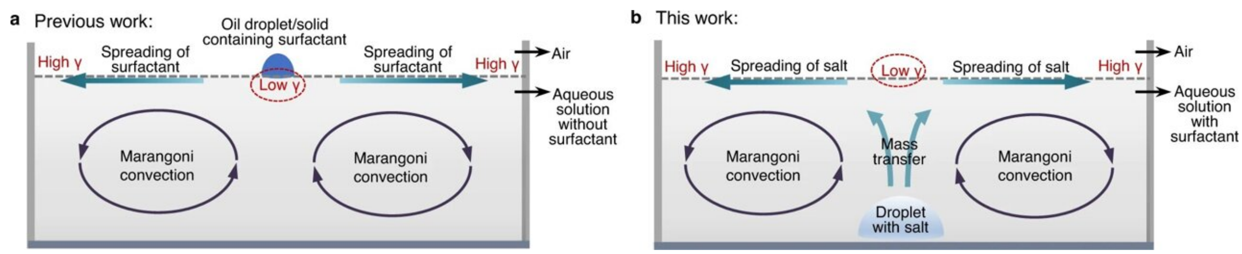
Generating Fermat's spiral patterns using solutal Marangoni-driven coiling in an aqueous two-phase system

February 20 2023



Mass transfer based on solutal Marangoni effect. **a** Generation of SFT (γ) gradients by the addition of an oil droplet or a solid containing surfactant to an surface of the aqueous solution, and the resulting Marangoni-driven spreading and Marangoni convection. **b** Marangoni transport from a droplet to the bulk solution surface (by Marangoni convection), and then at the air/water interface (by Marangoni effect). Credit: *Nature Communications* (2022). DOI: 10.1038/s41467-022-34368-5

The team led by Professor Anderson Ho Cheung Shum of the Department of Mechanical Engineering, The University of Hong Kong (HKU) has accomplished a key breakthrough in fluid dynamics, by developing a three-dimensional Marangoni transport system in an aqueous two-phase system. The project was conducted in collaboration with Professor Neil Ribe from University Paris-Saclay.

The Marangoni effect has garnered considerable attention due to its fundamental role in numerous directional fluid transport processes in nature, since its first identification by James Thomson in 1855 and subsequent study by Carlo Marangoni. The study of the solutal Marangoni effect has flourished in recent years with a particular interest in Marangoni-driven spread of liquids and the resulting patterns, and the Marangoni convection in the bulk liquid. However, these reported transport processes are mostly two-dimensional.

Professor Shum's team has developed a new type of continuous Marangoni transport system based on Marangoni-driven spread and Marangoni convection. The interaction between a salt ($CaCl_2$) and an anionic surfactant (sodium dodecylbenzenesulfonate) generates surface tension gradients, which drive the transport process.

This three-dimensional Marangoni transport consists of the upward transfer of a filament from a droplet located at the bottom of a bulk solution, coiling of the filament near the surface, and formation of Fermat's spiral patterns on the surface.

The system is comprised of aqueous solutions of polyethylene glycol (PEG) and dextran (DEX), which belong to the class of aqueous two-phase systems, that have attracted growing interest due to their simplicity and biocompatibility.

"The utilization of an aqueous two-phase system can on the one hand sustain a continuous transfer of salt between the droplet and the bulk solution, while on the other hand may be able to inspire some biological applications," said Dr. Yang Xiao, the first author of this paper and a postdoctoral fellow in Professor Shum's group.

The system is in a non-equilibrium state due to the transfer of $CaCl_2$, yet interestingly, the output is highly ordered Fermat's spiral patterns. "The automatic transport of materials from the droplet in the bulk solution to the air-water surface occurs in a highly ordered way. This feature may inspire the development of novel methods for fiber fabrication by utilizing non-equilibrium systems," Professor Shum added.

The discovery is now published in *Nature Communications*.

More information: Yang Xiao et al, Generation of Fermat's spiral patterns by solutal Marangoni-driven coiling in an aqueous two-phase system, *Nature Communications* (2022). DOI: 10.1038/s41467-022-34368-5

Provided by The University of Hong Kong

Citation: Generating Fermat's spiral patterns using solutal Marangoni-driven coiling in an aqueous two-phase system (2023, February 20) retrieved 27 April 2024 from https://phys.org/news/2023-02-generating-fermat-spiral-patterns-solutal.html