Centre Interdisciplinaire de Nanoscience de Marseille

www.cinam.univ-mrs.fr

Campus de Luminy
Case 913
13288 Marseille cedex 09

T. +33 (0) 491 411 XXX
F. +33 (0) 491 411 916
UMR 7325

Aix Marseille université

THESIS TOPIC

CENTRE INTERDISCIPLINAIRE DE NANOSCIENCE DE MARSEILLE – CINaM - FRANCE

Supervisor: Anne Charrier

Lipid layers as functional dielectric layers in ISFET sensors: from molecular organization to physical properties

Field Effect Transistor sensors (ISFET) are integrated devices allowing for ion detection in solution. In these devices the sensing component is a thin dielectric layer playing a role both for the chemical recognition and its electrical transduction. Our group has recently developed a new concept of FET sensors involving lipid monolayers as dielectric layer.

Lipids exhibit remarkable natural properties that make them very attractive for the realization of functional thin layers:
1- they self-assemble into mono- or bi- layers and can be used as ultra-thin layers of nm thickness to functionalize a broad range of solid surfaces , 2- Within the layers, lipids have a lateral mobility which can be thermally controlled allowing for tuning the layer structure/molecular organization, 3- The polar head groups can be used as anchoring sites to attach functional entities and build up molecular architectures with tailored chemical properties, and 4- Lipid layers are very good electrical insulators and constitute natural barriers to both ion and electron transport which make them good candidate as dielectric layer.

In recent works, we have shown that the mechanical and chemical stability of lipid layers as well as their dielectric performances can be improved by changing the molecular structure of the lipids and by achieving intra-chain reticulations within the layer, and that surprisingly both these properties are correlated. However, how mechanical and dielectric properties correlate and how they are related to the molecular organization of the lipids within the layer remain open issues. Understanding the structure/properties relationships of supported lipid layers is an important issue with respect to the optimization of ISFET sensors and the improvement of their performances.

In this thesis PhD project, we propose to investigate how the structural properties (the lipid structure, their surface density, the reticulation degree,…) of lipid layers influence/affect their mechanical and dielectric properties. The chemical composition of the supported lipid layers and the changes induce at molecular level by the reticulation process will be studied by highly sensitive FTIR Spectroscopy (collaboration with Catherine de Villeneuve, LPMC, Ecole Polytechnique Palaiseau). The chemical characterizations will be completed by structural characterizations using Grazing Incidence X-ray Scattering (GIXS) at SOLEIL Synchrotron) to get insights on the 2D molecular organization within the layers. The layers morphology and their mechanical robustness will be investigated by Atomic Force Microscopy (AFM) using indentation methods to assess the force required to disrupt the layer. Electrical measurements will be performed to characterize the dielectric properties (leakage current, dielectric strength and layer capacitance).

This project will be conducted in strong collaboration with Catherine de Villeneuve of the Physique de la Matière Condensée Laboratory (PMC) in Palaiseau, who has strong experience in surface functionalization by monolayer grafting and surface characterization by FTIR spectroscopy. The candidate will spend some time in LPMC to carry out ATR/FTIR measurements. The candidate will also experience X-Ray measurements using synchrotron facilities at SOLEIL.

The candidate shall be a physicist or physico-chemist, with skills in material sciences.

Starting date: 1st October 2018

Please send your application to Anne Charrier (charrier@cinam.univ-mrs.fr).

Please provide:
- Master 1 & 2 marks and ranking and list of courses
- Short summary of master 2 internship
- Recommendation letters and references

APPLICATION DEADLINE: MAY 2018

Some references:

- Subpicomolar Iron Sensing Platform Based on Functional Lipid Monolayer Microarrays. A. Kenaan, et al., Analytical chemistry (88) 3804-3809 (2016)
- A field effect transistor biosensor with a γ-pyrone derivative engineered lipid-sensing layer for ultrasensitive Fe^{3+} ion detection with low pH interference, T. D. Nguyen et al., Biosens. Bioelect. 54, 571-577 (2014)
- Label free femtomolar electrical detection of Fe(III) ions with a pyridinone modified lipid monolayer as the active sensing layer, T. Nguyen Duc et al., J. Mat. Chem. B 1, 443 (2013)
- Supported lipid monolayer with improved nano-mechanical stability: Impact of polymerization; R. El Zein et al., *J. Phys. Chem. B* *116,* 7190 (2012)
- Autonomic Self-Healing Lipid Monolayer: A New Class of Ultrathin Dielectric, C. Dumas et al. Langmuir *27*, 13643 (2011)
- Direct stabilization of a phospholipid monolayer on H-terminated silicon, A. Charrier et al., Langmuir 26, 2538 (2010)
- Main phase transitions in supported lipid single-bilayer, A. Charrier et al., Biophysical Journal, 89, 1094 (2005)
- Well-defined carboxyl-terminated alkyl monolayers grafted onto H-Si(111): Packing density from a combined AFM and quantitative IR study, A. Faucheux et al., Langmuir 2006, *22*, 153
- Thermal decomposition of alkyl monolayers covalently grafted on (111) silicon, A. Faucheux et al., Applied Physics Letters 2006, *88*
- Quantitative IR Readout of Fulgimide Monolayer Switching on Si(111) Surfaces, C.H. de Villeneuve et al., Advanced Materials 2012, *25*, 416