PATHFINDER

EMERGING TECHNOLOGIES

Multiphoton fabrication of bioelectronic biomaterials for neuromodulation (MFBBN)

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Electromagnetic fields affect a variety of tissues (e.g. bone, muscle, nerve and skin) and play important roles in a multitude of biological processes. This has inspired the development of electrically conducting devices for biomedical applications, several examples of which have been clinically translated, including: cardiac pacemakers, bionic eyes, bionic ears and electrodes for deep brain stimulation. This project aimed to print electrically conducting polymer-based materials with nanoscale features that may enable the electrical stimulation of individual nerves which may be used to treat a variety of debilitating chronic diseases.

Objectives:

1) Preparation of conducting polymer-based materials using multiphoton fabrication on hard and soft/flexible substrates.

2) Characterisation of the physicochemical and electrical properties of the materials.

3) Validation of the efficacy of the bioelectronic devices to interact with brain tissue ex vivo in collaboration with Frances Edwards at UCL Neuroscience.

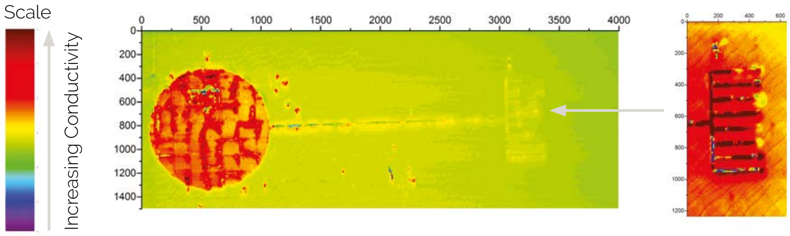
The project entailed a variety of challenges, including: printing a range of conducting polymer-based structures (squares, rectangles, pillars, wires) on hard and soft/flexible substrates (glass and polydimethylsiloxane, respectively); ensuring sufficiently high fidelity of reproduction of the computer assisted design file to guarantee functionality; demonstration of biological utility by recording a physiological response to electrical stimulation of the brain slice using patch clamp methodology.

The project achieved its aims and objectives, and over its course we have demonstrated our capability to print conducting polymer-based structures (squares, rectangles, pillars, wires) on hard substrates and soft/flexible substrates with micron scale and nanoscale features. Excitingly, we found it is possible to print conducting polymers within a flexible substrate (polydimethylsiloxane) with protruding contact points for the polymer with a power source and biological tissue, and we demonstrated the biological utility of the structures by recording a physiological response to electrical stimulation of the brain tissue.

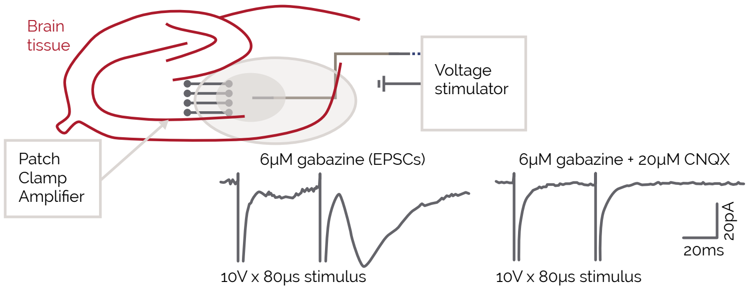
The intellectual property that resulted from the project has been disclosed to Lancaster University. An EPSRC First Grant was awarded to Dr Hardy for a tangential but related project to manufacture bioelectronic devices via multiphoton fabrication (e.g. drug delivery devices), and follow-on projects are being co-developed with the industrial partners (Galvani Bioelectronics) to further explore the potential of this printing technique to manufacture useful devices that may eventually be clinically translated.

"Together this academic-industry partnership has the mutual objective of advancing clinical opportunities in medical technology, advancement of scientific endeavor through publications, and providing security for intellectual property for the purpose of securing a path to commercialisation."
Dr Daniel Chew, Director Neuromodulation Translational Sciences, Galvani Bioelectronics

Technical efficacy: Conducting polymer structure printed on a soft/flexible substrate



Biological efficacy: Conducting polymer structure interacts with brain tissue



Industry interaction

The field of bioelectronics, neuroprosthetics, and implantable medical devices in general, are progressing at a fast pace. Traditional medicinal applications have focused on the central nervous system, and severe and rare disorders and trauma, including deep brain stimulation, neuropathic pain, and bladder control. More recently the peripheral nerves have been targeted, with applications focused on disease applications; such as vagus nerve stimulation for the treatment of epilepsy and arthritis. The field is still seen as a last line treatment, and this is primarily due to the route of application (surgical), but also due to the general lack of technological advancement in critical areas. One such area is the neural interface; the connection between biology and engineering. Here the tissue-material mismatch leads to significant foreign body reaction, and lack of treatment efficacy. New materials that are more biocompatible, more conforming to the tissue shape, and which can be manufactured in miniaturised form and bespoke to each patient's anatomy, will greatly benefit the biology/anatomy, the treatment efficacy, and overall patient access.

Dr Daniel Chew at Galvani Bioelectronics (GSK subsidiary) has been involved in the project, in an advisory capacity, shaping the overall objectives toward clinical and commercial aims. Galvani Bioelectronics has, since its inception within GSK, nurtured an externalised R&D effort focused on leveraging the world-wider expertise of academics and the facilities of Universities.

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