Experimental Report

Proposal: **9-13-530** **Council:** 4/2014

Title: Ceramide lipids/Cholesterol/Fatty acid interaction with thermoresponsive nanogels at the air-water interface

This proposal is a new proposal

Researh Area: Soft condensed matter

Main proposer: **ZARBAKHSH Ali**

Experimental Team: ZIELINSKA Katarzyna
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SUN huihui

Local Contact: CAMPBELL Richard

Samples: Cholesterol
Ceramides

Instrument	Req. Days	All. Days	From	To
FIGARO Langmuir trough	3	3	04/11/2014	07/11/2014

Abstract:

Skin is an important target for drug delivery. However the stratum corneum (SC), which is mainly composed of mixture of ceramides, cholesterols and fatty acids, provides a strong barrier to drug penetration. In this proposal we aim to investigate the interaction of thermoresponsive cross-linked organic nanogels with a mixed lipid monolayer of ceramide lipid/cholesterol/fatty acid, designed to mimic the lipid organization of the human SC.

ILL Experimental Report Ex. Number: 9-13-530		29/01/2015	Local Contact:	Richard Campbell
Principal Proposer:	Ali Zarbakhsh, Marina Resmini		**Instrument:**	Figaro
Experimental Team:	Huihui Sun, Ali Zarbakhsh, Katarzyna Zielinska		**Date of Experiment:**	04-07/11/14

Introduction:

Thermosensitive nanogels show great promise as intelligent materials, for example in biomedical applications, separation techniques and as Pickering emulsions and foams[1]. They have a unique characteristic of being able to alter their size and hydrophobicity as a result of changes in the temperature. These occur because of the loss of hydration shell and the subsequent increase in the free energy of the system. Hence *N*-isopropylacrylamide (NIPAM) based materials tend to be surface active. Understanding the adsorption dynamics and mechanisms of these systems in the context of their molecular architecture are the questions that need to be addressed in relating functionality to the molecular conformation.

The principal objective of this experiment was to use Neutron Reflectometery (NR) to probe the interfacial properties[2] of NIPAM nanogels and to examine how the related interfacial structure varies with the temperature at the air-water interface. A series of thermoresponsible nanogels with different amount of cross-linker (in this studies *N*,*N'*-methylenebisacrylamide, MBA, 10, 20, 30 and 50%) and appropriate deuteration labelling have been deployed. NR technique was used to determine both the adsorbed amount and changes in conformations of the nanogels at the air/water interface as a function of temperature.

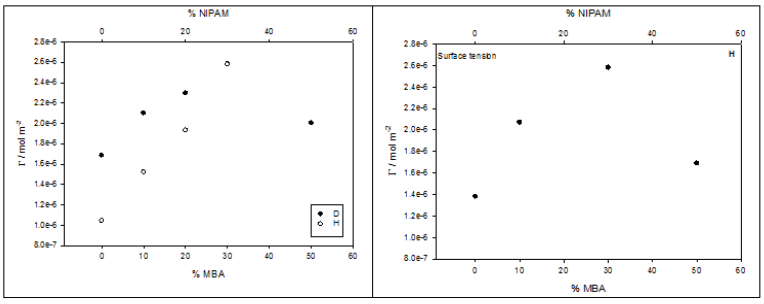


Figure 1. Surface excess obtained by NR and surface tension for nanogels with different % of crosslinking.

The adsorption kinetic of the nanogels was measured at the air/CMAir water for different % of cross-linker. The adsorbed amount determined from both NR (one layer Box fitting) and surface tension measurements are shown in Figure 1. There is good overall agreement for both profiles from NR and surface tension data. The neutron data suggest different surface activity for the H and D nanogels, with H being more surface active (layer composition for H and D also estimated to be 65 and 54% respectively) as expected because of strength of H-bonding. In equilibrated samples influence of cross-linker, monomer and temperature on interfacial behavior of nanogels was investigated.

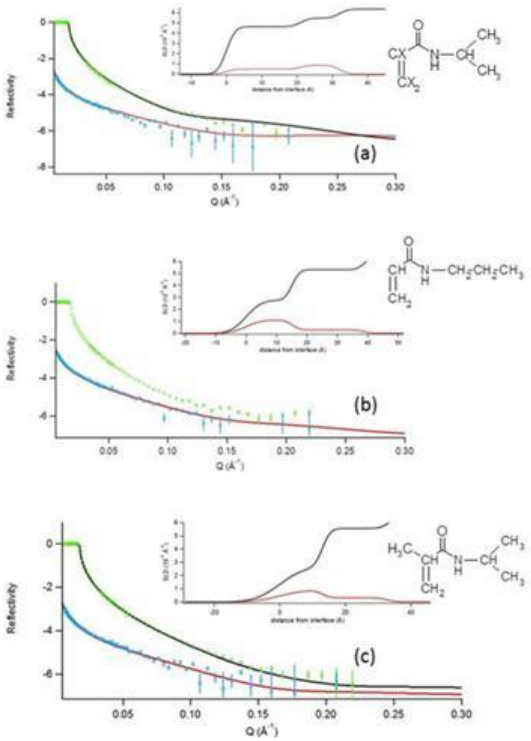
Influence of cross-linker: both NR and surface tension measurements show that the amount of nanogels adsorbed at air/water interface increases as the % of cross-linker increases up to 30%, after which is begin to drop. This could be due to the substantial increase in hydrophobicity but also due to decrease in

[1] M. Hamidi, A. Azadi, P. Rafiei, Advanced Drug Delivery Reviews 60 (2008) 1638.

[2] A. Zarbakhsh, J.R. Webster, J. Eames, Langmuir 25 (2009) 3953.

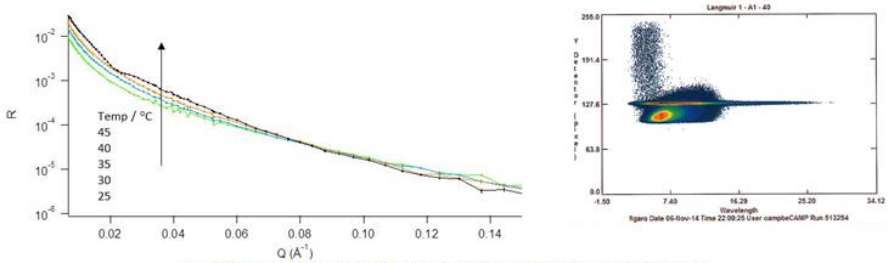
conformational entropy, as % cross-linker increases. At 50% MBA the nanogels have a more rigid structure and their behavior is probably more similar to semi-solid particles rather than soft gels. It is worth noticing that the experiments were carried out at 37°C – a temperature where the nanogels did not reach yet their VPPT[3] in the bulk.

Figure 2. Reflectivity spectra R(Q) for a nanogels prepared with 20% MBA and different monomers: a) NIPAM; b)NnPAM ; c) NIPMAM.



Influence of monomer structure: experiments with nanogels with 20% MBA as a cross-linker and different monomers, i.e. NnPAM, NIPAM, NIPMAM, (Figure 2) clearly suggest that its chemical structure impacts the interfacial behavior of nanogels and adsorbed amount (NnPAM > NIPAM > NIPMAM). The linear structure of the hydrophobic part NnPAM is better packed at the surface while the additional hydrophobic unit in NIPMAM provides steric hindrance and limits adsorption at interface. A relatively rougher layer formation for NIPMAM is also observed.

Influence of temperature: deuterated nanogels containing 20% of MBA were measured in the function of temperature (Figure 3). Increase in temperature leads to higher adsorbed amounts and it is accompanied by changes in nanogels conformation. At 40°C, temperature below VPTT of 47°C, the neutron data suggest strong GISANS scattering from an order structure (Figure 3, 2D contour plot). This is tentatively related to a possible association of nanogels below the surface layer to minimize the free energy of the system. This is then followed by the phase separation which occurs at VPTT. This is supported by the data obtained for the bulk aggregation using DLS.



Reflectivity spectra R(Q) for a nanogels with 20% MBA for a series of increasing temperatures; b) 2D detector image for nanogels at 40°C.

When the temperature was further increased towards the VPTT, there was a drastic reduction in scattering intensity as the result of aggregation followed by depletion and phase separation.

In a future experiment, the interaction of these nanogels with *stratum corneum* lipids at different temperatures will be carried out, both at the air-water and supported lipid multilayer system.

[3] VPTT – volume phase transition temperature