CAN A MATERIAL PERFORM AS AN ENGINE?

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Recently a number of reports demonstrated successful developments of microswimmers. These are small objects with the size of micrometers or even smaller. Qualification of polymer objects to undergo autonomous motion, i.e., driven and directed (i) rotation, (ii) vibration/oscillation or (iii) translation requires the particles to do work. This in turn requires a local energy input. Examples in which a micro-object can undergo a directed motility by body shape deformation, mimicking the locomotion of bacteria, are rare and incomplete. In the case of low Reynolds numbers, the actuation must not generate a reciprocating change in the particles conformation or shape and furthermore, such a motility requires that the micro-objects undergo a displacement directed by itself, just like a human swimmer, who moves forward by recurring strokes. A cyclic body shape deformation, however, represents a clockwise repetition. If this should be autonomous, it will represent another challenge.

Here we report on LCST-hydrogel micro objects for which the body shape variation can be precisely controlled by the (i) design of the geometrical shape, (ii) the widely variable material properties and (iii) by the energy intake via infra-red irradiation. The volume change is not caused by heating of the whole system, but by strictly localized heat generation inside the particles. For this purpose the gels were equipped with 1-4 gold nanorods per $\mp m^3$ that absorb light at 780 nm and convert it practically instantaneously to heat. It will be shown that a cyclic deformation can be controlled to follow a different path in space and time during the "forward" and the "backward" stroke. In first instance the deformation cycle has been controlled from outside by switching on and switching off the irradiation as the driving energy input. In a higher developed version, we attempted and succeeded to cause the repetitive deformation by continuous irradiation. This required the introduction of an autonomous feedback mechanism by which the energy uptake ceased upon raising the temperature and a hysteretic bistability by which we could prevent that the system could adopt a shape corresponding to a steady state equilibrium.

References
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