Soft Matter Adsorption 2: Controlling Membrane Architecture

The different available surface coatings on Insplorion's sensors enable control over the material composition of the surface. In this application example lipid membrane platforms (vesicles and bilayers) are assembled on Insplorion sensors with different surface chemistries (bare gold disks on glass and TiO_2 and SiO_2 coatings, respectively). Due to the extreme surface sensitivity of Insplorion's Nanoplasmonic Sensing (NPS) technique information is obtained not only on the lipid adsorption but also on the membrane architecture and subsequent membrane-peptide interactions.

Introduction

There is a strong interest to develop biosensing platforms for lipid membrane applications in order to, for example, track interactions between a membrane and various analytes (e.g. proteins, peptides, nucleotides, nanoparticles).
Lipid vesicles in solution adsorb to surfaces and self-assemble to form different architectures depending on the surface properties. Using NPS, both the assembly process into different structures and subsequent interactions of the formed lipid layers with peptides can be studied.

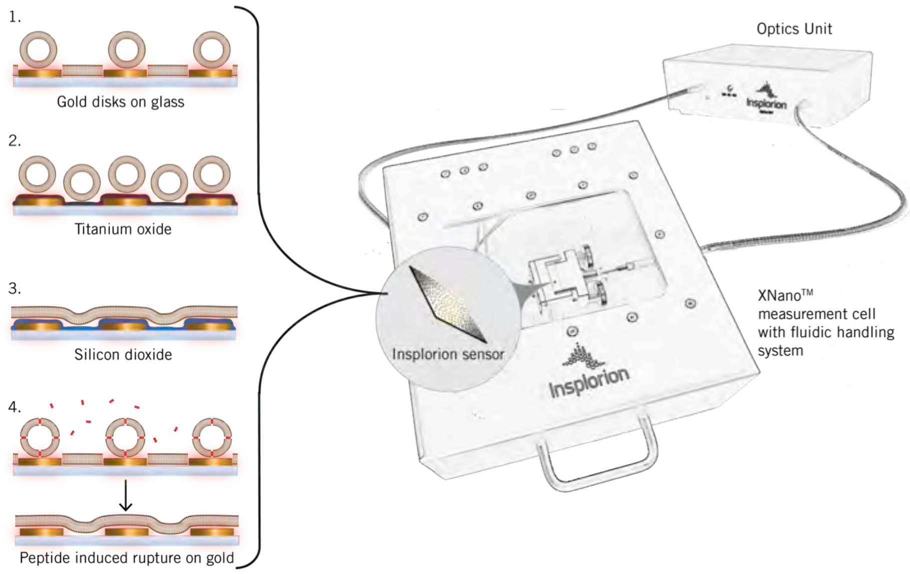

Figure 1: Insplorion system setup. The cartoon shows a schematic illustration of the different sensor and surface structures investigated in this application example (not to scale).

Experimental Procedure

Solutions of small unilamellar vesicles composed of 1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine (POPC) were prepared using the extrusion method. Vesicle adsorption and lipid layer formation was studied with NPS using the Insplorion XNano system. Three different types of Insplorion sensors were used as substrates; TiO_2-coated, SiO_2-coated and bare gold disks on glass. The vesicle adsorption process was tracked by measuring the NPS signal shift over time during introduction of vesicles in solution. The rate of adsorption and layer formation was analysed by taking the derivative of the time-resolved NPS signal.

Results

Figure 2 shows typical response curves for the three different sensor surfaces. On SiO_2 (Figure 2A) a supported lipid bilayer (SLB) is formed on the surface as indicated by the characteristic acceleration in the response at point 4 (Figure 2A). The different steps of lipid bilayer formation as indicated in figure 2A are: 1) Baseline, 2) Vesicle introduction, 3) Adsorption, 4) Rupture of adsorbed vesicles, 5) Bilayer formation, and 6) Complete bilayer. Similar steps can be observed in the response obtained for the bare gold nanodisks on glass (Figure 2B). In this case, a SLB is formed only on the glass areas in between the gold nanodisks. The gold disks themselves are covered with intact vesicles. On TiO_2 a completely different response pattern is observed (Figure 2C). In this case, intact vesicles are found to cover the whole sensor surface. The different steps of adsorption are: 1) Baseline, 2) Vesicle introduction, 3) Diffusion-limited adsorption, 4) Gradually reduced adsorption due to sterical hindrance from already adsorbed vesicles, 5) Saturation.

To prove that there were intact vesicles on the gold nanodisks on the uncoated sensor, a curvature-sensing peptide with a high affinity to curved membranes was introduced to the substrate. At low concentration (0.2 μM, Figure 3A) the increase in NPS response indicates binding of the peptide to the intact vesicles. At higher concentration (13 μM, Figure 3B), the peptide ruptured the membrane to form SLBs on top of the gold nanodisks.

Conclusions

Due to the extreme surface sensitivity of NPS it is an ideal method to study self-assembly processes at surfaces and interactions at the nanoscale. The various available surface coatings on Insplorion's sensors constitute a versatile platform for material-selective fabrication of lipid membrane nanostructures.

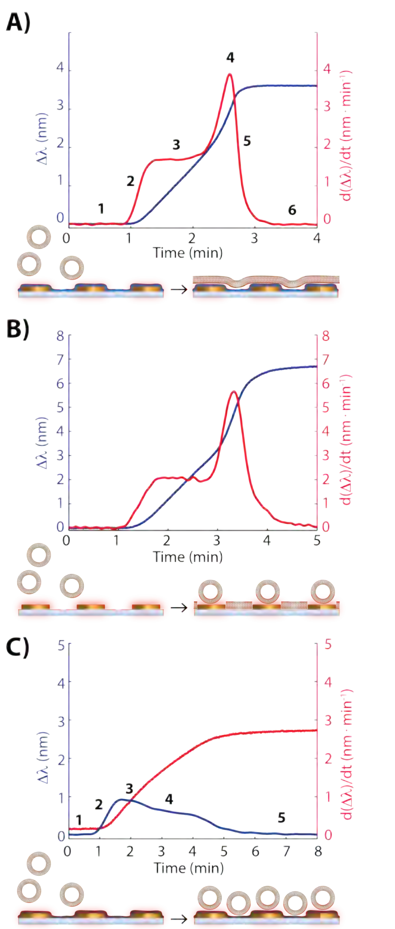

Figure 2: Typical response curves during introduction of vesicles in solution to different sensor surfaces. A) SiO_2, B) Bare gold disks on glass, and C) TiO_2.

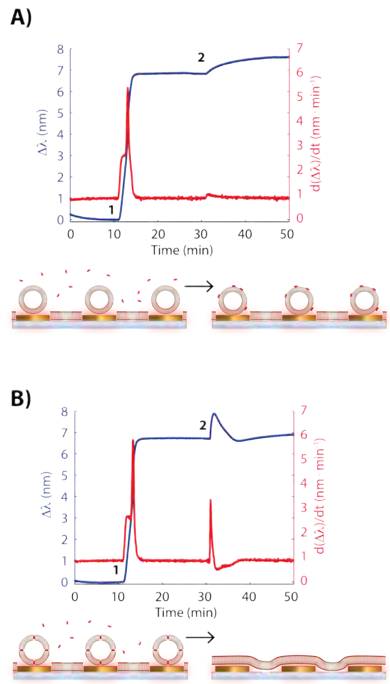

Figure 3: Formation of lipid structures (step 1) and interaction with a curvature-sensing peptide (step 2) at low concentration (A), and high concentration (B). At low concentration, the peptide binds to the intact vesicles, at high concentration, the vesicles rupture and form a SLB.

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] *Controlling Lipid Membrane Architecture for Tunable Nanoplasmonic Sensing*, Goh Haw Zan, Joshua A. Jackman, Seong-Oh Kim, and Nam-Joon Cho, *Small* **2014**, DOI: 10.1002/smll.201400518