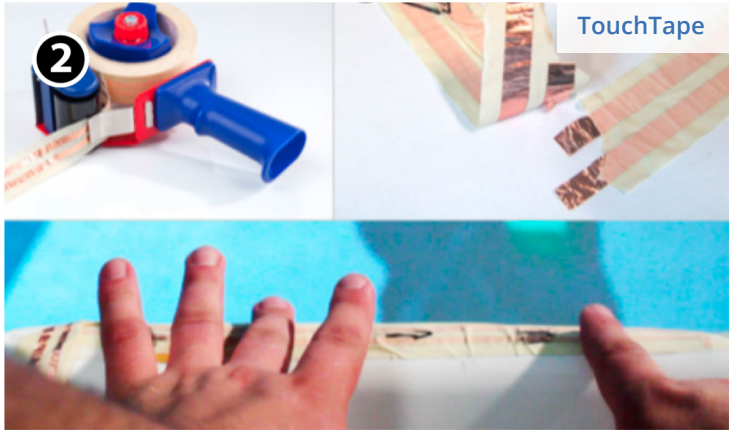
❷ TouchTape
Wimmer & Baudisch
ACM UIST '11

❸ SensorTape
Dementyev et al.,
ACM UIST '15

❹ AMOHR Tapes
Christoph Mohr
https://www.amohr.com

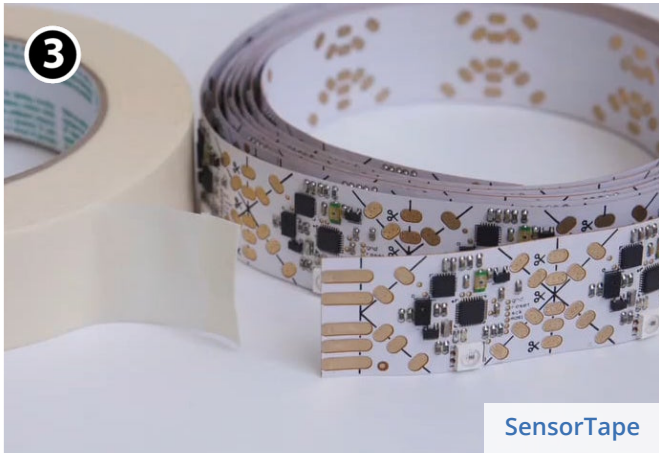


ShapeTape

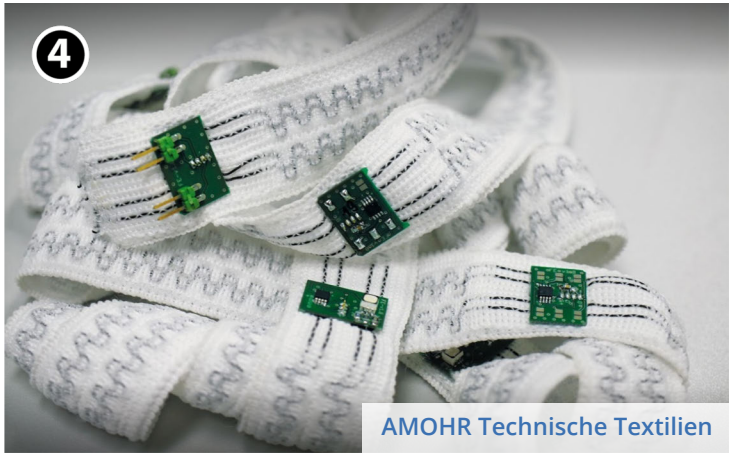


TouchTape

Smart Tapes



SensorTape



AMOHR Technische Textilien

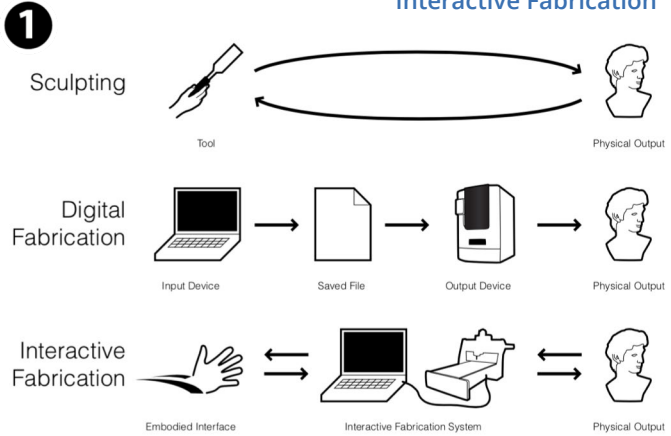
Related Work

❶ Interactive Fabrication
Willis et al.,
ACM TEI '11

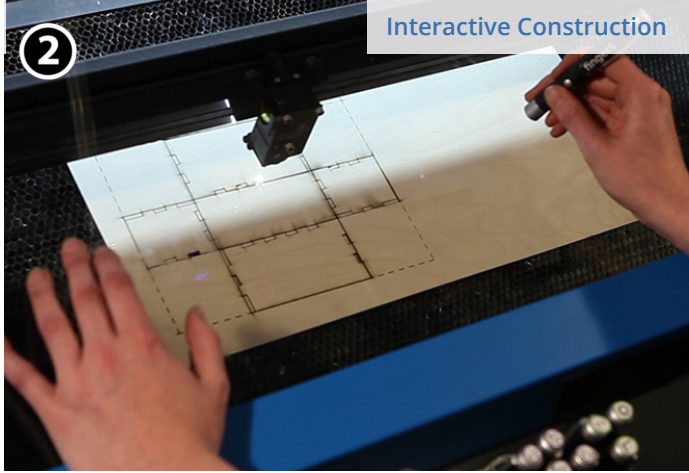
❷ Interactive Construction
Mueller et al.
ACM UIST '12

❸ Sketch&Stitch
Hamdan et al.
ACM CHI '18

❶ Interactive Fabrication

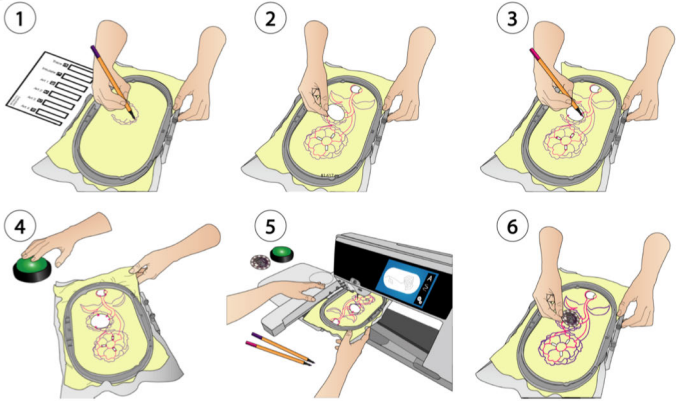


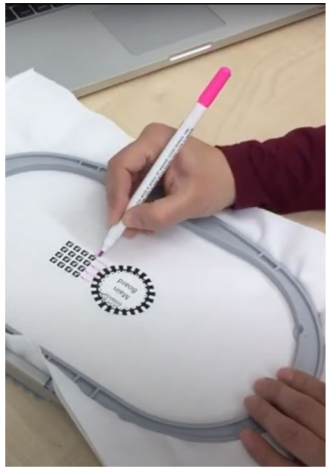
❷ Interactive Construction



Interactive Fabrication & Construction

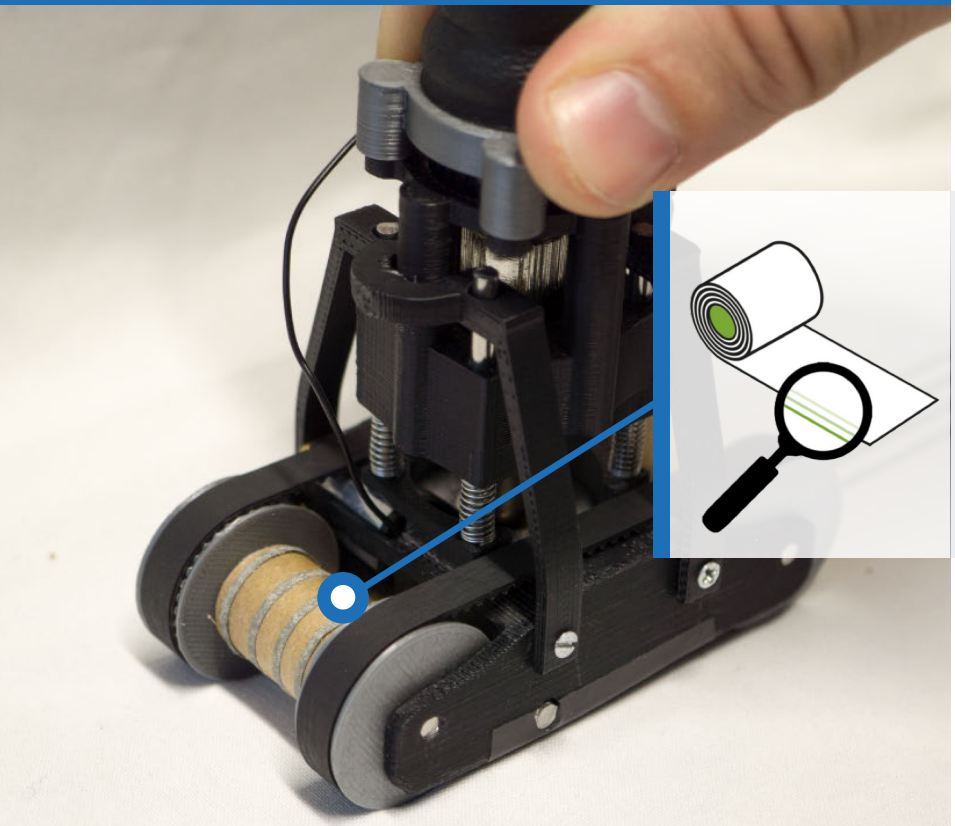
❸





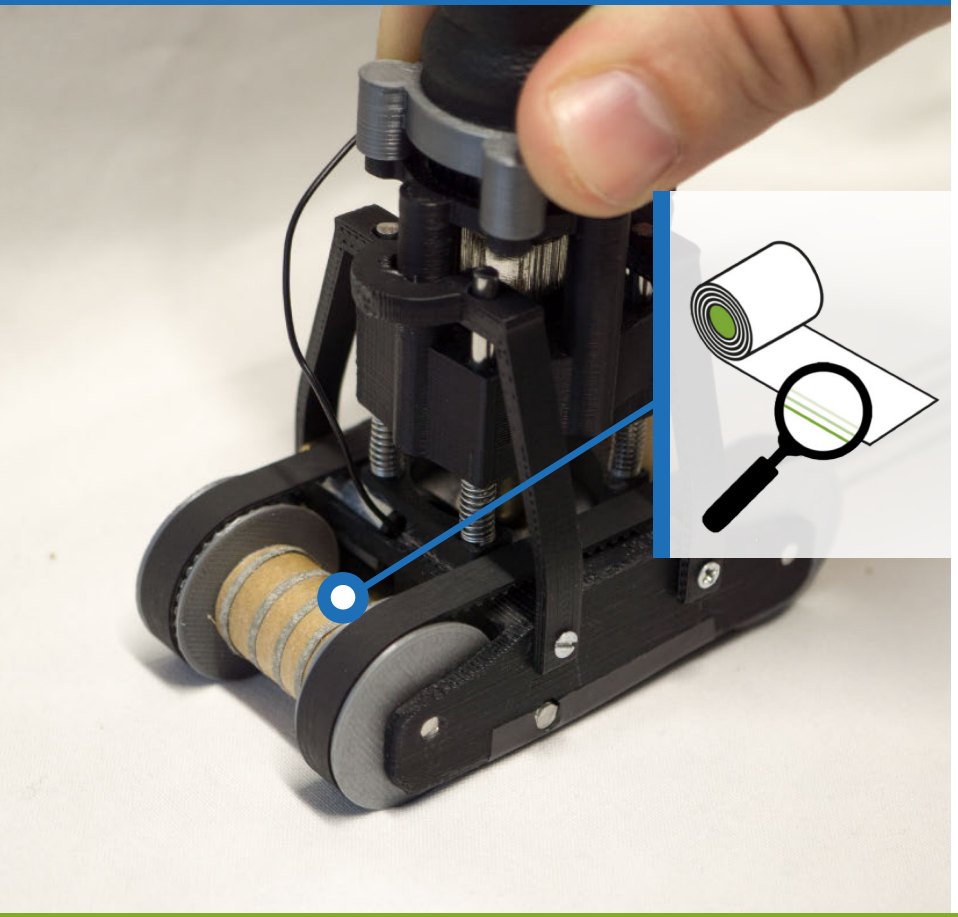
Sketch&Stitch

Rapid Iron-On User Interfaces



How the material spools are **constructed**?

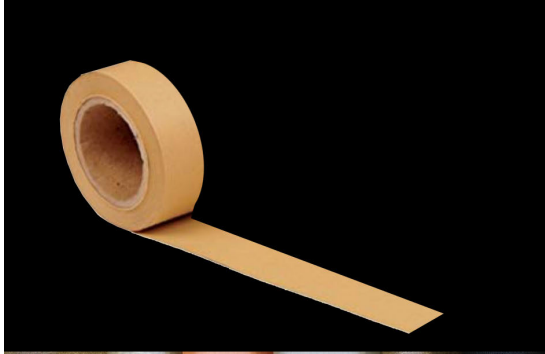
Iron-On Material Stack



1. **Carrier** Layer

2. **Functional** Layer

3. **Adhesive** Layer



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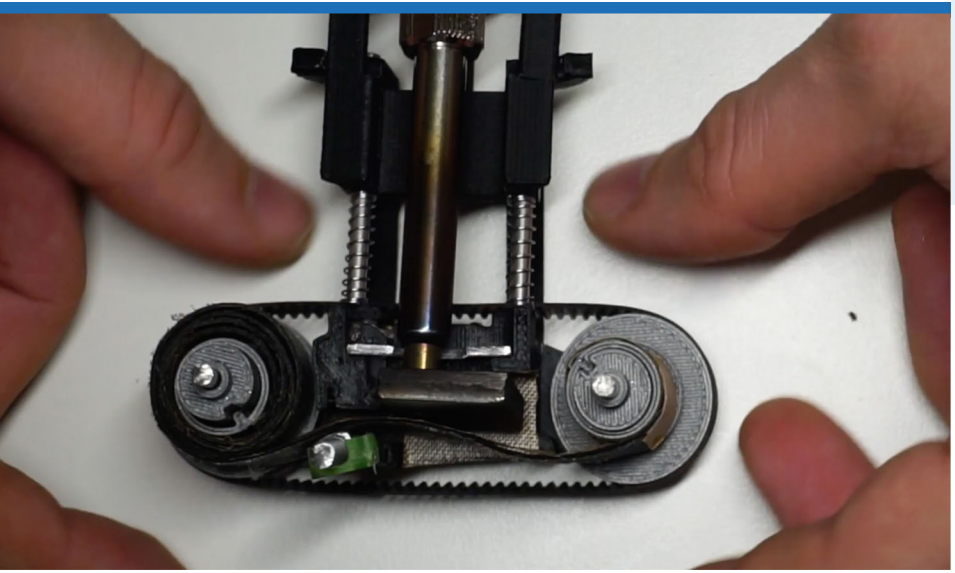

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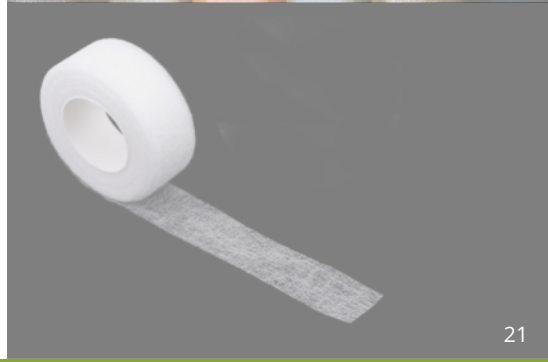

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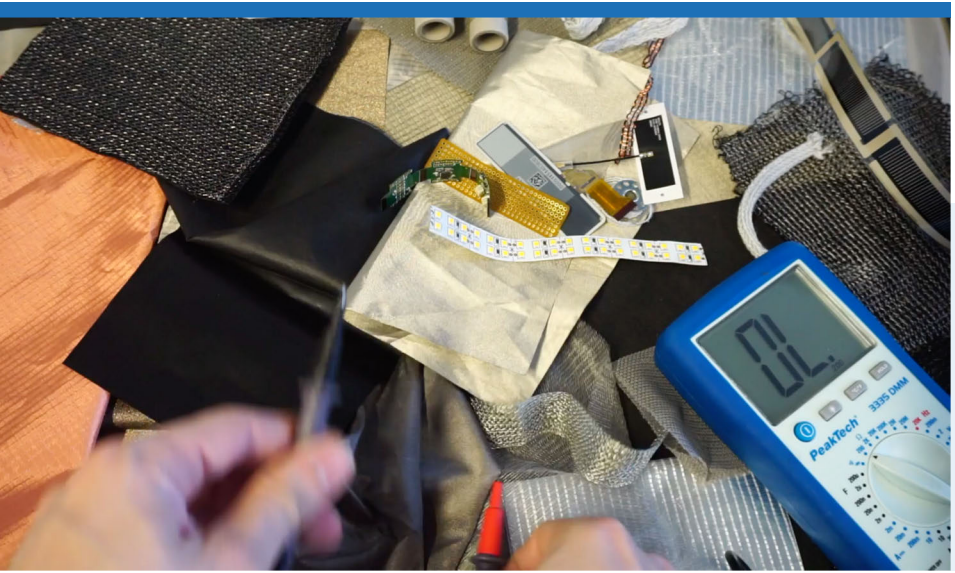

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Iron-On Material Stack

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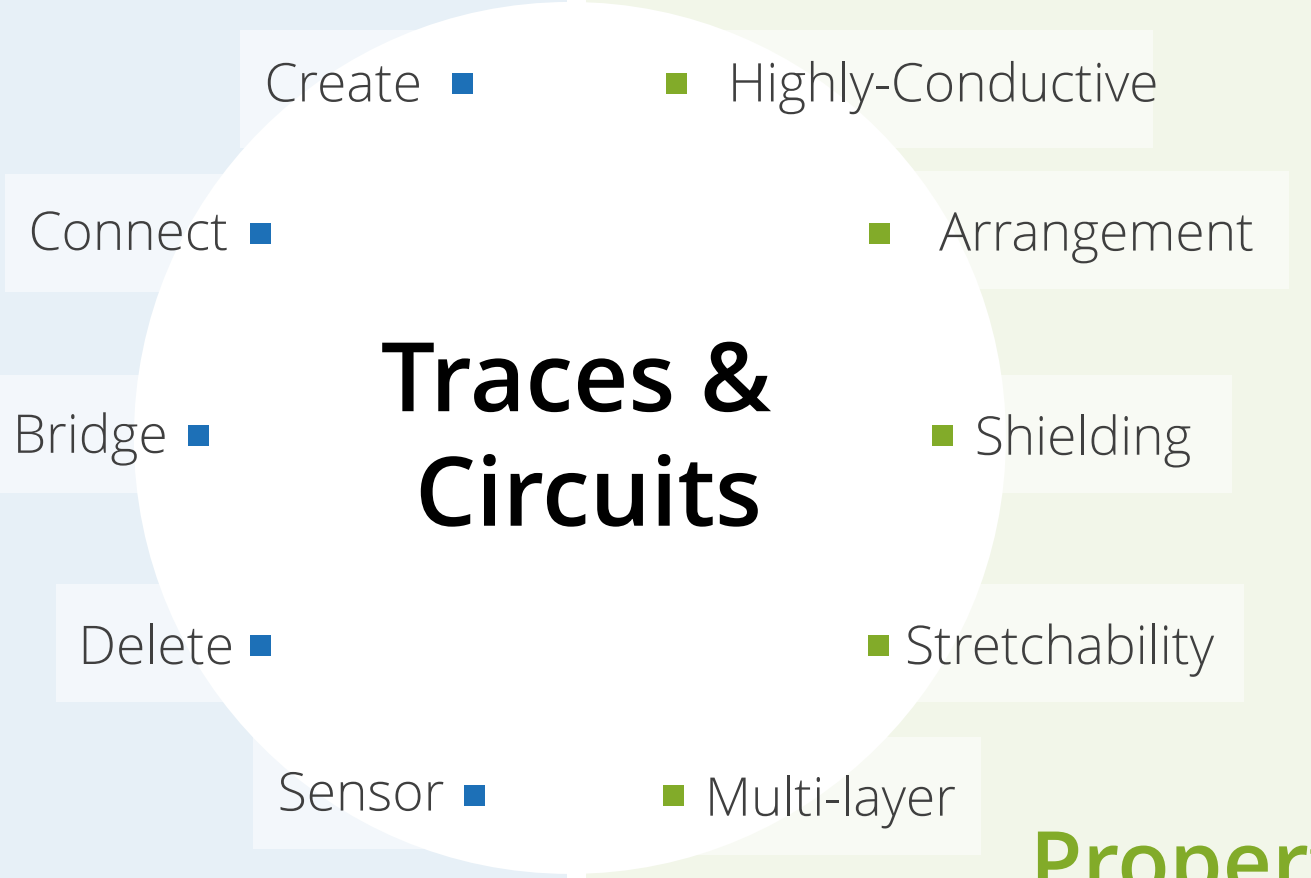
What can we do with the Rapid Iron-On Tool?

Actions

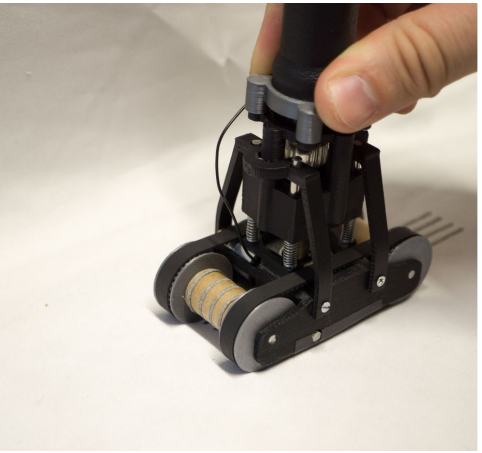


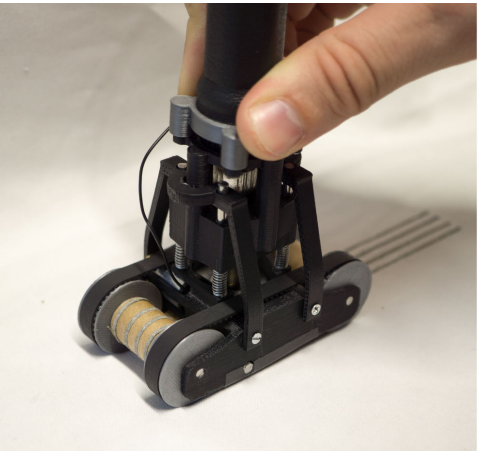
Properties

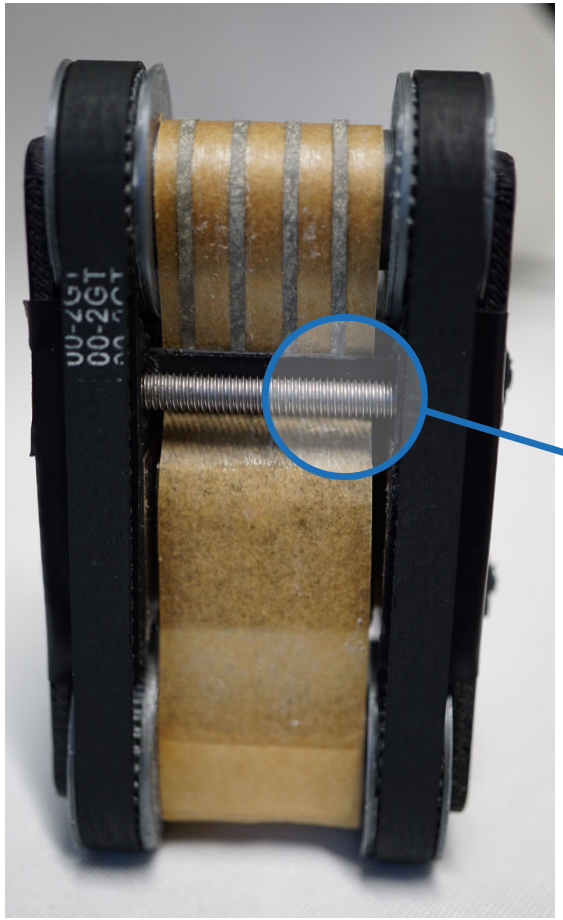
Standard Traces
in different sizes

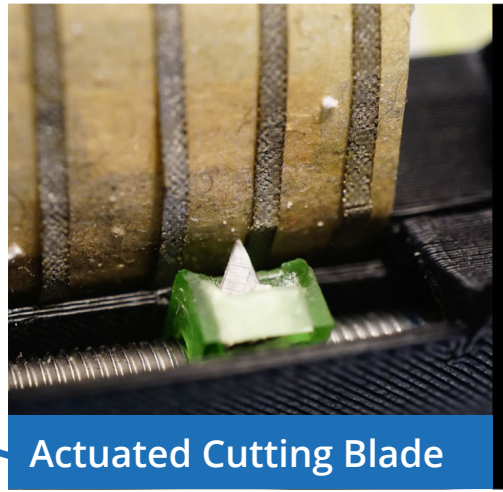
Stretchable Traces
in different sizes

Standard Traces

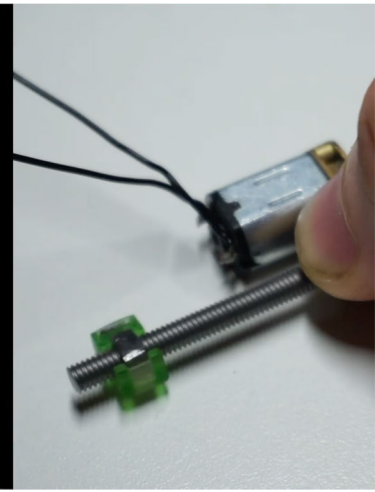






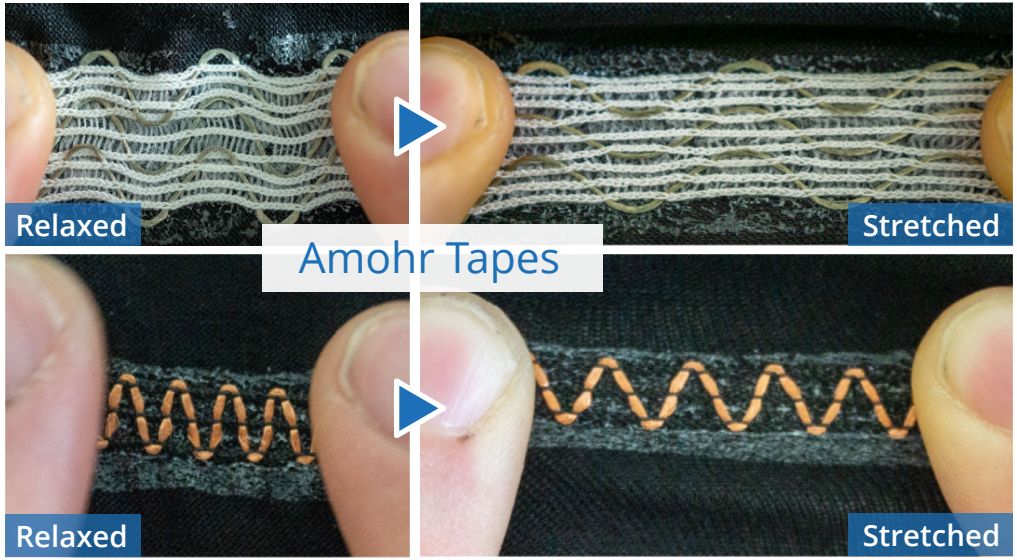


Actuated Cutting Blade



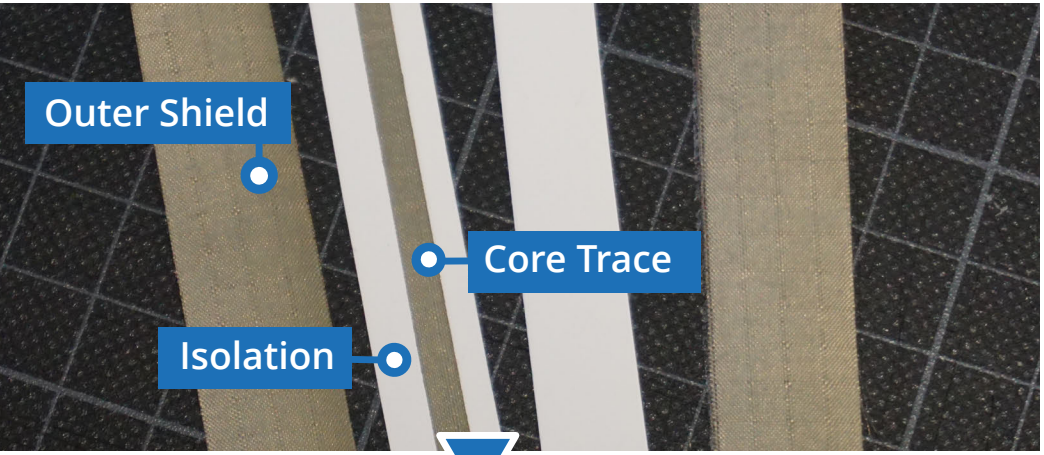
- **Material:** Shieldex, Zell - RS
- **Conductivity:** 0.1Ω / 1cm
- **Thickness:** 110µm
- **Pitch:** 5.08mm
- **Trace Width:** 1.50mm

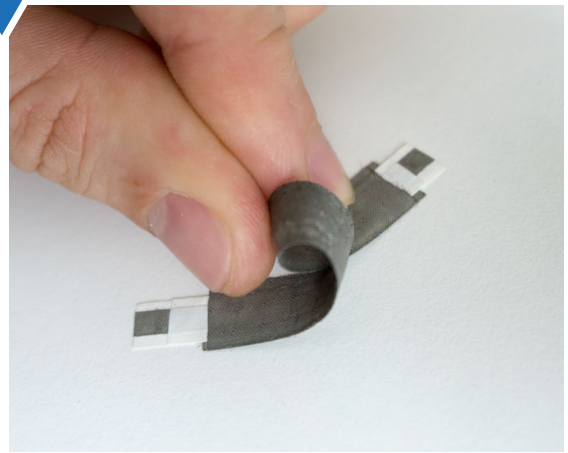
Stretchable Traces



- **Design:** horse-shoe pattern
- **Elasticity:** up to 40 %

Shielded Traces



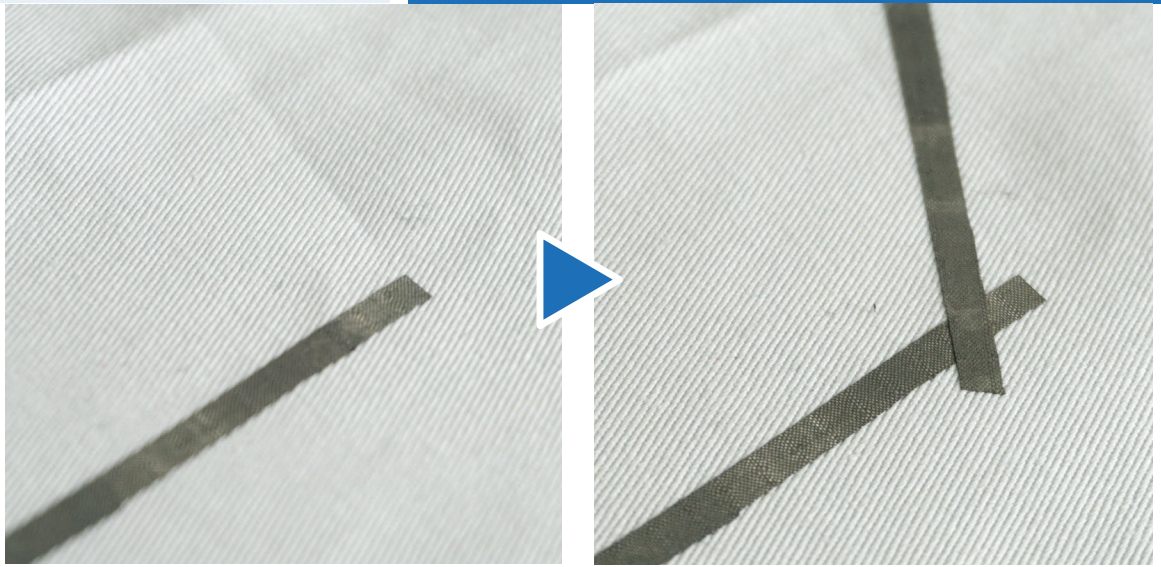


- **Material:** sandwiched ultra-thin dialectic and conductive fabrics
- **Thickness:** 350µm
- **Usage:** CapSense, Antennae

Extending Traces

- **Single-Wire Traces …**

… can be easily connected by **ironing on each other**.

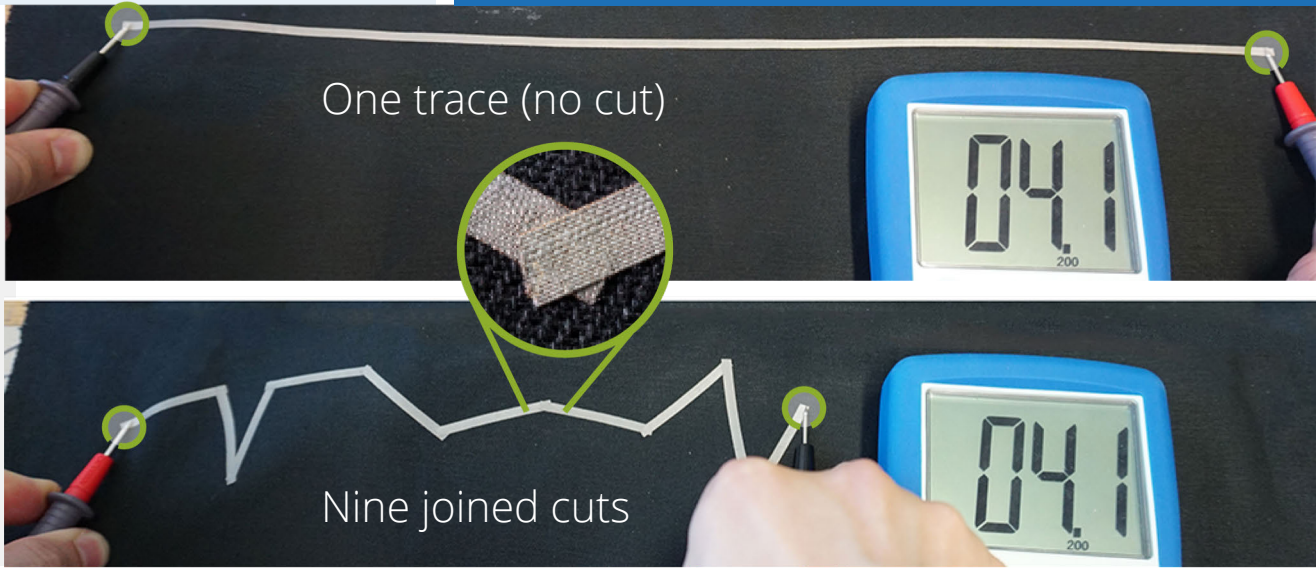


Extending Traces

- **Single-Wire Traces …**

… can be easily connected by **ironing on each other**.

In addition, there is **no change in resistance**.



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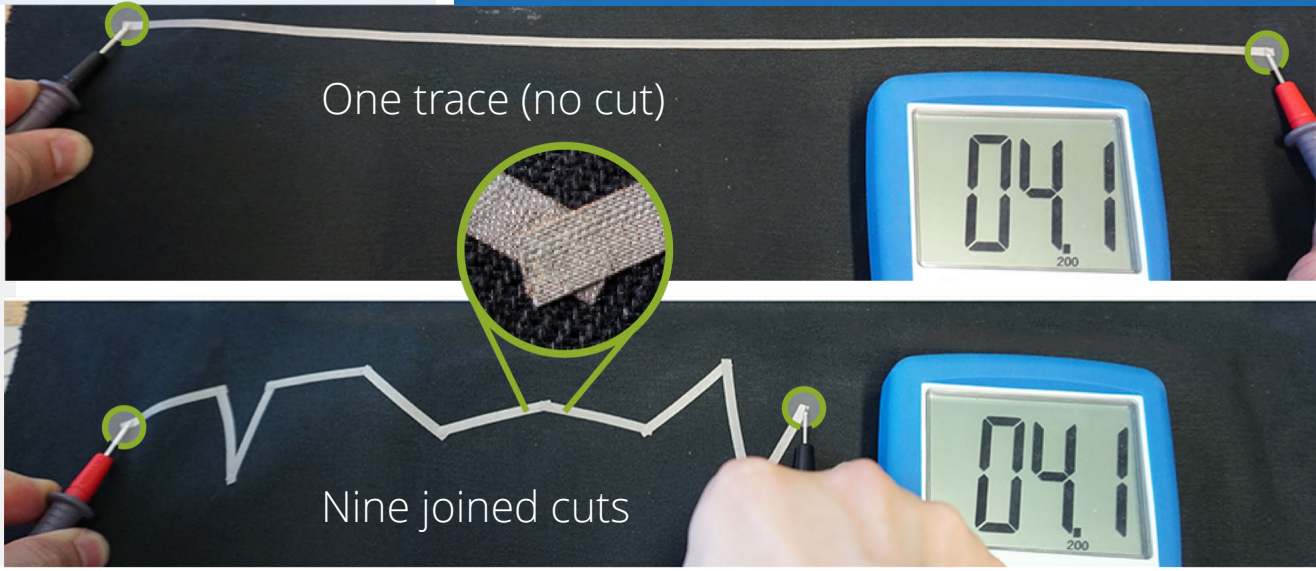
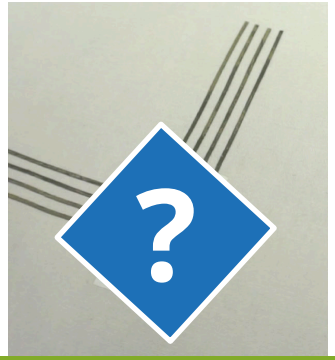


- **Multi-Wire Traces …**

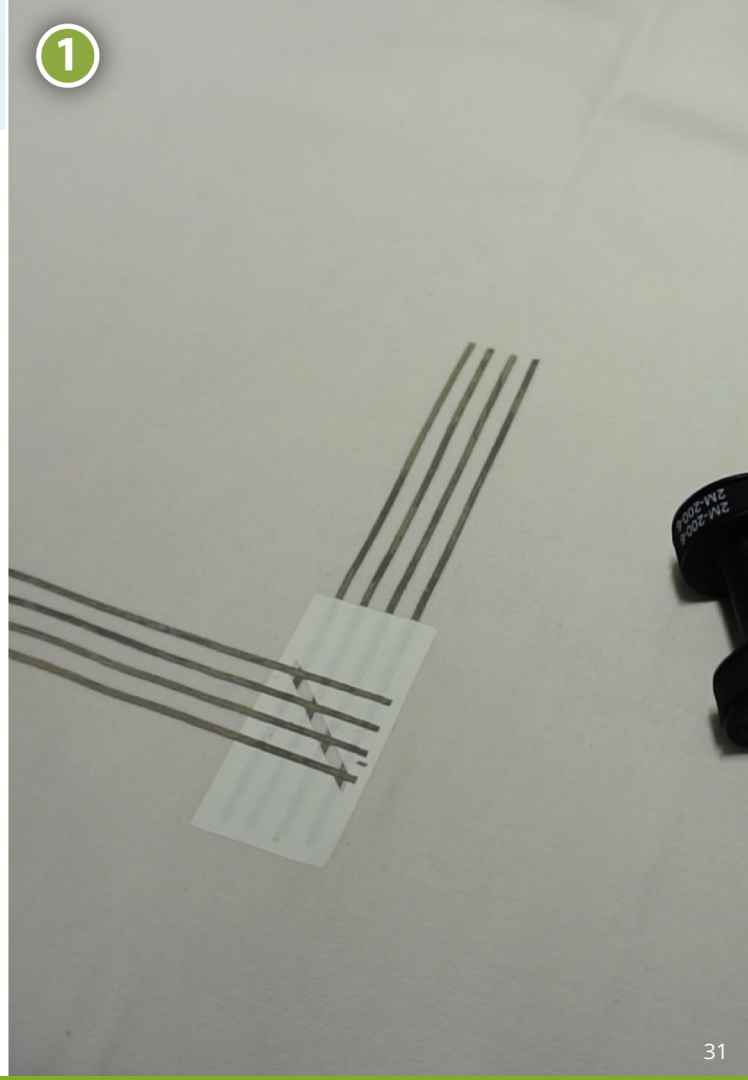
  … can be extended in the **same direction** if the user aligns the front axis to the existing one.



- But how to realize angles and crossings for multi-wire traces?

Angles and Crossings for Multi-Wire Traces

1. **Place**
2. Iron-on
3. Peel-off
4. Insert trace spool
5. Sketch traces
6. Check Connectivity



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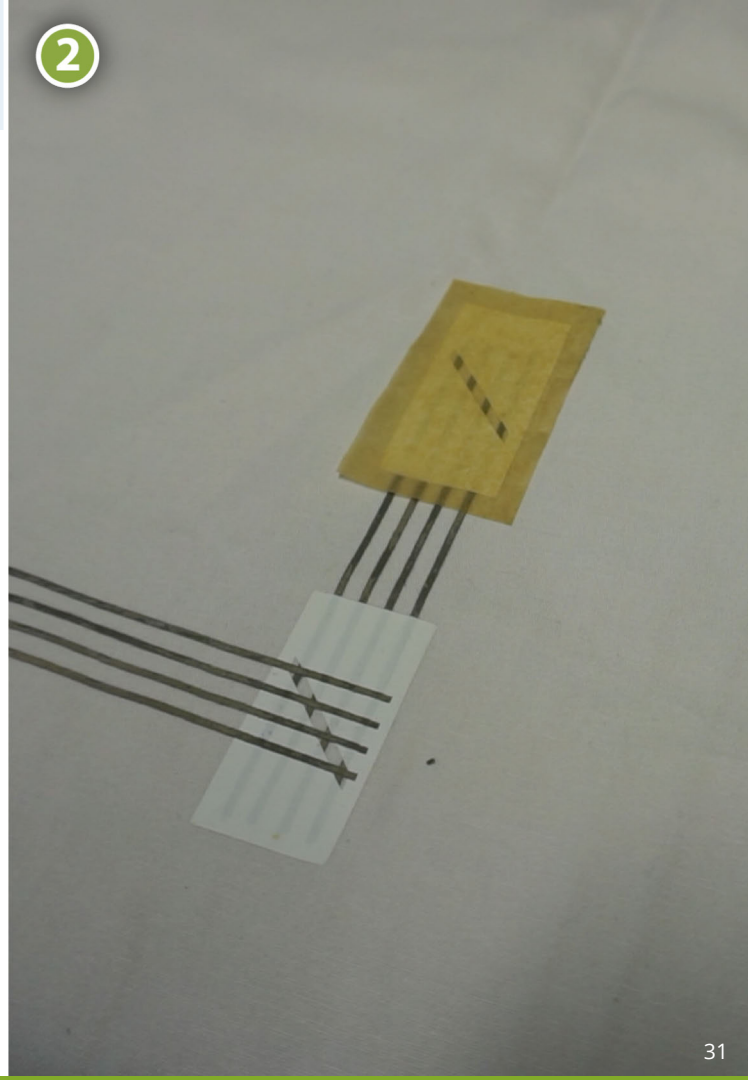

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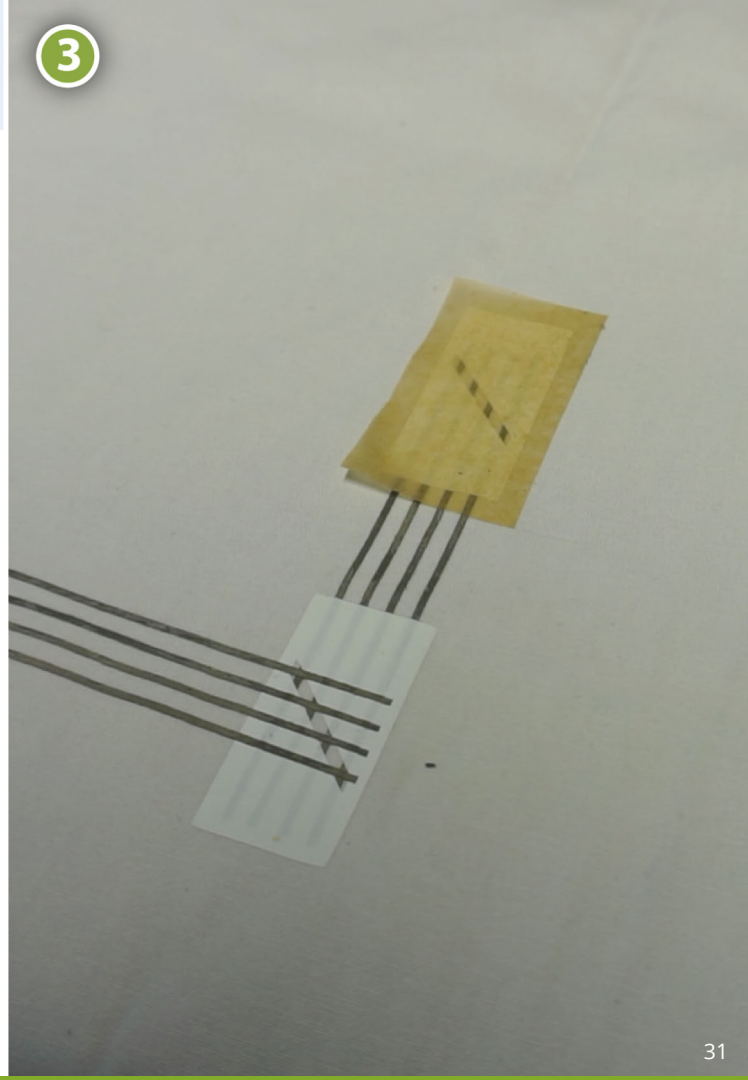

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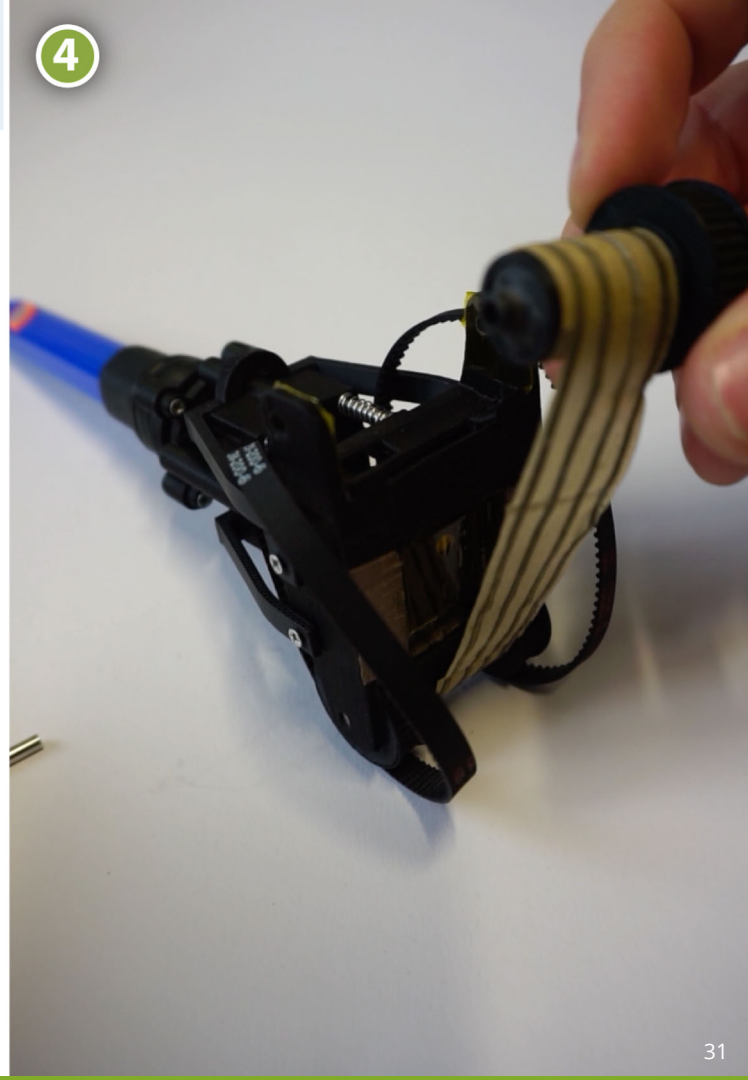

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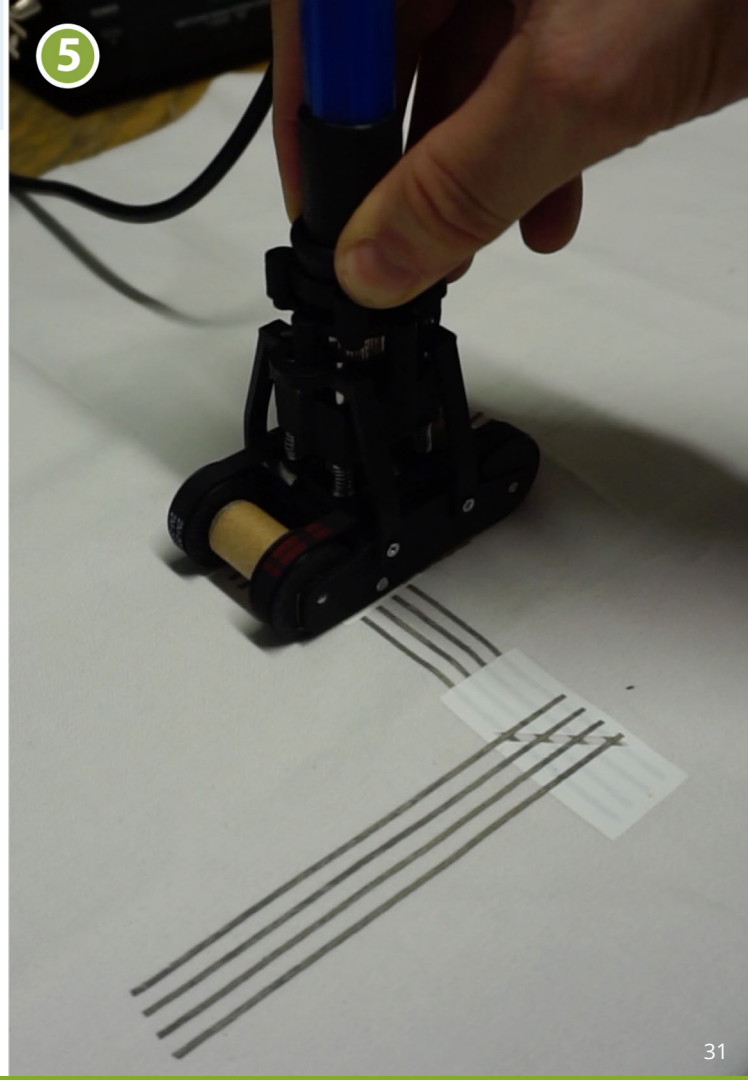

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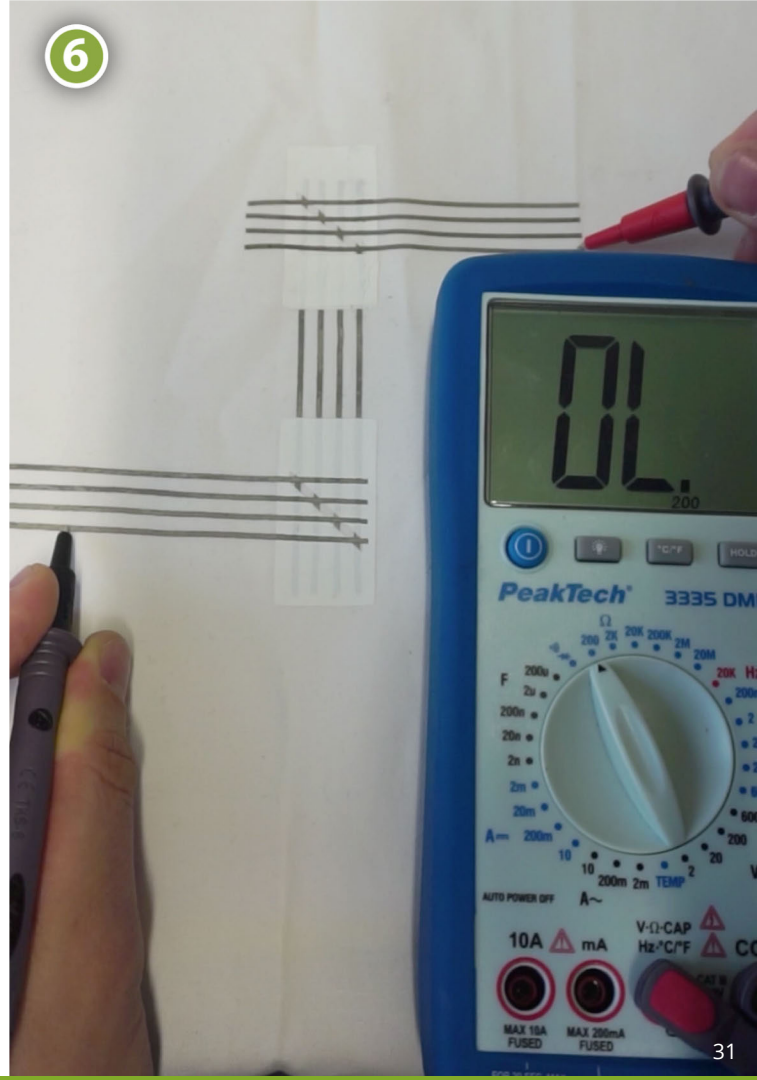
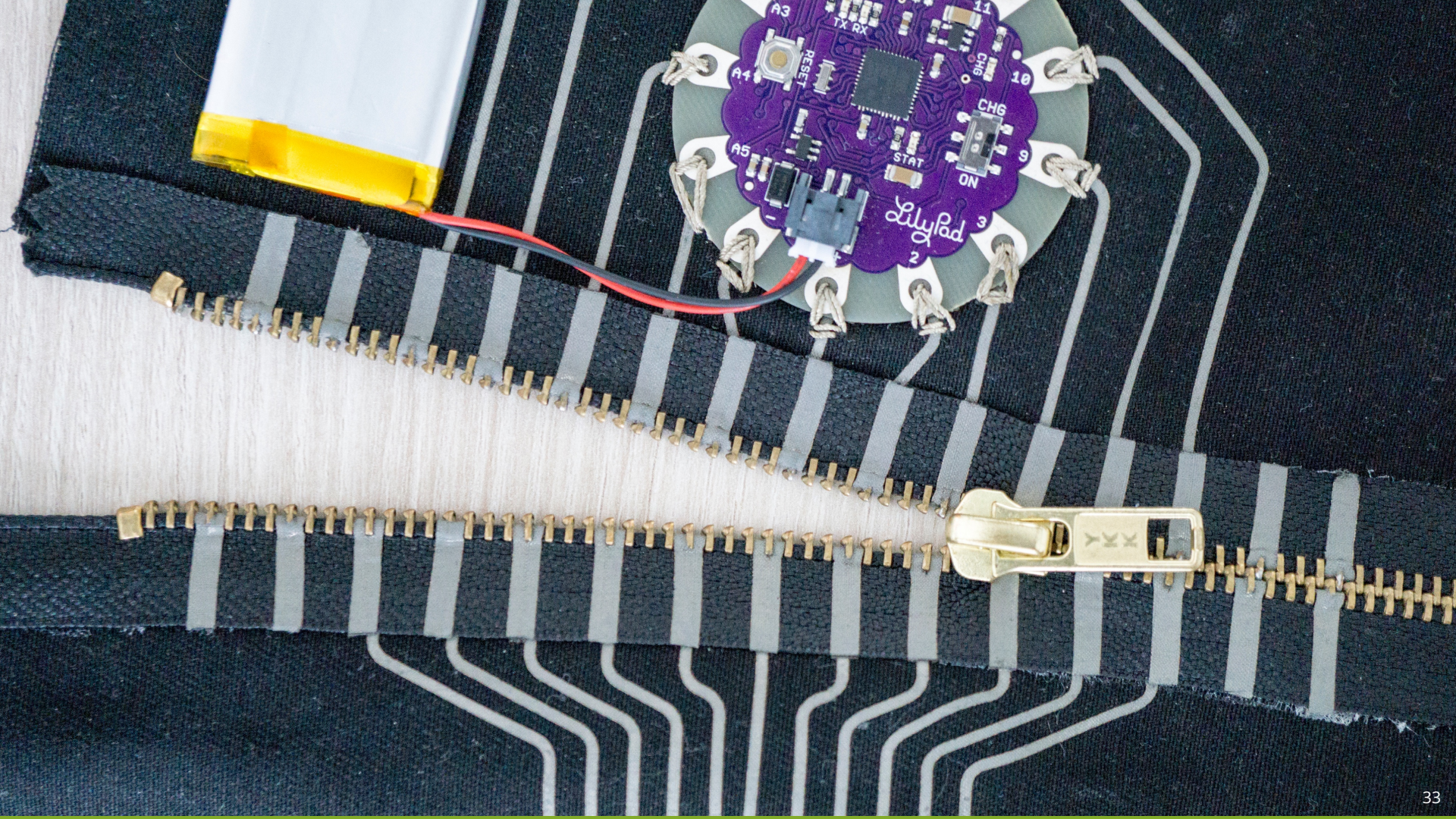
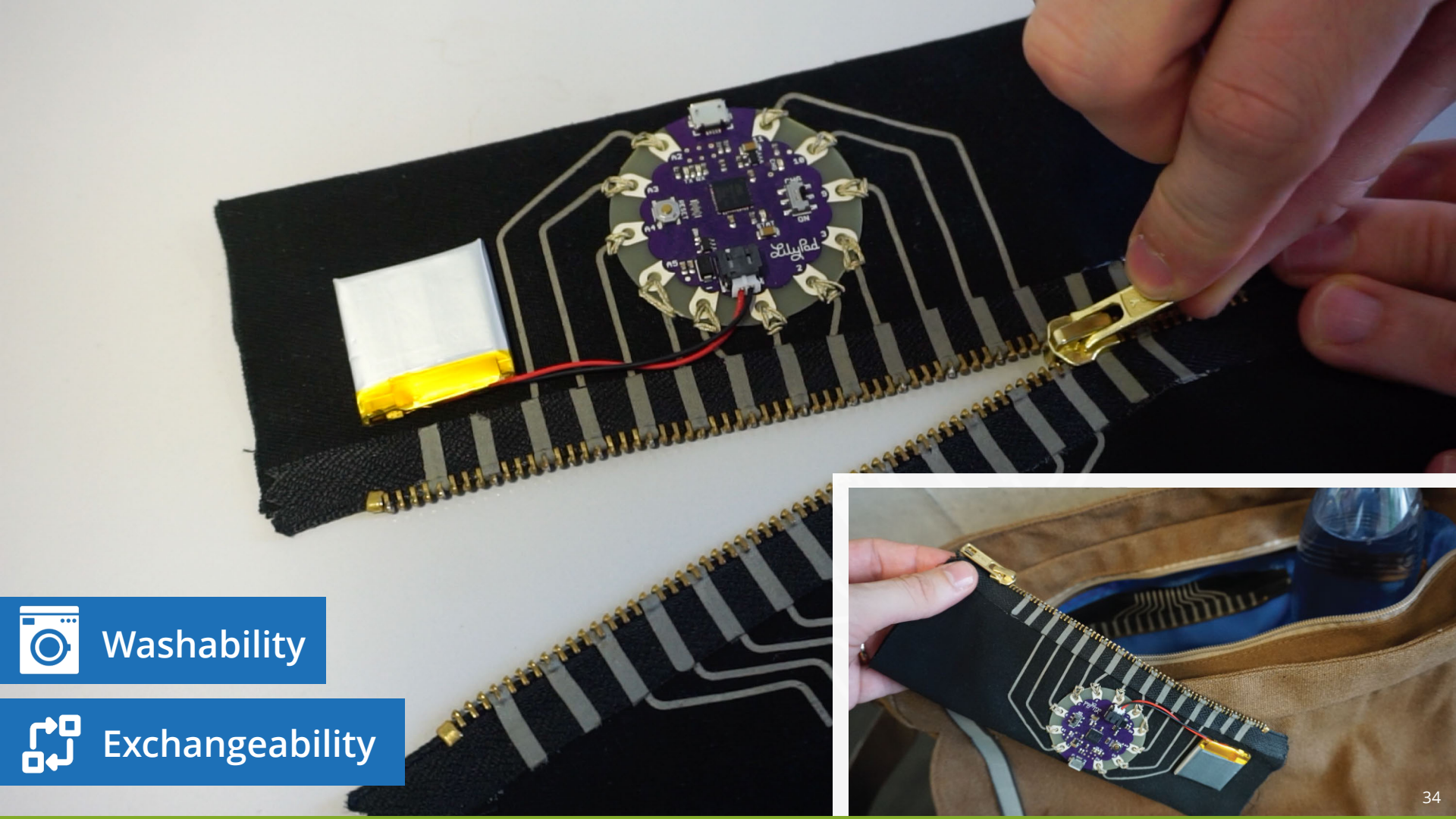
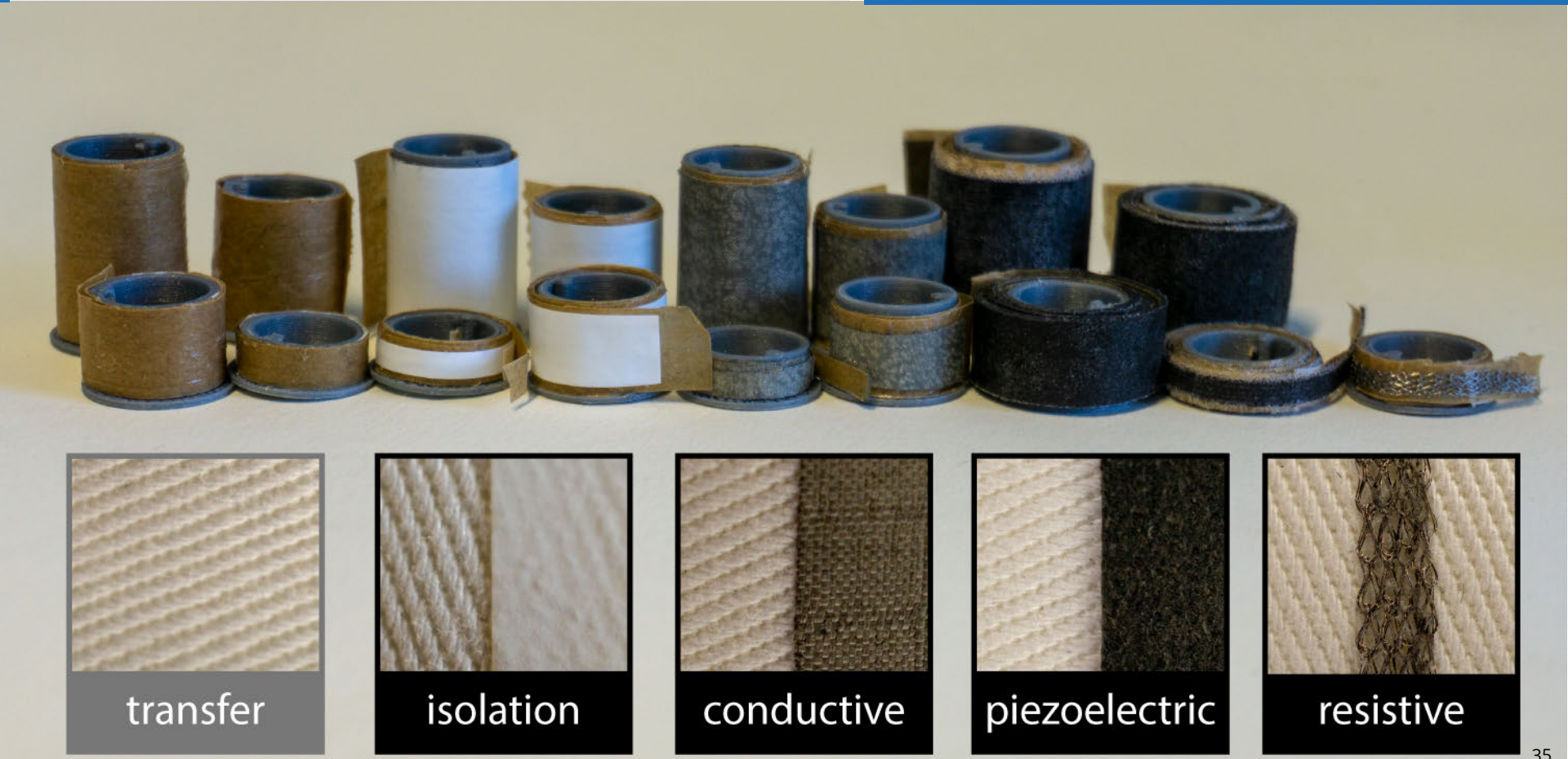



But what about
reversible connections?


A3
TX RX
11
A4
RESET
CHG
10
CHG
A5
STAT
9
ON
LilyPad
3
2

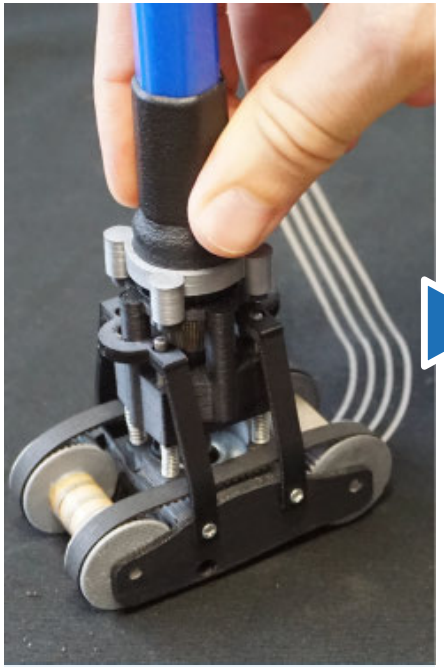

Washability
Exchangeability

Spool Materials



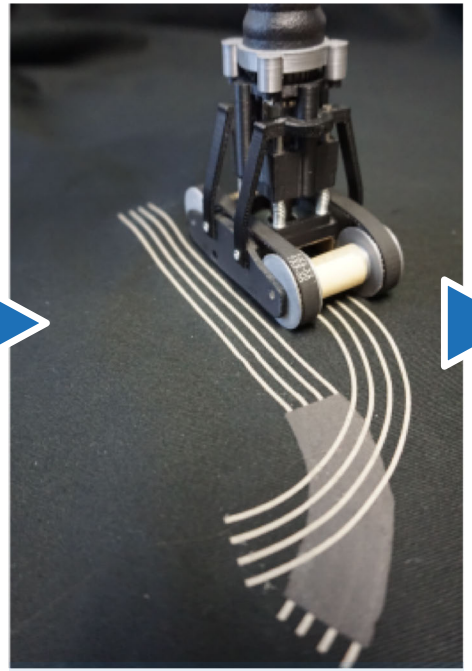
Sensor Matrices

- Custom Pressure-Touch Sensing Matrix

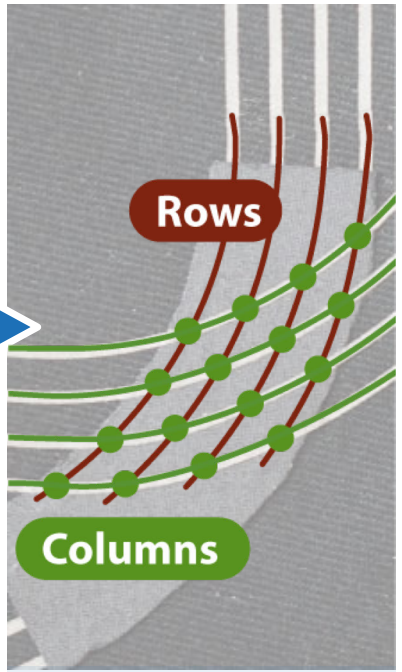


Sketch rows

Sketch piezoelectric



Sketch columns



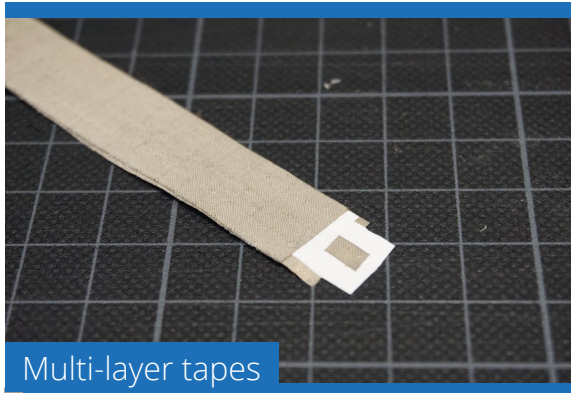
Sensor result

Composition Techniques

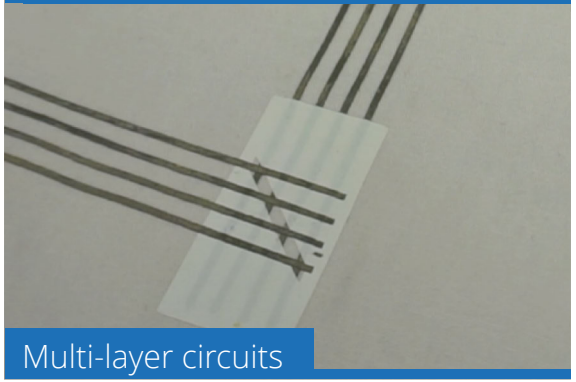
Arranging

Arrange different spools

Layering

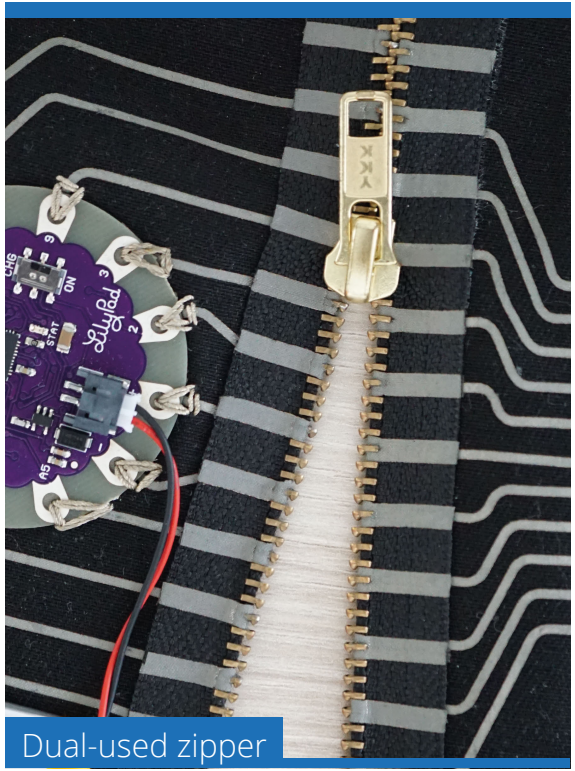


Multi-layer tapes



Multi-layer circuits

Utilizing Textile Accessories



Dual-used zipper

Input

Pressure 

Deformation 

Touch 

Identify 

...

Wiring

Traces 

Fabric Resistors 

Breakouts 

...

Output

Heating 

Displays 

Light 

Actuation 

...

Computing

Semi-Flex MCUs 

Inductive Charging 

Solar Cells 

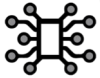
...

Library of Components

Input

- Touch 
- Pressure 
- Deformation 
- Identify 

Wiring

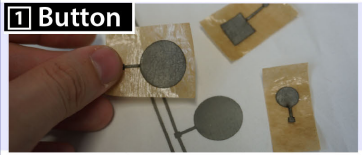
- Traces 
- Fabric Resistors 
- Breakouts 
- Semi-Flex MCUs 
- Inductive Charging 
- Solar Cells 

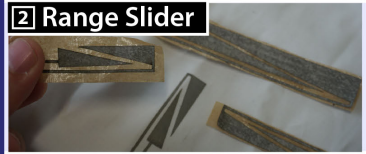
Output

- Heating 
- Displays 
- Light 
- Actuation 

Computing

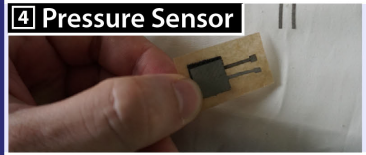
A Input

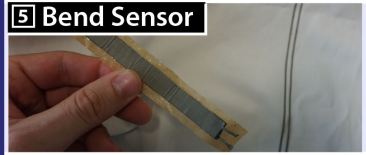
1 Button

Thickness 110µm
Sensing C
Form Type

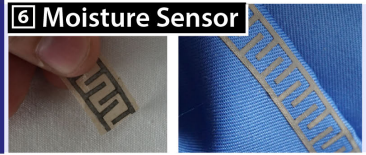
2 Range Slider

Thickness 110µm
Sensing C
Form Type

3 Slide Joystick

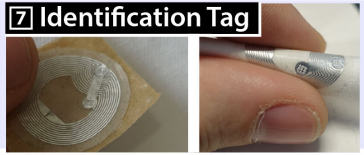
Thickness 110µm
Sensing C
Form Type

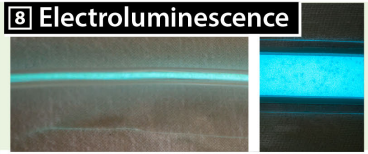
4 Pressure Sensor

Thickness 580µm
Sensing
Form Type

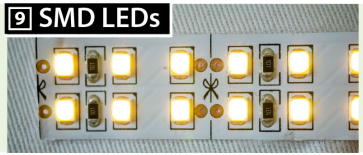
5 Bend Sensor

Thickness 580µm
Sensing
Form Type

6 Moisture Sensor

Thickness 110µm
Sensing
Form Type

B Output

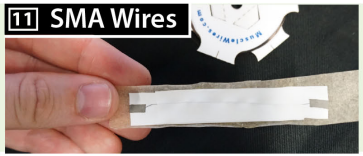
7 Identification Tag

Thickness 250µm
Sensing NFC
Form Type

8 Electroluminescence

Thickness 230µm
Driver 120V AC
Form Type

9 SMD LEDs

Thickness 1mm
Driver 5-12V DC
Form Type

10 E-Ink Display

Thickness 300µm
Driver Chip, IC
Form Type

11 SMA Wires

Thickness 250µm
Driver 5-12V DC
Form Type

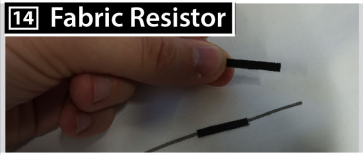
12 Heating

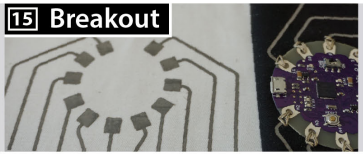
Thickness 110µm
Driver 5-12V DC
Form Type

C Wiring

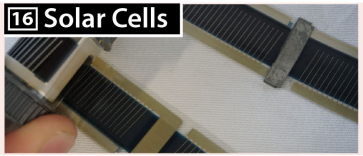
13 Traces

Thickness 110µm
Conductivity 0,1 Ω/cm
Form Type

14 Fabric Resistor

Thickness 500µm
Conductivity Ω, kΩ, mΩ
Form Type

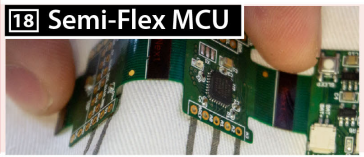
15 Breakout

Thickness 110µm
Conductivity 0,1 Ω/cm
Form Type

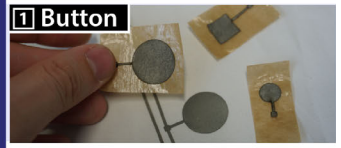
D Computing

16 Solar Cells

Thickness 150µm
Power 5-12V DC
Form Type

17 Inductive Charging

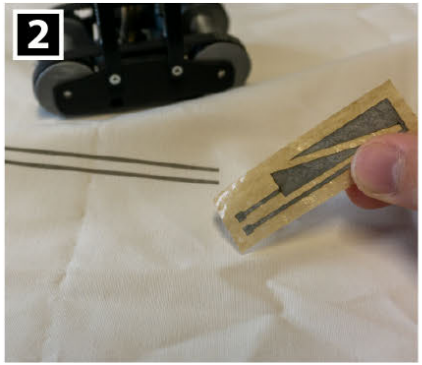
Thickness 110µm
Power 5-12V DC
Form Type

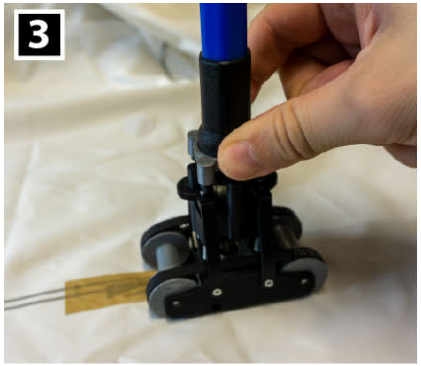
18 Semi-Flex MCU

Thickness 1,7mm
Capbilitites Arduino
Form Type

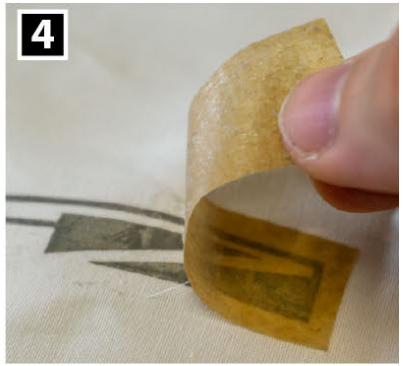


Touch: Buttons & Sliders

Example how to integrate capacitive user controls







Input

1 Button

2 Range Slider

3 Slide Joystick

4 Pressure Sensor

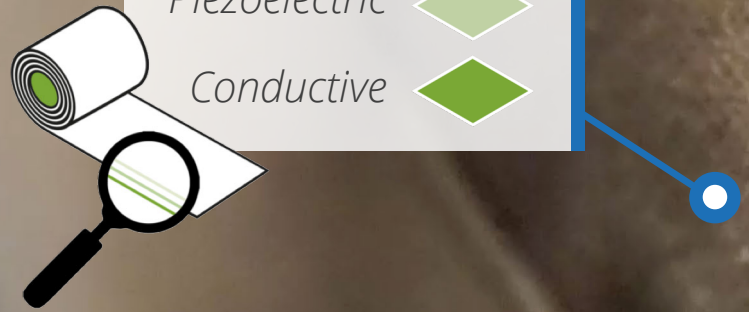
5 Bend Sensor

6 Moisture Sensor

7 Identification Tag

Force: Pressure & Bend

Example how to integrate resistive sensors



Input

1 Button

2 Range Slider

3 Slide Joystick

4 Pressure Sensor

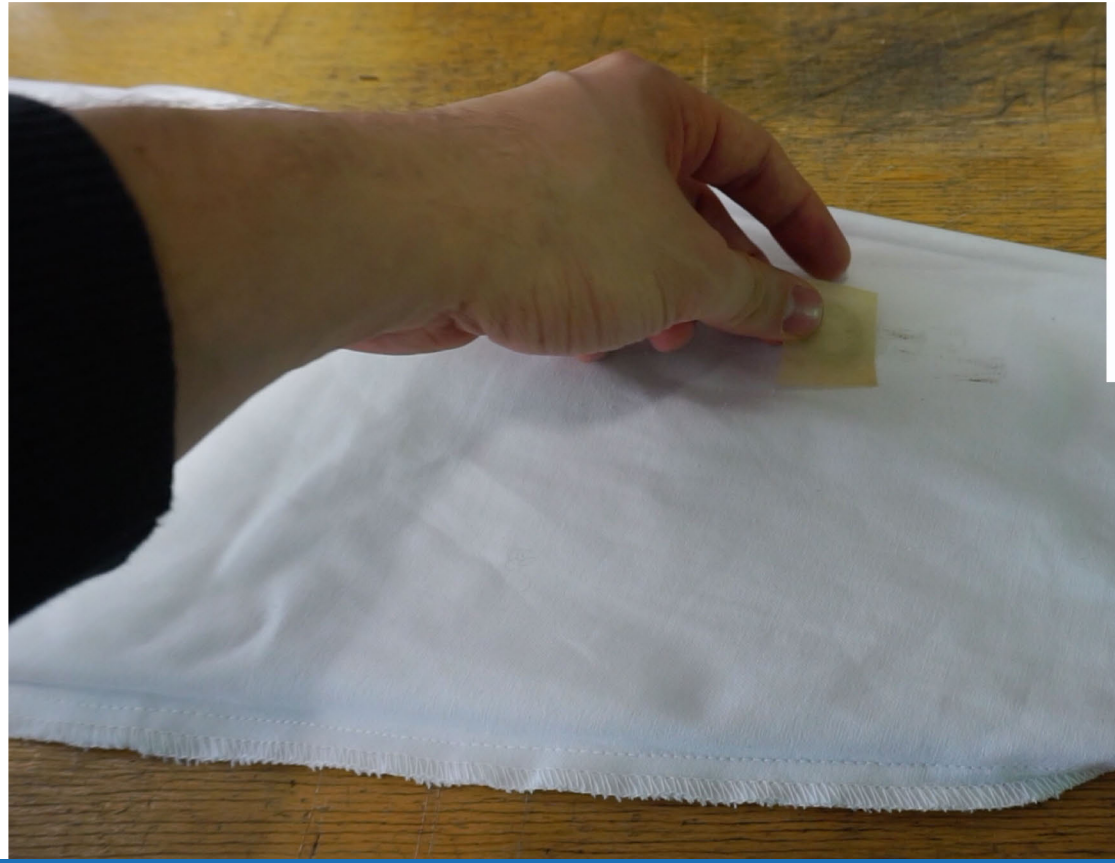
5 Bend Sensor

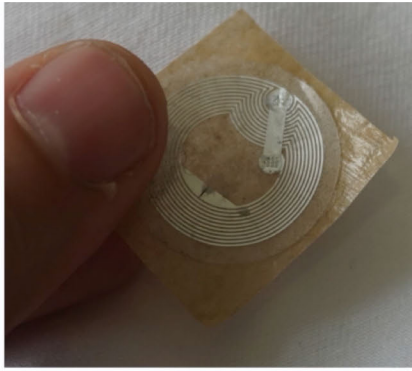
6 Moisture Sensor

7 Identification Tag

Identify: NFC Tags

Example how to integrate existing printed electronics components





NFC Tag

Output

8 Electroluminescence

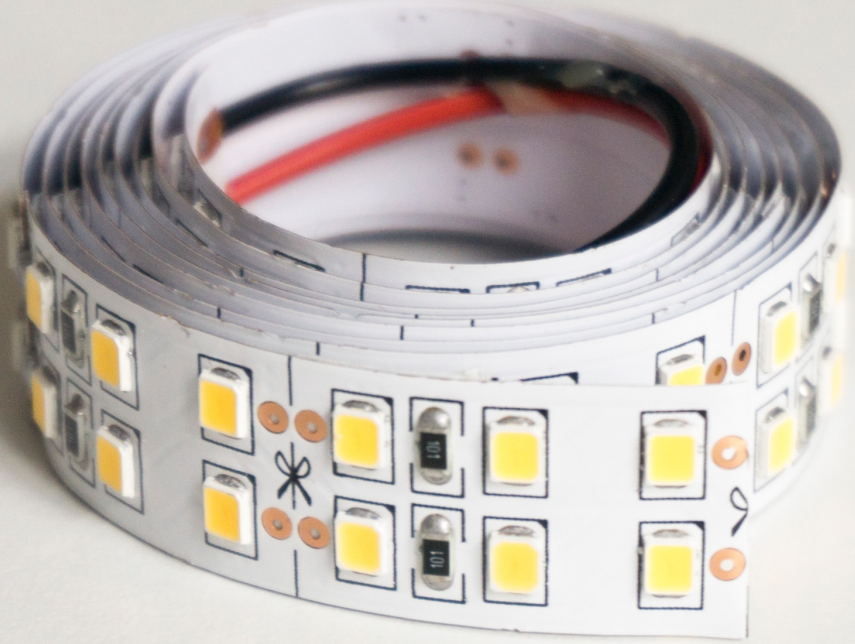
9 SMD LEDs

10 E-Ink Display

11 SMA Wires

12 Heating

How to iron semi-flex SMD electronics?



8 Electroluminescence

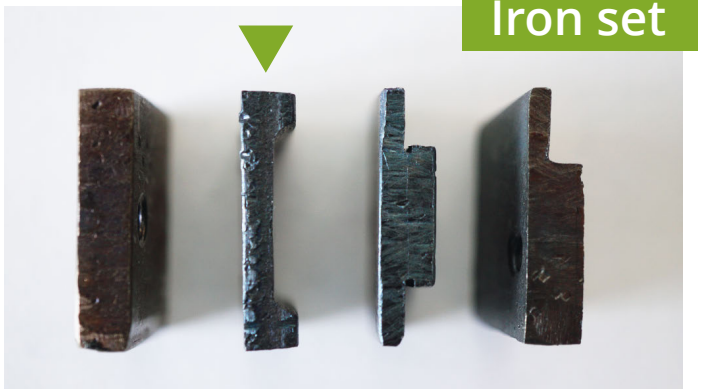
9 SMD LEDs

10 E-Ink Display

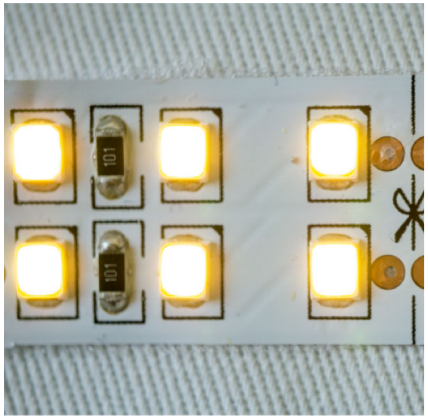
11 SMA Wires

12 Heating

Iron-on
SMD-LED tape



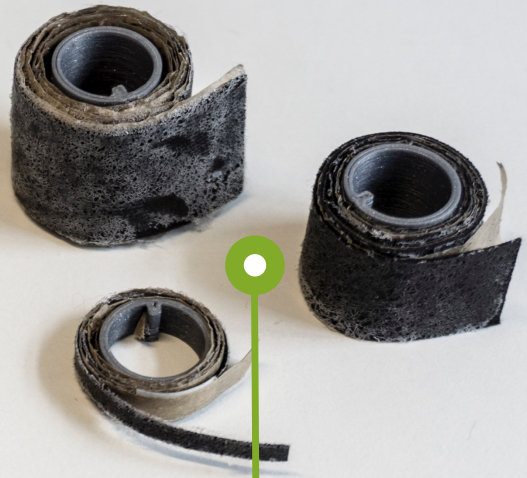
Iron set



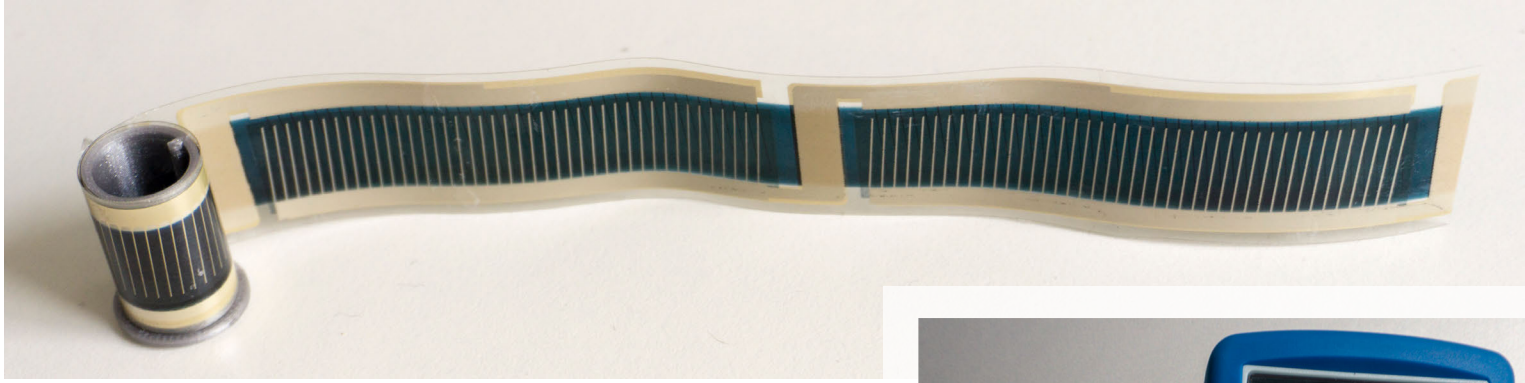
U-shaped iron
heats only edges

Heating Components

Resistive Heating Patch



Resistive Heating Tape

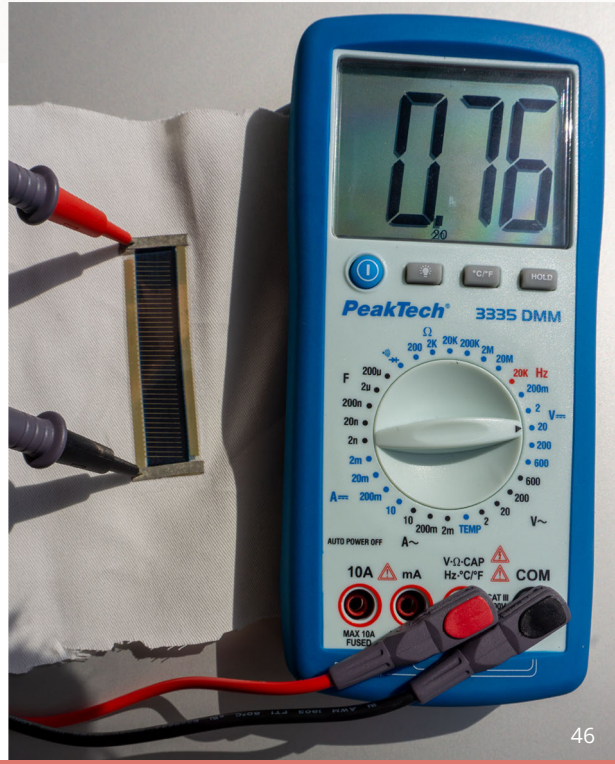


Printed Organic Solar Cells

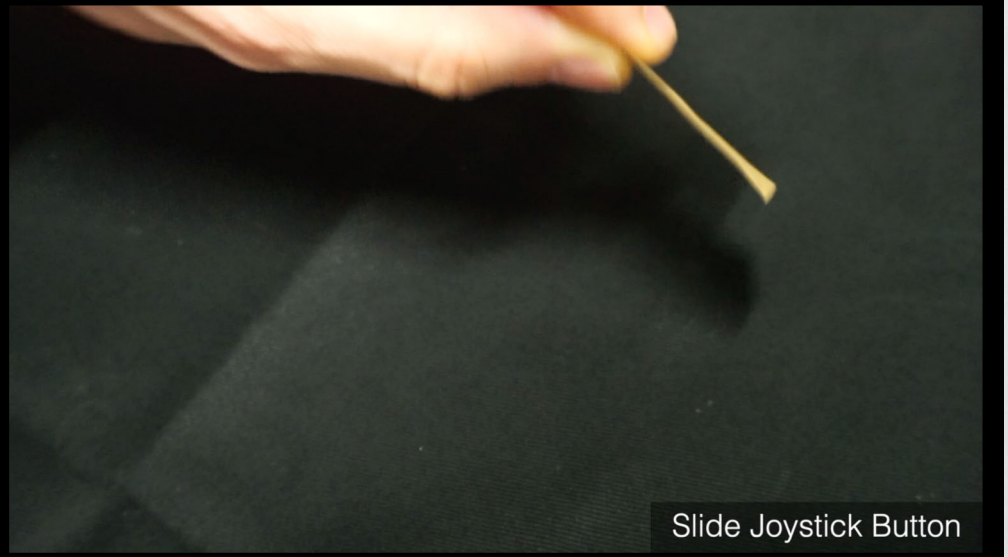
(infinityPV)

Example how to integrate existing printed electronics components

- **Cuttable:** at any position
- **Thickness:** 150µm
- **Voltage:** 8- 9V / m
- **Power:** 40-50mA / m



Example Applications



1 Smart Cuff

slide joystick patch

- demonstrates how ***existing garments*** can be easily augmented using functional patches.

Example Applications

1 **Smart Cuff**

slide joystick patch

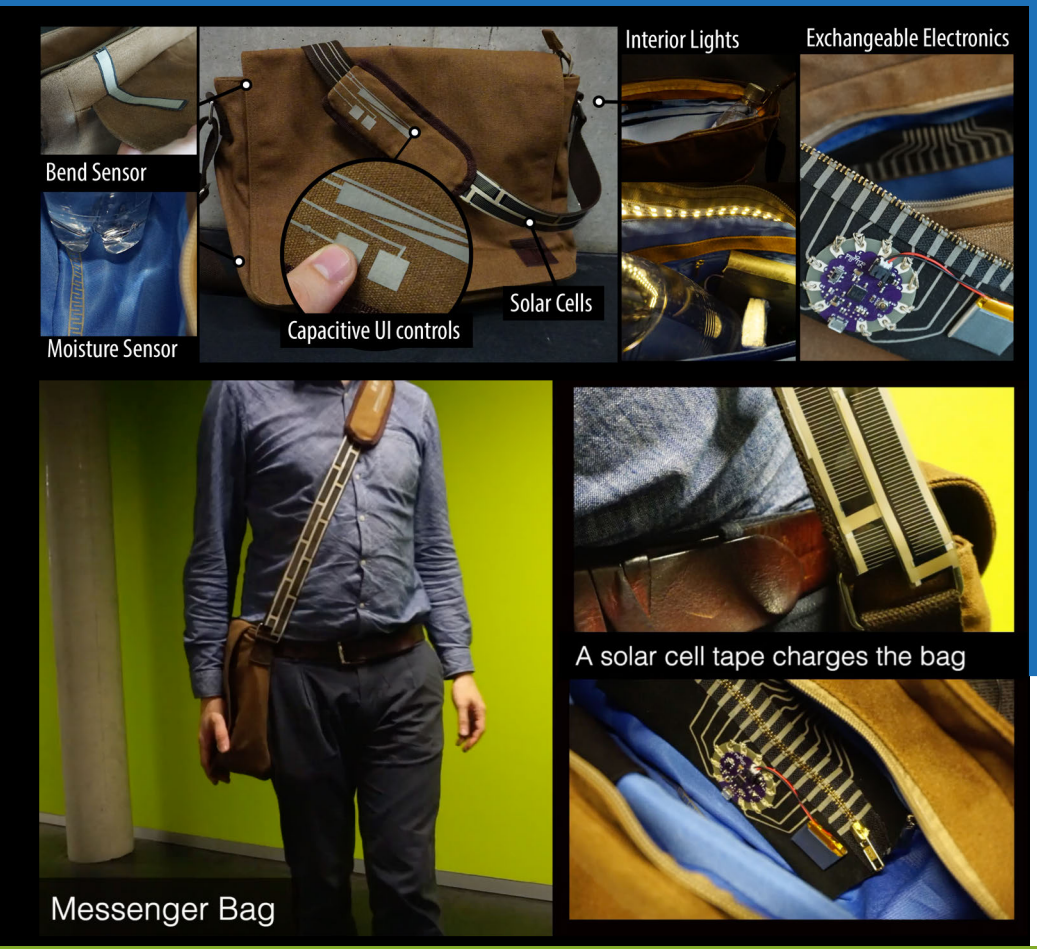
▶ demonstrates how ***existing garments*** can be easily augmented using functional patches.

2 **Doctor's White Coat**

NFC tag, e-ink display

▶ demonstrates how ***advanced electronics*** can be easily integrated by ironing.

Example Applications



1. **Smart Cuff**
   slide joystick patch

   ▶ demonstrates how ***existing garments*** can be easily augmented using functional patches.

2. **Doctor's White Coat**
   NFC tag, e-ink display

   ▶ demonstrates how ***advanced electronics*** can be easily integrated by ironing.

3. **Interactive Messenger Bag**
   bend sensor, capacitive controls, SMD-LEDS, zip-on electronics, solar tapes, moisture sensor

   ▶ demonstrates how ***complex textile products*** with non-planar surfaces can be enhanced with smart functions.

Expert Reviews

Textile Design Expert (P1)
Co-director of the textile & materials design department of an internationally recognized French design university.

Fashion Design Expert (P2)
Has expertise in practice-based and design-led research investigating tailoring.

Machinery & Fiber Expert (P3)
Research associate working at a large textile machinery research institute in Germany

Approx. 60 min. per session

Semi-structured interview

Hands-on sessions

Study I: Textile & Fashion Experts

Study II: Machinery & Fiber Expert

Interviews & Hands-On Insights

Textile & Fashion Experts

» *The iron-on roll & patch approach is in-between large-scale production and manual crafting – this makes absolutely sense* «

» *... important to work from the beginning with final materials to consider the visual and sensory qualities in the whole design process.* «

Machinery & Fiber Expert

... compared the rapid iron-on approach with other e-textile solutions like embroidery and knitting:

- ⊕ Production time
- ⊕ Required knowledge
- ⊕ Costs

- ⊙ Comparable in the scope of functionality

- ⊖ Durability
- ⊖ Degree of integration

Conclusion

Rapid Iron-On User Interfaces

- Novel Fabrication Technique for E-Textiles
- Handheld Ironing Tool
- Library of Components
- Example Applications
- Technical Experiments & Expert Reviews

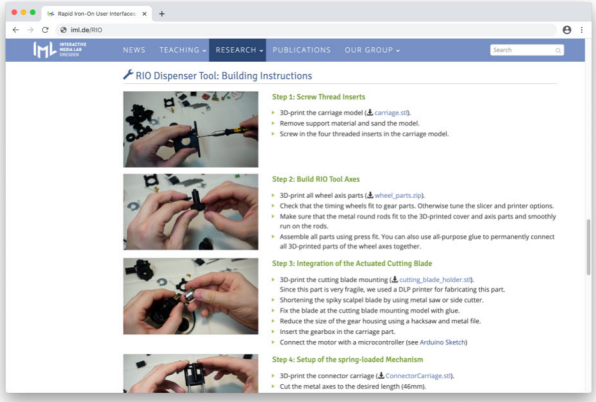
Thank you for your attention!

Additional Resources

Rapid Iron-On User Interfaces:

Hands-on Fabrication of Interactive Textile Prototypes

Konstantin Klamka, Raimund Dachselt, Jürgen Steimle



Questions?

klamka@acm.org

Project Website

imld.de/RIO

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