CDT in Advanced Characterisation of Materials

PhD Project Proposal

Project Title Nanomechanical characterisation of soft biomimetic materials

Project Supervisors

Supervisor 1: Prof. Philip Jones (UCL), e-mail: philip.jones@ucl.ac.uk web-site: www.ucl.ac.uk/~ucapphj

Supervisor 2: Dr Valeria Garbin (ICL), email: v.garbin@imperial.ac.uk web site: garbinlab.ce.ic.ac.uk/

Abstract

The project objective is to develop and utilise a suite of advanced analytical techniques, including optical tweezers and microfluidics, for characterising the (nano)mechanical properties of 'soft' biomimetic materials such as liposomes or biomembranes. The principal aims of this project are:
(i) to study the mechanical properties of biomimetic vesicles undergoing extreme deformations as a result of an applied external stress, e.g. optical, acoustic, or fluid shear forces;
(ii) to study phase separation and rupture in artificial vesicles under external forcing;
(iii) to use the result of the above studies to engineer membrane materials with properties optimised for applications including controlled drug release and microreactors.
During the project the student will acquire skills in microfluidics, microdevice fabrication, optics, modelling (including light scattering and transport phenomena), image analysis, and (micro)rheology.
This is a new collaboration between the UCL and ICL groups, which together possess the complementary expertise required for this project. The UCL partner (PJ) has recently co-authored the first textbook on optical tweezers[1]. The UCL laboratory has the necessary apparatus, including an optical tweezers and a recently developed optical fibre trap ('optical stretcher') that can be used to trap, manipulate, and apply mechanical forces to nanomaterials[2] and soft or biological matter[3]. The ICL partner (VG) has expertise in fluid dynamics and soft materials for formulated products and drug delivery. The ICL laboratory is equipped with high-speed video microscopy, particle-tracking microrheology, and acoustofluidics, which have recently been used for dynamic measurements of deformation and rupture of biomimetic vesicles[4], and controlled release[5]. The project will therefore require the combination of expertise from both partners. For example, on the theoretical side, in light scattering for the calculation of stress distribution on a membrane subject to optical forces (UCL), and in the deformation properties of soft materials to quantify the mechanical response to applied stress (ICL); on the experimental side, in the synthesis of vesicles and actuation of fluid flows using microfluidics (ICL), and optical trapping and stretching of microscale 'soft' materials (UCL).

Project Partner

The three-month placement will take place in the laboratory of Dr Siva Vanapalli in the Department of Chemical Engineering at Texas Tech University. Here the student will learn to apply microfluidics to the mechanical phenotyping of cancer cells.
Website: http://sivaav.wixsite.com/microfluidics

[1] P H Jones, O M Marago & G Volpe, Optical Tweezers: Principles & Applications, Cambridge University Press (2015)
[2] O M Marago, P H Jones et al, '*Optical trapping and manipulation of nanostructures*', Nature Nanotechnology **8** 807-819 (2013)
[3] R Agrawal et al, '*Assessment of red blood cell deformability by optical tweezers in diabetic retinopathy*', Scientific Reports **6** 15873, doi:10.1038/srep15873 (2016)
[4] A Pommella, N J Brooks, J M Seddon, V Garbin, '*Selective flow-induced vesicle rupture to sort by membrane mechanical properties*', Scientific Reports **5**, 13163 (2015)
[5] V Poulichet and V Garbin, '*Ultrafast desorption of colloidal particles from fluid interfaces*', Proceedings of the Natural Academy of Sciences **112**, 5932 (2015)