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School of Electronics and Computer Science

INTEGRATION OF FLEXIBLE CIRCUITS IN TEXTILES FOR WEARABLE HEALTH MONITORING

13th Vienna International Workshop on Functional Electrical Stimulation

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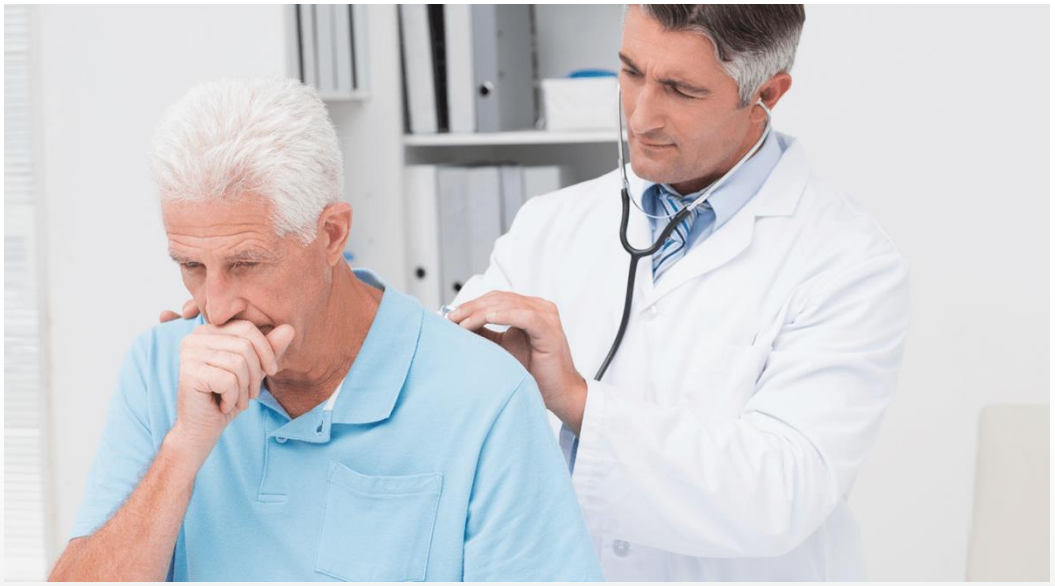
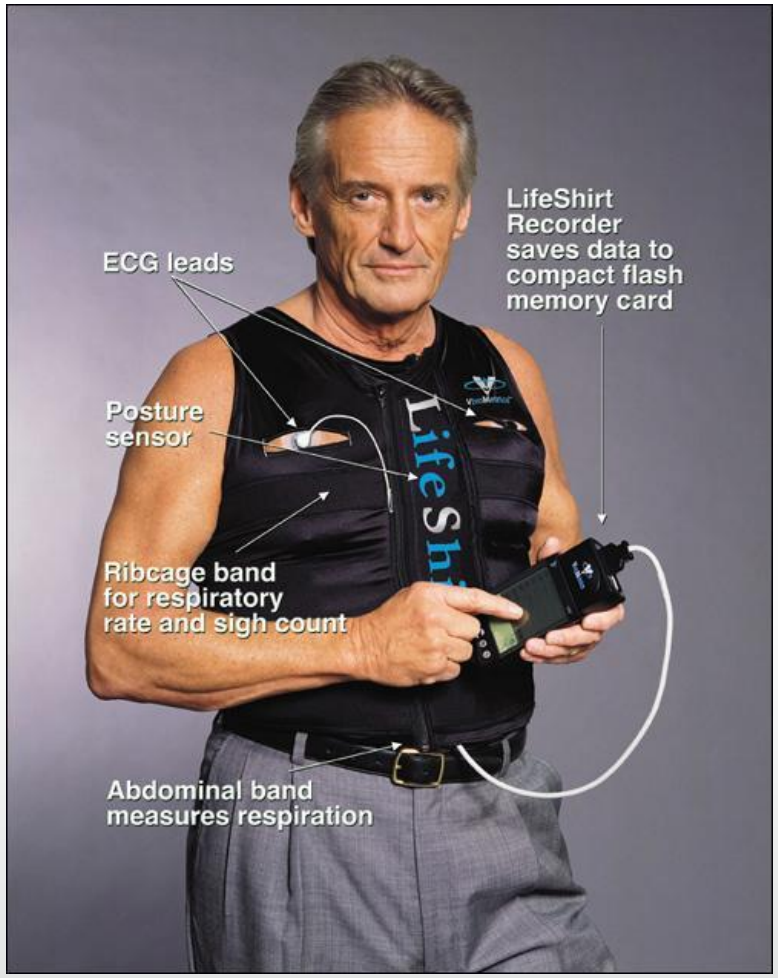
WHY?

- Health monitoring (in some cases in real time) is necessary for early diagnosis, prevention or managing certain type of diseases.
- Patients can easily manage their health with access to portable health monitoring devices
- Textiles can become the nearest and non-invasive clinic to a patient if properly functionalised.
  - With minimal or no effort from the patient



Real-time health monitoring of patient

First generation approach



a. The Lifeshirt by Vivometrics (2001)

b. ICD+suit by Levi and Phillips Electronics (2003)

c. Solar powered SCOTT eVest (2004)

First generation approach

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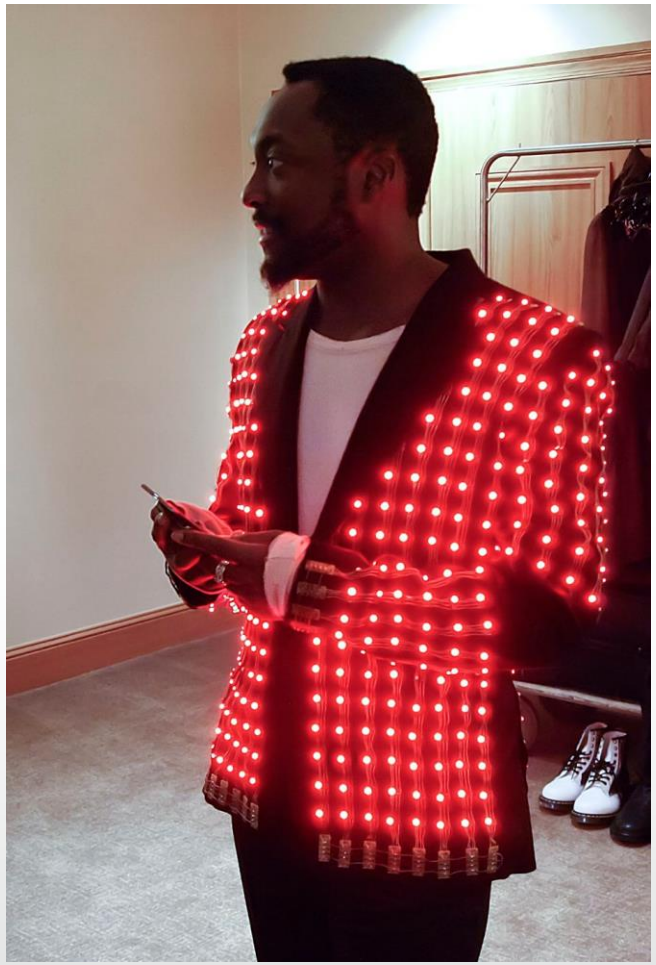
- E-textiles
  - Enclosed conventional portable electronics into pockets within the textile.
  - Can be uncomfortable to wear over extended periods due to the rigidity and accumulative weights of enclosed electronics.
  - Can lack desired fashion or aesthetics.
  - Electronics need to be detached before washing.



LED jacket for performance artists

E-textiles: Early techniques

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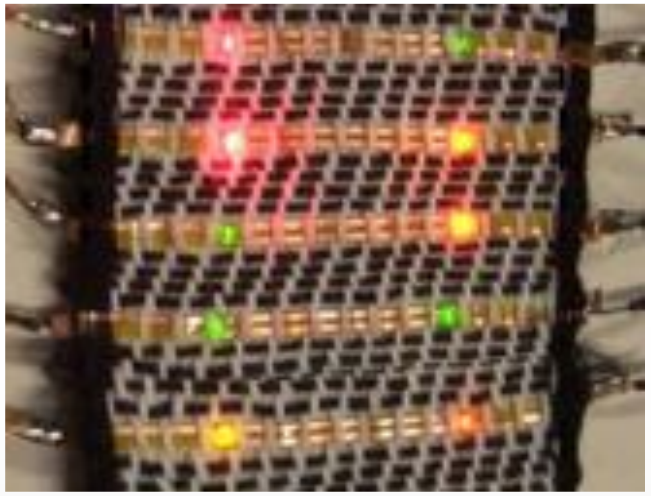
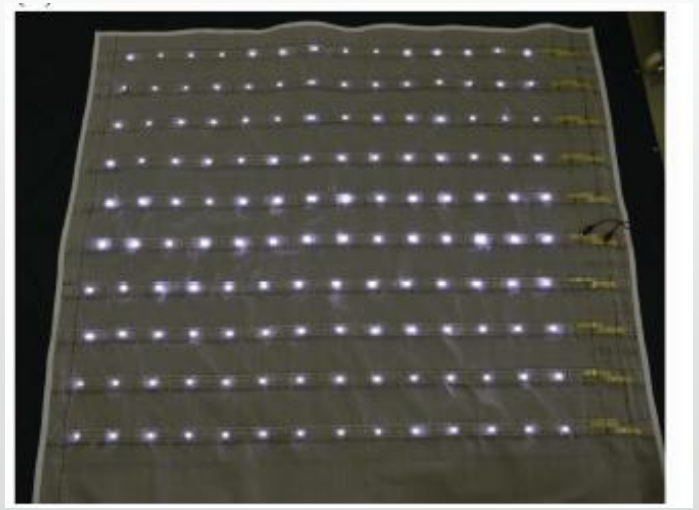
- Conductive inks:

- Conductive yarns:

- Conductive plastics:





Exploiting miniaturized electronic components

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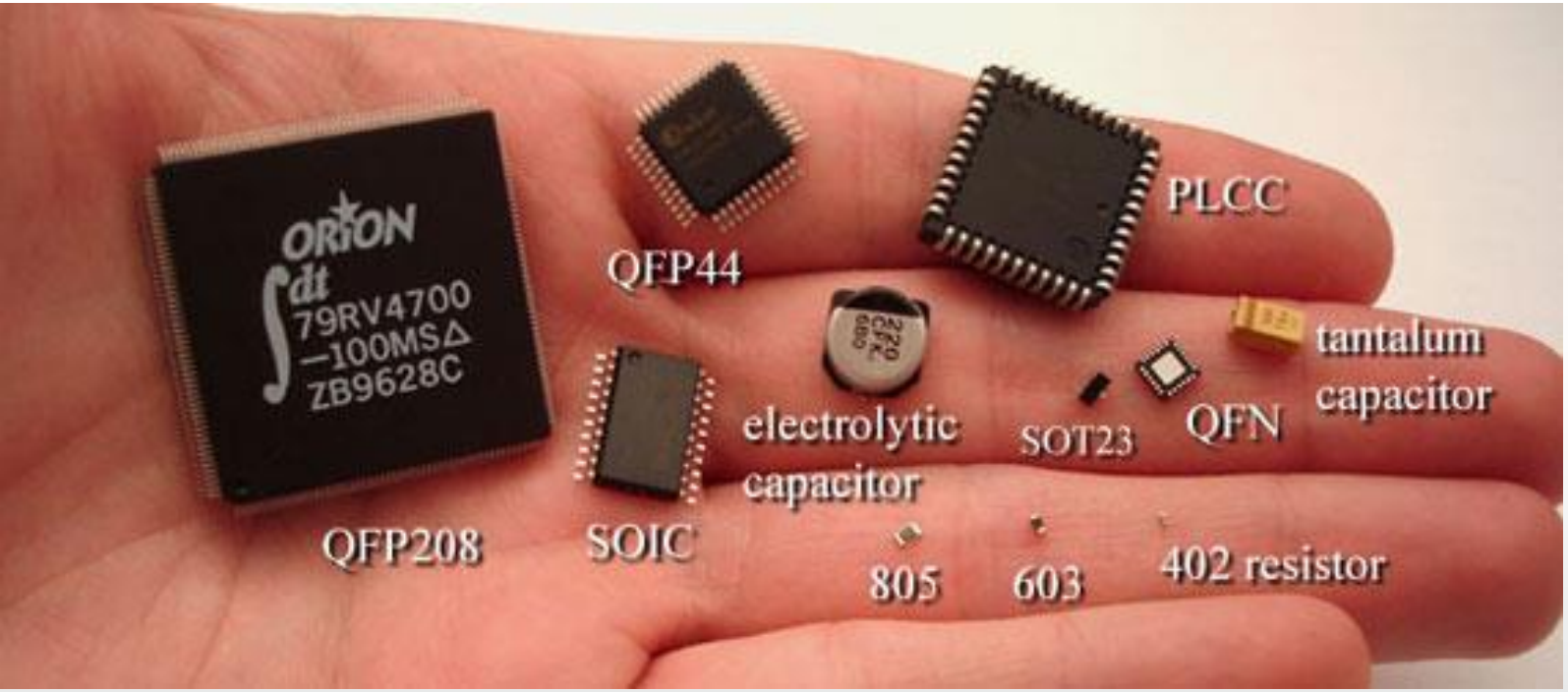
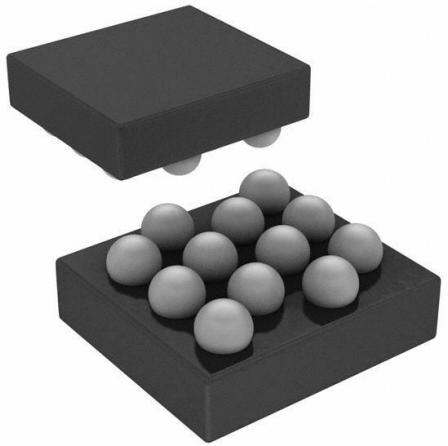
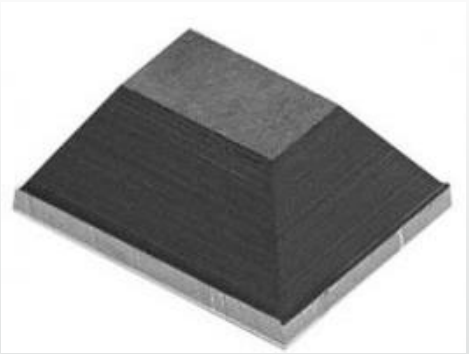




Smallest Microcontroller
Size: 1.56 mm x 1.4 mm x 0.54 mm



Smallest LED
Size: 0.24 mm x 0.32 mm x 0.14 mm

Typical pin head for comparison

E-textiles: The state of the art

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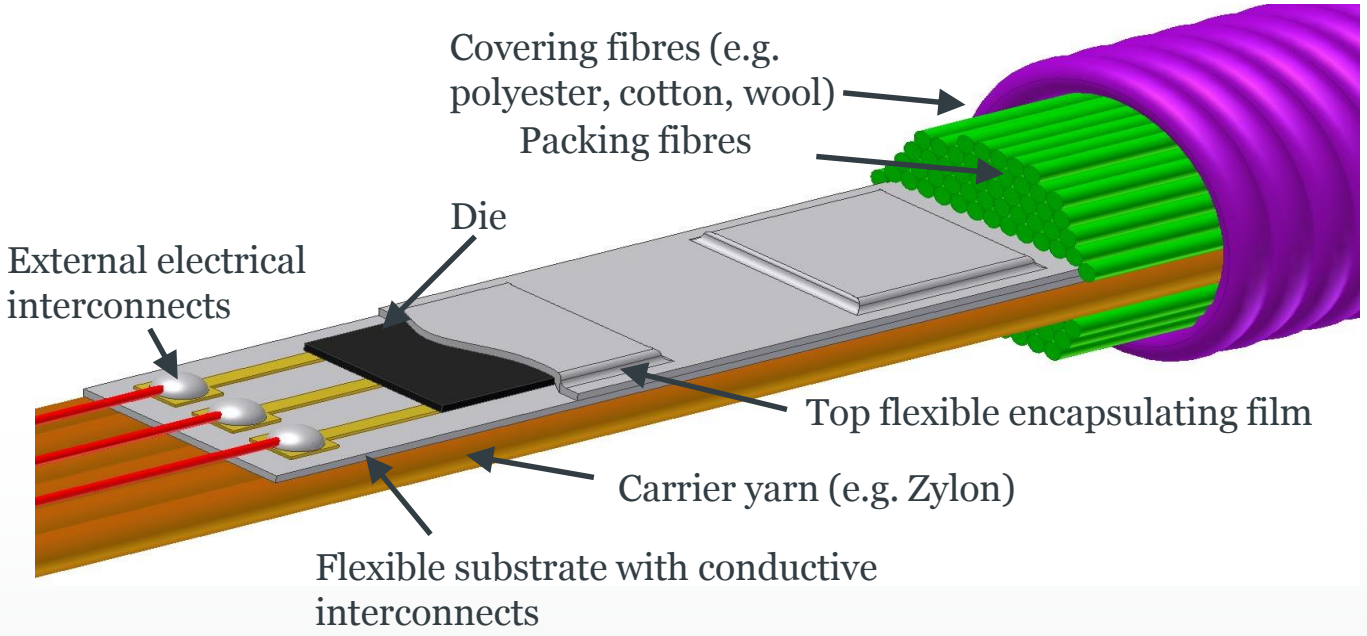
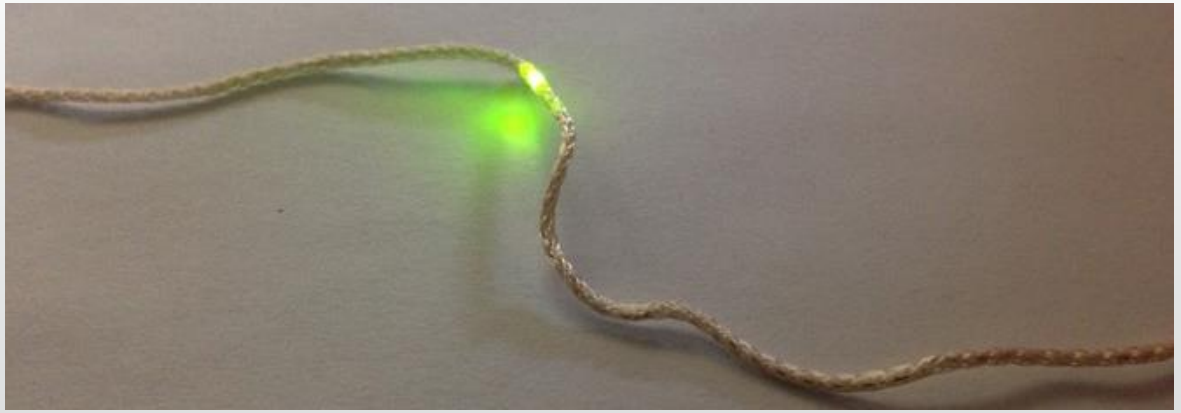
- UoS research and development of new scalable manufacturing and assembly methods that add electronic functionality to textiles.
- Adopted techniques:
  - Knitting of electronic yarns
  - Weaving of electronic filaments (< 2mm wide) into fabrics during manufacture

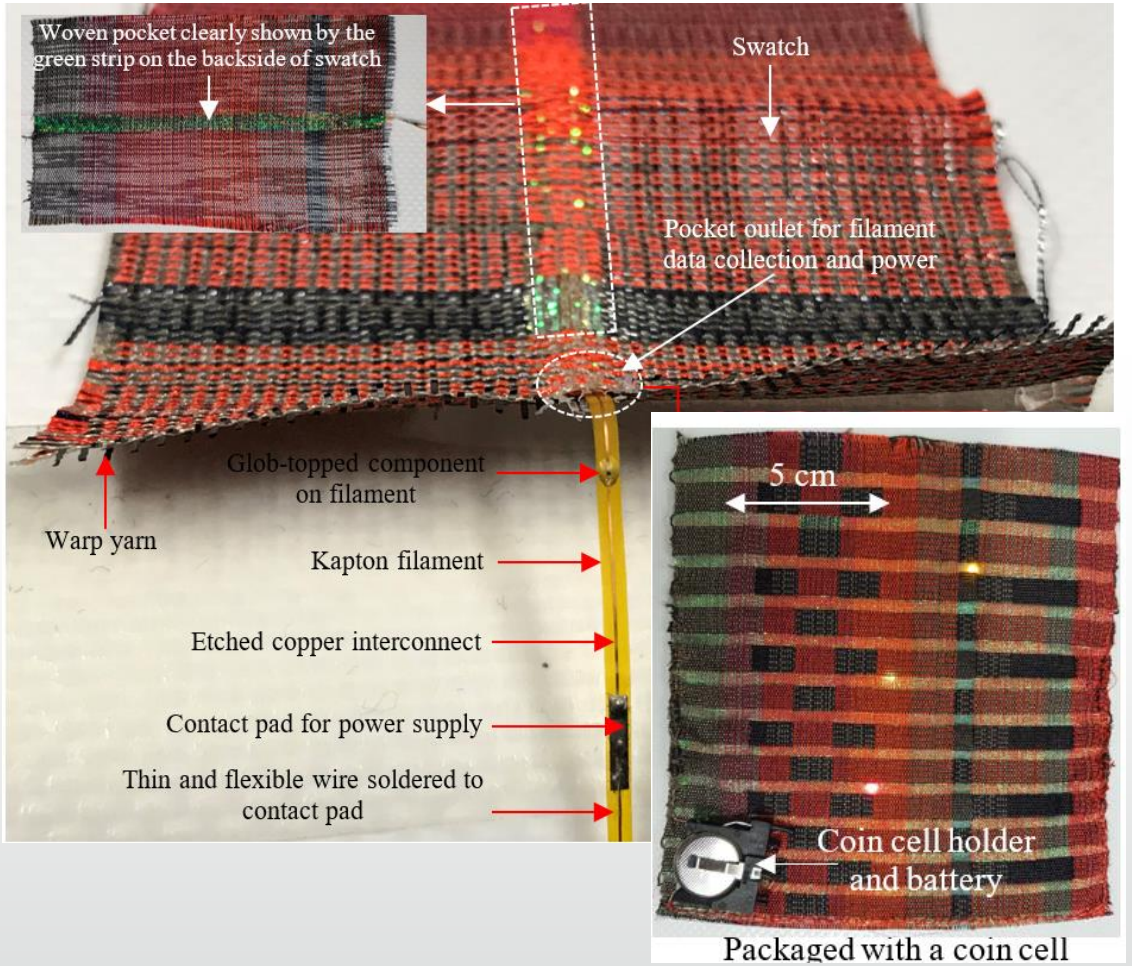




State of the art integration

- To improve wearability of emerging fabrics after electronic integration

- Challenges include circuit fabrication, electrical connections, integration within the yarn/fabric, manufacturability, ***reliability***.



State of the art integration

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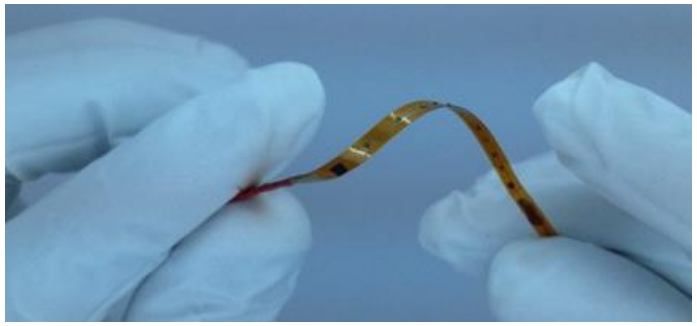
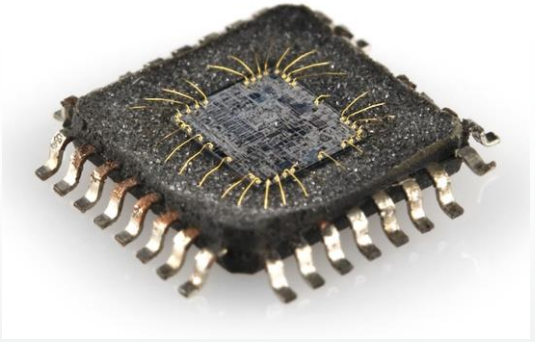
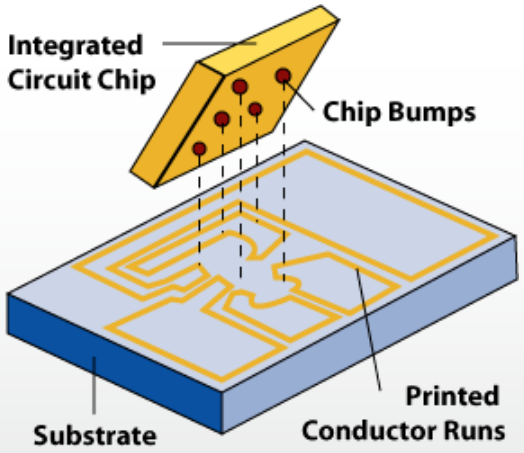
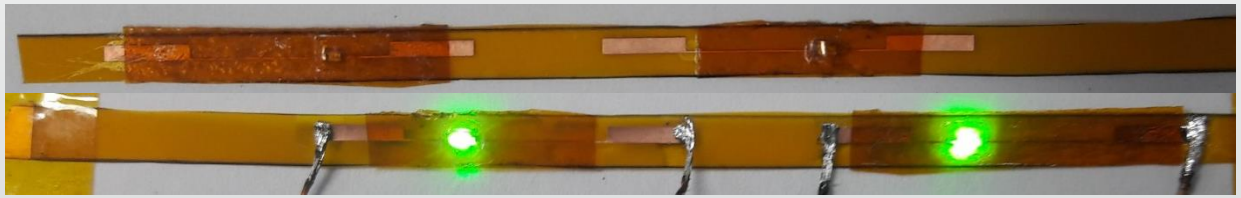
- Key stages:
  - Flexible circuits fabricated by photolithography and etching.
  - Minimise size by using bare silicon chips and flip chip packaging techniques.
  - Circuit encapsulation and protection using two layers of Kapton.
  - Yarn/woven textile integration and electrical connection.



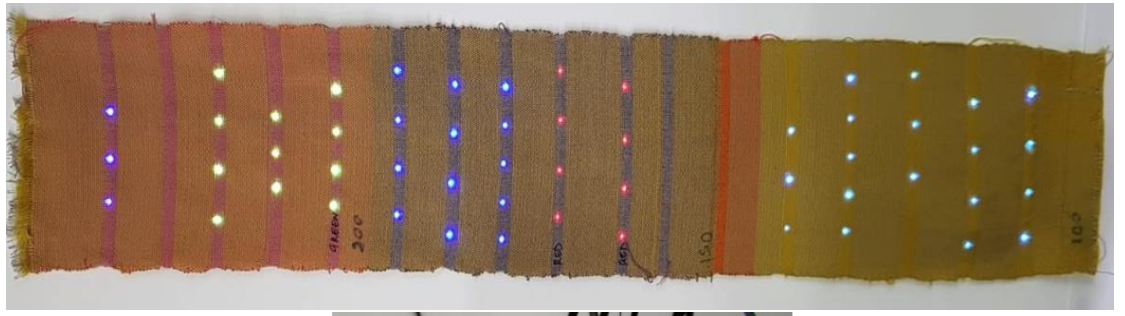


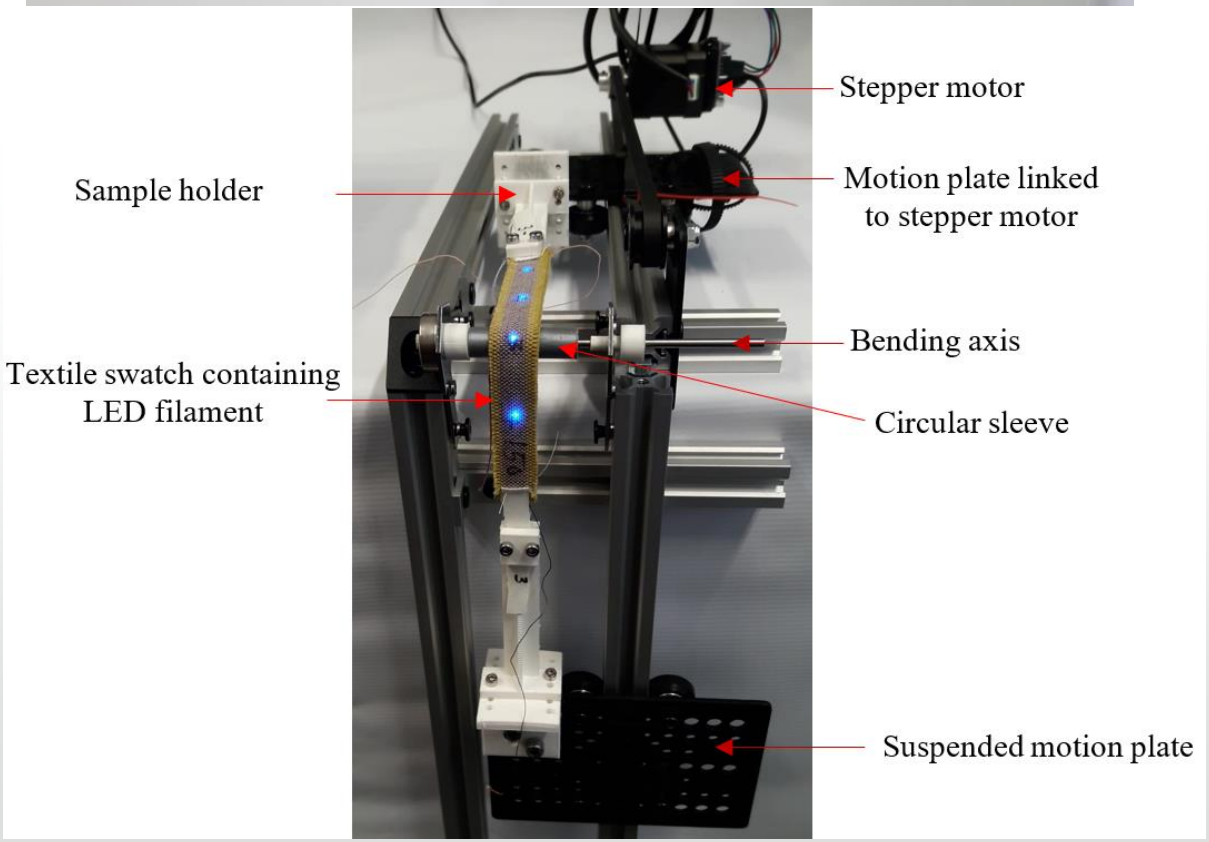




Reliability questions

- This a reliable process for manufacturing e-textiles of different garment sizes.
- Integrated circuits, die and electrical connections need to withstand the physical weaving and knitting processes plus the rigors of use.
  - Prototypes already survive weaving and knitting process
  - Post integration, prototypes survive up to 45 wash cycles and more than 1500 bending cycles





Health applications of prototype filaments

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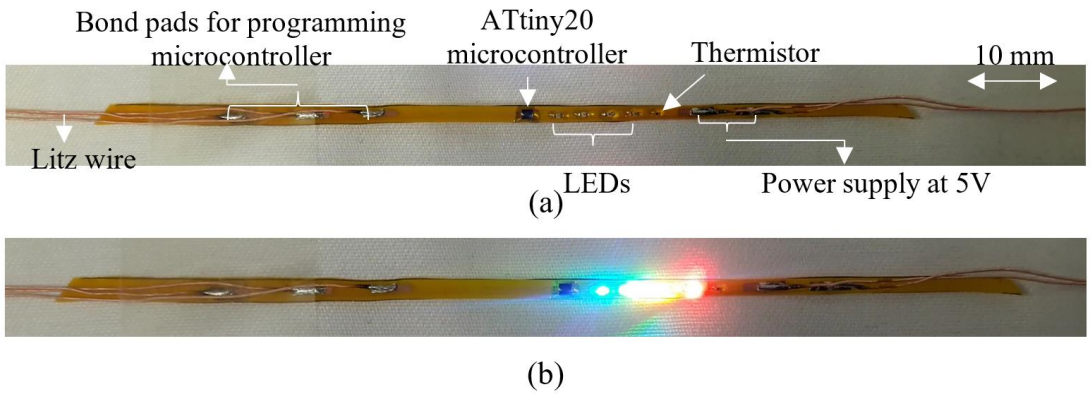
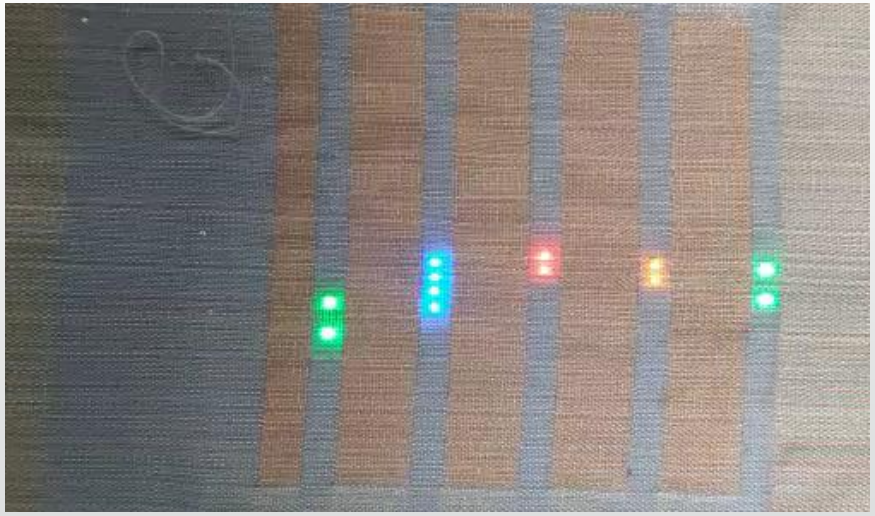
LED/Temperature sensing filament





- LEDs can be used as a light source for pulse oximetry (the measurement of oxygen saturation i.e. oxygen-carrying haemoglobin in the blood)
- Temperature sensing filaments can be used in the monitoring of foot ulcer and wound infections of diabetic patients, changes in skin or ambient temperatures and for cardiovascular health evaluations.

Accelerometer filament

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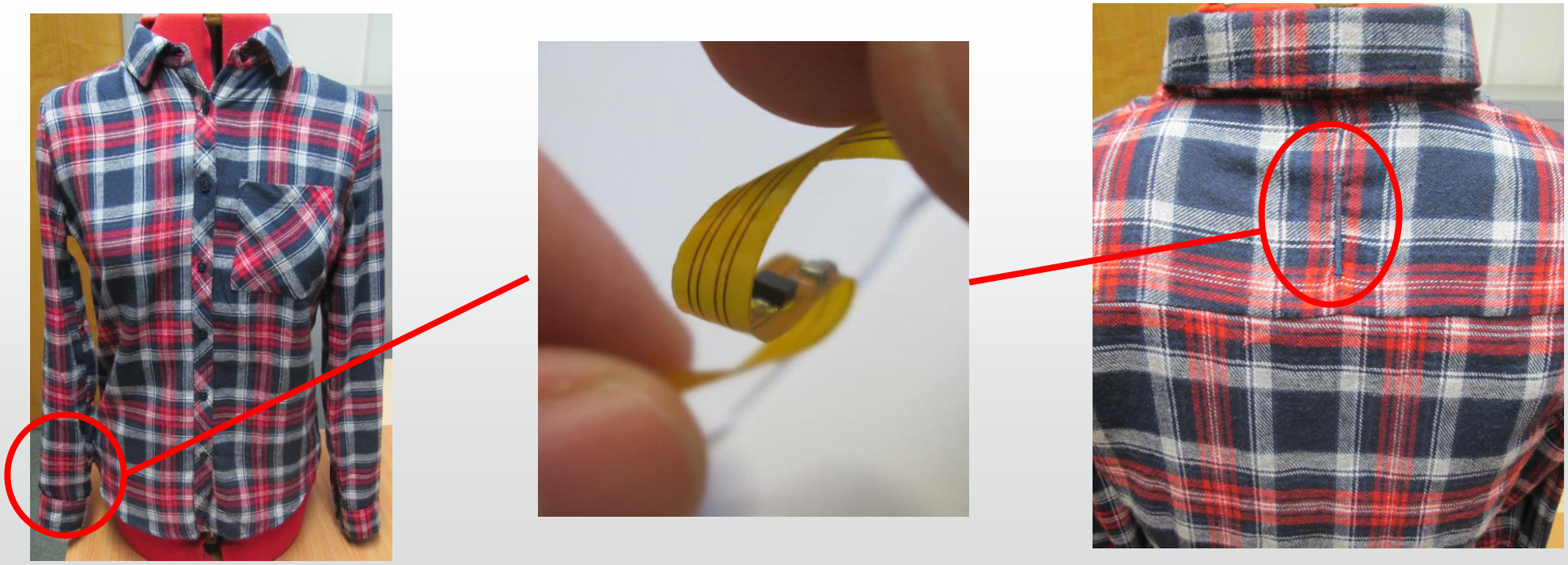
- Accelerometer filaments of 2.4 mm width are also connected together and integrated within a garment.
- Detects motion of the wearer which is useful for health monitoring for sportsmen.
- Can be used to detect wearer's location



Enhancement to WEARPLEX

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The fine circuit resolution of the UoS process will be used to realise

- The H-bridge switching circuits within the fabrics using bare die components to enhance integration of the entire FES electrodes and circuitry with the fabric.
- To provide flexible and robust interconnects between the printed FES/EMG electrodes and external circuits.

Screen printed functional electrical stimulation electrodes

Conclusions

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- Electronics are crucial for health diagnosis and disease prevention.
- As the size of electronic component reduce, seamless integration of electronics functionality in fabrics will benefit patients by providing continuous, remote and in-situ health monitoring.
- The WEARPLEX project aims to use a hybrid process consisting of screen printing of conductive inks and weaving of electronic filaments to achieve robust electrodes and electronics for recording of electrophysiological signals or delivering targeted electric charge.
- This will benefit stroke patients and be adapted to treat other neurological conditions such as head injury, multiple sclerosis as well as musculoskeletal problems such as joint and back pain.

Thanks