High-aspect-ratio Magnetic Tunable Nanopillar Array

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Tunable active nanostructures, with their special advantages, have been studied for various applications, such as dry adhesion [1], sensors or actuators on microfluidics [2-3]. Inspired by biological organisms such as gecko feet and magnetic cilia, such active systems allow dynamic tenability. In these systems microscopic pillars can be actuated using a global magnetic field to alter the pillar alignment angle to control surface properties. However, these works are mostly about micro-scale periodic structure or smaller scale structure with random order. Their optical properties, for example chromatic tuning, can be improved if their length scale is closer to the light wavelength plus the order becomes periodic. Here we introduce a simple method to fabricate sub-micrometer-scale periodic tunable structure with high aspect ratio.

Regarding magnetic flexible material, composite of highly permeable magnetic particles and flexible polymer matrix is a basic way to solve the confliction of mechanical flexibility and magnetic tunability, but there's still the difficulty of avoiding the aggregation of magnetic particles in polymers. Ferrofluid PDMS (FFPDMS), a mixture of Fe_3O_4 nanoparticles suspended into the copolymer of polydimethylsiloxane and aminopropylmethylsiloxane (PDMS-co-APMS) [3] has been chose in this work because of its high flexibility, permeability and nanoscale homogeneity. The fabrication process is shown in Fig 1(a-c). The negative photoresist SU8 has been exposed by using Lloyd's mirror interference lithography with 325nm laser to form two-dimensional periodic holes array to serve as the mold. Then FFPDMS was applied onto SU8 mold by spincoating and went into holes array afterward in vacuum environment. After that, SU8 mold was etched away by oxygen plasma under 600 mTorr pressure with 300 W power for 5 to 15 minutes, resulting in FFPDMS periodic pillar array. Preliminary results of a 2μm period array are shown in Fig 2(a). The height of the pillar can be as high as 12μm with aspect ratio around 24, shown in Fig 2(b). Also, preliminary testing has been done under optical microscope, which observes *in. situ.* during actuation by external magnetic field, shown in Fig 1(d). N_dF_eB permanent magnet with the maximum field of 1.5 T was applied to oscillate horizontally within a short distance (1-2 cm) under the structure while the microscope view was focused on the top of nanopillar array, as shown in Fig 2(c). Once the pillar was actuated by magnet, a displacement of the movement could be observed, shown in Fig 2(c-d). The pillars all have displacement to some extent by comparing Fig 2(c) and Fig 2(d), especially the pillar marked within white ring moves ahead along x axis about 0.2μm, demonstrating the structure is tunable.

In this work, a simple method of fabrication has been discussed for micro-nano-scale periodic tunable structure. Furthermore, the preliminary test indicates that the nanopillar array is tunable. In the future, the tenability will be enhanced by improving the structure aspect ratio. The water-soluble polystyrene sulfonate (PSS) will be used under ARC to help separate structure and silicon substrate with higher yield. The testing method will also be improved to make results more convincing. As for application, this structure can be multifunctional, such as resisting to rain due to the high hydrophobicity [4], and chromatic tuner by actuating of nanostructures.

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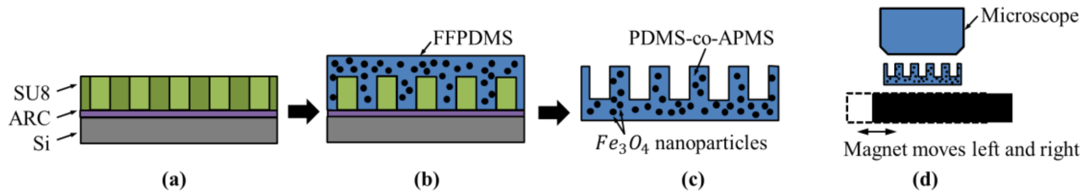

Fig 1. Fabrication and testing set up of magnetic tunable nano-pillars. (a) Lloyd's mirror interference lithography is applied on SU8 to form periodic holes; (b) FFPDMS is cured inside the SU8 mold; (c) SU8 mold is etched away; (d) the magnet is moved left and right to actuate FFPDMS nanopillars.

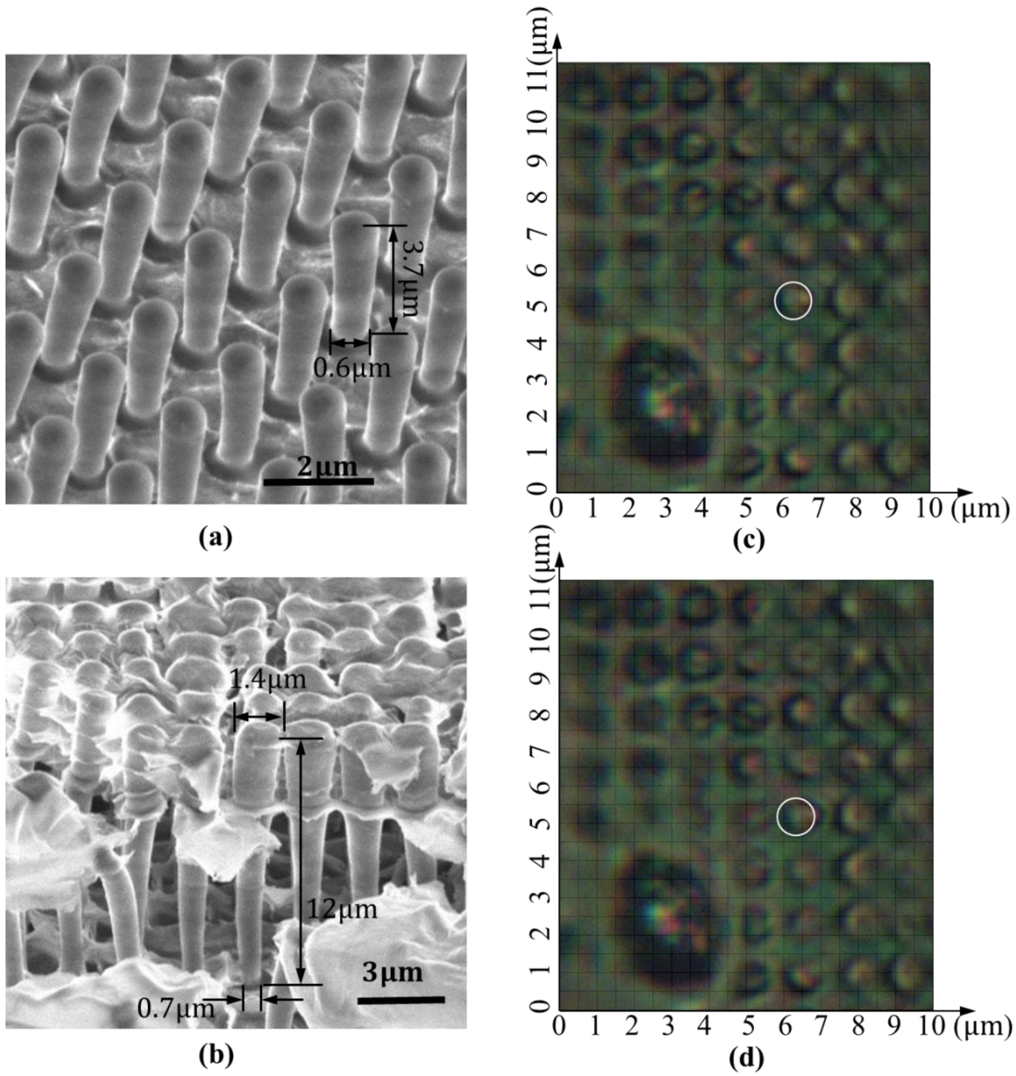

Fig 2. SEM images and preliminary testing of FFPDMS nanopillar array. (a) the pillar height is about 3.7 µm with aspect ratio around 6; (b) the aspect ratio is around 24, with some organic contaminants; (c) pillars are located at the leftmost side; (d) pillars move to the rightmost side.

Reference:

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