Liquid crystals

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Liquid dipole lattice

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Geometrically confined apolar nematic liquid crystals lose rotational symmetry and form a multifunctional polar lattice of fluid elastic dipoles with controllable orientation. The lattice is of interest from a fundamental science perspective as well as having potential applications.

Multifunctional materials whose properties can be reversibly adjusted by external stimuli or adapted to changing environments are desirable for biosensing and information technologies and more. Nematic liquid crystals, with their fluid orientational order, are well suited for this purpose because of their sensitivity to weak external fields – electric, thermal, optical or mechanical. Polar order is a property that could be conveniently exploited for achieving multifunctionality, but it rarely occurs in liquid systems. Now writing in *Nature Physics*, Ufuoma Kara and colleagues propose a strategy to realize a lattice of liquid elastic dipoles whose orientation can be programmed and reconfigured through shear flow[1].

Reconfigurable polar order in ferromagnetic and ferroelectric materials and in their anti-ferro counterparts impart to these systems unique electrical, magnetic and optical properties[2,3]. Polar systems typically consist of solid materials with low symmetries, which limits their tuneability in response to external stimuli. The recent emergence of polar liquids, namely ferroelectric nematic liquid crystals[4], offers the possibility of applications leveraging the combination of polarity and fluidity. These systems are a lower-symmetry variant of nematic liquid crystals – well studied fluids composed of structurally anisotropic molecules exhibiting long-range orientational order[5].

Although recently observed in a certain number of nematic compounds, spontaneous polarization does not usually occur in conventional materials exhibiting the nematic phase. Polar ferroelectric nematics are typically unstable, often do not operate at room temperature and can exhibit unexpected and still not fully characterized behaviours. Overall, knowledge about these systems is still not sufficient for a widespread use of their high polarity.

Kara and colleagues demonstrated the possibility of artificially realizing a controllable polar liquid system based on conventional apolar nematic liquid crystals, in which the dipole orientation can be programmed and reconfigured using the shear flow of an immiscible liquid, typically water. They achieved this by confining conventional nematic liquid crystals into a lattice.

Using treated silicon micropillar arrays as geometric boundaries, they realized a fluid lattice of topological elastic dipoles with a free top interface in contact with an immiscible fluid (Fig. 1). Each dipole resulted from the elastic interaction between topological defects in the nematic orientational field (introduced by geometric confinement) and the nearest neighbourhood micropillar. Vacancies – micropillars without an associated defect – and double occupancy – two-point defects surrounding a single micropillar – were also observed, making the fluid system similar to a two-dimensional crystal lattice with mobile dipoles.

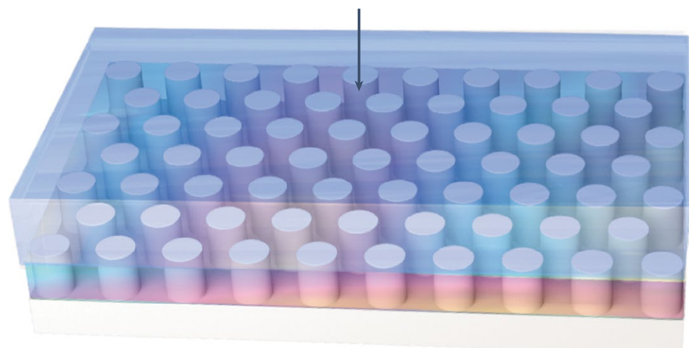

Fig. 1 | Liquid polar lattice obtained by confined nematic liquid crystals. Silicon micropillar array infused by a conventional apolar nematic fluid. The free surface of the system is in contact with water. Geometric confinement of the liquid crystals (LC) locally perturbs the nematic order. The resulting topological defects (not shown in the figure) couple to the nearest neighbourhood pillar to form an array of elastic dipoles.

The liquid character of the lattice enabled real-time control of dipole orientation using surface shear. By programming the flow of the top fluid, specific orientations could be encoded and kept stable for hundreds of days after cessation of flow. This was thanks to the orientational multistability of dipoles coming from the hexagonal symmetry of the micropillar array, which allowed six possible orientations.

The encoded information could easily be erased by heating the system above the nematic–isotropic phase transition. A large number of writing–erasing–rewriting cycles could be performed without system degradation. Complex dipole patterns could be generated by sliding water droplets over the free surface of the fluid lattice, by underwater streaming or by introducing air bubbles sliding underwater.

The combination of polarity, multiscale structural complexity and high reconfigurability of the proposed system could be used for a range of applications such as multifunctional sensing, optical switches, energy harvesting and storage. As an example, the possibility of encoding and reconfiguring directional information allows the detection and recording of flow profiles, which is desirable in microfluidic platforms for flow sensing. Finally, from a fundamental science perspective, the liquid dipole lattice realized by Kara and colleagues is an experimentally accessible system for studying complex polar topological configurations that could help us to explore exotic phases and nontrivial emergent phenomena.

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Competing interests

The author declares no competing interests.