

## Time-Dependent Stopping of Self-Propelled Droplets in Ionic Surfactant Solutions

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Motility is a hallmark of life, enabling organisms to navigate their environments and fulfill essential functions. Inspired by biological systems, self-propelled droplets have emerged as synthetic analogs capable of autonomous movement. In these systems, droplets chemotactically swim toward regions with more surfactants while avoiding their self-generated solute gradients. This movement is facilitated by Marangoni flow via a gradient in interfacial tension along the droplet's interface. Despite this understanding, the precise mechanism behind this process remains elusive. Specifically, the molecular processes that govern the initial inhomogeneous surfactant coverage around the droplet are not well understood. Here, we investigate the behavior of active oil-in-water droplets in ionic surfactant solutions, observing transitions from active swimming to irreversible stopping motion. Our objective is to explore this motility transition to uncover the fundamental mechanisms behind droplet self-propulsion. By analyzing the droplet flow profile, we observed that active droplets exhibited a shift from “repulsive” flow to static flow upon immobilization. To gain deeper insights into this behavior, we systematically examined the influence of various parameters, including surfactant type and concentration, oil carbon chain length, and droplet size, on droplet stopping behavior. Additionally, we investigated the impacts of salts on droplet behavior by characterizing the motility of stopped droplets in salt-added aqueous surfactant solutions. Our findings provide insights into the dynamic transport of molecules in non-equilibrium systems and elucidate the factors that govern interfacial tension gradients driving droplet self-propulsion.