New method discovered for controlling molecular patterns on liquid droplets

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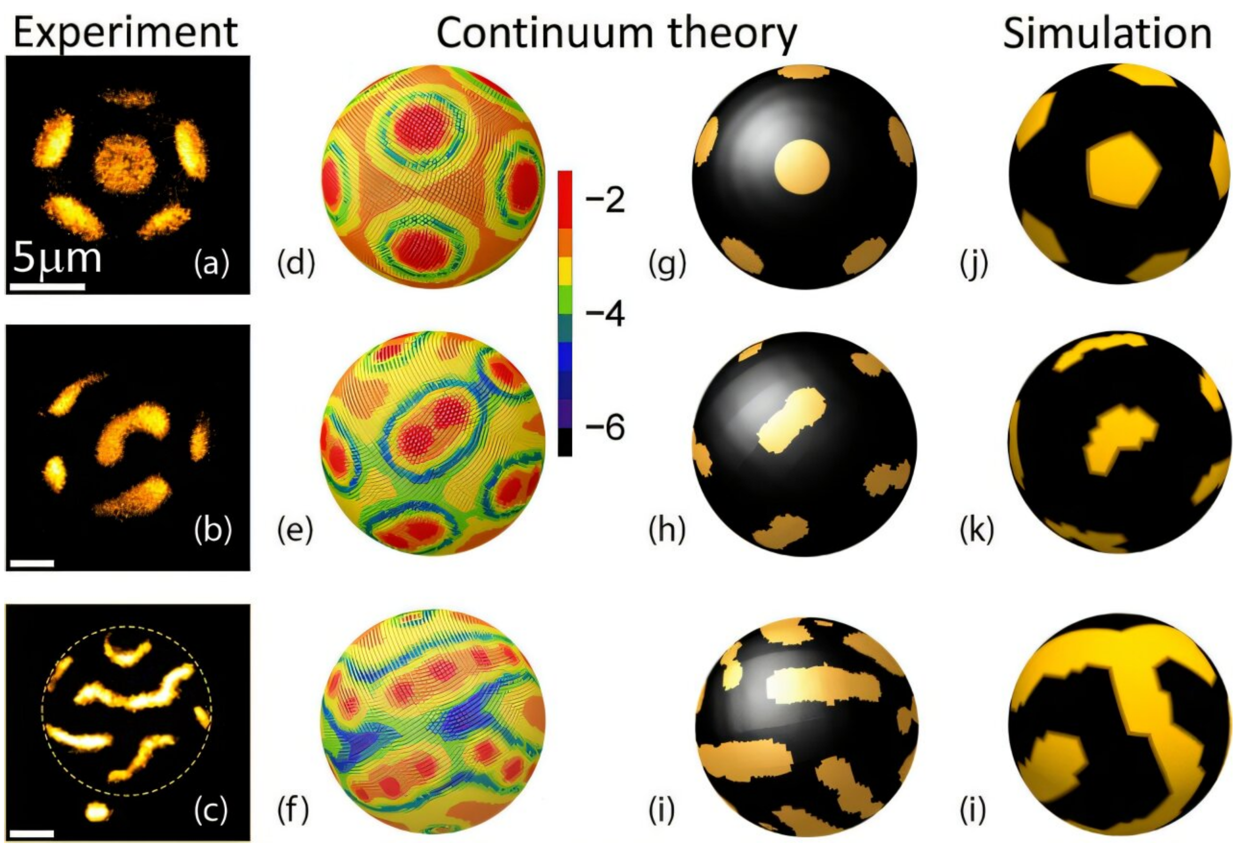

Credit: *Physical Review Research* (2024). DOI: 10.1103/PhysRevResearch.6.043098

A team of researchers has uncovered a previously unknown phenomenon that could improve the way we design materials at the molecular level.

By unlocking a transformation between two types of structural defects on the surface of liquid droplets, the research opens new possibilities for controlling molecular patterns with unprecedented precision. This discovery has broad applications across a range of technologies, including vaccine design, the creation of self-assembling structures, and the synthesis of complex nanoparticles.

When guest molecules are positioned on liquid droplet surfaces, they typically spread out quickly due to diffusion, making it challenging to achieve precise control over their placement. However, the researchers discovered that droplets made from certain materials undergo a process known as "interfacial freezing," in which the droplet's surface forms a crystalline molecular monolayer while the bulk of the droplet remains liquid.

This process leads to a spherical shape with a hexagonal surface structure, where the curvature of the surface dictates the formation of structural defects. The defects thus formed are critical to controlling the behavior of guest molecules.

The research team, through a combination of experiments, simulations, and theoretical modeling, identified a previously unseen transformation between two defect states. At low ion concentrations, these defects organize into 12 rounded "clouds" evenly distributed across the droplet's surface. As the ion concentration increases, the clouds stretch into elongated "scars."

This change in defect structure also impacts how surface-bound molecules behave: those bound to clouds are fixed in place, while those attached to scars may be able to move along the scar, offering new flexibility in designing materials which are composed of nanoblocks, decorated by precisely-positioned guest molecules.

"By controlling the position and behavior of guest molecules on the surface of droplets, we can potentially optimize the design of vaccines, create advanced nanomaterials, and even guide the formation of complex molecular structures," Prof. Eli Sloutskin, of the Department of Physics at Bar-Ilan University, who led the research in collaboration with researchers from Leiden University and Complutense University of Madrid.

"This discovery, led by an outstanding student from my team, Shirel Davidyan, offers exciting new tools for engineering molecular patterns in ways that were not previously possible."

This transition from clouds to scars represents a fundamental shift in how surface-bound molecules can be manipulated. The implications of this research extend beyond liquid droplets, with similar defect state transformations expected in other systems, such as superfluid films and spherical superconductors. As a result, this breakthrough could pave the way for new approaches in a wide range of scientific fields, including material science, chemistry, and biomedical engineering.

This research was recently published in the journal *Physical Review Research*.

More information: Shirel Davidyan et al, Controlling clouds-to-scars dislocations' transitions on spherical crystal shells, *Physical Review Research* (2024). DOI: 10.1103/PhysRevResearch.6.043098

Provided by Bar-Ilan University

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