MICROFABRICATION OF POLYMER SURFACE USING COLLOIDAL LITHOGRAPHY AND REACTIVE ION ETCHING

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ABSTRACT

In this study, we propose a method to fabricate precisely ordered pillar-array structures on polymer surfaces by hydrodynamically arranging microparticles and employing a newly developed electron cyclotron resonance reactive ion etching (ECR-RIE) system. The arranged particles function as a mask for the micropillars, utilizing the difference in etching rates between the particles and the substrate. Our method enables the direct fabrication of pillars with various shapes and sizes on polymeric transparent materials when the particle size, materials, and/or etching duration are changed. In the experiment, various types of pillar arrays with high aspect ratios were successfully fabricated on PMMA plates by controlling the etching duration.

KEYWORDS: polymer microdevice, colloidal lithography, pillar array

INTRODUCTION

Polymer microdevices are usually fabricated by using the molding techniques such as hot embossing or injection molding, which enable the low cost and rapid mass production. However, they are unsuitable for the precise microfabrication and high-mix low-volume production of model devices needed at R&D stages, since expensive metallic molds are indispensable. On the other hand, colloidal lithography is an efficient technique to fabricate pillars or array-structures, but it has not been employed for the microfabrication of polymeric materials, due to its limitations in the surface morphology, anisotropy, uniformity, and the etching rate of RIE processes [1, 2]. Here we employ the combination of a particle-arranging technique [3] and a newly-developed ECR-RIE system (Fig. 1) [4], which enables the fabrication of high-aspect-ratio pillar/array structures on polymeric substrates.

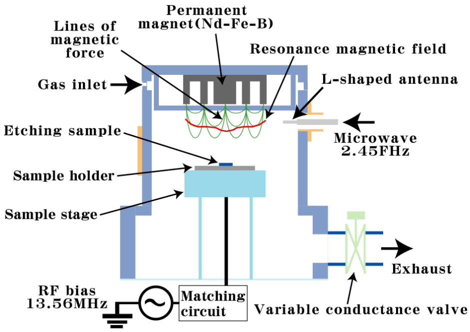

Figure 1. Schematic illustration of the developed ECR-RIE system.

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EXPERIMENTAL

The procedure of particle assembling is shown in Fig. 2. Particles are hydrodynamically trapped only inside the wells, with the help of the receding meniscus in a microchannel. Two procedures are used for particle assembling; (1) directly trapping particles in SU-8 well structures on the polymer substrate, and (2) transferring the initially trapped particles in PDMS wells to the substrate (Fig. 3). In this way, a monolayer of microparticles is obtained which can be used as the etching mask.

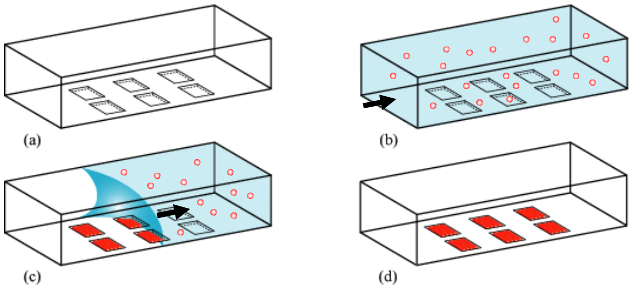

Figure 2. Principle of hydrodynamic particle assembling; (a) a microchannel with wells for trapping particle, (b) introduction of a microparticle suspension, (c) exhaust the fluid with the air, and (d) assembled particle monolayer inside the wells.

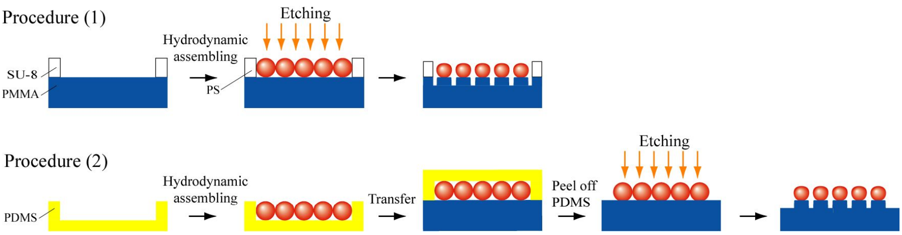

Figure 3. Preparing the particle mask and the etching processes of ECR-RIE.

RESULTS AND DISCUSSION

In this study, we fabricated pillar structures on PMMA plates, by using monodisperse polystyrene particles. Fig. 4 shows the photographs of the trapped and arranged particles; monolayer closest-packing was achieved for particles with different sizes. Next, the PMMA plate masked by the particles was etched using the ECR-RIE device with the 75 mol% O_2-CF_4 gas mixture at the pressure of 0.2 Pa for 3-10 min.

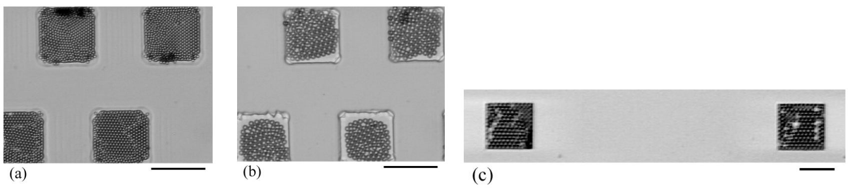

Figure 4. Trapped particles with various sizes; (a) 3.0 (b) 5.0, and (c) 6.8 µm particles. Scale bars, 60 µm.

Fig. 5 shows the etched substrate, before and after the removal of the residual PS particles by ultra-sonication. When the etching period was short, cylindrical pillar arrays were formed, while cone-shape pillars were obtained under the long-term etching conditions. This method is highly useful in the sense that we can easily obtain micropillar arrays on transparent materials with various shapes, sizes, and aspect ratios, by changing the fabrication procedures and the etching conditions.

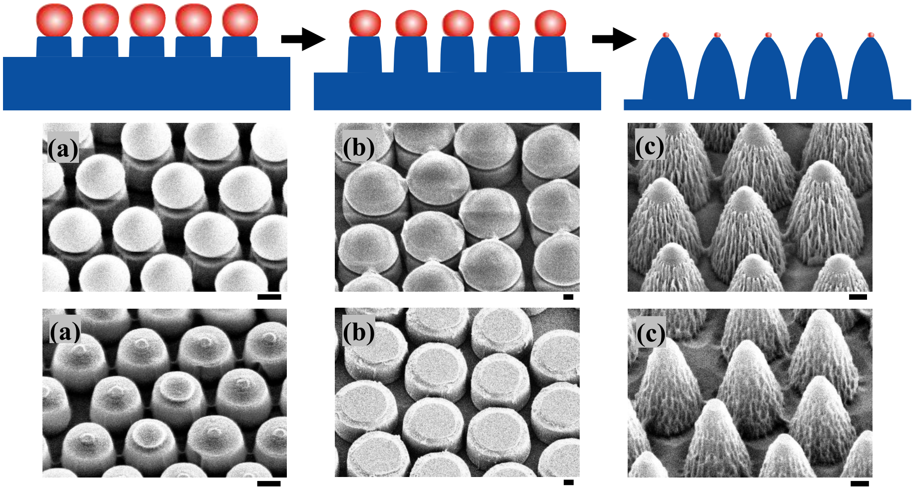

Figure 5. SEM images of the etched polymer surfaces before and after the removal of the residual particles, and corresponding schematic diagrams. Etching durations were (a) 3 min, (b) 5 min, and (c) 10min. Scale bars, 1 μm.

CONCLUSIONS

We demonstrated the fabrication of polymer pillar-array structures using precisely ordered particles and controlling the etching duration. The fabricated structure will be useful for optical devices, LSI, and water repellent finishing, as well as chemical and biological applications.

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REFERENCES

[1] H. Ageli and D. S. Sutherland, *IEEE Trans. Nanobiosci.*, **5**, 9 (2006).
[2] X. Zhang et al., *Langmuir*, in press (2009).
[3] M. Yamamoto, M. Yamada, N. Nonaka, S. Fukushima, M. Yasuda, and M. Seki, *J. Am. Chem. Soc.*, **130**, 14044 (2008).
[4] H. Nabesawa, T. Hitobo, S. Wakabayashi, T. Asaji, T. Abe, and M. Seki, *Sens. Actuators B*, **132**, 637 (2008).