Optically controllable manipulation of cholesteric liquid crystal micromotor

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In addition to optical manipulation for linear motion in three dimensions, rotating objectives is also an extensively exploited subject with optical tweezers. Friese et al. first demonstrated the optical rotation and the alignment of a calcite wave plate by varying the polarization of the incident optical tweezers beam.\[1\] The optical rotation and alignment of the wave plate is attributable to the phase shift between the two orthogonal components of incident optical field experiencing ordinary and extraordinary indices, which results in the transformation of the angular momentum of light and hence induces a torque to the wave plate. This phenomenon opens a possible way toward the realization of optically-driven micromachines controlled by optical beam and their related applications on microsensing and microfluids.\[2\] Although solid state based architectures can be exploited as micromachines, the use of in situ reconfigurable micro-elements of optics is preferred for which liquid crystals (LCs) are potential candidates owing to their high sensitivity to external fields and high birefringence. Dispersing LCs in an immiscible host fluid, such as glycerol or water, LC droplets with almost perfectly spherical shape can be formed spontaneously because of the interfacial tension. The fabrication process of the LC droplets is much easier than that of solid state microgears and micromotors.

This study aims to develop an optically controllable micromotors based on cholesteric liquid crystal (CLC) microdroplets added with a chiral azobenzene for the first time. The CLC microdroplet shows an axial structure of helical axis with a ring-defect on the equator of the microdroplet such that the circularly polarized red beam of the optical tweezer may transfer its angular momentum to the microdroplet and then induce rotation motion. The rotation velocity of the CLC microdroplet with various diameters can be optically controlled in different evolutions with one UV beam irradiation with different intensities (Fig. 1). The irradiations of the UV beam can trigger the trans→cis isomerization of the chiral azobenzene doped in the microdroplet and induce the isothermal phase transition of the CLC from CLC to isotropic state, resulting in the decrease of the rotation velocity of the microdroplet (Fig. 2). After turning off the UV irradiation, the CLC structure recovers via thermal cis→trans isomerization.

Fig. 1. Optical control of the rotation of the microdroplet manipulated under the optical tweezers: evolution of the angular velocity of the microdroplet with 5, 10, and 15 μm radii at Iuv = (a) 21, (b) 30, (c), 48, and (d) 82 mW/cm².

Fig. 2. Variations of the image for the CLC microdroplet with diameter of 15 μm under the observation of POM with crossed polarizers (a) before and after the UV irradiation with 82 mW/cm² at tuv = (b) 20 and (c) 60 s, and (d) after turning off the UV irradiation for 50 s. Schematic structure of the CLC microdroplet (e) before and (f) after weak UV irradiation and (g) after tuning off the weak UV irradiation.

References:

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