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

Russel Torah[1], Abiodun Komolafe[1], Steve Beeby[1], Milos Kostic[2], Matija Strbac[2], Thierry Keller[3], Nikola Perinka[4], Senentxu Lanceros-Mendez[4], Peter Andersson Ersman[5], Yusuf Mulla[5], Maxim Polomoshnov[6], Arved Huebler[6], Luis Pelaez Murciego[7], Strahinja Dosen[7], Erika Spaich[7], Rune Wendelbo[8], Azadeh Motealleh[8], Séverine Chardonnens[9], Katja Junker[9], Jenni Isotalo[10], Roelof Aalpoel[10], Antti Tauriainen[10]

*[1] **University of Southampton, UK**,[2]Tecnalia Serbia, [3]Tecnalia Spain, [4]BCMaterials, Spain, [5]RISE AB, Sweden, [6]Chemnitz University of Technology, Germany; [7]Aalborg University, Denmark; [8]Abalonyx, Norway, [9]IDUN Technologies, Switzerland, [10]Screentec, Finland.*

InnoLAE 2020
22 January 2020

innoLAE 2020

UNIVERSITY OF Southampton
screentec
tecnalia Inspiring Business
Abalonyx Innovative materials
TECHNISCHE UNIVERSITÄT CHEMNITZ
BCMATERIALS BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
IDUN Technologies
AALBORG UNIVERSITY DENMARK
RI.SE

H2020-ICT-02-2018

Overview

» 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
» Early results
» Workshops
» Contacts

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
31 December 2021

Funded under:
H2020-EU.2.1.1.

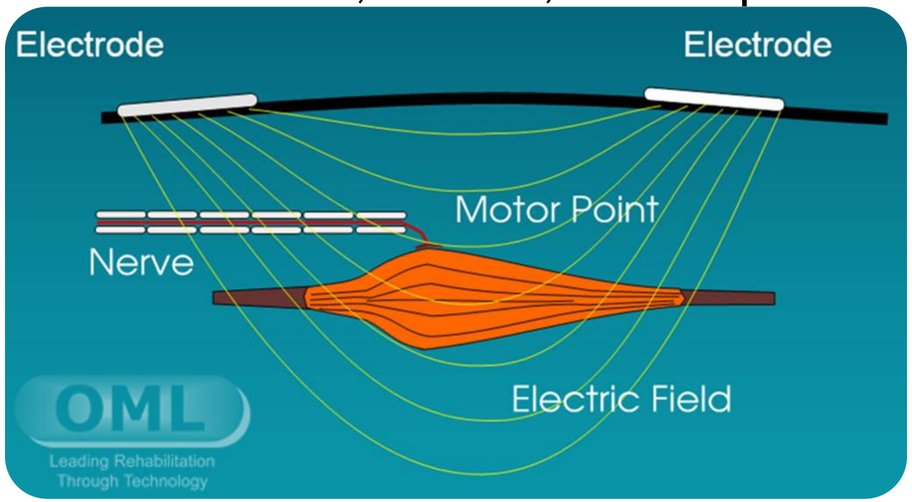
Overall budget:
€ 3 732 749,29

EU contribution
€ 3 732 748,75

Coordinated by:
UNIVERSITY OF SOUTHAMPTON
United Kingdom

What is FES?

- Functional Electrical Stimulation (FES) is used to electrically stimulate motor nerves in order to activate paretic (partially paralysed) muscles.
- The stimulation is controlled and targeted to specific nerves to provide useful movement of a limb (e.g grasping, stepping).
- Treatment for Stroke survivors for upper limb therapy, drop foot for Stroke and Multiple Sclerosis sufferers, muscle pain relief.
- Typical stimulation signal between 10 and 100 Hz, 5-50 mA, 200-500 µs.



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.
- We specifically look at surface EMG, measuring the electrical activity at the skin closest to the muscle.
- By measuring EMG we can determine the health of muscles and their control nerves.
- EMG can also be used to estimate the motor intention of the subject for the purpose of myoelectric control.
- Signal is typically in the mV range with useful frequency content up to 150-200 Hz.
- More electrodes provides more muscle specific information for a given movement or gesture.
- This allows increased selectivity and quality of EMG recording and electrical stimulation delivery; leads to improved assessment and motor intention estimation (EMG) and better movement generation (FES).

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, posture, 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)
  - Combined EMG and FES:
    - Electrotactile feedback – VR interaction, haptic telecommunications, tele-manipulation, prosthetics.
    - Neuromuscular Rehabilitation – user/clinical feedback 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

- 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? - What will we do?

» WEARPLEX is developing printed logic circuitry that allows embedded multiplexing

» Printed electrode pads will be addressable into virtual electrodes.

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

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

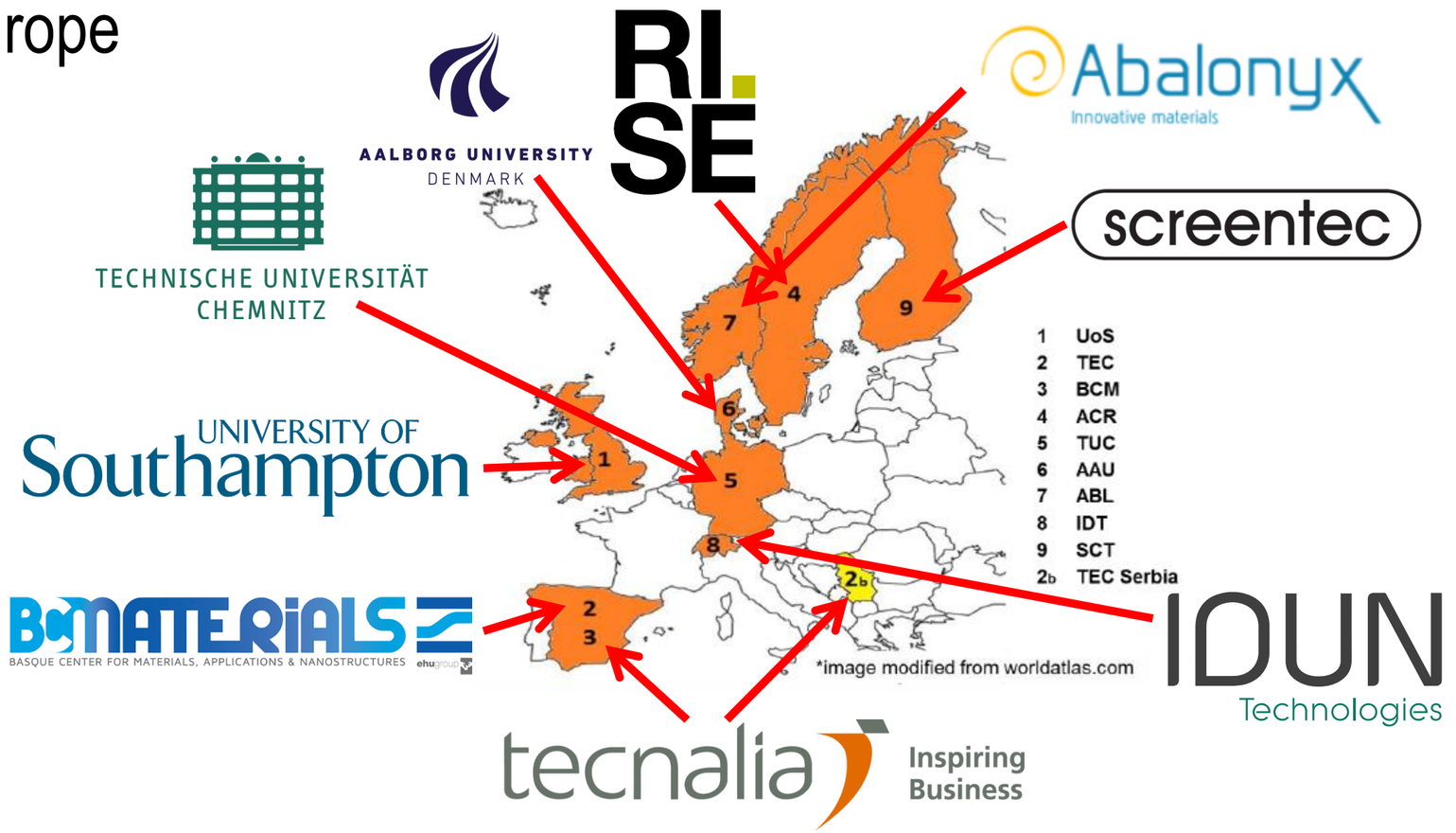
Project Partners - Locations

9 Project partners across Europe

» 3 Universities

» 3 Research Institutes

» 3 SME's



Project Partners - Roles

Universities

» ***University of Southampton* (UoS)** – Coordinator – expertise in printed electronics on fabric and e-textile fabrication.

» *Technical University of Chemnitz* (TUC) – Printed electronics mass manufacturing.

» *Aalborg University* (AAU) – Expertise in recording and analysis of EMG signals, FES applications & clinical assessment.

Research Institutes

» *Tecnalia Research and Innovation* (TEC) (Spain and Serbia)– Expertise in multi-pad electrodes, FES applications and biomaterials.

» *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

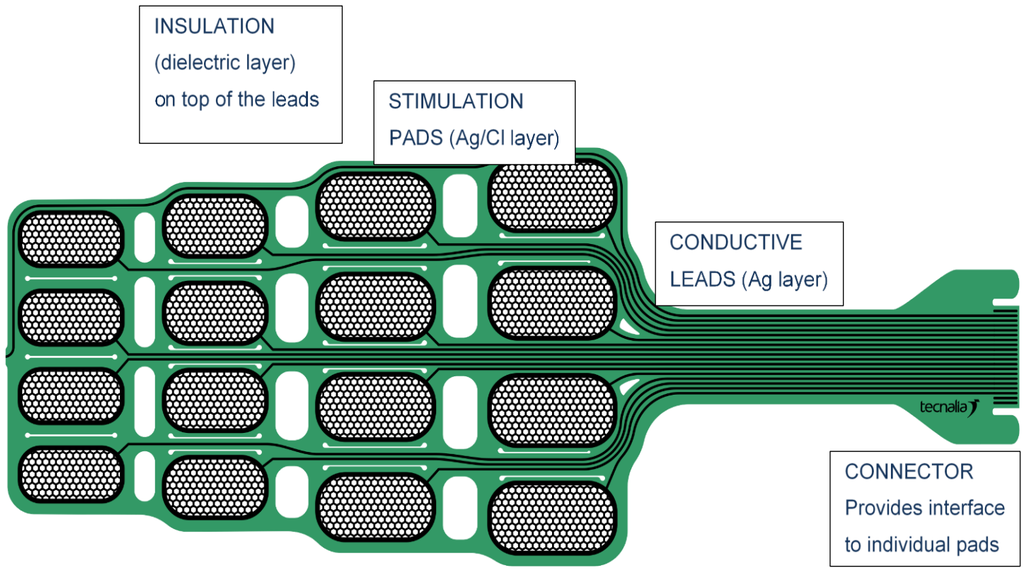
» *Abalonyx* (ABL) – Expertise in GO and rGO for printed electronics.

» *IDUN Technologies* (IDUN) – Expertise in electrode design and biopotential monitoring.

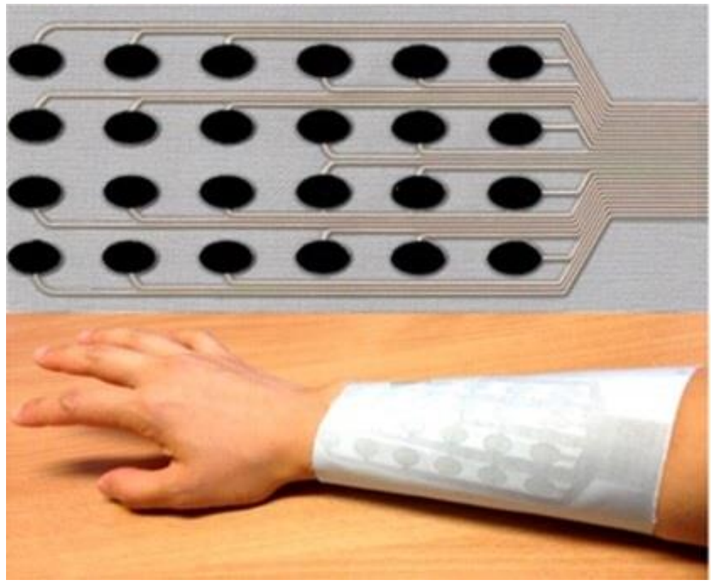
» *Screentec* (SCT) – Expertise in industrial printed electronics and medical devices.

State of the Art Electrode Technology

» Existing multi-pad electrode structure using printed electronics on flexible plastic and FES electrode array printed directly on fabric.



Printed FES electrode array on plastic (TEC)

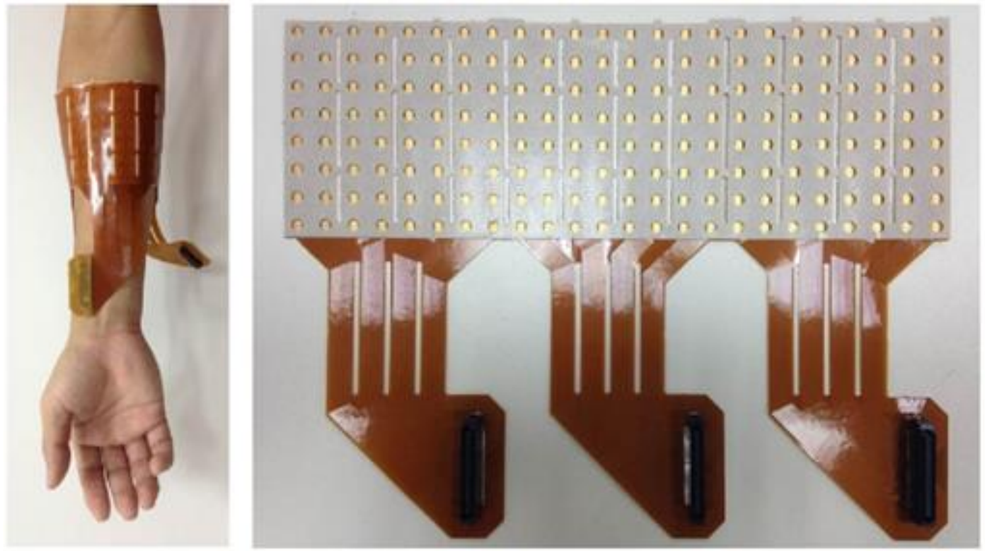


Printed FES electrode array on fabric (UoS)
(Yang et al - Sensors (2018)- 18(8), 2410)

» For each device, the **electronics** are **connected separately** and are **not integrated** within the electrode structure.

State of the Art Electrode Technology

» High density EMG electrodes exist (192 channels) but all switching is performed using external electronics and flat cables.



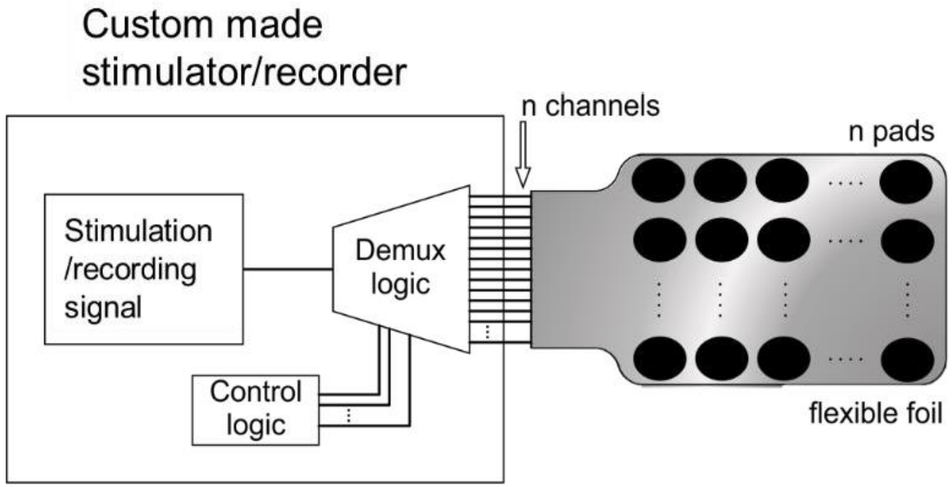
Etched copper EMG electrode array on plastic

Extensive cabling required

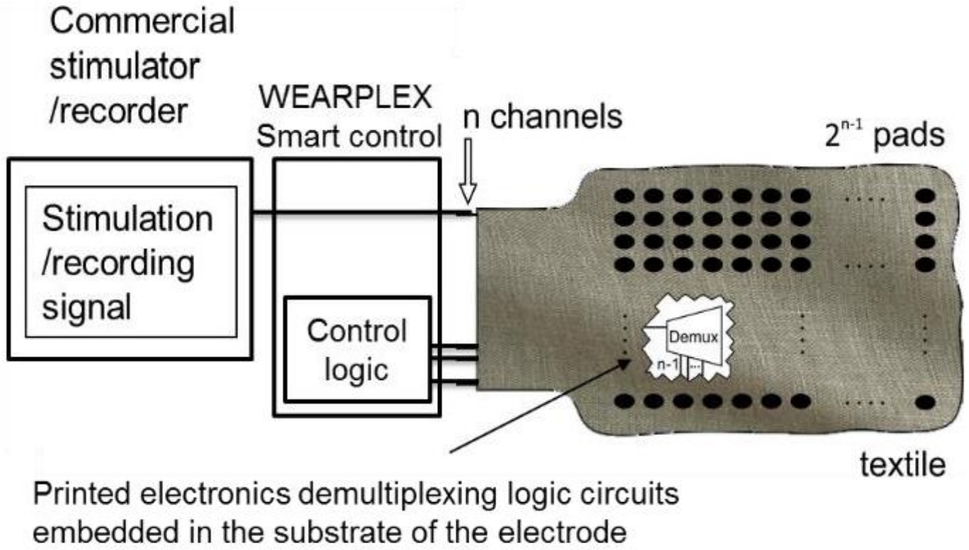
» No commercially available devices combining EMG and FES and no fully printed examples in the literature.

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.

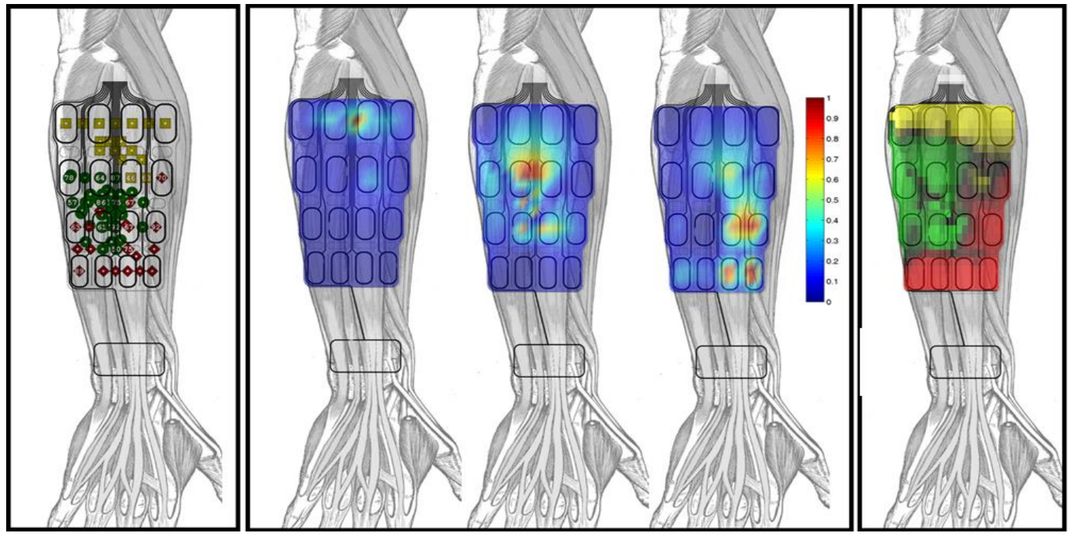
» Exponentially advancing the number of supported pads, usability and comfort.

WEARPLEX concept of ‘virtual’ electrodes

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

Progress Beyond the State of the Art

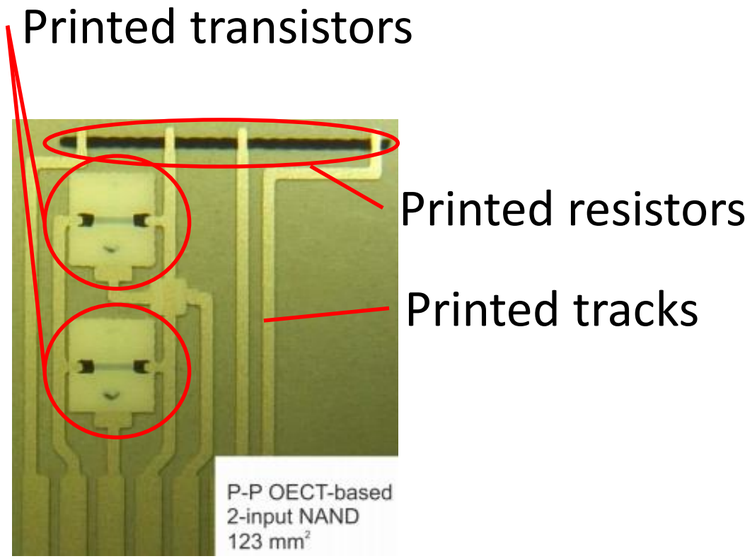
- Increase in the number of pads implies an exponential increase of electrode setup complexity
- TEC and AAU are developing the methods for automated system calibration to enable personalisation and high usability.
- Methods for printed circuit control for optimised current propagation and mitigation of printed electronics limitations are also investigated.
- Demonstrator for FES and EMG recording applications will be developed during the Beta and Gamma stage of the project



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 (~5mA) at low driving Voltage (~1V)
- Significantly less sensitive to layer thickness (1-10 µm) compared to OFETs (100nm), 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 Acreo 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, ABL, 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.

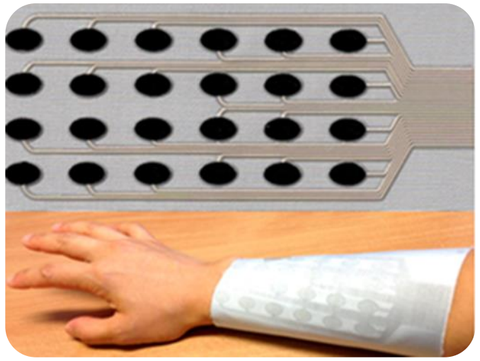
» Conductive inks (BCM) – used for conductive tracks between electrodes and interconnects with printed logic circuits.

» Skin interface (IDUN, TEC, UoS) – adherence, comfort, transfer of energy.

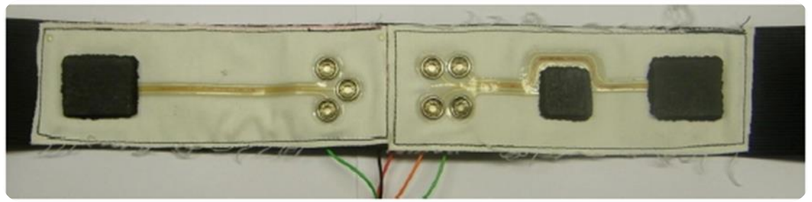
E-Textile Integration

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

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



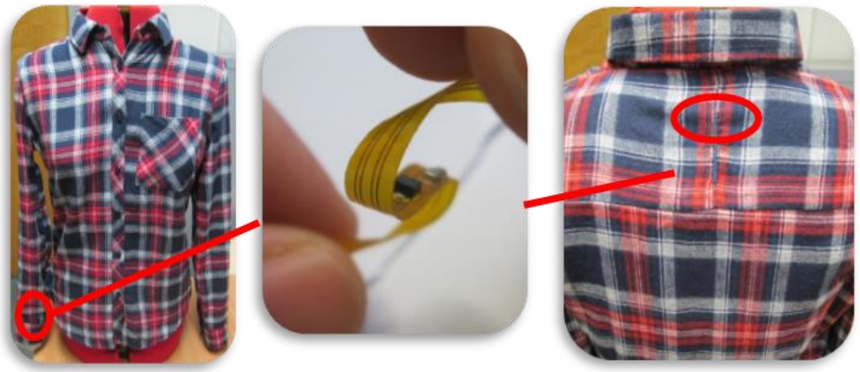
Printed FES array on fabric



Printed ECG electrodes on fabric

Printed Full Frank ECG configuration

» And integration of flexible electronic circuits into textiles.



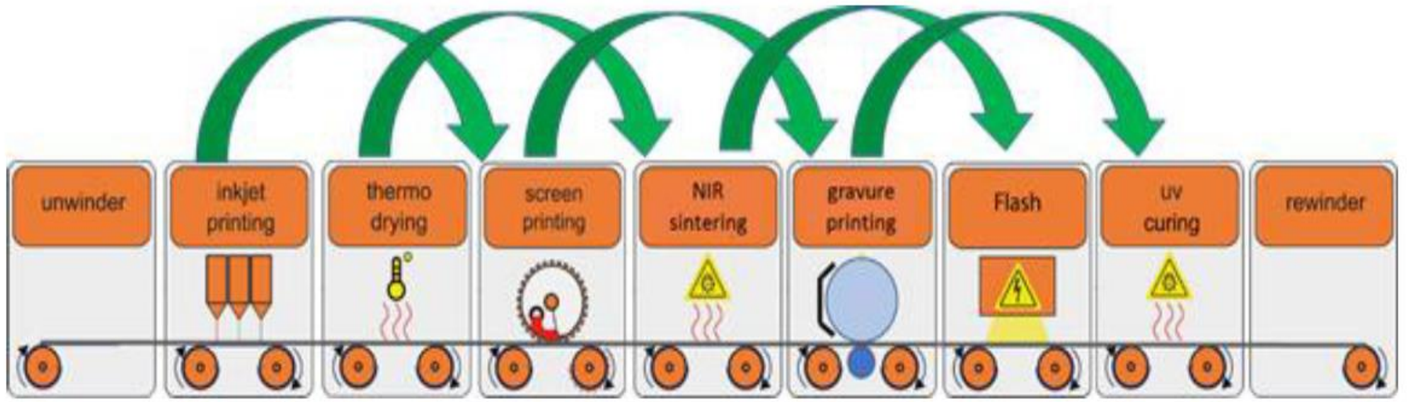
Mass Manufacturing

» 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

Alpha Prototype Results

» Results slides have been removed for the public version due to ongoing publication process.

» Please see our website for further updates and links to new publications and results.

» http://wearplex.soton.ac.uk

Stake Holders Board and Workshop

» Seeking members for a Stake Holders Board for the project.

» Representatives from the relevant industries, health and sports professionals, patient associations.

» 3 workshops to be held during the project:

- WS1 – Alpha demonstrators - Specifications: Half day event, held at the 13th Vienna International Workshop on FES, 25th Sept. 2019 – Completed.
- **WS2 – Beta demonstrators – Technological leap: 1 day event adjacent to a Wearable electronics international conference in Q4-2020.**
- WS3 – Gamma demonstrator – WEARPLEX powered products: 1 day event at Medica fair or Wearable electronics international conference in 2021.

Acknowledgements

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

» Thanks to other colleagues also working on the WEARPLEX project:

Kai Yang, Helga Nunes-Matos, Monika Glanc-Gostkiewicz, Jovana Malesevic, Goran Bijelic, Vladimiro, Erik Hernandez, Raquel Gonzalez, Siamek Eqtesadi, Simon Bachmann, Moritz Thielen.

How many WEARPLEX members can you fit in a lift?

Call to Action

» Join our mailing list – www.wearplex.soton.ac.uk

» Join the stakeholder board; industrial and academic partners wanted.

» Beta Workshop targeted for Q4 2020

Contact the coordinator

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

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

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