Experimental report

27/09/2021

Proposal: **9-11-2018** **Council:** 10/2020

Title: Engineering thermoresponsive Branched copolymer surfactants: Polymer structure at oil/water interface

Research area: Materials

This proposal is a new proposal

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Samples: $H_2C{=}C(CH_3)CO(OCH_2CH_2)_nOH{-}CH_3(C_6H_{11}NO)_nCH_3$
$H_2C{=}C(CH_3)CO(OCH_2CH_2)_nOH{-}C_8H_{13}NO$
$H_2C{=}C(CH_3)CO(OCH_2CH_2)_nOH{-}CH_2{=}C(CH_3)COOCH_2CH_2N(CH_3)_2$

Instrument	Requested days	Allocated days	From	To
FIGARO	3	3	22/03/2021	25/03/2021

Abstract:

Thermoresponsive emulsions are promising materials that offer bespoke rheological behaviour triggered by mild temperature changes and have applications in advanced therapeutics, tissue engineering and soft robotics. We have designed superior thermothickening materials based on "engineered emulsions" stabilised by branched copolymer surfactants (BCS). These BCS are branched copolymers comprising thermoresponsive polymers terminated by hydrophobic chain ends, which are grafted with hydrophilic blocks. BCS hydrogels structure and properties depend on how the components interact at the nano-scale level, which are dictated by its structural organization. There is a lack of understanding on how the different BCS domains interact at the interface, which complicates the BCS engineering. We propose to use Neutron Reflectivity to achieve an understanding of the structure of these new constructs at the liquid-liquid interface, both above and below the LCST. These experiments will give us critical insight into how the different BCS domains interact with the oil/water phase, allowing us to correlate bulk and nanoscale properties to better fine-tune the final thermothickening emulsions.

Introduction

Thermoresponsive hydrogels are promising materials that offer bespoke rheological behaviour triggered by mild temperature changes and have applications in advanced therapeutics, tissue engineering and emerging fields such as soft robotics.[1] Thermothickening materials, specifically, an increase in viscosity with heating, are of specific interest in this project for drug delivery, where medicines exhibit low viscosity during application (easing administration), before transitioning to a retentive viscous state when warmed by the body, thus prolonging local therapeutic effects and enhancing duration of absorption. In these systems, the macroscopic temperature response originates from nanoscale level changes in the supramolecular assemblies present in these materials. In order to obtain the desired response in a rational manner, a fine understanding of the supramolecular assembly is necessary. There is currently only a single excipient with regulatory approval for use in medicines which possesses this thermothickening property: poloxamer 407 (or Pluronic F127). In this project (funded by EPSRC grant # EP/T00813X/1), we have designed superior thermothickening materials based on "engineered emulsions"[2] stabilised by branched copolymer surfactants (BCS). These BCS are branched copolymers bearing thermoresponsive polymer chains terminated by hydrophobic chain ends, which are grafted with hydrophilic blocks. These BCS solutions are thermothickening in their own right. Furthermore, they are effective emulsifiers and BCS-stabilised emulsions are thermothickening. These materials have potential in "smart" formulations, which are able to flow through applicators and undergo a sol-gel transition upon application to the body whilst containing sizeable hydrophobic domains for drug solubilisation. In order to guide a formulation rationale however, the BCS behaviour at the oil-water phase needs to be understood; for this purpose, neutron reflectivity at the oil/water interface is the only technique that will give us access to the level of molecular detail sought.

Experiments and discussion

In this proposal, we investigated interfacial behaviour of PNIPAM-PEGMA in water/oil interface. Specifically for this work, the oil phase used was perfluorooctane (PFO) due its low neutron absorptivity, which allows the use of thicker interface and greatly simplifies the experimental set-up. Two PNIPAM-PEGMA system were investigated, low and high Mw PNIPAM-PEGMA, as these two systems show distinct rheological behaviour. PNIPAM-PEGMA low Mw emulsions show thermal-thinning, while PNIPAM-PEGMA high Mw emulsions show thermal-thickening. Two different contrasts were also investigated. D_2O/PFO and H_2O/PFO. D_2O/PFO system should show the overall polymer contribution as the main contrast will be the polymer vs water/oil phases. For H_2O/PFO, the contrast now is the polymer vs the oil phase. The reflectivity data obtained is shown in figure 1.

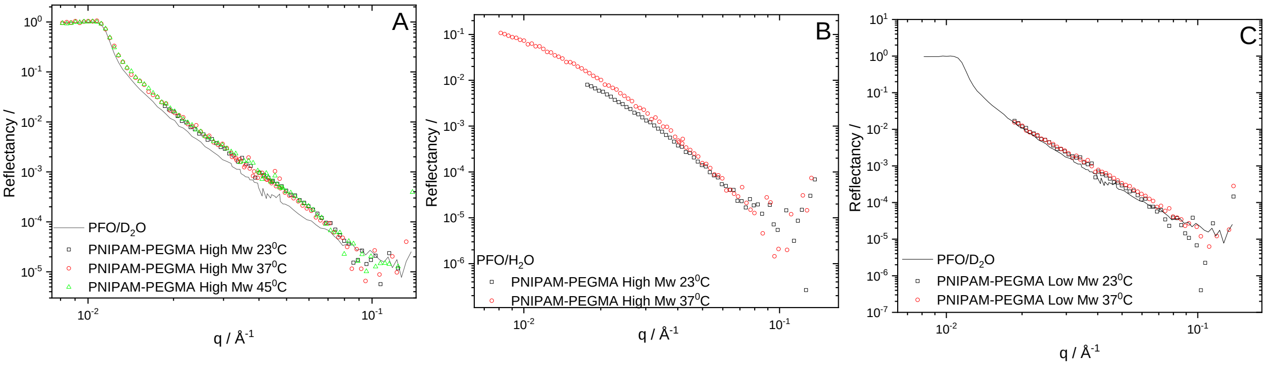

Figure 1 – Neutron reflectivity profiles of PNIPAM-PEGMA High Mw in (A) PFO/D_2O, (B) PFO/H_2O and PNIPAM-PEGMA Low Mw in (C) PFO/D_2O at different temperatures.

The data analysis is still in progress and at this stage only qualitative data evaluation is available. The main difference observed in this data set is observed when comparing the different contrasts. For both low and High Mw PNIPAM-PEGMA, no observable change is present in PFO/D_2O for the data above and below transition (Figure 1A and C), while small change is observed for PNIPAM-PEGMA High Mw in PFO/H_2O (Figure 1B). The nature of this difference is not clear at this point.

References:

[1] Stuart MAC, Huck WTS, Genzer J, Müller M, Ober C, Stamm M, Sukhorukov GB, Szleifer I, Tsukruk VV, Urban M, Winnik F, Zauscher S, Luzinov I, Minko S *Nat Mater* **2010** 9(2):101
[2] Weaver JVM, Rannard SP, Cooper AI Angew. Chem. Int. Ed. 2009, 48, 2131–2134
[3] Scoppola E, Micciulla S, Kuhrts L, Maestro A, Campbell RA, Konovalov OV, Fragneto G, Schneck E *Molecules* **2019**, 24, 4113