Fabrication of Magnetically Tunable Periodic Nanostructures

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Tunable structures are attractive as components for dynamic systems that can be reconfigured in real time. In particular, tunable nanostructures can induce dynamic physical properties, such as wetting, mechanical, and optical properties, in a fundamental way which traditional macroscopic structures could not. Magnetically tunable microstructures have previously been demonstrated in fluid manipulations [1,2], reversible dry adhesives [3], and cell manipulations [4]. However, little effort has been put into fabricating and characterizing tunable nanostructures. In addition, existing structures are based mostly on composite polymer materials with embedded nanomaterials, where the magnetic parameters can only be controlled by the species and volume fraction of the magnetic material. Here, we propose a fabrication method for tunable periodic nanostructures where the mechanical compliance and magnetic actuation can be independently controlled using standard micromachining techniques and interference lithography.

The proposed fabrication approach is shown in Figure 1. First two-dimensional periodic hole arrays of SU8 were generated using Lloyd's mirror interference lithography for polydimethylsiloxane (PDMS) molding. The demolded PDMS nanopillars were then deposited using electron-beam evaporation with magnetic materials, such as nickel and cobalt, for potential magnetic actuation. Due to the low Young's modulus of PDMS, the demolded PDMS pillars have a limited aspect ratio without any structural collapsing, which is found to be ~3 from various experiments. To further increase the aspect ratio, a PDMS trimming process using SF_6 reactive ion etching (RIE) was developed. The trimming process parameters were optimized to favor lateral over vertical etching to reduce pillar diameter more than height, as shown in Figure 2(a) and (b). As a result, a highest aspect ratio of ~11 was achieved after 9 min etching. The relationship between aspect ratio versus time was characterized, as shown in Figure 2(c), and will be discussed in more details. Initial fabrication of tunable PDMS nanopillars with deposited nickel and cobalt are shown in Figure 3(a-b) and (c-d), respectively.

In this work, a fabrication process towards magnetically tunable nanostructures is demonstrated and high-aspect ratio PDMS nanopillar arrays were fabricated with integrated magnetic materials. We will discuss the role of fabrication processes in the independent control of PDMS and magnetic material geometries. In future work, the mechanism of actuation using magnetic field will be studied in detail in order to induce observable nanopillar displacement. Such tunable nanopillar arrays can find many potential applications, such as in nanofluidic manipulation, dynamic photonic structures, and reversible dry adhesives.

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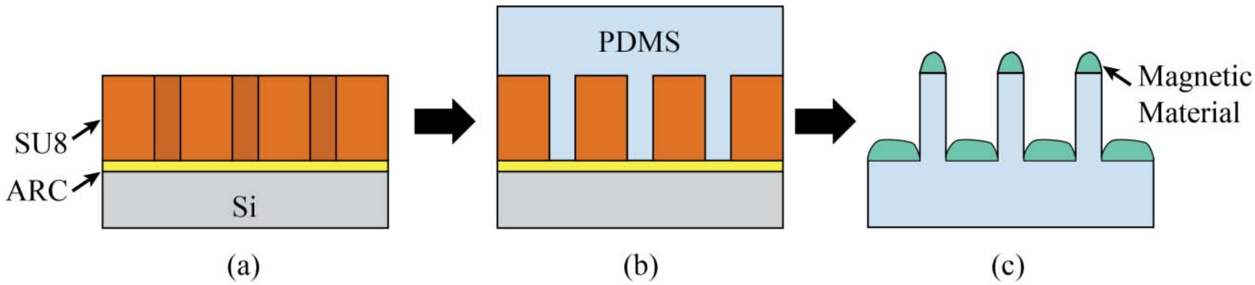

Figure 1. Fabrication process of tunable nanopillars. (a) SU8 2D hole arrays defined by Lloyd's mirror interference lithography. (b) PDMS replication. (c) Magnetic material deposition.

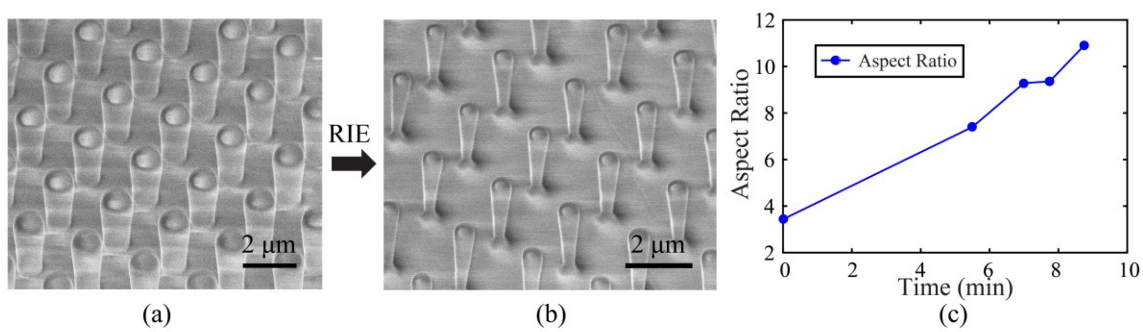

Figure 2. (a) Replicated PDMS from SU8 mold. (b) Reactive ion etching to increase nanopillar aspect ratio. (c) Relationship between aspect ratio and etching time.

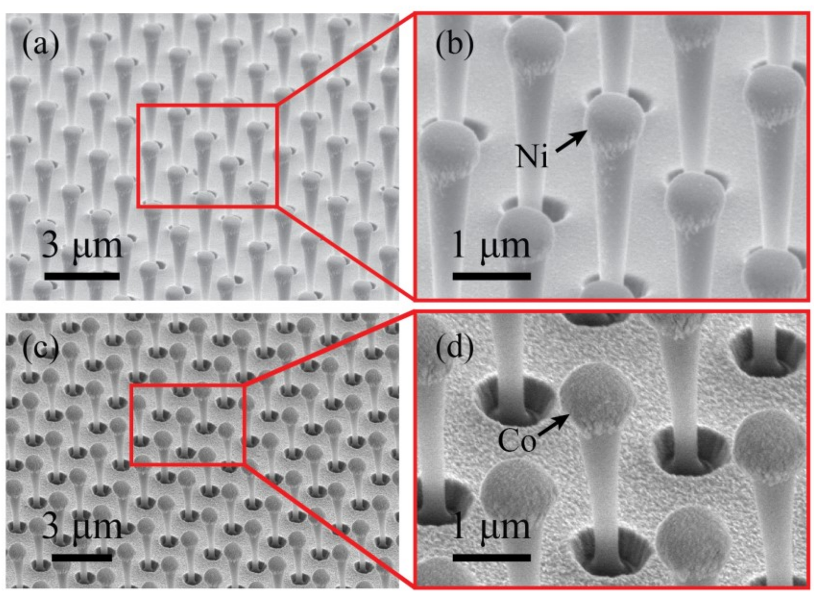

Figure 3. PDMS periodic nanopillars with deposited nickel (a-b) and cobalt (c-d).

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