**PhD PROJECT PROPOSAL**

***PhD Project Title***

Two-Photon Polymerized Hydrogels 3D Nano and Microstructures for Healthcare Applications

***PhD Supervisory Team***

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***Project Abstract***

Three-dimensional (3D) direct laser writing based on two-photon polymerisation (TPP) enables the precise fabrication of 3D hydrogel micro- and nanostructures for applications in biomedical engineering. However, 3D hydrogels fabricated by TPP are usually confronted with low spatial resolution and long fabrication time due to the characteristics of TPP and the lack of water-soluble initiators with a high efficiency.

To address the above, this project will focus on the development of a new hydrogel formula suitable for the world's highest resolution 3D printer (Nanoscribe Photonic Professional GT). Such hydrogels will be shrinkable after laser writing to effectively achieve better fabrication resolution than that offered by Nanoscribe. A recipe for metallisation of patterned hydrogels nanostructures will also be developed.

***Detailed Project Description***

*Research background, intended outcomes and methodology;*

**Background:** This project is inspired by the work done on expansion microscopy where imaging of subwavelength objects (e.g. cellular nanostructures) has been achieved by conventional diffraction-limited optical microscopy by increasing the geometrical dimensions of these objects using expandable hydrogels [1]. In 2018, Boyden and his team demonstrated the suitability of shrinking hydrogels and metallisation to fabricate silver nanowires [2]. However, hydrogels with anisotropic expansion/contraction factors and the application of shrinking hydrogels combined with metallisation for making optical metamaterials are not yet being reported.

**Outcomes:** In this project, photopatternable hydrogels with required geometrical contraction factors will be designed and their application for fabricating sub-wavelength geometrical features using photolithographic methods will be investigated. More specifically, swollen hydrogels will be patterned using diffraction limited photolithography instruments (e.g. Nanoscribe Photonics Professional). Patterned hydrogels will then shrunk to obtain geometrical structures with sizes, which can currently only be fabricated using e-beam. Equally, patterned shrunk hydrogels may act as a mould for metal deposition, thereby replicating the structures in metals, which are typically used for making plasmonic metamaterials.

**Methodology:** The methodology is as follows:

* **Synthesis**: A library of monomers and crosslinkers will be created to obtain photopatternable hydrogels with different expansion/contraction factors. In the first instance, poly(acrylamide-co-acrylonitrile) (Poly(AAm-co-AN)) and poly(acrylamide-co-acrylic acid) (Poly(AAm-co-AA)), which are known to change their geometrical dimensions with temperature and pH respectively, will be used.
* **Characterisation**: Synthesised monomers and crosslinkers will be characterised using standard analytical methods such as NMR, mass spectrometry, and FTIR. Optical properties (e.g., absorption, scattering) of hydrogel sheets will be determined. Wavelength and energy required for photopatterning of hydrogels will be determined. Subsequently, swelling and shrinking of hydrogels will be characterised by imaging and weight measurements.
* **Fabrication of micro- and nano-structures:** Structures will be written in swollen hydrogels using conventional photolithography. Studies will then be conducted to investigate if geometrical shapes of structures are preserved in shrunken hydrogels. Examples of optical structures that will be fabricated in hydrogels will include gratings, array of nanoholes, and square shaped metamaterial rings. Subsequently, suitability of methods such as electrochemical deposition for faithful replication of structures from hydrogels to metals will be investigated.

**References:**

1. F. Chen *et. al.*, Expansion microscopy, Science, 347, (2015), 543.

2. D. Oran *et. al.*, 3D Nanofabrication by Volumetric Deposition and Controlled Shrinkage of Patterned Scaffolds, Science, 362, (2018), 1281.