Nafion-based micromotors in water: fundamentals and collective motion

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The development of micro/nanomachines which can move controllably and autonomously in a fluid while carrying out targeted tasks is one of the current challenges of nanoscience and nanotechnology [1]. Many self-powered devices have been developed in recent years either as motors (in a free-standing configuration) or micropumps (immobilized on substrates). Among them, motors (also termed swimmers) that are self-propelled by chemical processes have attracted significant attention for their potential use in relevants areas such as biomedicine and water remediation. However, most of the devices developed so far are typically activated by toxic chemicals, which strongly hinders their applicability or cannot work at high salt concentrations. Among the different explored mechanisms to achieve chemical self-propulsion, ion exchange has emerged as a valuable strategy, with the significant advantage of using innocuous salts as fuels and being able to work under biologically relevant conditions. Recently, micropumps of the ion-exchanger Nafion polymer have been prepared that are capable to trigger interfacial electro-osmotic flows in water induced by chemical gradients with the subsequent local generation of electric fields [2]. Nafion is a well-known material and widely used in application areas such as fuel cells, biosensors, filtration/separation/purification technologies, antifouling coatings, etc. These Nafion micropumps can work in a wide range of salt concentrations, are activated using different cations, including heavy metal ions, and can be regenerated for reusability, showing their potentialities for effective and fast water purification strategies for environmental remediation. Note that that pumping is self-driven by the own contaminant ions. By properly nanostructurating Nafion into microarrays and tuning the surrounding surface zeta potentials, it is also possible to redirect electro-osmotic flows into unidirectional pumping [3].
Exploiting the same ion-exchange based propulsion mechanism, we have recently succeeded in the high throughput fabrication of Nafion-based micromotors using colloidal lithography and reaction ion etching. We will report on the collective behaviour of Nafion-based micromotors under crowding in water. Nafion swimmers tend to self-assemble under motion into flocks, increasing their collective velocity upon assembly, as compared to those of individual motors. The chemical gradients and interfacial fluid flows generated at the moving flock attract other micro/nanoobjects toward the flock. The attraction and trapping capacity of micro/nano-objects has been evaluated with passive polystyrene microparticles. The high trapping efficiency of these Nafion-based micromotors flocks may open the door to their future use for microplastic scavenging in water.

References

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