Dynamic Responses of Quasi-One Dimensional Free-Standing Liquid Crystal Structures

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Quasi-one dimensional fluid structures are commonly found in nature, but may be formed from any material that can suppress the Rayleigh-Plateau instability, which prohibits many isotropic Newtonian fluids from achieving a length-to-diameter ratio greater than π. Some liquid crystal phases, such as the B7 mesophase, can overcome this instability and achieve length-to-diameter ratios over 1000. An interesting feature of these materials is not only how they form so-called fibers, but also their response when exposed to external mechanical, thermal, acoustical or electrical perturbations. It was shown that quasi-one dimensional fibers formed in the PM-SmCP and B7 liquid crystal phases could be electrically and acoustically plucked, with the decay time of their oscillations proportional to their length [1]. Additionally, fibers formed in the B7 liquid crystal phase can assemble into quasi-*three* dimensional structures when sheared (Figure 1) [2]. Fiber stability could also be maintained through liquid crystal phase transitions for liquid crystals composed of star-shaped oligobenzoates [3]. Knowledge of these dynamic responses and the causes find relevance in technological applications, where materials are subjected to a variety of external stimuli, which may (or may not) be desired or useful.

Figure 1: "Seashell" structure formed along a liquid crystal fiber dilated with velocity ≥ 7.1μm/s [2].

Here, I will discuss our most recent results on the dynamic responses of free-standing liquid crystal structures using a modified force sensing technique. We investigate the strain- and strain rate-dependent stress response of liquid crystalline fibers [4], including the formation of quasi-three dimensional structures along the fibers. We also found that slight variations in temperature could actuate the fiber, with an oscillation period proportional to the temperature fluctuations. A viscoelastic model that takes into account the fiber's structure is necessary in order to fully establish the complex interplay between the material's molecular self-assembly and the fiber's macroscopic features. We hope to further elucidate this complex interplay such that it may be harnessed for applications in soft electronics and robotics, and open new avenues in theoretical fluid dynamics.

References

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