## Steady viscosity oscillations in a nonionic lamellar phase

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Lyotropic liquid crystalline phases under shear flow are typically in a non-equilibrium steady state where the energy is continuously dissipated. The planar lamellae are found to be unstable under shear flow due to the bending elastic moduli of few  $k_BT$  and the lamellar-to-multilamellar vesicles (MLVs) transitions is allowed. The mechanism of lamellar-to-MLVs transition has been widely studied and several details have been discussed and explained [1]. However, periodic viscosity oscillations have been observed in a nonionic surfactant lamellar phase system under steady shear in the shear thickening regime [2].

Time-resolved and spatially-resolved flow-small angle neutron scattering (SANS) experiments were performed in order to correlate the periodic viscosity oscillations to the microstructure of the fluid texture. In Figure 1 (right) the evolution of the apparent viscosity ( $\eta$ ) and small angle neutron scattering (SANS) intensity at the shear rate of 2 s<sup>-1</sup> are shown. The oscillations in the apparent viscosity are plotted together with the neutron-scattered intensity in the flow (x) and vorticity (z) directions. The correlation between intensity and viscosity oscillations indicate a fluctuation in MLV and planar lamellae fractions [3].

Here, *in-situ* flow-SANS experiments were performed using a novel 1-2 flow couette sample environment, figure 2, [4] in order to characterize lamellae and MLVs coexistence under constant shear flow. Two *d*-spacing were observed in the flow-shear gradient plane, while only one *d*-spacing was observed in the neutral-flow direction. This evidence can be useful to correlate unstable viscosity behaviour and the observed shear banding phenomenon. Moreover, these results can used to understand the driving force of the unstable viscosity behaviour.



**Figure 1** Evolutions of the apparent viscosity ( $\eta$ ) and SANS intensity, at the lamellar Bragg peak in the vorticity (y) and flow (x) directions in the radial beam configuration, as measured with a shear rate of 2 s<sup>-1</sup>. Between viscosity and scattering intensity selected SANS patterns at  $\eta_{max}$  and  $\eta_{min}$  are shown. The inset shows the selected x and y directions where the averaged profiles cover 10 pixels (i.e. 0.014 Å<sup>-1</sup>) for both directions



**Figure 2** Schematic diagram of the flow-SANS setup: velocity gradient (2 axis), shear flow direction (1 axis), and neutral vorticity (3 axis). The neutron beam passes through the sample along the neutral vorticity direction. Anisotropic 2D-scattering patterns are subsequently recorded in the flow-shear gradient plane.

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