Model membranes interfaced with optical tweezers: a versatile microfluidics platform for nanomanipulation and mechanical characterization

Aurora Dols-Perez[1], Guillermo J. Amador [1,2], Victor Marin [1], Roland Kieffer [1], Daniel Tam [2] and Marie-Eve Aubin-Tam [1]

[1]Department of Bionanoscience, Kavli Institute of Nanoscience, Delft University of Technology. Van der Maasweg 9, Delft 2629 HZ, The Netherlands.
[2] Laboratory for Aero and Hydrodynamics, Delft University of Technology, 2628 CD Delft, The Netherlands

a.dolsperez@tudelft.nl
m.e.aubin-tam@tudelft.nl

Membranes are the site of vital biological processes, such as sensing, communication and trafficking, involving many of them mechanical forces. But to elucidate the relationship between these membrane processes and mechanical forces it is required the use of tools able to apply and to measure picoNewton-level forces, like optical tweezers. Here, we introduce the combination of optical tweezers with free-standing lipid bilayers, which are fully accessible on both sides of the membrane [1]. In the vicinity of the lipid bilayer, optical trapping would normally be impossible due to optical distortions caused by pockets of solvent trapped within the membrane. We solve this by drastically reducing the size of these pockets via tuning of solvent and flow cell material. In the resulting flow cells, lipid nanotubes are pushed or pulled, and reach lengths above half a millimeter. Moreover, the controlled pushing of a lipid nanotube with an optically-trapped bead provides an accurate and direct measurement of important mechanical properties. In particular, we measure the membrane tension of a free-standing membrane composed of a mixture of DOPC and DPPC to be 4.6 × 10-6 N/m. We demonstrate the potential of the platform for biophysical studies, by inserting the cell-penetrating TAT peptide in the lipid membrane. The interactions between the TAT peptide and the membrane are found to decrease the value of the membrane tension to 2.1 × 10-6 N/m. This method is also fully compatible with electrophysiology measurements, and presents new possibilities for the study of membrane mechanics and the creation of artificial lipid tube networks of great importance in intra- and intercellular communication.

References

[1] A. Dols-Perez, G.J. Amador, V. Marin, R. Kieffer, D. Tam and M.-E. Aubin-Tam, ACS Appl. Mater. Interfaces 11, 37 (2019) 33620-33627

Figures

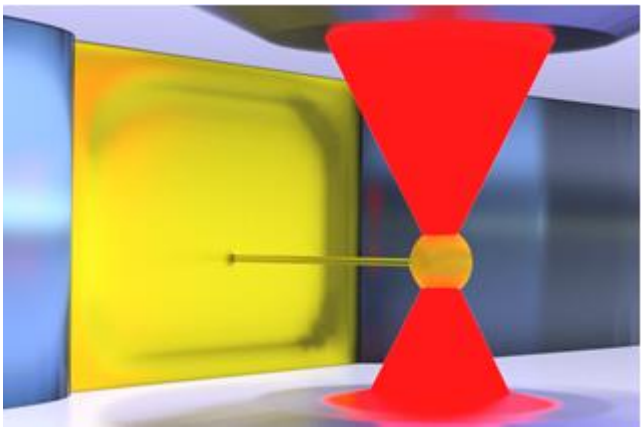

Figure 1. Schematic representation of an optical tweezers (red) pulling a lipid nanotube from a free-standing lipid membrane. The system consists of an artificial lipid bilayer (yellow) assembled on a rectangular aperture (blue) allowing free access to both sides of the membrane.