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Designing self-oscillating cilia using active polymer gels
PRATYUSH DAYAL, AMITABH BHATTACHARYA, OLGA KUKSENOK, ANNA C. BALAZS, University of Pittsburgh — Using theory and simulations, we model the dynamic behavior of synthetic cilia made from soft, active materials. In designing this system, we harness the properties of polymer gels that undergo photosensitive Belousov-Zhabotinsky (BZ) reaction. Driven by the periodic reduction and oxidation of a ruthenium catalyst that is grafted onto the polymer backbone, these BZ gels undergo rhythmic swelling and de-swelling by chemo-mechanical transduction. When these BZ gels are tethered to a substrate, they form cilia that can pulsate autonomously in response to the BZ reaction. To simulate the behavior of the BZ cilia, we developed a nonlinear 3D model that captures the effect of the diffusive exchange of BZ reagents between the gel and the fluid. Using this approach, we determine the factors that govern the bending and beating of individual cilium. We then turn our attention to multiple cilia and show that their collective dynamics strongly depends on the spacing between them. We also establish criteria to regulate the collective behavior of multiple cilia using light as the external stimuli. Our findings provide guidelines for designing ciliated surfaces that can exhibit biomimetic functionality.

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