Supporting Information

Photonic Labyrinths: Two-Dimensional Dynamic Magnetic Assembly and *in situ* Solidification

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Materials and Methods

Chemicals: Iron(III) chloride anhydrous ($FeCl_3$, 98%) was purchased from Riedel-de Haën, German. Diethylene glycol (DEG, reagent grade), ethyl alcohol (denatured), sodium hydroxide (NaOH, 98.8%), and Norland optical adhesives (Edmund) were purchased from Fisher Scientific. Ammonium hydroxide solution (28%) was obtained from Fluka. Poly(acrylic acid) (PAA, Mw = 1800), tetraethylorthosilicate (TEOS, 98%), Sylgard 184 silicone elastomer base and curing agent (Dow Corning) were purchased from Sigma-Aldrich. Poly(ethylene glycol) (Mw = 1500) was obtained from Acros Organics.

Fabrication of labyrinth structures. Superparamagnetic Fe_3O_4 CNCs were obtained using a high-temperature hydrolysis reaction and then coated with silica using a modified Stöber method, as reported previously.[1,2] In a typical synthesis of labyrinth structures, an ethanol solution of $Fe_3O_4@SiO_2$ CNCs (4 μL, ~ 50 mg/mL) was mixed with NH_4OH (4 μL) and TEOS (2 μL) and sandwiched in between two glass slides. A 1500 G magnetic field was applied and rapidly switched a few times between a vertical position and a 15° angle for 10 seconds, at which point the sample was allowed to sit undisturbed for 20 minutes above the magnetic field in a vertical position.

Pattern preparation. In order to manipulate the labyrinth structures by modulating the local magnetic field, lithographically patterned substrates were used as for assembly. All patterns were initially defined in photoresist films deposited on silicon wafers by photolithography, then transferred into polydimethylsiloxane (PDMS) stamps by molding. Final polymeric patterns are obtained by sandwiching a layer of liquid polyurethane prepolymer between a clean glass slide and the PDMS stamp, followed by UV exposure to solidify the prepolymer. No further surface treatment was performed before the subsequent assembly processes.

Characterization. A Tecnai T12 transmission electron microscope (TEM) was used to characterize the morphology of the core/shell colloids. A Philips FEI XL30 scanning electron microscope (SEM) was used to investigate the morphology of the labyrinth structure. A Zeiss AXIO Imager optical microscope was used to observe the formation of the labyrinth structure. The diffraction spectra were measured by an Ocean Optics HR2000CG-UV-NIR spectrometer coupled to a six-around-one reflection/backscattering probe. The probe was perpendicular to the glass cell.

Simulation of magnetic field. The 2D cross-section magnetic field distribution around different patterns was simulated using COMSOL MUTLIPHYSICS software. The volume susceptibility of the ferrofluid was set at 1.4. The simulation of magnetic field was done based on the difference in the magnetic susceptibility of different sub-domains. The model in the simulation has two sub-domains of interest (see Figure S8 for an example). The volume susceptibility of the pattern was 0.15T set at 1. The external magnetic field was set uniform and in the vertical direction.

References

1. Ge, J., Hu, Y. & Yin, Y. Highly tunable superparamagnetic colloidal photonic crystals. *Angew. Chem. Int. Ed.* **46**, 7428-7431 (2007).

2. Ge, J. & Yin, Y. Magnetically tunable colloidal photonic structures in alkanol solutions. *Adv. Mater.* **20**, 3485-3491 (2008).

Supporting images

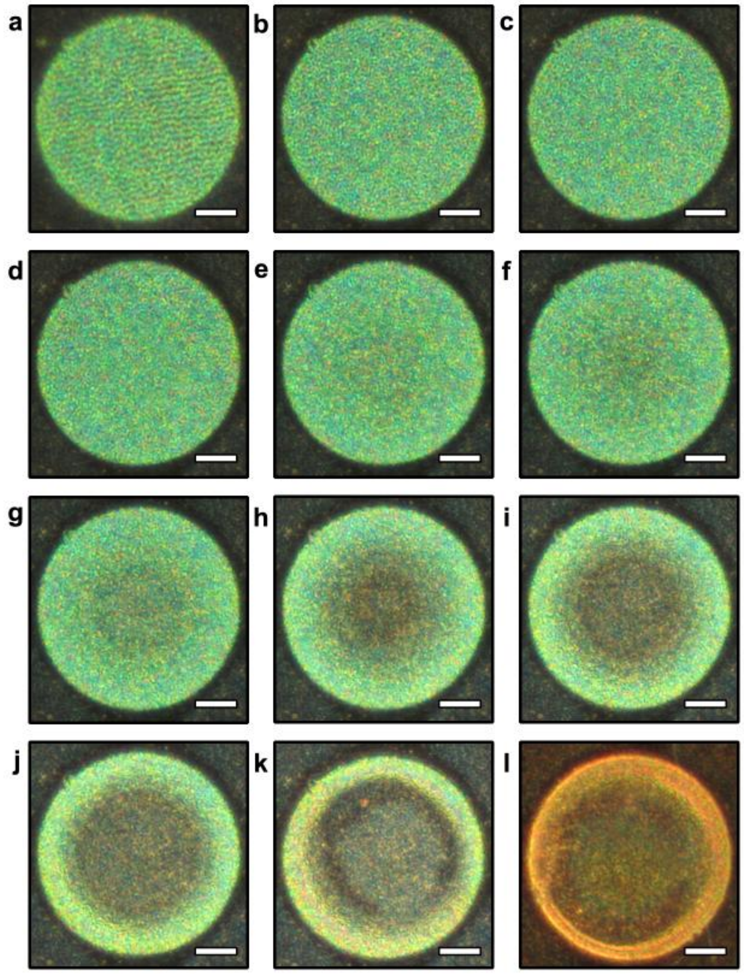

Figure S1. For clear imaging, photonic labyrinth structures were fabricated in a round hole with diameter 50 μm and height 2.25 μm using 20 mg/mL of $Fe_3O_4@SiO_2$ CNCs as the building blocks. As time goes by, the photonic labyrinth structure gradually collapses. Finally, only 3D crystals are left without any photonic diffraction. All scale bars are 10 μm.

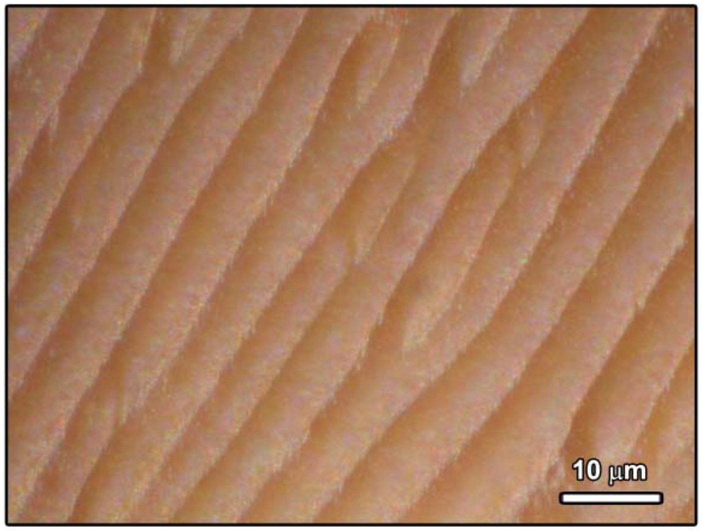

Figure S2. Optical image of photonic labyrinth structure shows its sheet-like nature when the magnetic field is tilted about 30^o.

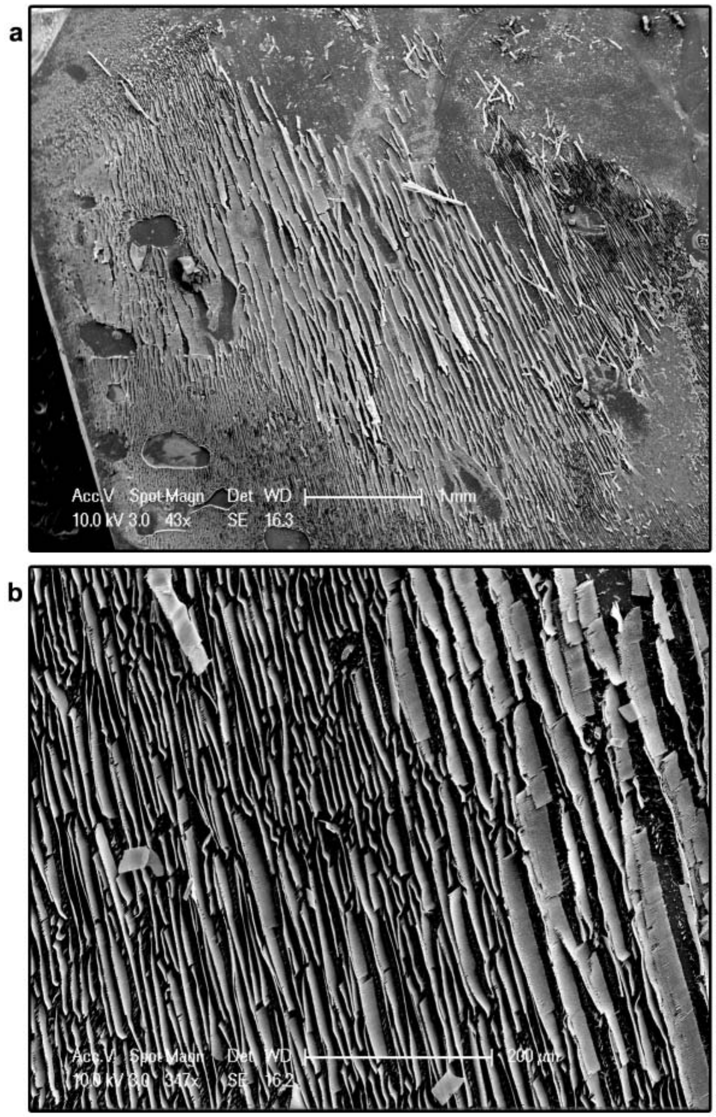

Figure S3. SEM image of ultra-long photonic labyrinth with length up to several millimeters.

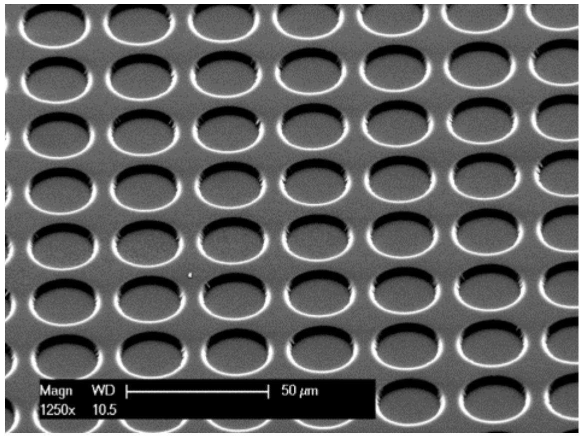

Figure S4. SEM image of a typical PDMS stamp with patterned holes.

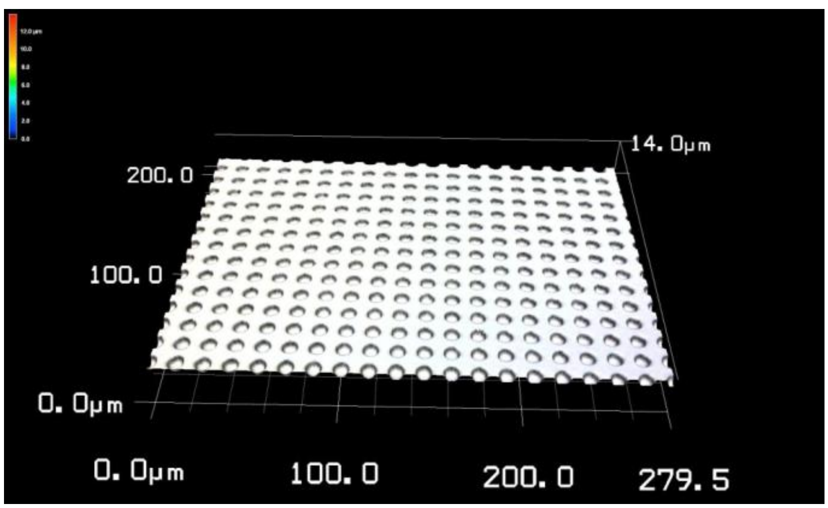

Figure S5. A 3D optical image of a typical PDMS stamp with patterned holes.

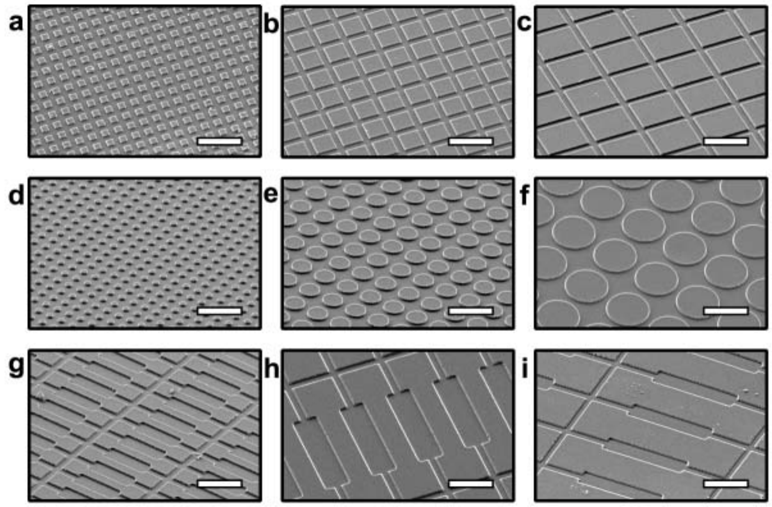

Figure S6. SEM images of various types of patterns used in this paper. All the scale bars are 50 μm.

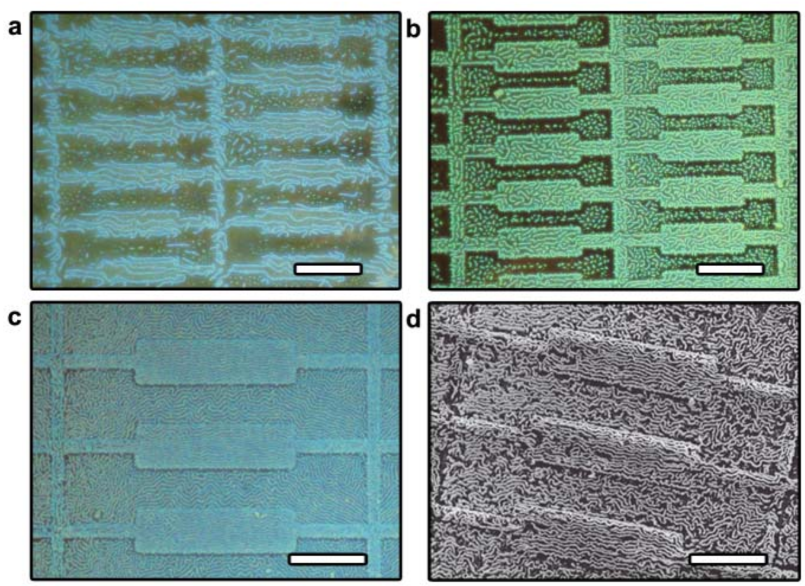

Figure S7. Optical images (a, b, c) and SEM image (d) showing various types of photonic labyrinth structures can be obtained by using an I-shaped nonmagnetic pattern as the substrate. Scale bars are 20 μm in (a, b) and 50 μm in (c, d), respectively.

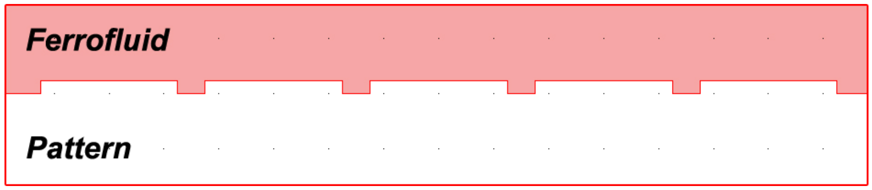

Figure S8. A sample model with two sub-domains of interest used in the simulation.