Research Grant – Successful Submission

Mr Salman Malik – PhD Student University College London – Awarded £2500

Electrospray Fabrication of Conductive Polymer Patches for Cardiac Restoration

1. Aim of the Project

Restoring full functionality of the heart muscle post-cardiac arrest has proven to be an immense challenge for the clinical community. A suitable processing technique in addition to a biocompatible polymer matrix has not been established although electrospray aerosols could offer a simple yet economic technology to overcome this huge hurdle. This project investigates the use of electrosprays to fabricate conductive, biocompatible thin film wound patches for cardiac tissue regeneration.

Restoring full heart function after a heart attack is a huge challenge. The aim of the proposed work is to use an effective, widely used laboratory-based aerosol technique to manufacture patches to enable those affected to live longer.

Despite the ongoing hurdle of providing patients with a long-term solution to cardiac muscleredevelopment, there has not been a suitable, scalable and cost-efficient technique to create cardiac patches for providing a means for the muscle to restore it's electrophysiological function. Previous work has reported on the use of electrospinning nanofiber patches utilising metallic gold nanoparticles to patch onto a patient's heart without much success and other methodologies in the literature have reported using tissue engineering and other chemical-based methods that require harsh starting materials and costly manufacturing schemes that are unscalable. There is in particular a lack of information and data on reported methods that have been effective despite the needs for a biological material that provides a conductive medium for cells to communicate with each other and hence restore long-term functionality.

Over the last decade, the electrospray aerosol technology has been reported as an effective means of synthesizing polymeric patches utilising a whole host of polymers and solvents with great control over thickness and morphology. Internationally, groups have used the technique to manufacture thin films of polymers for a range of applications, such as nanotechnology, tissue engineering, filtration membranes and drug delivery systems. Collaborators also at UCL (Mechanical Engineering) have utilised the electrical aerosol as means for electrospraying biological compounds for clinical use and would be our primary collaborators for the proposed project.

2. Programme of Work

The project will involve the continuous collaboration between the departments of Electronic Engineering and Mechanical Engineering throughout the entire duration of research. Additionally facilities at the London Centre for Nanotechnology (LCN) will be used to help characterise the samples. The project work plan (for the duration of the small grant scheme) would be the following:

1. Electrospray thin films using two different conductive polymers using a class III (FDA-approved) solvent system (i.e. one, two or three miscible solvents to ensure conductivity of solution is sufficient for electrospraying). The two conductive polymers listed would be the following: a. Polypyrrole (PPy) b. Polyaniline (PANI).

2. Physical characterisation to image morphology and thickness of thin films. Assess uniformity and reproducibility of manufacture for thin films with suitable morphology for wound patches. There is a critical need for establishing processing methods that are effective on the nanoscale yet are applicable to macroscopic processing and therefore scalability will be considered at this stage before additional processing and characterisation.

3. Measure Current-Voltage (I-V) performance and repeatability to assess electrical characteristics and behaviour of thin film wound patch under a range of environmental conditions, i.e. temperature and humidity dependant measurements. These measurements would be used to assess the electrophysiological potential of the conductive polymer patch.

4. Micro---Electrode Array (MEA) measurements will be used to electrospray polymer patches/thin films onto the electrodes with cardiac cells (cardiomyocytes) to test electrophysiological communication between the cell contacts on the MEA cartridges and provide further proof to conduct in vivo studies. (NB: Cartridges are reusable).

The proposed work provides the opportunity for two key exploitation routes. An industrial/charitable partner's support will be sought for a Knowledge Transfer Partnership to develop a clinical scenario for animal studies (long-term goal). With clinician support, a database of cardiac wound patch in vitro performance will be gathered to then take these preliminary studies forward and eventually to in vivo studies.

3. Potential Applications

The end intended application of the work outlined here would be for restoring cardiac functionality to a patient (although animal studies and clinical trials would precede this). Testing the conductive polymer patches and characterising them, i.e. using Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Spectroscopic techniques and electrical characterisation could potentially open doors for other applications (i.e. nanoelectronics) once a study has been performed to understand the (electrosprayed) processed materials.

This project will involve working across multiple engineering departments (primarily Electrical and Mechanical Engineering) across UCL and the UCL Hospital (UCLH). I will be working directly with the research groups of Dr Suwan Jayasinghe (Reader in Bioengineering and Biophysics) in addition to my own research group, lead by Professor Tony Kenyon (Professor of Nanostructured and Nanoelectronic Materials). Additionally Dr Wing Ng will aid with image analysis and physical characterisation at the London Centre for Nanotechnology, Dr Adnan Mehonic with electrical performance analysis and High-Resolution Scanning Transmission Electron Microscopy (HR-STEM) will be performed at the A*Star Institute, Singapore by Mr Manveer Munde.

Our collaborator Dr Suwan Jayasinghe has several industrial collaborations with current projects and his experience and understanding of the technologies proposed here would aid with the initial industrial upscale pending the output of the electrosprayed cardiac patch. Preceding industrial exploitation, animal studies and clinical trials would be the first initial steps to ensuring the patch lifetime longevity and sustainable performance. Additionally his current projects with the British Heart Foundation (BHF) would be the gateway opening to take this through the innovation pipeline and commercialise a patch in the future (pending the output of the proposed project and success of this grant).

The duration of this project will be 1 year.