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Microneedle graphene field-effect transistors for wearable biosensing

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Microneedle-based biosensing provides an attractive path towards continuous health monitoring - the use of microneedles causes substantially lower pain to the user than traditional hypodermic needles while providing accurate sensing information [1]. Due their small footprint and ease of application, such biosensors are easily worn with minimal nuisance to the user, enabling wearable health sensing anywhere and at any time. Graphene and other two-dimensional materials have emerged as a suitable plaLorm for high performance printed electronics, enabling graphene field-effect transistors (GFETs) on ubiquitous substrates [2,3].

We have recently developed a scalable method for crea%ng high resolu%on GFETs by spraycoaying graphene inks onto specially designed printed circuit board (PCB) substrates [4]. To deliver this, we prepared biocompatible graphene inks which are optimised for spraycoating. With this platform, we demonstrated its use in portable sensing by functionalising GFET test strips for sodium ion detection. This Lab-on-PCB platform can also be also easily adapted for creating organic field effect transistors (OFETs) and fully flexible GFETs.

Taking the learnings from the PCB platform, we created a new type of sensor is by forming the GFETs directly on the tips of polycarbonate microneedles to enable biosensing of interstitial fluid within the skin. The GFETs are fabricated on the three-dimensional needles through a scalable combination of laser lithographic patterning and spray-coating and uses injection-moulded polycarbonate microneedles. The graphene channels are approximately 20 mm wide and 60 µm long, with a resistance of ~50 Ohms and display characteristic ambipolar modulation under solution gating. We fully characterise the sensors through microscopic and electrochemical methods and demonstrate their biosensing properties through in solution and ex-vivo skin measurements. Their safety is also tested, by an in-vitro cytotoxicity study. The sensor developments are also accompanied by the development of specialised deposition and patterning equipment, and custom source-meter unit. The results demonstrate a new class of sensors that can take advantage of the FET signal amplification directly in situ and enable the development of more sensitive and accurate microneedle biosensors in the future.

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