

Single Particle Tracking in Lyotropic Liquid Crystals

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Lyotropic liquid crystal (LC) systems exhibit both the maintained structural properties resembling solids and the flow properties of liquids. LCs are formed by mixtures of water, oils and surfactants and can form a variety of complex three-dimensional structures, including, but not limited to, lamellar bilayers, aligned micellar systems, or bicontinuous cubic phases. One of the simpler LCs, the lamellar bilayer phase is best described as alternating oil and water layers separated by surfactant layers. These systems are therefore structurally analogous to lipid structures in biological systems, which, alongside their unique rheological properties, makes them useful in biotechnology as models^{1,2}, as delivery and transport devices,¹ and as solvents or sensors in microfluidic devices³. For the design, synthesis, and assessment of new LC systems, innovative and complementary experimental approaches are used, including small-angle neutron or x-ray scattering (SAXS/SANS) for structural analysis, polarising light microscopy (PLM) for phase identification, and a suite of rheological techniques in tandem with single particle tracking (SPT) for an understanding of the particle transport capabilities and flow properties¹⁻⁴.

SPT visualises the movement of fluorescent species through a fluid sample, and can be used to examine the movement of various types of cargo, including molecules, complexes, organelles, or viruses, in systems ranging from pure solvents to complex cellular landscapes. SPT has been applied to many of these systems previously, for example to study the pore wall permeability of mesoporous silica⁴ and to study intracellular transport⁵. In depth analysis of SPT data reveals both the mass transport properties and structure of the medium⁶. SPT can also elucidate how species within the system behave, including the dimensionality and directionality of diffusion⁷. Though there is interest in the use of SPT to understand the diffusion of particles within LC systems, current studies are limited primarily to diblock copolymers⁷ or one-dimensional structures⁸ rather than lipid-like surfactant systems that more closely resemble lipid structures.

Here we present SPT analysis of various fluorescently labelled species, within a number of lyotropic LC systems constructed from a water/Triton X-100/*para*-xylene ternary phase of varying composition. In particular, we examined the propensities of different LC systems to affect the rate and dimensionality of diffusion of any cargo. To begin, a lamellar LC system comprised of water, *p*-xylene, and Triton X-100 was studied because of its well-known robustness and extensive previous characterisation.⁹

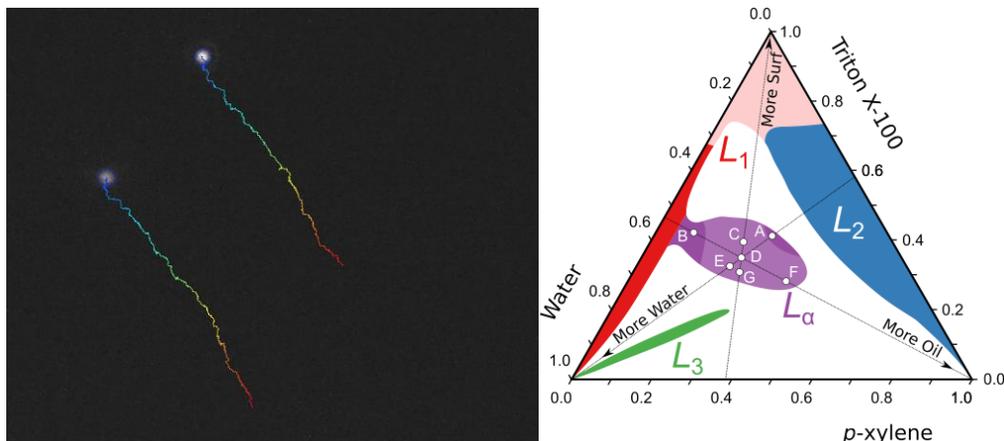


Figure 1

SPT of 100 μm tetraspecks tracked through a lamellar liquid crystal phase consisting of Triton X-100 and water (left); a phase diagram depicting the different compositions the ternary phase of water, Triton X-100 and *p*-xylene can form at different concentrations, including lamellar bilayers (L_0), micelles (L_1), inverted micelles (L_2), and a bicontinuous cubic phase (L_3) (right, adapted from reference 9) LC Systems labelled A-G have been characterised in work that has a manuscript in preparation, and a greyed area representing more viscoelastic samples is depicted.

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