Introduction to EU-H2020 project WEARPLEX: Wearable multiplexed biomedical electrodes

Gamma Workshop

Dr Russel Torah

Project coordinators: University of Southampton, UK

Gamma Workshop
17th February 2021

H2020-ICT-02-2018

Overview

» Agenda for Workshop

» Introduction to WEARPLEX project and concepts

» Project Partners

» State of the art multi-electrode systems for FES and EMG

» Printed logic De-multiplexor

» Printed ink development

» E-textile integration

» Mass manufacturing

» Contacts

Agenda

- 14:00 – 14:20 - Project overview
- 14:20 – 15:10 - Introduction to Technologies used in WEARPLEX
- 15:10 – 16:05 – WEARPLEX demonstrations.
- 16:05 – 16:25 – End user partner presentations
- 16:25 – 16:35 – Q&A discussion with consortium
- 16:35 – Concluding remarks and future collaborations
- 16:40 – Workshop ends

Introduction

WEARPLEX

ICT-02-2018 - Flexible and Wearable Electronics

Grant agreement ID: 825339

- **Aim:** Integrate printed electronics with flexible and wearable textile-based biomedical multi-pad electrodes.

- **Key Focus:**
  - Printed multi-pad electrodes with integrated logic circuits for FES and EMG
  - Printed electronics on textiles
  - Optimised use of high-density multi-pad electrodes

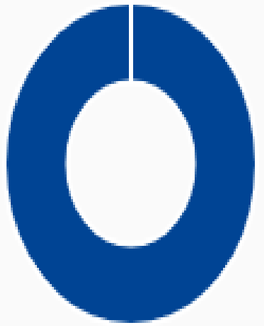
Start date
1 January 2019

End date
28 February 2022

Funded under
H2020-EU.2.1.1.

Overall budget
€ 3 732 748,75

EU contribution
€ 3 732 748,75



Coordinated by
UNIVERSITY OF SOUTHAMPTON

United Kingdom

University of Southampton
tecnalia MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE
BCMATERIALS BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
IDUN Technologies
TECHNISCHE UNIVERSITÄT CHEMNITZ
LayerOne screentec
AALBORG UNIVERSITY DENMARK
RI.SE

What is FES?

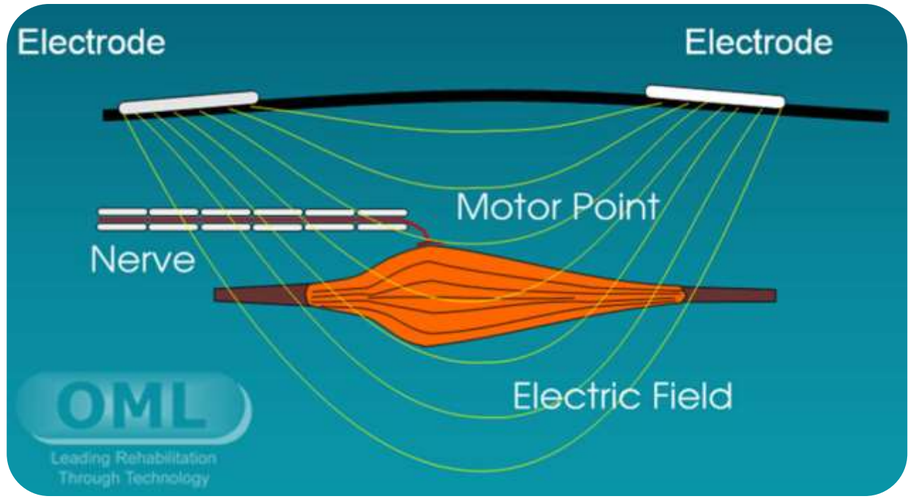
» Functional Electrical Stimulation (FES) is used to electrically stimulate motor nerves.

» Targeted to specific nerves to provide useful movement of a limb (e.g. grasping, stepping).

» Treatment for e.g. stroke survivors and spinal cord injuries: drop foot, reaching, grasping, etc.

» Typical stimulation signal between 10 and 100 Hz, 5-50 mA, 200-500 µs.

» Electrical stimulation can also be used for pain relief and haptic feedback.



Electrical stimulation of nerve to drive muscle contraction
(source: Oddstock Medical Ltd)

What is EMG?

- EMG is Electromyography – a process for measuring the electrical potential generated by muscles.
- Surface EMG: electrical activity at the skin closest to the muscle.
- Determine health of muscles and their control nerves.
- Estimate motor intention for myoelectric control.
- Signal is typically in the mV range at 10-250 Hz.
- More electrodes = muscle specific info for movements/gesture.
- Allows increased selectivity and quality.
- Improves assessment and estimation of motor intention.

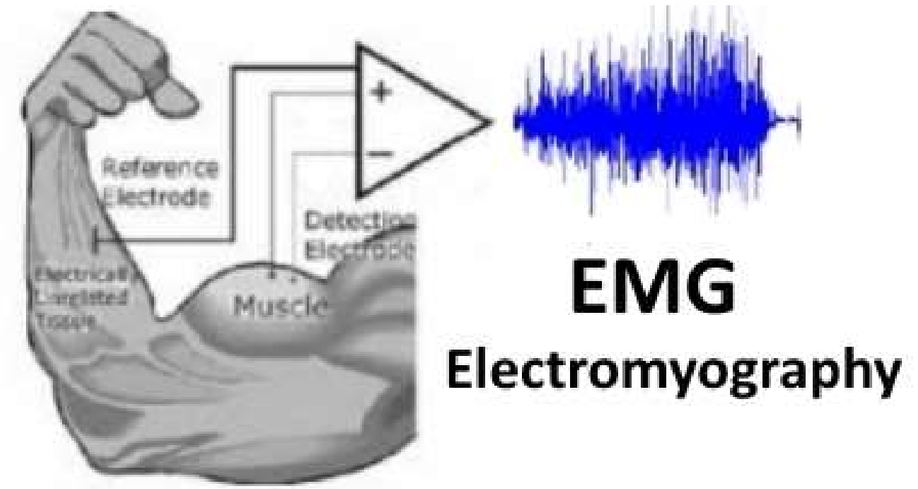


Image from: https://www.delsys.com/downloads/TUTORIAL/semg-detection-and-recording.pdf

Why WEARPLEX? - Applications

- Medical electrodes market is $1B globally, despite being mostly lab or clinic use.
- Several markets for wearable EMG and FES devices:
  - Electromyography (EMG):
    - Human-machine interfacing, EMG control – gaming, drones, smart home solutions, assisted living.
    - Muscle monitoring – sports, body posture correction, rehabilitation
  - Functional Electrical Stimulation (FES):
    - Neuromuscular Rehabilitation – e.g. Stroke:1 every 2 seconds, expected to be 70 million survivors by 2030
    - Pain relief (TENS - transcutaneous electrical nerve stimulation)
    - Reducing muscle atrophy in long term COVID patients
  - Combined EMG and FES:
    - Electrotactile feedback – VR interaction, haptic telecommunications, tele-manipulation, prosthetics.
    - Neuromuscular Rehabilitation – clinical application for rehab exercises, personalised healthcare.

Why WEARPLEX? – Multi-pad solutions

- State of the art multi-pad solutions have many advantages:
  - Simple positioning
  - Dynamic stimulation patterns
  - Fatigue offset
  - Broader recruitment level
  - High-fidelity recording of EMG

- There are two main practical limitations to their use:
  - Number of pads limited by number of leads and available connectors
  - Limited adherence to curved body parts

Why WEARPLEX?

» WEARPLEX focused on developing printed logic circuitry that allows embedded multiplexing/demultiplexing.

» Creating printed electrode pads addressable into virtual electrodes.

» Software methods developed for automatic personalization of the virtual electrodes.

» Combining with textiles will allow easier setup and adherence to all body parts.

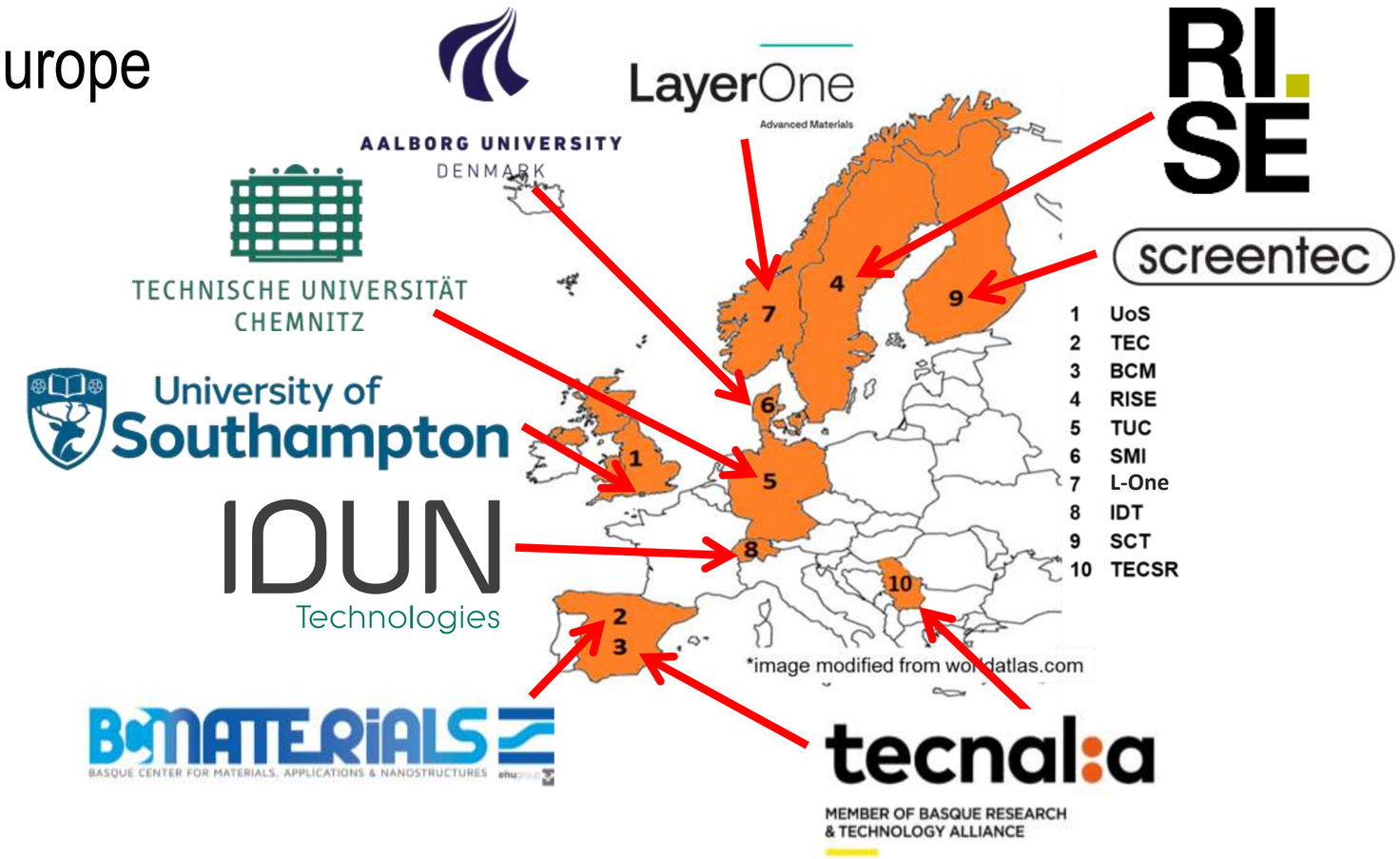
Project Partners - Locations

10 Project partners across Europe

» 3 Universities

» 4 Research Institutes

» 3 SME's



University of Southampton
tecnal:a
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE
BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
IDUN Technologies
TECHNISCHE UNIVERSITÄT CHEMNITZ
LayerOne
screentec
AALBORG UNIVERSITY
DENMARK
RI. SE

Project Partners - Roles

Universities

- ***University of Southampton* (UoS)** – Coordinator – expertise in printed electronics on fabric and e-textile fabrication.
- *Aalborg University* (AAU) – Expertise in recording and analysis of EMG signals, FES applications & clinical assessment.
- *Technical University of Chemnitz* (TUC) – Printed electronics mass manufacturing.

Research Institutes

- *Tecnalia Research and Innovation* (TEC/TECSR) (Spain and Serbia)– Expertise in multi-pad electrodes, FES applications, biomaterials and stimulation/recording electronics.
- *Basque Centre for Materials, Applications and Nanostructures* (BCM) – Expertise in printed ink development.
- *Research Institutes of Sweden* (RISE) – Printed electrochemical transistors and logic devices.

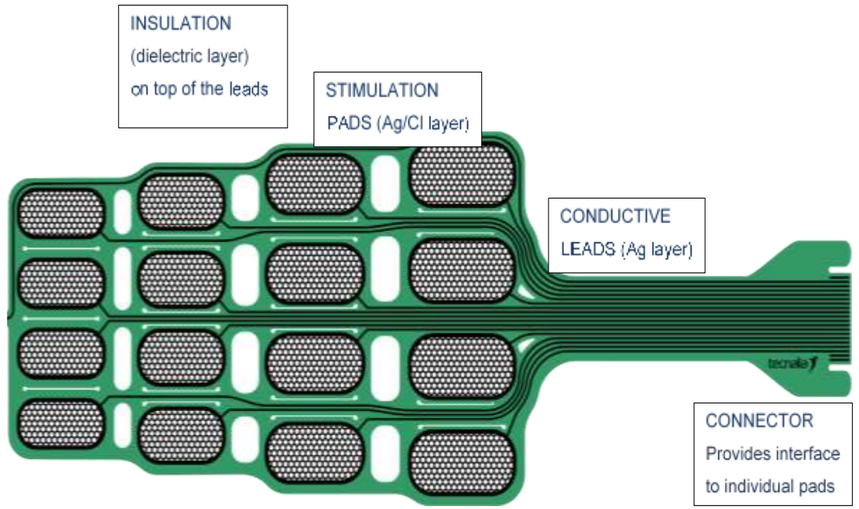
SMEs

- *IDUN Technologies* (IDUN) – Expertise in electrode design and biopotential monitoring.
- *LayerOne* (L-One) – Expertise in GO and rGO for printed electronics.
- *Screentec* (SCT) – Expertise in industrial printed electronics and medical devices.

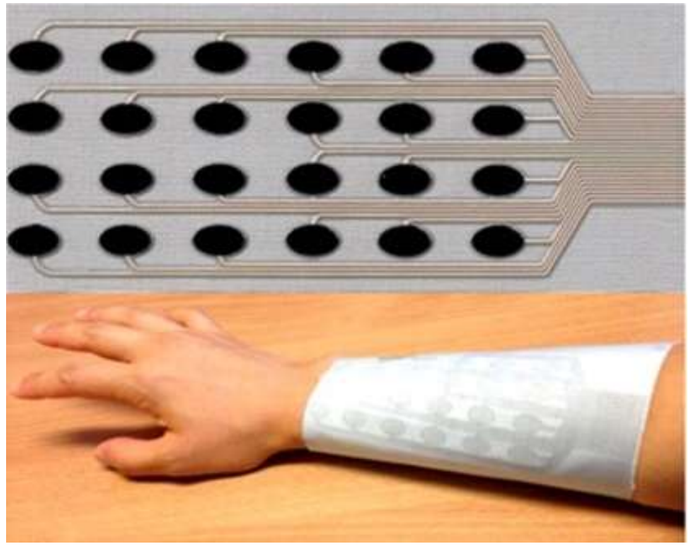
University of Southampton
tecnalia MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE
BCMATERIALS BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
IDUN Technologies
TECHNISCHE UNIVERSITÄT CHEMNITZ
LayerOne
screentec
AALBORG UNIVERSITY DENMARK
RI.SE

State of the Art Electrode Technology

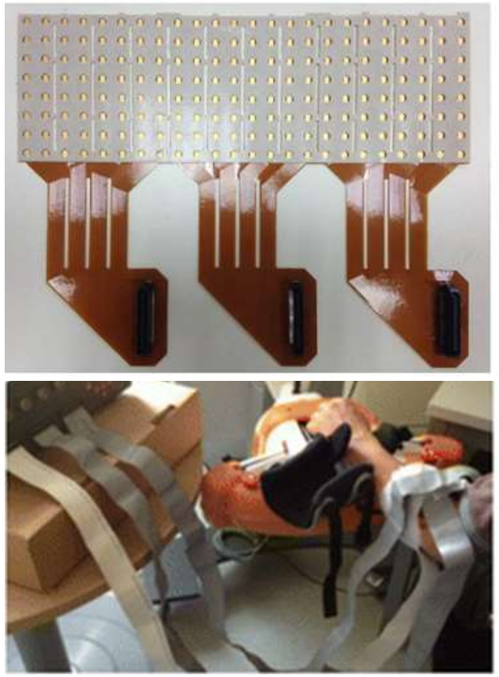
» Existing multi-pad electrode structures using printed electronics on flexible plastic and fabric.



Printed FES electrode array on plastic (TEC)



Printed FES electrode array on fabric (UoS)
(Yang et al - Sensors (2018)- 18(8), 2410)



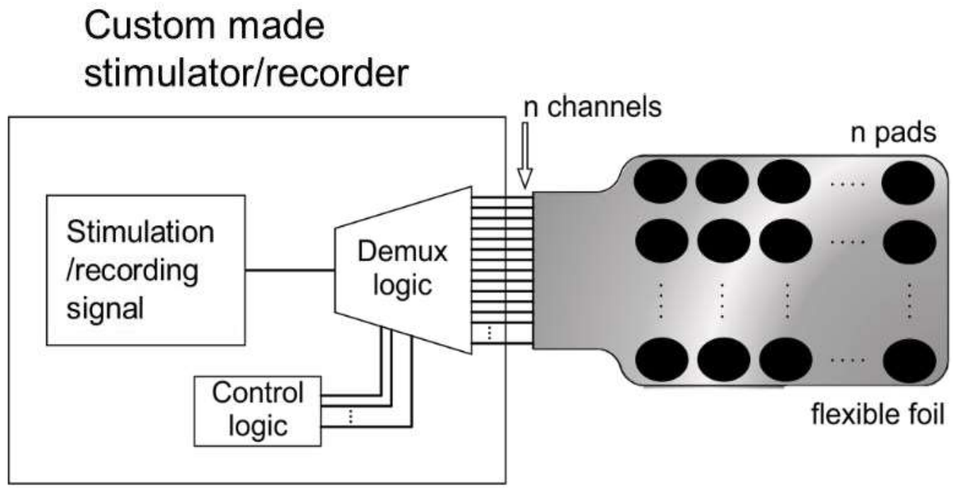
Etched copper EMG electrode array on plastic, extensive cabling required

» For each device, the **electronics** are **connected separately** and are **not integrated** within the electrode structure. No commercial printed devices combining FES and EMG.

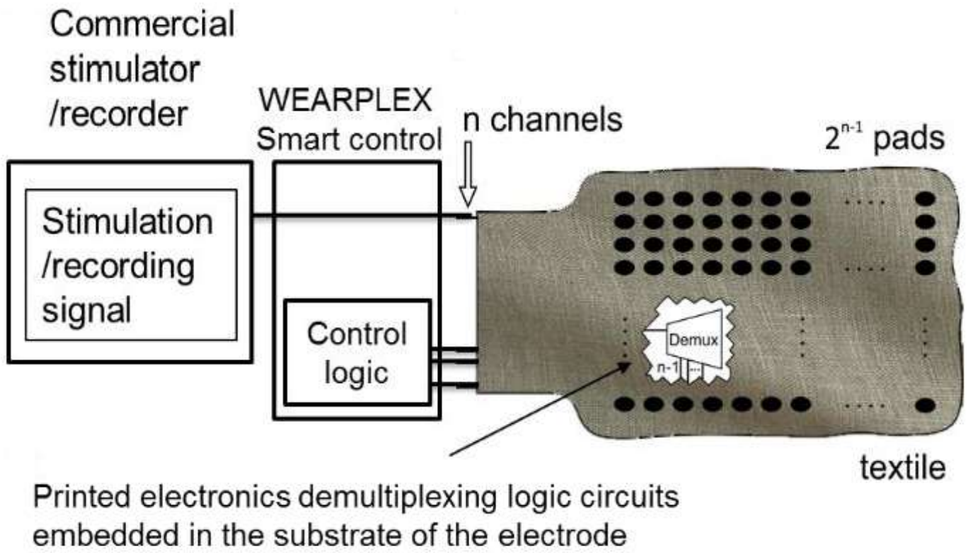
University of Southampton · tecnalia MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE · BCMATERIALS BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES · IDUN Technologies · TECHNISCHE UNIVERSITÄT CHEMNITZ · LayerOne · screentec · AALBORG UNIVERSITY DENMARK · RI.SE

Progress Beyond the State of the Art

» Proposed WEARPLEX solution combining electrode structure and multiplexing circuitry on one smart textile device.



Current state of the art multi-electrode system



Proposed WEARPLEX solution

» Can increase the number of addressable pads, or reduce the number of input wires, depending on desired configuration.

Progress Beyond the State of the Art

» Proposed WEARPLEX solution combining electrode structure and multiplexing circuitry on one smart textile device.

» Exponentially advancing the number of supported pads, usability and comfort.

WEARPLEX concept of ‘virtual’ electrodes

*modified from
http://www.rockbandaide.com

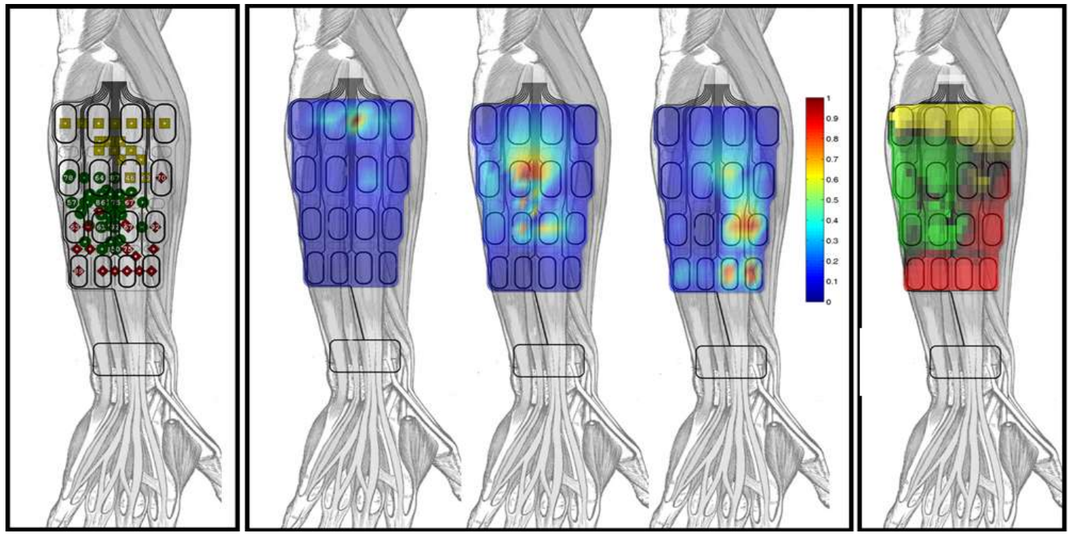
University of Southampton
tecnalia MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE
BCMATERIALS BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
IDUN Technologies
TECHNISCHE UNIVERSITÄT CHEMNITZ
LayerOne screentec
AALBORG UNIVERSITY DENMARK
RI. SE

Progress Beyond the State of the Art

» Increase in the number of pads implies an exponential increase of electrode setup complexity

» TECSR and AAU are developing the methods for automated system calibration to enable personalisation and high usability.

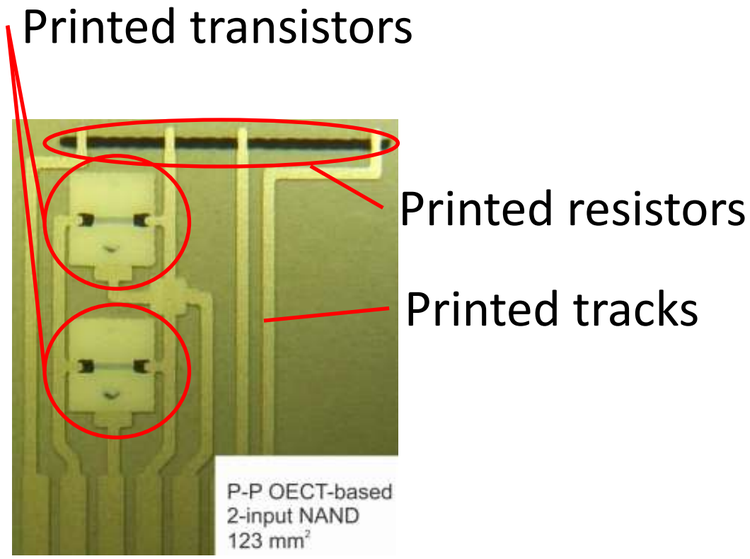
» Optimising printed OECT structure for stimulation and recording.



Modified from Malešević et al. (2017) "Temporal and spatial variability of surface motor activation zones in hemiplegic patients during functional electrical stimulation therapy sessions." *Artificial organs*

Printed Logic - Demultiplexer

- **Organic Electro-Chemical Transistors** based embedded logic and current-routing circuitry
- OECT can achieve large current throughput (~5 mA) at low driving voltage (~1 V)
- Significantly less sensitive to layer thickness (1-10 µm) compared to OFETs (100 nm), making them the viable option for printing on textiles (primer surface roughness is 1-5 µm).
- Relatively slow switching time (10+ ms)
- FES/EMG provides a great application for an architecture/material not yet suitable for high end digital applications.
- RISE is the global leader in development of printed OECT technology.



Screen printed digital circuits based on vertical organic electrochemical transistors, P. Andersson Ersman, et al., Flexible and Printed Electronics 2 (2017) 045008.

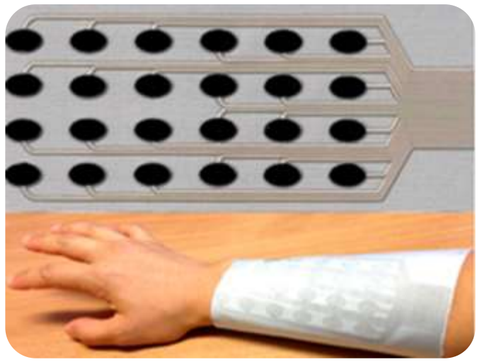
Materials development - Printed Ink

- Breakthroughs in material science are needed for two reasons:
  - To enhance the printed electronics performance (speed, throughput, robustness)
  - To enable transfer to textile substrate and better adherence to the body.
- Semiconductor inks (BCM, L-One, RISE) – high performance printed logic circuits.
- Primer ink (UoS) - provides smoothing layer on the fabric; printed only where required to minimise loss of fabric properties.
- Conductive inks (BCM) – used for conductive tracks between electrodes and interconnects with printed logic circuits.
- Skin interface (IDUN, UoS) – adherence, comfort, transfer of energy.

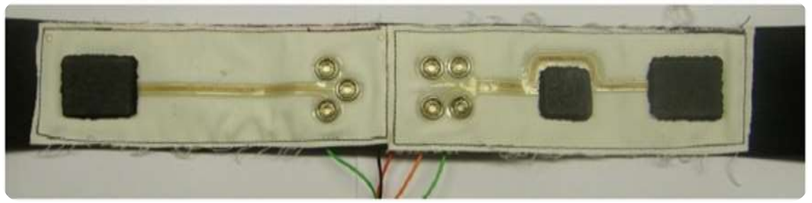
E-Textile Integration

» WEARPLEX combines printed electronics with textiles to create e-textiles.

» UoS has developed a number of printed electrode devices on textiles.



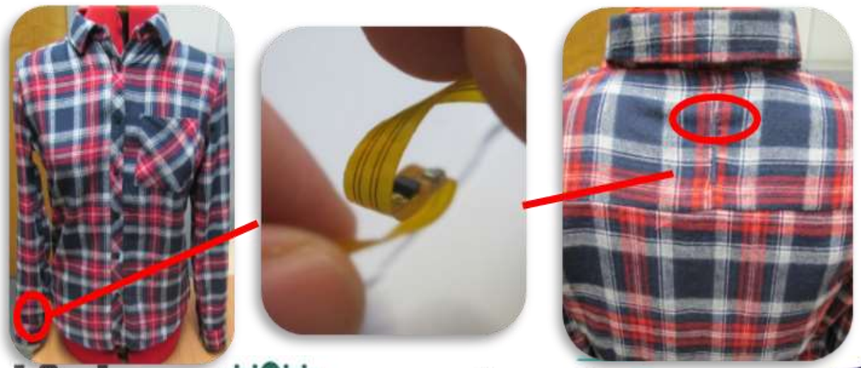
Printed FES array on fabric



Printed ECG electrodes on fabric

Printed Full Frank ECG configuration

» And integration of flexible electronic circuits into textiles.



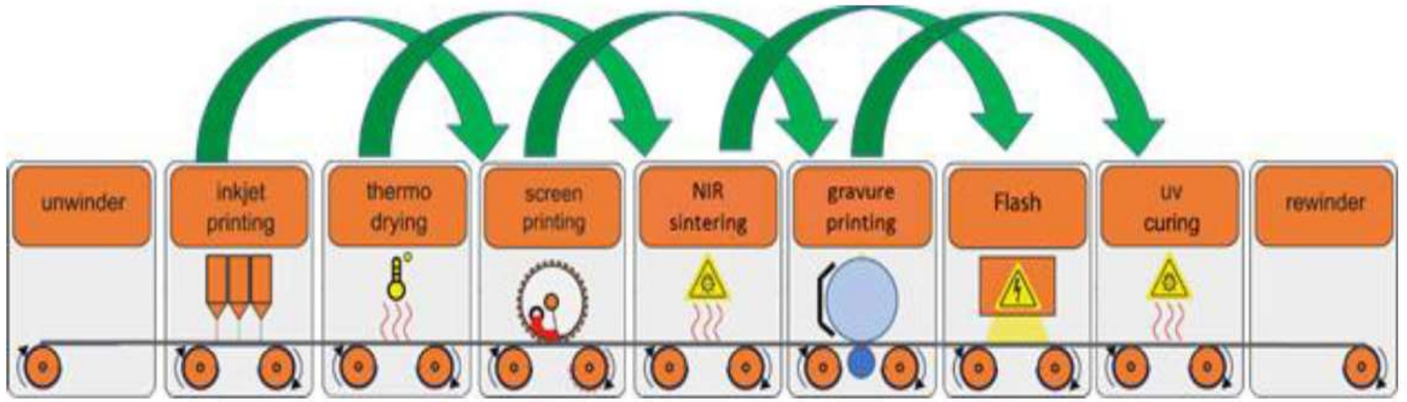
Mass Manufacturing

» To ensure maximal impact, novel fabrication processes are addressed

» Scale up of WEARPLEX system production is aimed through modular approach that leverages r2r and s2s approaches for printed electronic applications.

» Delivery is at the end of the project for Gamma prototype

» Lead by Technical University of Chemnitz and Screentec.

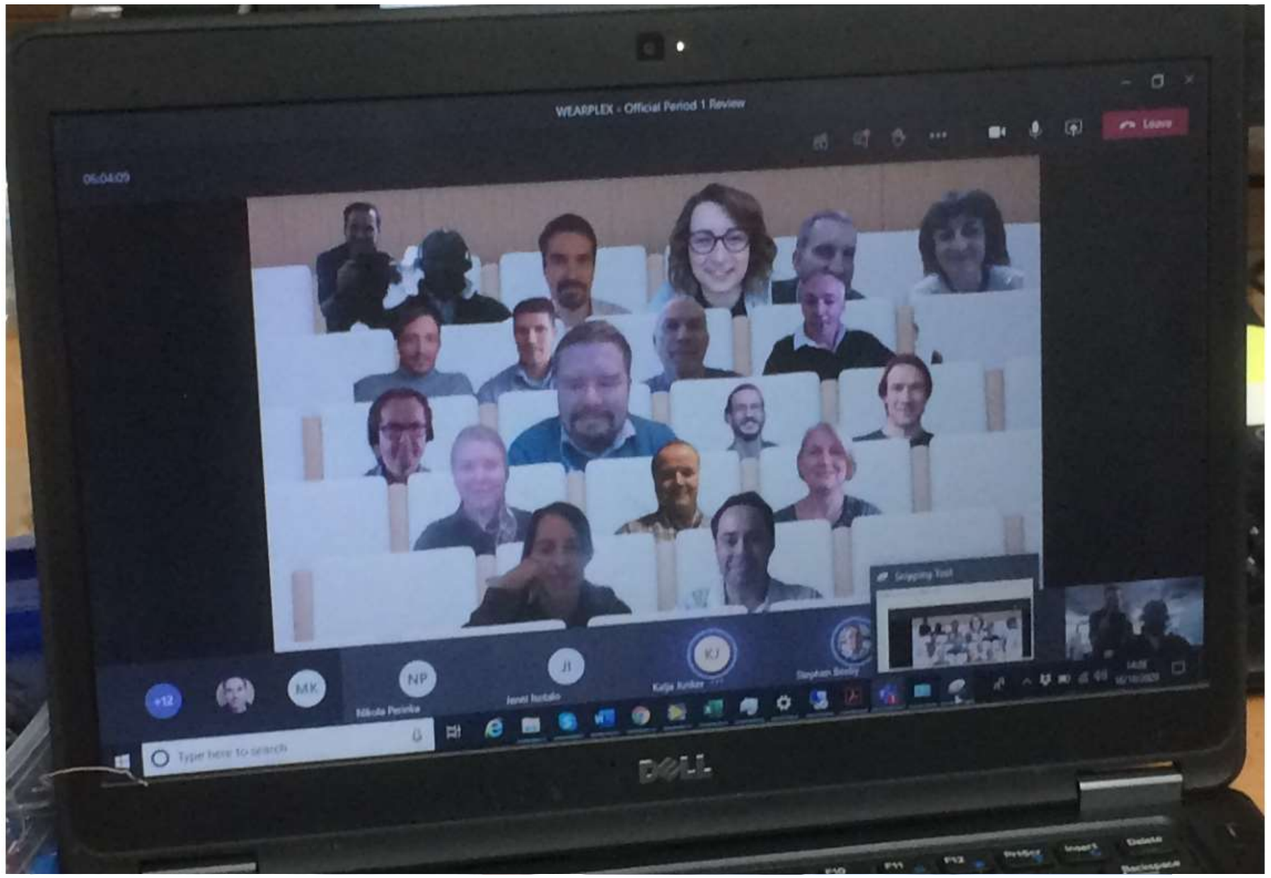


Modular roll to roll process machinery concept from TUC

Acknowledgements

» Gratefully acknowledge Horizon 2020 EU funding – ICT-02-2018

» Thanks to all our other colleagues also working on the WEARPLEX project.



WEARPLEX consortium Post-COVID

University of Southampton
tecnalia
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE
BCMATERIALS
BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
IDUN Technologies
TECHNISCHE UNIVERSITÄT CHEMNITZ
LayerOne
screentec
AALBORG UNIVERSITY DENMARK
RI.SE

Contact us

» Project website: http://wearplex.soton.ac.uk

» Join our mailing list – https://wearplex.soton.ac.uk/wearplex-subscription

http://wearplex.soton.ac.uk

https://uk.linkedin.com/company/wearplex-project

https://twitter.com/wearplex @wearplex

https://www.instagram.com/wearplexproject/

https://www.youtube.com/channel/UCER_bp0sOqU3N5j0CW-B9dA

Contact the coordinator

Dr Russel Torah rnt@ecs.soton.ac.uk

Prof Steve Beeby spb@ecs.soton.ac.uk

University of Southampton

tecnalia MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

BCMATERIALS BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES

IDUN Technologies

TECHNISCHE UNIVERSITÄT CHEMNITZ

LayerOne Advanced Materials screentec

AALBORG UNIVERSITY DENMARK

RI.SE