Richard Löffler Warsaw, 25.05.2021

Summary of the Ph.D. thesis entitled:

"New materials for studies on nanostructures and spatio-temporal patterns self-organized by surface phenomena"

The field of exact and natural sciences. Scientific discipline - Chemical Sciences.

My Ph.D. project was concerned with new materials and experimental systems that show interesting and complex self-propelled motion resulting from interfacial and surface phenomena. The experiments are of great use to study life-like behavior and test theoretical models for the active matter. They are a vital part of understanding the conversion of chemical energy into mechanical in dissipative, far-from-equilibrium systems and certain aspects of behavior observed in living systems. Therefore, the research on self-propelled motion advances fields such as non-linear chemistry, artificial life, and origins of life. The results can be applied to new technologies within the field of soft robotics.

In this thesis, I describe multiple new materials and improved experimental setups based on the physicochemical interaction between condensed- or soft-matter- and interfaces of the aqueous phase combined with dissolution, reactions or evaporation effects that cause and support Marangoni convection. The investigated systems range from boats actuated on a water surface by solid-state crystalline camphor, hybrid, wax-like materials containing camphor, camphene, and polypropylene that are self-propelled on a water surface to soft droplets of organic oil that release the surface-active agent.

For the research on camphor boats, a new type of experiment was designed in which the boat is on a forced circular trajectory along the edge of a Petri dish (Part 1). Such an arrangement allows to study various types of boat motion over a long period of time in a stationary regime, without contact between the boat and the dish walls. The types of boat motion (continuous motion, intermittent motion, inversive motion) were investigated. Transitions between different types of boat motion were examined considering the location of the camphor pill driving the boat with respect to the boat center as the control parameter.

Malleable semi-soft-matter hybrid materials containing camphor, camphene, and polypropylene are important new discoveries described in the thesis (Part 2). They provide the perfect material for the investigation of the relationship between the shape and trajectory of self-propelled objects.

Richard Löffler

Warsaw, 25.05.2021

Furthermore, a potentially useful, microporous, superhydrophobic polymer foam that very effectively can absorb pollutants such as oils was discovered as a side product of this project.

The effect of dyes on the behavior of the self-propelled camphor-paraffin droplets and on the time evolution of ethyl salicylate – surfactant system is the third subject discussed in the thesis (Part 3). I discovered that a common dye, Oil red O, decreased the interfacial tension between oil and water and, depending on its concentration, the time evolution of such droplets was qualitatively changed. Therefore, the dye concentration is an additional control parameter that influences droplet behavior. It has been demonstrated using two similar dyes (Oil red O vs. Sudan black B) that both the individual and collective spatio-temporal evolution of such droplets can be affected by the presence of a dye in different ways. Work on the ethyl salicylate system ultimately yielded a previously unknown predator-prey interaction between a decanol and ethyl salicylate droplet on a clean water surface.

25.05.21

Löffler