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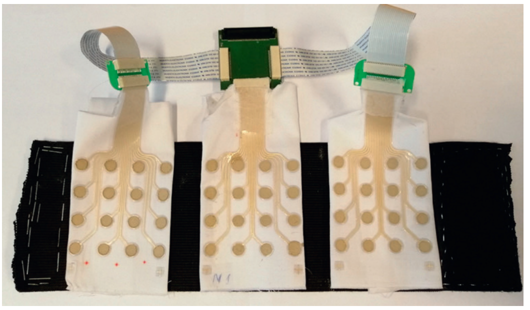
A stimulating approach to wearable electronics


WEARPLEX textile electrode arrays protoype (Southampton, Aalborg).

Wearable electrodes can be used to both monitor electrophysiological signals and stimulate muscles. Researchers in the WEARPLEX project are developing printable electrodes which can be screen-printed onto textiles and adapted to the specific needs of the user, part of the new generation of 'smart' electrodes, as Dr Russel Torah explains.

A variety of different e-Textiles are available on the market today, with electrodes integrated into the fabric to enable the monitoring of heart rate and other electrophysiological signals. At the moment electrodes are often made using moulds, and in many cases individually, now researchers in the WEARPLEX project are exploring a different approach. "We are developing printable electrode arrays, so the electrodes can be in any position on a garment. It's also possible to retroactively fit these electrodes on a garment," says Dr Russel Torah, the project's coordinator. These electrodes can be used to both record muscle signals and also stimulate them, a topic that researchers in the project are investigating. "We're interested in stroke rehabilitation for example. The idea is that people recovering from a stroke have some movement, some recognition of how to move their arms – we can pick up those signals, and then amplify it through our own electrical stimulation," explains Dr Torah. "The idea is that they will gain that movement back themselves over time, by essentially re-learning how to move their hands."

WEARPLEX project

The aim in the project is to develop a multiplexed array of biomedical electrodes, which involves research across many different disciplines, including electrical engineering and software development. The project overall brings together ten partners from across Europe, with Dr Torah and his colleagues at the University of Southampton focusing primarily on the textile side and making the electrodes, which differ from those typically used in hospitals. "These are 'dry' electrodes, so no additional gel is required to maintain contact with the body. The textile holds the electrodes in place, and so the electrodes don't need to be sticky," he explains. These electrodes are integrated with fabrics worn on the body, so durability and reliability are important considerations, particularly given that they are designed to be used multiple times. "The idea is that you just clean it and then it's ready to go again – either on the same person or someone else," says Dr Torah. "We're trying to develop materials to make the electrodes more flexible whilst maintaining performance. We want the printing to be reliable and consistent, so that each electrode is the same."

Researchers are looking to maximise the number of electrodes that can fit within a given area, so that more data can be recorded. It's also important to minimise the number of wires needed to control the outputs or inputs, depending on whether the electrodes are to be used for functional electrical stimulation (FES) or for recording signals from muscles using electromyography (EMG). "For EMG it's more inputs, for FES, it's more outputs. But it's essentially the same circuitry," says Dr Torah. Rather than each individual electrode having its own individual control, stimulation and recording circuitry, Dr Torah and his colleagues are developing a different system. "The idea is that you have say one stimulator, and then a junction box – the multiplexor – which just switches between electrodes," he outlines. "The more switching you can put into the controller, the more electrodes you can have for the same amount of electronics. Normally these multiplexors are quite big, bulky electronics, now the aim is to print it all directly onto the textile."

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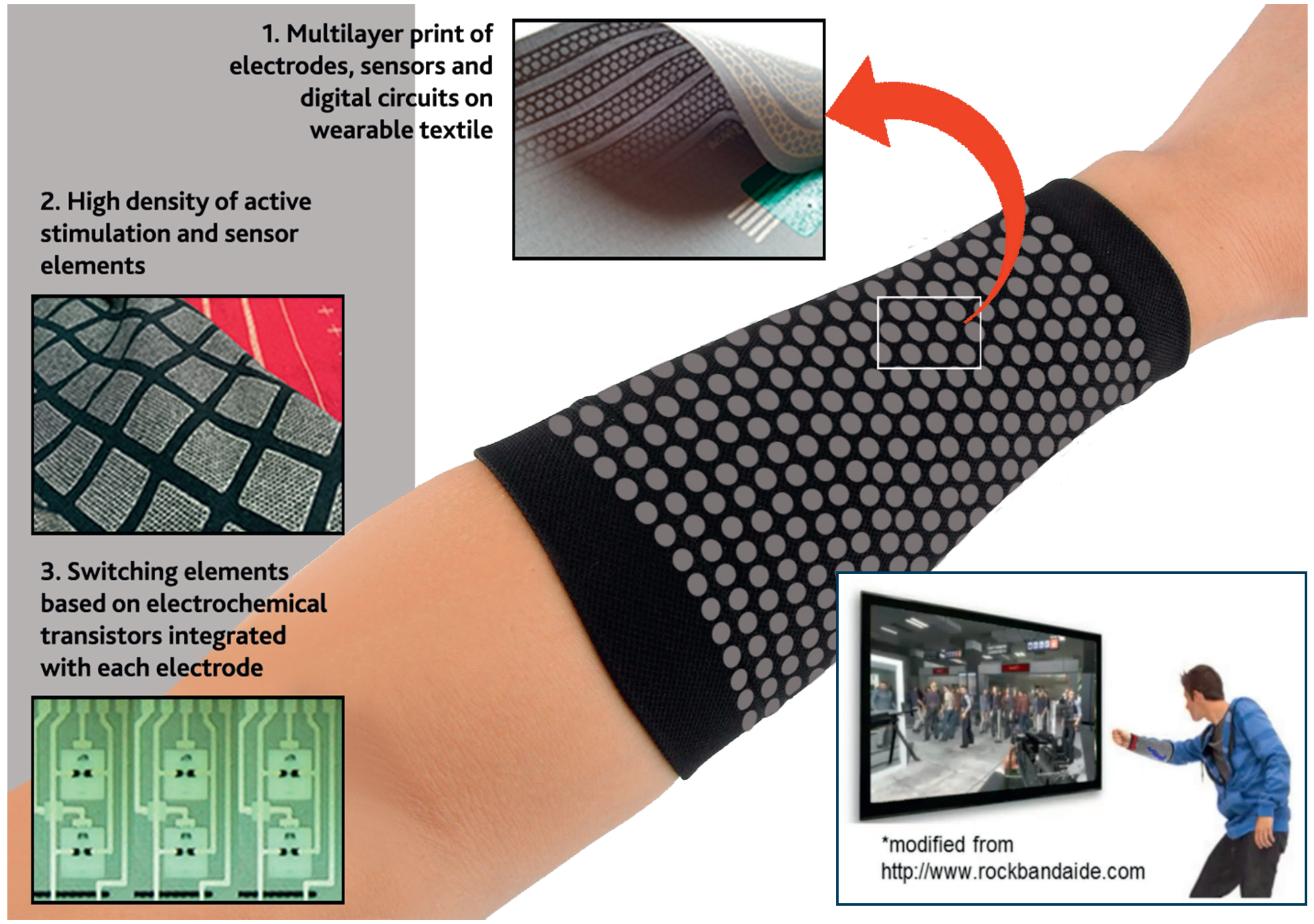
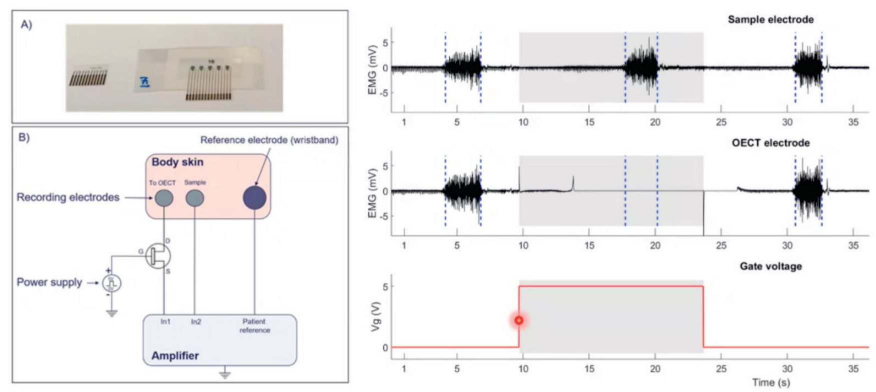


The formulation of the electrodes may vary depending on the intended application. If it's going to be used for recording, it should ideally be very conductive to record the signal effectively, while Dr Torah says the requirements for stimulation are different. "One partner in the project is trying to find an optimum point where you can use just the one material, but it may be that two are required. So, we're looking at adjusting the properties of the conductive inks and skin/electrode interface that are used to print the electrode," he outlines. A conductive ink printed directly onto the textile is likely to soak into it, so researchers at Southampton have developed a primer layer, which Dr Torah says helps improve durability. "This effectively turns the textile into a smoother, plastic film, and everything else can then be printed on top, and encapsulated with the same primer material," he continues. "This approach effectively seals in all the delicate conductive materials, preventing them being washed off when you put it in the washing machine, or damaged in any other way."

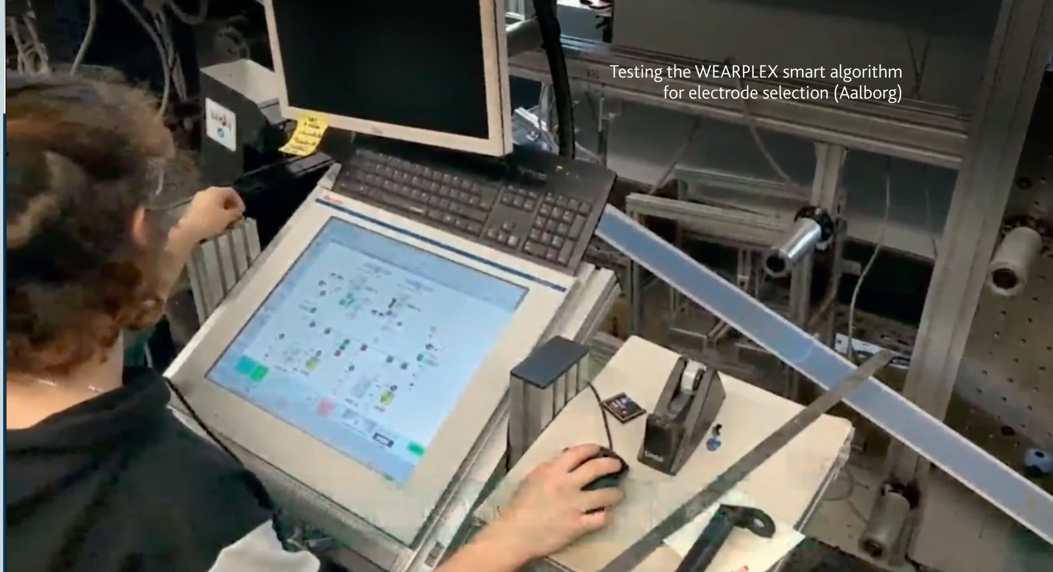
This primer layer opens the possibility of printing the electrodes onto pretty much any textile, including polyester, cotton and silks. The main criteria is that the fabric isn't too rough, and in general the smoother the fabric the easier it is to print on. "We've printed on all sorts of different fabrics, such as ®Kermel for instance, which is used in firefighter uniforms. We've also printed on other fabrics," says Dr Torah. This approach could also help to accelerate the production of wearable electronics and improve cost-efficiency. "Printing is a roll-to-roll process. So you can print out lots of devices really quickly – and the more you produce, the cheaper it is," points out Dr Torah. "The most expensive material we use is silver for the conductive tracks. Silver is expensive, but we only print a 5 micron layer, which is all we need. The primer layer means that we can use less silver, because we smooth the layer out first, and we effectively turn it into a little piece of plastic, but only where we need to, leaving the rest of the garment as normal fabric."

Improving reliability

A major priority now in the project is to improve reliability, which will ultimately help encourage adoption in the textile industry. Screen printing is already commonly used in the textile industry, which is one of the main reasons Dr Torah and



WEARPLEX future work: OECT switching (RISE, Aalborg, Tecnalia).



Testing the WEARPLEX smart algorithm for electrode selection (Aalborg)

WEARPLEX

Wearable multiplexed biomedical electrodes

Project Objectives

WEARPLEX is a multidisciplinary research project to integrate printed electronics with flexible and wearable textile-based biomedical multi-pad electrodes. It focuses on the development of the printable electronics for textile based multi-pad electrodes with integrated logic circuits enabling a significant increase in the number of electrode pads (channels) and facilitate the creation of new products in the sectors of medical electronics and life-style.

Project Funding

WEARPLEX is funded under the European Commission's Horizon 2020 research program via the ICT-02-2018 Flexible and Wearable Electronics call. Grant agreement ID: 825339.

Project Partners

There are 10 partners in the project: University of Southampton is the coordinator. We have 3 University partners (Southampton, Aalborg, Chemnitz), 4 research centres (Tecnalia Spain, Tecnalia Serbia, BC Materials and Research Institutes of Sweden) and 3 SME's (Abalonyx, IDUN Technologies and Screentec).

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Russel Torah

Russel Torah is a Principal Research Fellow at the University of Southampton. His research interests are currently focused on smart fabric development but he also has extensive knowledge of energy harvesting, sensors and transducers. He co-founded Smart Fabric Inks Ltd, which specialises in printed smart fabrics.

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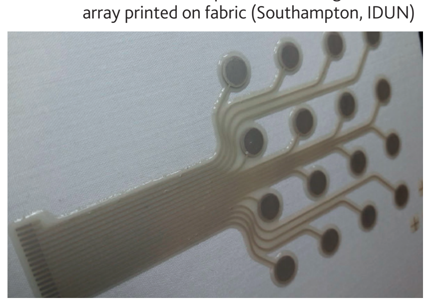
his colleagues chose to use this approach. "The textile industry is the most likely to take up this technology, so we have to work on improving reliability," he says. A lot of progress has been made in this respect, and Dr Torah believes the technology would be relatively easy to adopt for manufacturers. "Because you can print it, any textile manufacturer that already produces printed patterns can just swap their coloured ink for our functional ink straight away. No extra equipment is required and no other changes," he stresses. "That's one of our key selling points. It's easy to adopt, and also easy to adapt straight into mass manufacturing. So if they have a pattern and they want a particular structure, then they can print it pretty quickly."

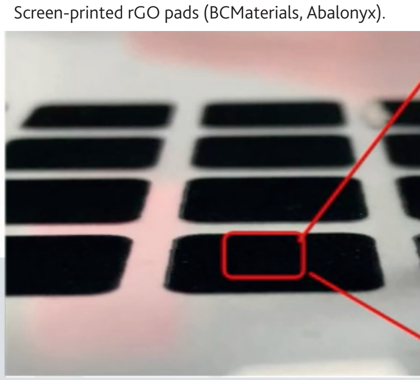
The next step could involve bringing some of these technologies to the commercial market, and researchers are already in the process of trying to patent some elements of the project's research. The project's research could have a significant impact on manufacturing efficiency, for example. "One of our partners makes basic stick-on electrodes, which they do by hand, so with very small runs. If they can use screen printing for mass manufacturing of electrodes, then that opens up new opportunities for them," outlines Dr Torah. Another possibility is patenting the technology and licensing out the different elements to companies who might be interested. "We've used FES and EMG as demonstrators, but in principle the electrodes and the electronics can be used on anything to do with biopotentials," says Dr Torah. "We could say to companies; we've got this basic technology. We know how to print it onto textiles, we know the properties, we know how long it will last. What do you want for your application?"

The different technologies are however at different levels of maturity. While the electrode technology - and the printing process - is on the cusp of commercialisation, Dr Torah says the printed multiplexing electronics side is less advanced. "It works, and we've shown that it works, and hopefully by the end of the project we'll get it working in a fully integrated demonstrator. But it's still at a relatively early stage," he acknowledges. Alongside exploring commercial possibilities, Dr Torah and his colleagues plan to pursue further research. "We could look to establish another research project, to try and make the technology more reliable," he says.

Screen printed recording electrode array printed on fabric (Southampton, IDUN)



Screen-printed rGO pads (BCMaterials, Abalonyx).



Cross-sectional images of printed rGO layer.