Chemically propelled motors: an introspection into their operational mechanisms

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One of the main challenges in the engineering of micro/nanomachines is the quest for efficient mechanisms to power them without using external driving forces. Under this context nature is a source of inspiration. The engineering of self-propelled micro/nanomachines with the capability to emulate biological motors has become a research line of growing interest since the pioneering studies at the beginning of this millennium. These micro/nanomachines generate and harness local physicochemical gradients to drive their own motion and at the same time, they can perform multitasking activities. Although the proofs of concept for applications have been significant, the progress on the comprehension of the physicochemical fundamentals behind the self-generated actuation has been more moderate. In many cases, the precise motion mechanism is still not unambiguously identified, and the key physicochemical parameters are not well-characterized. A complete and deep understanding of such issues would help to improve the control levels for applications and to better assess perspectives and challenges of these self-propelled machines.
In this presentation, we will focus on chemically driven motors whose motion is the result of a complex interplay of chemical reactions and (electro)hydrodynamic phenomena. A reliable study of these processes is rather difficult with mobile objects like swimming motors. Therefore we have resorted to pumps, which are the immobilized motor counterparts. Thus pumps emerge as simple manufacturing and well-defined platforms for a better experimental probing of the mechanisms and key parameters controlling the actuation.
We will review a combined set of techniques that we have implemented to study chemically propelled micropumps[1,2,3]. These techniques have turned out to be very useful for mapping chemical reactions and for extracting physicochemical parameters (e.g. electric fields, fluid flows) and thus to achieve a more complete characterization of the mechanisms driving fluid motion. We will mainly focus on metallic/semiconductor motors to analyze light-controlled motion mechanisms through photoelectrochemical decomposition of fuels. In these systems, we found a very interesting competition between two different mechanisms for fluid propulsion stemming from different chemical pathways in the fuel decomposition. The studies with pumps are very relevant for their swimmer counterparts, shedding light on their motion mechanisms and providing useful clues for the design and optimization of phoretic systems.

References

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