Soft Matter Adsorption 1: Kinetics of Lipid Vesicle Attachment and Deformation

The extreme surface sensitivity of Insplorion's Nanoplasmonic Sensing (NPS) technique makes it especially suited to study surface adsorption phenomena on the nanoscale. In this application example it is shown how NPS can be employed in a quantitative study of the kinetics of lipid vesicle adsorption. NPS provides information on both the attachment and deformation of adsorbed vesicles.

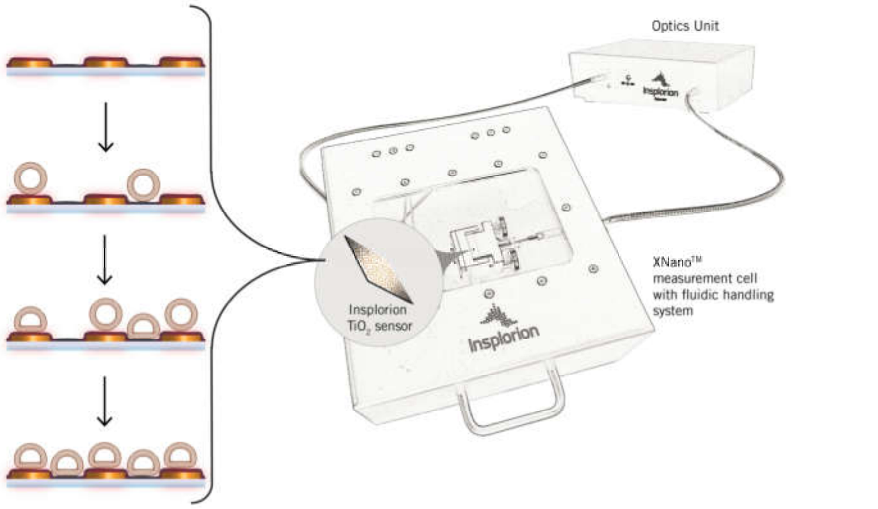

Figure 1: Insplorion system setup. The inset shows a schematic illustration of the sensors used in this application example (not to scale).

Introduction

An understanding of the mechanisms of vesicle adsorption provides valuable insights into fundamentally important cellular activites such as the structural transformations associated with membrane transport and vesicle fusion. It is also key to improving the fabrication of artificial membranes on solid supports for use in for example interaction studies of lipid layers with biomacromolecules, peptides, or nucleic acids.
The extreme surface sensitivity of NPS enables kinetic measurements that can clarify the vesicle adsorption and deformation process.

Experimental Procedure

Solutions of vesicles with varying lipid concentrations were prepared from lipids (1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine, POPC) using the extrusion method. Vesicle adsorption and deformation was studied with NPS using the Insplorion XNano system. Insplorion's TiO_2-coated sensors were used as substrates. The vesicle adsorption process was tracked by measuring the NPS signal shift over time during introduction of vesicles in solution. The liquid sample was supplied at a constant flow rate of 100 μL/min. Immediately before the first use the sensors were cleaned with an oxygen plasma. The sensors were reused up to 8 times and were cleaned with 1% SDS in between the experiments.
The rate of adsorption was analysed by taking the derivative of the time-resolved NPS signal.

Results

A series of experiments were performed where the lipid concentrations were varied between 0.2 and 0.0125 mg/mL (Figure 2a).
At all concentrations a monotonic increase in NPS response was observed until saturation coverage was reached. Furthermore, the final coverage was observed to increase with lipid concentration.

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The kinetics of the adsorption process was scrutinized by analysing the time derivative of the NPS response signal (Figure 2b). Depending on the concentration of lipids in solution, up to three different kinetic stages of the adsorption process were identified. A constant rate, consistent with diffusion-limited adsorption, was observed at low to intermediate vesicle coverage. As the coverage increases the rate of increase in the NPS response decreases. Theoretically, if vesicles are deformable and the adsorption rate is controlled by diffusion, the rate of adsorption is expected to be linear up to the saturation coverage. The deviations from linear adsorption rate observed in the NPS signal are consistent with shape deformation at high vesicle coverage.

Conclusions

In contrast to alternative measurement techniques for tracking soft matter adsorption the NPS signal is highly sensitive to the local environment immediately adjacent to the substrate. In this application example it has been shown how NPS can be used to monitor the lipid vesicle adsorption process as well as to analyse the behaviour of adsorbed vesicles (i.e. deformation).

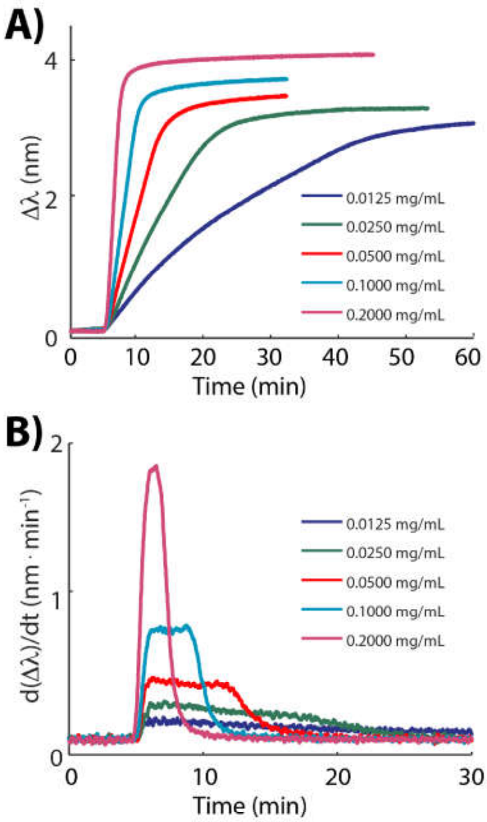

Figure 2: A) Adsorption profile of vesicles at different concentrations onto titanium dioxide. The arrow indicates the start of vesicle injection. **B)** The rate of adsorption (time derivative of the curves in A).

This application note is a short summary of a study performed by researchers at the Centre for Biomimetic Sensor Science, Nanyang Technological University (NTU), Singapore. A more detailed description of the experiment, theory and results can be found in [1].

References

[1] *Nanoplasmonic Biosensing for Soft Matter Adsorption: Kinetics of Lipid Vesicle Attachment and Shape Deformation,* Josh A. Jackman, Vladimir P. Zhadanov, and Nam-Joon Cho*, Langmuir.* dx.doi.org/10.1021/la502431x