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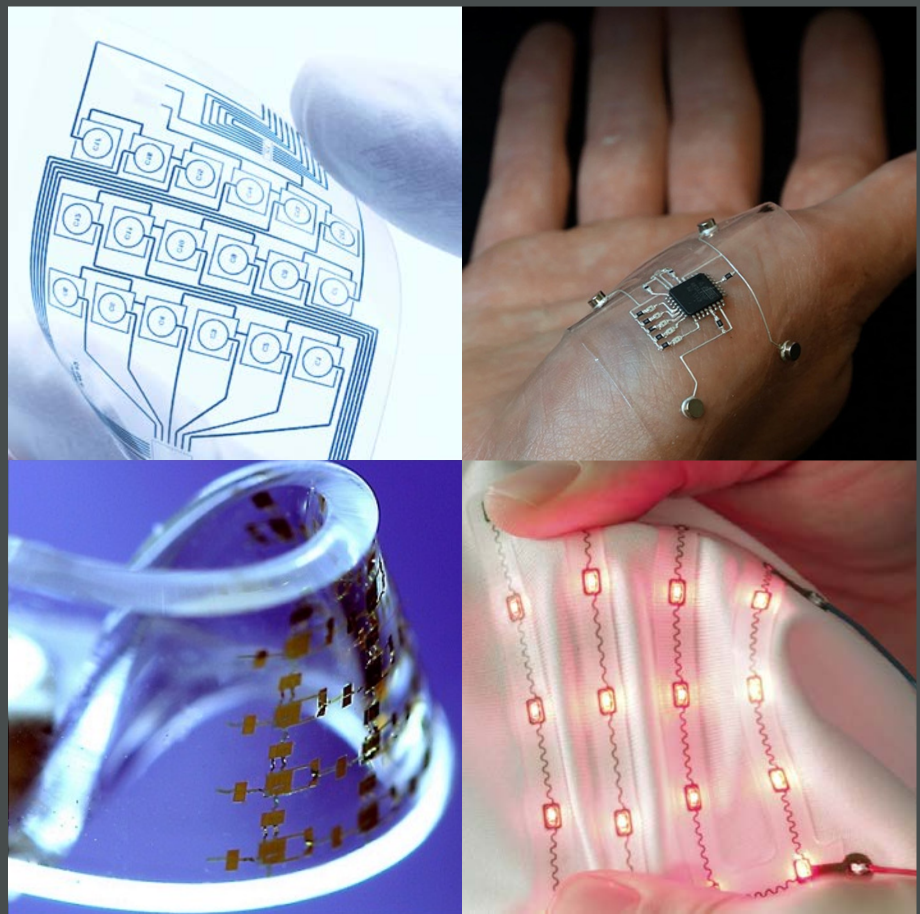

A Brief Guide to Flexible & Stretchable Electronics for the Life Sciences

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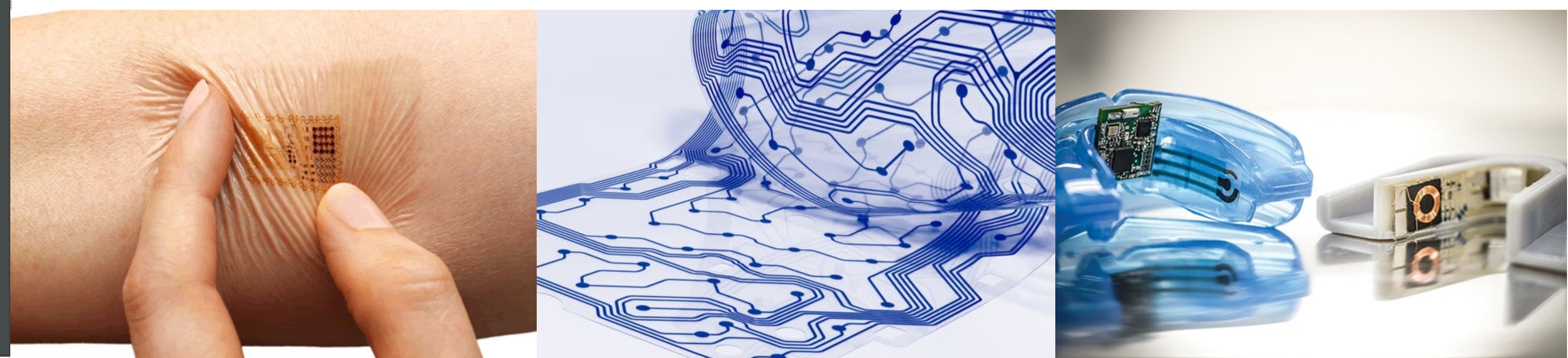

Flexible and Stretchable Electronics for the Life Sciences research overview

Flexible and stretchable electronics could consist of complete electronic systems including sensing, data processing, own info display or communication via other electronic device, power source, and can adapt to its environment like a human interface, a plant monitor, or when integrated in a garment. The scope of the selected topic area is focused on associated technology platforms, rather than application specific developments.

In 1903 the concept of a "flexible circuit" appeared for the first time in an English patent by Albert Hansen. Much later in the 1950s Sanders Associates' inventors (Nashua, New Hampshire) Victor Dahlgren and company founder Royden Sanders developed and patented the first flexible circuitry processes for printing and etching flat conductors on flexible base materials to replace wire harnesses. In recent decades, flexible circuits/ electronics development has been significantly driven by Japanese electronics packaging engineers who have found many new ways to employ flexible circuit technology. With the enhancement of stretchable electronics and wearable technologies, it has become one of the fastest growing sectors within interconnection product markets.

One such rapidly growing market is in the area of health and biomedical informatics, people will be able to assess more and more personal health data and also utilise treatment plans. The benefits of decentralising these personal assessments & treatments are numerous, for instance it would be quicker, cheaper, less invasive, and more convenient than traditional ways. On the other hand having electronics on a bendable/ twistable/ stretchable base is challenging for the system functionality. Sensors and conductors will behave unpredictably with various displacements in the system. Some systems go through a transition phase whereby a number of components stay rigid, and flexibility is obtained within the interconnect between these rigid components. Other systems only have a flexible/ stretchable interface, but still conventional power source and data display.

Importance of Flexible and Stretchable Electronics for the Life Sciences?

Flexible electronics has been around for at least two decades. At that time the norm was stiff Printed Circuit Boards (PCB) stacked and fitted in rigid boxes like desktop PC's.

A flexible PCB then could be 200 microns thick, which would be a factor 10 thinner than the norm, and would allow to some extent to follow the contour of a chest for instance for radiation dose monitoring. Since then new materials, components and processes have been developed that have been resulting in small incremental steps towards more flexible & stretchable systems.

Within about 5 years Polyimide substrates could be metallised with an overall thickness of les than 20 microns. What is significant about that flexibility is that it could be used as an artificial retina for an eye. Novel form factors have been emerging over time ranging from limited flexibility to ultra-elastic and conformable electronics, and is now beginning to make a substantial commercial impact. The reason for this is that new functionalities are discovered, and with that come new applications, and new users.

An example is the new capability of being able to roll up the circuitry and integrate it in a minimal invasive device. This can be used to obtain sensor data from locations that couldn't be explored before, which could lead to better disease understanding.

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Current research in Flexible and Stretchable Electronics for the Life Sciences at Tyndall National Institute and how this could impact industry?

The Tyndall Institute is involved in various forms of microelectronic fabrication, from silicon chips, to sensors, other components, interconnections, system integration. Also there is a capability for material modelling & development and there are various material (e.g. polymers) characterisation systems. Thus there is a strong and well equipped infrastructure for exploring flexible & stretchable electronics. Life Science Interfaces is a strategic group within Tyndall, always looking for biomedical and industrial interaction. Many of the activities involve "on-the-body" and "in-the-body" (implants and minimal invasive applications) systems. Part of the activities are focused on making systems smaller, cheaper, faster and more sensitive while trying to overcome large hospital based test equipment. Another part is based on more fundamental research with an eye on developing new functionality/ technology, which could lead to new products and procedures. For instance a new product area would be smart wound dressings for more efficient wound healing or transdermal patches for drug delivery. This requires mini-systems which could involve microfluidics, sensing, actuator, power, flexible form factor to conform with relevant body part, wireless communication, or alert system. Sometimes a concept is generated in consultation with a physician who expressed a need for a particular device. Examples during the last two decades:

- a radiation dose distribution monitoring system – this consisted of a flexible substrate with an array of Radfets mounted on it for on-the-body use;
- a drop foot stimulator – this involved an externally, inductively, rechargeable silicone embedded implant under the knee with stimulating electrodes attached to the peroneal nerve;
- a deep brain stimulator – an alternative was designed for the conventional chest implant, consisting of a very thin, but larger area, skull implant;
- electroporation device for treating oesophageal tumours – a flexible polyimide substrate with 2 gold electrode pads was designed to fit into a tumour suction device to deliver an electric pulse to open cell membranes for targeted drug delivery;
- a swallowable diagnostic capsule for investigating the digestive track – here the challenge was to fit a chemical sensor and circuitry, inc. a battery, into a small sized capsule. A flexible serpentined printed circuit board was used.

The radiation monitoring device chip has been licensed and recently a Tyndall spin-off company was launched. The drop foot stimulator has become a UK company product. The electroporation device has been further developed in an external spin-off company. The other ideas have not been commercialised. However, there is a lot of expertise available, that could be a great resource for start-up companies with new product ideas, but no technology background.

Application of research into Flexible and Stretchable Electronics for the Life Sciences ?

The previous section described the initial development of flexible systems. The research associated with it was mostly concentrated on developing more flexible interconnect between components and the more flexible substrates. Integrated circuits, sensors, diodes, usually were provided as plastic moulded packages. Assembling these onto a flexible substrate would make it quite rigid, so for that reason a transfer to "bare die assembly" was made. There were two types of bare die assembly: wire bonding and encapsulation (Chip-on-Board) and chip mounted face down using stud bumps (flip-chip). The flip- chip option has the lowest profile and a polymer underfill is used in combination with a soft encapsulant.

In recent years this assembly method has been pushed to the limit and was experienced during a European research project in which a "rolled-up" circuit flex was required for a catheter application. The shear stresses generated in the component interconnections were getting too high, despite having minimised all the thicknesses and applied stress relief cut-outs. This is where "stretchable electronics" can come in.

Tyndall's first experience with stretchable electronics was with a soft elastomeric silicone substrate Ecoflex™ in combination with a silver based conductive ink. The mechanical mismatch between the two materials lead to delamination. Then research was carried out on soft elastomeric structures integrating liquid metals. Indeed significant levels of stretching could be obtained, but with increasing levels of resistance due to narrowing channel widths. For niche applications such as adjustable antenna's, this looks like a good option, but for standard circuitry it is too complicated and contains a reliability, leak, risk.

The last few years have seen a major increase in stretchable electronics applications, in particular "skin electronics" and "wearable electronics". This is supported by materials research and to date many different electrically conductive materials can be obtained, even with tailored interface adhesion additions and different curing regimes.

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Summary

As mentioned in the first section some flexible & stretchable applications are achieved using a mix of rigid components and elastic areas. Research is ongoing into making components such as batteries, connectors, displays and sensors stretchable, which can then result in more stretchable systems. It is expected that there will be quite a divide in commercial successes, some will die an academic death, while others might thrive by trend demands or maybe emergency drivers.

Reliability of new systems in the early days might not be great, like the smart watches that sell ECG, blood pressure, O2 level capability. Eventually, the sensors will become better, and like a “stretch sensor” new sensing options might appear. Power supply to these systems will also undergo different phases, depending on technical progress in energy harvesting/storage systems and battery technologies, but also in terms of stretchability. A general trend seems to be more sensors (internet of Things) and more data analysis power (Artificial Intelligence). The “wearables” area is difficult to predict, but has the potential to really start leading the way. “Google Glass” a few years ago seemed to have arrived too early, but what is happening at the moment is that sensors are appearing in gloves, sleeves, helmets, sports equipment, etc. and each with its own piece of intelligence.

Finally, researchers are exploring the new technologies with various processing solutions, it can be expected that industry will take over and start driving towards low cost manufacturing systems such as “transfer printing”. Also user comfort will be an important factor, so interesting times ahead!

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