

Probing the microscopic dynamics of deformable interfaces

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Ph.D. position available

This project is a collaboration between [Prabhakar Ranganathan](#) and [Edith Sevick](#) at the Australian National University (ANU). We are looking for somebody with a [H1 or equivalent](#) graduate degree in either engineering, physics or mathematics to take on the challenge of setting up computer simulations to study an important problem that has potential applications in nanotechnology, microfluidics, and biology. The project will involve lots of theoretical analysis, but there is also scope to do experimental work. A PhD in this multidisciplinary project can be the stepping stone to an exciting academic or research career in a number of fields: computer simulations, nanotechnology, mechanical/ chemical/ materials engineering, microfluidics, biophysics etc.

Scholarships are available from Monash University for applicants with a [strong academic background](#).

Aims and background

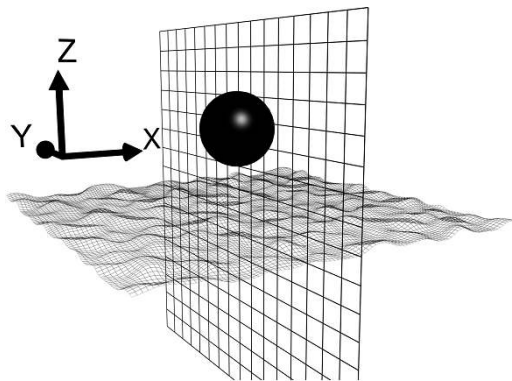


Figure 1: *Schematic of an optically-trapped bead localized a small distance above a soft surface using Optical Tweezers. A high numerical aperture objective traps the colloidal particle in the trapping plane (shown gridded) and localizes the particle about a focal point (shaded area of plane). In this manner, fluctuations of the particle in the plane perpendicular (shown) and parallel (not shown) to the soft interface are recorded and related to the mechanical properties of the soft surface through hydrodynamic theory/ computer simulations.*

length scales of the particle's motion.

The objective of this Project is to develop a new experimental technique based upon Optical Tweezers (OT), to measure the mechanical properties of soft surfaces, such as phospholipid bilayers which serve as model cellular membranes and liquid-liquid interfaces of ultra-low surface tension. The technique will use a focussed laser beam to localise a micron-sized colloidal particle near a soft surface. The motion of this colloidal particle is hydrodynamically coupled to the thermal fluctuations of the soft surface, which are in turn dictated by the surface's mechanical properties, such as its surface tension and bending rigidity. Since the colloidal probes will not be incorporated within the interface itself, we can study the dynamics of the latter without locally modifying its mechanical properties.

Currently, soft surface properties are found by direct measurement of the fluctuations of the surface, usually with video microscopy techniques. These techniques assume homogeneous surfaces, and probe only those fluctuations that can be captured with light microscopy. In contrast, our proposed technique using OT can measure particle fluctuations to the resolution of 10 nm, that is the particle probes the **local** surface properties, allowing for the proposed technique to distinguish heterogeneities on the time/

The OT is a relatively new device, promoted as a tool for nanotechnologists, biologists

and clinicians, providing colloid and cell sorting, and micro-dissection capabilities. In OT, a strongly focused beam of light forms a trap that holds a small colloidal particle. The trap is a result of the light's refraction through the micron-sized particle. The refracted rays differ in intensity over the volume of the particle and the change in the momenta of the photons upon refraction gives rise to a piconewton scale force ($1 \text{ pN} = 10^{-12} \text{ N}$) on the particle, drawing it towards the region of highest light intensity. By translating the focal point of the light, trapped objects can be moved and sorted. This tool is popularly used as an optical scalpel to dissect delicate parts of biological objects, such as the lining of ovum in clinical IVF procedures, and is a highly sought after tool in biological, medical, and clinical laboratories.

It is well known that a particle diffusing near a rigid surface experiences an increase in drag forces as it approaches that surface. These effects are due to hydrodynamic interactions with the hard wall: the particle motion causes a "wake" which is reflected off the rigid surface, further perturbing particle motion. However, the situation becomes more complex when the surface is soft and deformable, and is itself subject to thermal fluctuations: the motion of the particle and the soft surface are then coupled. Such hydrodynamic interactions are long-ranged and can be measured several particle diameters away from the interface. By developing the theoretical framework for the motion of colloidal particles near soft fluctuating interfaces, we can begin to interpret measurements of the spatial fluctuations of a colloidal particle held in a weak optical trap by an OT near an interface, and extract information about the interface itself.

Significance and Innovation

This technique will have immediate impact in studies of membranes, particularly in tracking changes in the biomembrane as it participates in cellular events, such as transportation by budding and vesicle formation. The biological cell-the very epitome of a microfluidic device-is conspicuously devoid of any hard surface and moreover, its soft walls are actively involved in the biochemical tasks of the micro-reactor. However, so far, microfluidic labonchip applications have remained grounded in the old paradigm of an engineers reaction vessel. This project will develop the theoretical framework for the hydrodynamics associated with soft fluctuating surfaces, which is crucial for understanding flows and interactions in microvolume fluids encapsulated in flexible membrane containers-an essential first step in building micro-reactors that truly mimic the cell. This study will lead to a fundamental understanding of the consequences of hydrodynamic coupling of particles and soft surfaces, and such knowledge could lead to the development of improved designs for immunological assays, where free antibodies bind with surface-coated antigens.

Interested candidates can mail prabhakar.ranganathan@eng.monash.edu.au for additional information.