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# CONSTRUCTION OF A 3-D DROPLET ARRAY IN A METABOLIC ELASTOMER

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**Summary:** Liquids exhibit useful functions that are unattainable with solids. Handling difficulty, however, restricts uses of liquids in components and devices. Construction of a liquid-solid composite is therefore essential for creating a solid that holds an excellent function of liquid. In this study, we fabricated liquid-solid composites by using a polydimethylsiloxane (PDMS) elastomer.
Gases and liquids diffuse rapidly in PDMS, since guest molecules can pass thorough the flexible polymer network. We created a toluene-PDMS composite for enhancing the diffusivity of dissolving molecules that exhibit useful functions, e.g., drugs and dye molecules. Molecular diffusion in the composite was visualized by dispersing a photochromic dye as a tracer. When a violet laser beam was irradiated at the sample center, a colored portion gradually expanded outward. The distribution of colored molecules was fitted by a theoretical curve (Fick's law). The diffusion coefficient of the composite (toluene: 60 vol%) was 0.0015 mm2/s, which was 15-fold larger than that of ordinary PDMS elastomer. This photochromic composite exhibits a metabolic self-healing function as follows. Since organic dyes generally lack durability against photochemical bleaching, photochromic color change becomes faint after coloration-decoloration processes of 1000 cycles. In the toluene-PDMS composite, however, damaged molecules are replaced by fresh molecules in the surrounding area owing to the high diffusivity. The current photochromic composite exhibited negligible degradation even after 30,000 cycles.
By contrast to nonpolar toluene, polar liquids (water and alcohol) create droplets in PDMS. The droplets, however, shrink gradually as liquid diffuses out of the elastomer. Consequently, dye molecules in droplets aggregate and lose activity. This damage is healable by dipping the elastomer in liquid for expanding droplets. Addition of surfactant is effective to prevent droplet shrinkage, since it forms a protection film on the droplet surface. Spherical droplets with smooth surface (10–200 μm diameter) are self-formed in PDMS owing to the surface tension. Since this composite is flexible, droplets are deformable into an ellipsoidal shape. The smooth surface and deformability are useful to create a tunable microlaser (droplet laser). We used an ink-jet nozzle to construct a 2-D droplet array in PDMS. However, 3-D array was difficult to construct by the ink-jet method. We therefore used an ultrasonic trapping method. A dye solution with a surfactant was poured into PDMS oil and stirred well to create droplets of ~20 μm diameter. After adding a curing agent, the mixed solution was put into an acoustic cell that was made of PDMS. Then ultrasonic transducers were attached to the three orthogonal surfaces of the cell, and glass plates were attached to the opposite surfaces. When the ultrasonic frequency was tuned suitably at ~8 MHz, standing waves were excited in three directions inside the cell. Since droplets were pushed to nodes of the standing waves, they were trapped at intersections of the nodal planes. In this manner, a droplet-elastomer composite with a 3-D periodic structure was constructed.