UNIVERSITY OF SURREY

Engineering Science for Health CDT – Project Descriptions

Patient Focussed Technologies Research Theme

The Engineering Science for Health (ESH) CDT explores research in engineering, mathematics and the physical sciences with applications to Healthcare technologies. The CDT is highly multidisciplinary and includes PGR students with backgrounds in Chemistry, Physics, Biosciences, Engineering, Computer Science and Mathematics. Our research is divided into 4 main research themes which are all focussed on Healthcare applications:

(1) Sensors and Imaging

(2) Biological and Molecular Systems

(3) Computational Methods and Modelling

(4) Patient Focussed Technologies.

A range of PhD research projects will be offered across all 4 themes, with students supported by a multi-disciplinary supervisory team.

This document gives more information about the projects offered within the Patient Focussed Technologies research theme.

Summary of Projects - Patient Focussed Technologies Research Theme

Ref Num:	Project Name	Primary suitability for applicants from these disciplines:					
		Physics	Chemistry	Bioscience	Maths	Computing	Engineering
3.1	Flexible, printed sensor electronics for accurate disease detection	**X**					**X**
3.2	Energy harvesting and self-powering for medical implanted devices	**X**					**X**
3.3	Thin-film mesh electronics system for chronic wound monitoring and therapy	**X**					**X**
3.4	Development of novel tools applied to sound stimulation for the modulation of brain rhythms affected by ageing and disease				**X**	**X**	**X**
3.5	Early and rapid detection of chemotherapy-induced nerve disorders					**X**	**X**
3.6	Sensor fusion for health diagnostics in respiratory disorders					**X**	**X**

For general information about any of the ESH projects, or the application process, please contact eshcdt@surrey.ac.uk

Research Theme Overview

The Patient Focussed Technologies research theme develops emerging topics bioelectronic engineering, which is the application of electrical engineering, physical and chemical principles to biology, medicine, behaviour or health, to create a better digitally connected society for its health and wellbeing. It uses electrical and photonic engineering approaches to integrated microsystems, with chemistry and physics leading to new biological and medical sensors and systems that interact and exchange data with the nervous system. These sensors consist of state-of-the-art ultrasonic, RF, optical, MRI, CT, Xray, electrical impedance transducers and are used to develop wearable and implantable devices, with decreasing size, weight, and power requirements and increased functionality.

Project Descriptions:

Ref Number:	3.1	**Project Title:**	Flexible, printed sensor electronics for accurate disease detection
		Project Supervisor(s):	Dr Vlad Stolojan http://www.surrey.ac.uk/ati/nec/people/vlad_stolojan/

Project Description: Enabling ultra-sensitive measurements of chemical and electrical signals produced by human organs with bio-compatible devices, without wires, on ultra-flexible substrates, is of paramount importance for future bio-medical devices targeting early stage diseases diagnostics as well as patients monitoring. This project will explore new approaches for both on-skin and also implantable flexible sensors that are fully compatible with bio-tissues and operate under realistic conditions when devices are interfaced with 'wet tissues' with bio-electrolytes. Novel organic semiconductor sensor devices will be incorporated onto soft substrates, and designed with specific response to either bio-chemical signals, or to very small changes of electric potential. Ultra-flexible, and also stretchable nature of the electronic part is the key to the future bio-medical sensors compatible with a variety of applications from cardiac monitoring to brain cells activity recording.

An advanced bio-medical sensing device in combination with in vitro cardiovascular model for drug testing will be suggested as the outcome of this project.

Supervisor team is highly interdisciplinary, with excellent level of expertise in the key areas of the project and Institutional support will ensure PhD student's access to equipment and corresponding training across University laboratories.

Applicant Specifications: First class undergraduate or masters degree and very strong background in either of the disciplines: engineering, materials science, bio-physics, physical chemistry, veterinary medicine, with excellent practical and analytical skills and demonstrated aptitude for interdisciplinary research.

Ref Number:	3.2	Project Title:	Energy harvesting and self-powering for medical implanted devices
		Project Supervisor(s):	Professor Ravi Silva

Project Description: Implantable medical devices (IMDs) are widely utilised to monitor body functions, drug delivery, cell stimulation, etc. However, these IMDs have as of yet not been self-powered. With their regular power needs, typically supplied by conventional batteries, it has introduced a bottleneck, with social, financial and physical inconveniences to the patients. The main aim of this research is to harvest biomechanical energies including body movements, internal organ motions, and daily human activities, via triboelectric nanogenerator (TENG) technology and employ it to operate the IMDs in autonomous mode without the need of a solid-state battery. TENGs are a new type of energy harvester that operate on the principle of contact electrification of dissimilar material surfaces, whose charge then can be consolidated and used to move a current through a load. Our research shows the output current from TENGs is double-peaked impulses with high voltage (100-500V) and power density of 1-20 mW/cm2, that can be coupled with the power requirements of IMDs. In order to achieve these goals, the research will develop wearable, biocompatible, and skin-friendly intelligent plaster-like TENGs by utilising electro-spun micro/nano-fibrous scaffolds from nature-driven materials (i.e., silk & cotton) and synthetic polymers (i.e., polyimide, PVDF-TrFE, and PEDOT:PSS). The Advanced Technology Institute (ATI) has world leading activities in both these areas.

This research conducted will involve several objectives including:

-optimization of the electrospinning synthesis process; so that the material can withstand and operate under harsh/outdoor environmental and in vivo body implanted conditions

-optimization of device structures; so that it can be easily adopt into various human body shapes and efficiently harvest the biomechanical activities

-optimizing the internal resistance of the device; so that it can match and fulfil the power requirement of IMDs, including external communication links on an intermittent basis

This project will also help target novel energy sources for the IoT sector to power small to medium-size devices in the micro- and milli-Watt range. Furthermore, as waste energy is captured, the potential gain of energy and reduced impact of this waste energy on the environment will help UK sustainability and healthy society impact on the SDG.

The potential of the technology will give the UK a major boost in healthcare, advanced therapeutics, autonomous motion sensors, healthcare sensors, IoTs, wearables, and remote power actuators. The time is right to promptly develop these multifunctional platform technologies for real-world applications.

Supervisor(s): Professor Ravi Silva, Yunlong Zhao, Vlad Stolojan, Maxim Shkunov

Ref Number:	3.3	Project Title:	Thin-film mesh electronics system for chronic wound monitoring and therapy
		Project Supervisor(s):	Dr Yunlong Zhao https://www.surrey.ac.uk/people/yunlong-zhao

Project Description:

Chronic wounds represent a significant burden to patients, healthcare professionals, and the healthcare system. It affects more than 40 million patients and incurs huge costs each year. Conventional wound therapy devices are usually bulky and may have limited functions for both continuous monitoring and treatments. How to further improve their biocompatibility and functionality will be the key to their wider applications. In this project, we are aiming to demonstrate novel bioelectronic devices for electrical & light stimulation and continuous multiparametric monitoring of wound healing by integrating multifunctional sensors, simulators and miniaturised powering units in the ultra flexible mesh layer.

Applicants with a background in electronics/nanofabrication are particularly encouraged to apply. The successful candidate will register for a PhD at Advanced Technology Institute (ATI), University of Surrey. The research will be mainly performed within a vibrant and dynamic environment in the laboratories under the supervision of Dr Yunlong Zhao (https://www.surrey.ac.uk/people/yunlong-zhao) at ATI and also collaborate closely with the School of Biosciences and Medicine at the University of Surrey and the Electronic and magnetic materials group at the National Physical Laboratory (NPL). The successful candidate will develop multidisciplinary skills in bioelectronics, nanofabrication, biosensing, would healing treatment, etc.

The ATI is one of the University of Surrey's world-leading research centres. It brings together researchers with an international outlook in Quantum Information, Nanotechnology, Energy and Advanced Materials, and has a wide range of facilities for material synthesis, device fabrication, measurement and characterisation. The successful candidate will also get the opportunity to work closely with NPL, which is one of the world-leading centres of excellence in developing and applying the most accurate standards, science and technology available.

UNIVERSITY OF SURREY

Ref Number:	3.4	Project Title:	Development of novel tools applied to sound stimulation for the modulation of brain rhythms affected by ageing and disease
		Project Supervisor(s):	Dr Daniel Abasolo and Dr Ines Violante

Project Description:

One of the greatest accomplishments of the 20th century was a remarkable gain in global life expectancy, with an increase of about 30 years in industrialised countries. Whether longevity is a burden or an opportunity to societies will depend on how well individuals age and how societies adapt to provide better health and health care for older adults.

Ageing is associated with alterations in brain dynamics that can be measured and monitored using electroencephalography (EEG). EEG records the electrical activity of neurons in the cortex of the brain and is, therefore, a very useful tool to characterise the changes associated with ageing and neurological disorders. A hallmark of ageing is a general increase in the power of slow oscillations and marked reduction in the amplitude of alpha activity. This is exacerbated in pathological conditions, such as Alzheimer's disease (AD), and has been shown to be associated with clinical progression of AD. Furthermore, measures of functional connectivity have shown that brain dynamics change with age and can provide an index of brain vulnerability. Moreover, a loss of complexity in EEG recordings has also been observed in healthy ageing and some neurodegenerative conditions.

Sound stimulation provides a non-invasive, cheap, and tenable strategy to modulate brain rhythms. Recent studies have shown that rhythmic auditory stimulation can impact disease pathology and cognition. In our labs we have established that closed-loop auditory stimulation can be deployed to modulate regional alpha oscillations and modulate long-range brain connectivity. We were able to modulate the amplitude and frequency of alpha oscillations in young adults at rest.

The successful candidate will work on the development of this technology for its use in older adults, by first tuning the parameters that lead to successful modulation of brain oscillations affected by ageing and developing advanced signal processing algorithms to capture patterns associated with this (Aim 1). This will be followed (Aim 2) by the development, testing and deployment of neuro-technologies that can be used at home by older adults and would pave the way to clinical applications.

Ref Number:	3.5	Project Title:	Early and rapid detection of chemotherapy-induced nerve disorders
		Project Supervisor(s):	Dr Matthew Oldfield

Project Description:

One of the unwanted side-effects of chemotherapy can be the development of a condition called peripheral neuropathy. This results in discomfort or a loss of sensation beginning in the hands and feet. The ability to balance while standing and walking is greatly affected by the ability to sense the ground through our feet. Consequently, the loss of this sensation can result an increased risk of trips and falls.

Peripheral neuropathy is a progressive condition and the long-term outlook for improvement is poor. Identifying the condition early and modifying treatment can mitigate its impact.

This project will look at how movement sensors can be used to detect the onset of peripheral neuropathy. It will consider the sensitivity and specificity of different activities in identifying the occurrence and progression of the condition. Using research grade sensors, data on static and dynamic balance will be collected for analysis. Factors investigated will include the types of activity that have a strong correlation with the onset of peripheral neuropathy as well as the best configuration of wearable sensors to capture useful data about the condition. Subsequently, the approaches identified using costly sensors will be adapted for use in low-cost sensor technology and at-home measurement. The ability to monitor a significant side effect of chemotherapy remotely has considerable benefits for patients dealing with further side effects and compromised immune systems.

The successful candidate will have an interest in conducting physical experiments with human participants. The project will require the ability to work with clinicians and members of the public and conduct studies of human movement. Analysis of the outputs physical experiments would suit a candidate with an enquiring mind and possibly an interest in using the data in the field of artificial intelligence.

UNIVERSITY OF SURREY

Ref Number:	3.6	Project Title:	Sensor fusion for health diagnostics in respiratory disorders
Project Supervisor(s):			Dr D. M. Birch

Project Description:

There have been repeated calls from the medical community for faster, more sensitive, and more functional respiratory diagnostic tools. Using the most advanced sensing technologies currently available within the aerospace sector, the University of Surrey's Centre for Aerodynamics and Environmental Flow - together with the Centre for Biomedical Engineering - have been developing compact, inexpensive new respiratory diagnostic and monitoring instruments. Unlike existing tools, these have demonstrated that they may be able to not only detect lung volume and air exchange, but also anything from severity of asthma to heart rate and pulmonary blood pressure - all from breathing normally through a tube. Further developments include techniques for inferring body core temperature and blood oxygen level. However, it remains unclear from the limited pilot and preclinical trial data how to interpret the data from these novel instruments.

The purpose of this project, therefore, is to (a) carry out an analysis of existing human trial data, and develop the numerical techniques required to reliably infer the patient's critical health indicators from the different sensor signals available (pressure, flow rate, temperature, humidity, vibration, etc.) together with estimates of the uncertainties, using appropriate statistical and/or machine-learning methodologies; (b) use this analysis and a review of existing low-cost biosensors to propose an improved instrument and methodology to reduce the uncertainty or extend the range of critical health indicators provided, and (c) carry out limited pilot tests where appropriate in order to validate the new technologies.