Experimental report

14/02/2019

Proposal:	**9-11-1850**	**Council:**	4/2017
Title:	Polymer Structure in Elastic turbulence.		
Research area:	Soft condensed matter		

This proposal is a continuation of 9-11-1787

Main proposer:	**Stuart M. CLARKE**
Experimental team:	Andrew HOWE Stuart M. CLARKE
Local contacts:	Philipp GUTFREUND Leonardo CHIAPPISI

Samples: Polyacrylamide

Instrument	Requested days	Allocated days	From	To
D11	3	3	16/03/2018	19/03/2018

Abstract:

Building on a recent successful ILL experiment, we aim to characterise the conformation and structure of a very high molecular weight polymer in aqueous solution under static and under shear conditions. This material undergoes elastic turbulence (i.e. an unusual form of turbulent flow at low Reynolds numbers) for which the underlying polymer structure is not known. The previous experiment completely changed how we visualise the polymer conformation and we now wish to complete this revised picture. The aqueous polyacrylamide solution is typically 10-100 times above its overlap concentration and therefore the reptation time is on the minute scale or even slower. This gives rise to non-linear rheology, e.g. elastic turbulence. By using in situ rheo-SANS we will be able to access the underlying molecular structure of the polymer chains.

9-11-1850

Title: Polymer Structure in Elastic turbulence.

Summary:

Very high molecular weight polymers have been identified to exhibit a very unusual rheology known as elastic turbulence and could have very significant potential in a number of industrial applications, such as enhanced oil recovery. However, the molecular origins of this behaviour is unknown. Hence in this experiment we aim to characterise the polymers in solution as (i) a function of concentration and (ii) under shear. The expected results might include a standard scattering of a high molecular weight polymer above its C* and some anisotropy under shear. Interestingly neither of these effects was observed.

Experimental details.

These SANS experiments are challenging for a number of reasons. With such high molecular weight materials, even pipetting them might lead to breakage and requires a good deal of careful handling. However, we are lucky to have Dr Andrew Howe, on the team who is very experienced in such matters giving us confidence that these practical issues were effectively addressed. Dr Howe was also able to make rheological measurements at ILL on the samples being studied so that we had full characterisation of the materials. These results did indicate that elastic turbulence was observed for these actual samples for the SANS measurements.

We are also particularly grateful to our local contact and co-applicant, Phillip Gutfreund for the access to the in-situ shear device. This has a number of additions and improvements for us since the previous experiment and is now well adapted for our measurements. Again, this is a non-trivial matter and is a key part to ensure the experiment can capture the correct rheological region, yet retains sufficient transmission to measure the scattering. We are also most grateful to Leo (Leonardo) Chiappisi who greatly facilitated the experiment practically and through great care and attention in reducing the data. This required significant attention due to several challenges, particularly transmission corrections.

The materials were D2O solutions of a neutralised, partially (30 mol%) hydrolysed poly(acrylaminde) at 0.1, 0.50 and 1.1% wt% in 0.5 or 1.0 M NaCl. The solutions were shear thinning at low rates but showed elastic turbulence at high rates: the onset rate increasing as the measurement cone-angle decreased.

Results:

1) The static samples exhibit a very pronounced Q^{-4} dependence. This is an unexpected result and not what would have been proposed for a polymer in a good solvent above it C*.

At present and after significant discussions with well-informed colleagues this may be attributed to a quite compact body (depending on the virial coefficient), which may show a Q^{-4} dependence. Hence we currently conclude that Q^{-4} is consistent with ‘microdomains’.

2) The shear does not seem to affect the SANS data: Again, this is somewhat unexpected, given the very pronounced changes observed in the rheology (increase of viscosity by a factor of 10!!).

At present, we can only conclude that the changes in structure of interest occur either out of the Q-range window we have explored on D11 or that the single chain scattering function is overwhelmed by the strong Porod-like scattering arising from the ‘microdomains’. We now plan to consider other low-q options, including light scattering under *in situ* shear which is also possible with the shear cell made of quartz.

3) Other interesting features included the absolute intensity with changes in solution concentration which was not as big as one would have expected, maybe owing to the ‘microdomains’ as well.