CDT ACM PhD Project– 2023 intake

Supervisors		
	Supervisor 1	**Supervisor 2**
Name	Prof. Louise Bradley	Dr Ali K. Yetisen
Email address	bradlel@tcd.ie	a.yetisen@imperial.ac.uk
Institution/Company	Trinity College Dublin	Imperial College London

Role of each supervisor & synergy *(100 words max; Every project must demonstrate a synergistic link between the partner individuals and institutions; it should not be possible to conduct the entire project at one of the institutions alone)*

Prof. Bradley, School of Physics in Trinity College Dublin, will lead the optical design and characterization. New materials for 3D printing by two-photon-polymerization and fabrication will be done in collaboration with Profs. Florea and Delaney from the School of Chemistry in Trinity College. Dr. Ali K. Yetisen, from the Department of Chemical Engineering is an expert on biochemical sensors, optical materials and devices in medical diagnostics. Dr. Yetisen specializes on lab-on-fibre devices for sensing applications in remote and real-time conditions.

Project theme *(select one)*				
Energy Materials	Biomaterials & Regenerative Medicine	Engineering Materials	Electronic & Magnetic Materials	Instrumentation & Technique Development
☐	☐	X	☐	☐

Project description	
Title	Next generation 3D printed photonic structures

Abstract *(250 words max; general description of the project, the specific research question(s) to be addressed, and the potential impact)*

Over the past number of years chemists have been engineering materials compatible 3D printing via two photon polymerization. This paves the way for next generation biomimetic inspired photonic structures, which despite being made of low refractive index materials such as chitin and guanine display bright saturated colour by exploiting complex structures. There are many spectacular examples of structural colour in nature such as butterfly wings, beetles, and chameleons, to name but a few. Coupling the structural freedom of 3D printing with emerging dynamic and responsive materials opens up a vast array of exciting possibilities. The challenge is to develop photonic structures which can take full advantage of these newly engineered materials in sensing, display and anticounterfeit applications. We recently demonstrated how the concentration sensitive expansion of a novel hydrogel printed photonic structure manifests as spectral changes in the transmission spectrum. In another example we designed structures for pattern transformation when structures are submerged in solution.

A current challenge is to extend the dielectric permittivity and polarization response of the materials compatible with direct laser writing by two-photon polymerization and to print the photonic structures onto the facet of a fibre for a fully integrated photonic sensor. This dielectric permittivity can be modified by incorporating metallic nanoparticles, higher refractive index dielectric nanoparticles or liquid crystal based components. The metal nanoparticles are formed in the host material using a light actuated chemical process. Such materials offer opportunities for reflective and transmissive applications with a dependence on the polarization of the incident or detected light. A unique offering of this project is the close collaboration between material scientists, Profs. Florea and Delaney, photonics expert, Prof. Louise Bradley and sensing expert, Dr. Yetisen. This project will include the design, fabrication and testing of the materials and photonic structures for lab on fibre sensing (vapor and liquid) applications.

[1] Delaney, Qian, Zhang, Potyrailo, Bradley and Florea, ***J. Mater. Chem. C***, 2021,**9**, 11674-11678

Characterisation technique(s) *(100 words max; describe the key characterisation technique(s) that will be used during the project, the type of information they will provide, and rate their importance for the completion of the project)*

The highly interdisciplinary project requires an array of essential characterization techniques:

- Angle dependent and polarization resolved reflection and transmission spectroscopy in air and when exposed to vapours and liquids - for testing the photonic structures and sensing performance.
- Polarization dependent dark field spectroscopy - characterization of the nanoparticle scattering and liquid crystal materials.
- Spectroscopic ellipsometry - to measure the refractive index of the engineered materials.
- Atomic force microscopy and scanning electron microscopy - to obtain structural information about the fabricated structures. The AFM measurements are carried out in air and in saturated state to measure the volume expansion of the materials when submerged.

Placement description *(150 words max; all projects must include a placement period of typically one to three months. This will usually take place in year 2 or 3, and should include at least one unbroken period of one month. Identify the intended host and confirm that they have accepted to host the student. Describe how the placement will benefit both the academic and personal development of the student. The placement is an integral part of the CDT experience and the committee will follow up on the successful completion of the placements at the end of year 3.)*

The student will spend 3 months in the lab of Dr. Yetisen in Imperial College during year 2. During this time they work on the techniques for integration of 3D printed hydrogel structures with fibre optic technology to produce a fully integrated lab on fibre sensor that can operate in reflection mode. Dr. Yetisen recently published Nanostructured Photonic Hydrogels for Real-Time Alcohol Detection *ACS Appl. Nano Mater.* 2022, 5, 6, 7744–7753. The student will be trained on the fabrication of the optical fibre sensors and the functionalisation of the distal end of the fibres for the quantifications of analytes in aqueous solutions. The quantification will be achieved through a in-house reflection spectrophotometer and analyses of the Bragg peaks in the visible spectrum. The student will also have an opportunity to create multiplexed sensors based on a bundle fibre system to obtain simultaneous measurements of different analytes.

Project partner *(if applicable; 100 words max; provide details of any industrial partner, research institute including large-scale facilities such as synchrotron light sources or national laboratories, or overseas university participating in the project)*

In addition to working in the labs of Prof. Bradley in TCD and Prof. Yeltsen in Imperial College London, the student will undertake a 1-month placement in Tyndall National Institute in Cork with Prof. Liam O'Faolain. This will occur during the second year of the project. Prof. O'Faolain is an expert in the fabrication and testing of integrated photonic sensors, including for thermal and gas sensing applications. The student will benefit from working in a group specialised in sensors and will be able to access testbeds for investigating the performance of the fibre-sensors developed in this project and to be able to compare with other sensors in the same test environment. The student will be able to bring this expertise back to TCD for the rest of their project and they will be able to continue to use the facilities in Tyndall throughout the project if required for additional experiments. The placement has already been confirmed with Prof. O'Faolain.