FABRICATION OF PMMA MICROPILLARS BY REACTIVE ION ETCHING TOWARDS SEPARATION OF WHITE AND RED BLOOD CELLS

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ABSTRACT

Fine, high aspect ratio, and smooth surface micropillars, which never realized by conventional hot-embossing fabrication method, were fabricated on poly(methyl methacrylate) (PMMA) substrates by reactive ion etching (RIE). The separation ability of PMMA micropillars for microbeads as pseudo erythrocytes and leukocytes are comparable to Si micropillars, while the features of PMMA are superior to Si in terms of disposability, cost, and surface treatment.

KEYWORDS

Poly(methyl methacrylate)(PMMA), Reactive Ion Etching, Micropillars, Separation, Blood cells.

INTRODUCTION

PMMA is one of the most widely explored biomedical materials because of its biocompatibility, and recent publications have shown an increasing interest in its applications as microfluidic devices. In comparison with other materials, PMMA has advantages in high light permeability, low cost, easy disposability, and mass production. But the fabrication method of PMMA substrates was mainly hot-embossing, by which it is difficult to fabricate fine structure with high aspect ratio. In this study, we demonstrated the fabrication of PMMA micropillars by RIE. This method is possible to realize fine, high aspect ratio, and smooth surface microstructures.

Furthermore, it is beneficial that a microfluidic device, which can separate erythrocyte, leukocyte, platelet, and plasma only from a drop of whole blood. Because these blood components are different diagnostic indicators of disease, these type of separation devices with parallel detectors help us to improve the quality of examination and diagnostic via a development of such microfluidic devices.

So we attempted to separate microbeads as pseudo erythrocytes and leukocytes using our PMMA micropillars device by reactive ion etching, and the fabrication contributes to the device with high feasibility for early diagnostics, prevention because of the fine structure, disposability and cost and surface treatment.

FABRICATION

Our RIE fabrication made it possible to control desirable size and shape. The fabrication method shows Figure 1. For the fabrication of micropillar devices, 100 nm titanium layer as a mask for following RIE was deposited on PMMA substrate, and then positive-type photoresist was coated on the substrate by a spinner. After UV irradiation by a contact mask aligner, the titanium layer was etched by CF_4, and then, PMMA substrate was etched by O_2 gas; etching rate is 1 μm/min (Figure 2). The patterned substrate and non-patterned substrate which has inlets and outlets holes were bonded each other at 90°C and 6.5 Nm for 10 min after ozone treatment for 1 hour.

This method can fabricate smooth surface and high aspect ratio micropillars not by hot-embossing which is conventional fabrication method for polymer resin substrates. As pattern is microscopic or high aspect ratio by hot-embossing, the resin softened by heating can not fill up mold patterns. Furtherrmore our method don't need a mold, and can quick etch substrates because of 1 μm/min etching rate.

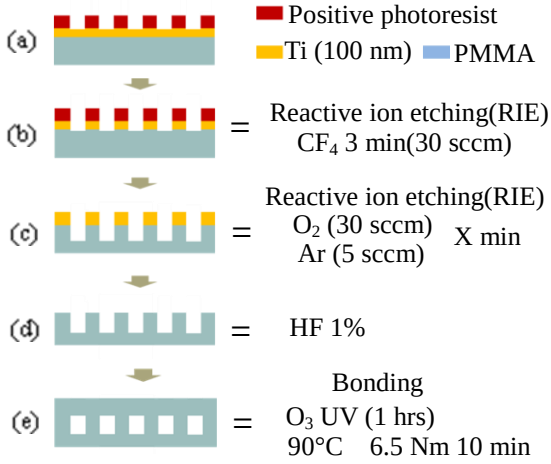

Figure 1. PMMA devices were fabricated as follows; (a) photolithography, (b) titanium layer etching with CF_4 (30 sccm) plasma for 3 min, (c) PMMA etching with O_2 (30 sccm) and Ar (5 sccm) plasma for arbitrary time, and (d) stripping with 1% HF for 1 min, (e) the patterned and non-patterned substrate were bonded each other 90°C and 6.5 Nm for 10 min after ozone treatment for 1 hour.

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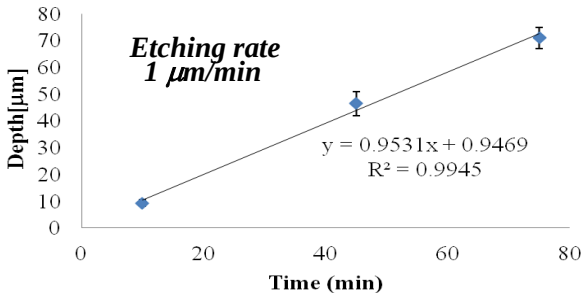

Figure 2. Time versus etched depth of PMMA substrate. Etching rate was estimated 1 μm/min from the linear relationship between and etched depth.

DESIGN

Our design of entire channel shows Figure 3(a). There are micropillar arrays in the main channel. We performed the separation ability of micropillar arrays on Deterministic Lateral Displacement (DLD) [1]. We attempted to separate 6 μm and 10 μm polystyrene beads as pseudo erythrocytes and leukocytes, respectively. Diameter of micropillars, gaps between them, angle of micropillar array, and the mechanism of DLD are shown in Figure 4. Large particles move along the micropillars array, while small particles move to the direction of flow and passed between micropillars. Recovery port is provided at the destination using this phenomenon, the movement of each particle size, were separated and collected.

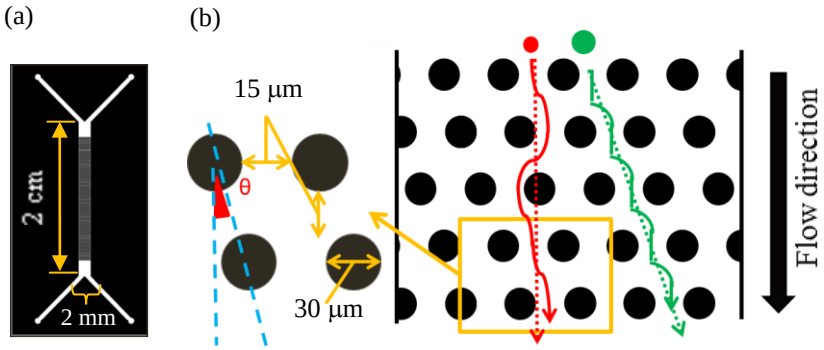

Figure 3(a) Entire channel design. (b)Principle of separation mechanism by a micropillars array.Red and green particles are 6 and 10 μm beads as pseudo erythrocytes and leukocytes, respectively. 10 μm beads move along the micro-pillar array, and 6 μm beads move to the direction of flow by passing through the micropillar array.

RESULTS AND DISCUSSION

We fabricated PMMA micropillars in channel by the RIE fabrication. The micropillars have smooth surface. This micropillar has etching wall in a vertical direction without underetching like wet etching. Although conventional hot-embossing fabrication method is of utmost difficult to realize high aspect ratio and fine pattern microfabrication, our PMMA micropillars by RIE fabrication method makes smooth surface, high aspect ratio, and fine pattern fabrication possible. Furthermore etching rate of the RIE fabrication method is 1 μm/min, so we can control the depth of micropillar.

Next, we discuss about separation ability of PMMA micropillars for microbeads as pseudo erythrocytes and leukocytes. Beads suspention and water were introduced from different inlets to maintain laminar flow (Figure 4(a)), and images of fluorescent trajectories of 6 and 10 μm beads at each position are shown in Figures 4(b) and (c). In comparison of displacements for 6 μm beads with those for 10 μm beads, we observed a clear difference in displacement of them at the end of micropillars area. 6 μm beads flowed straight direction without being affected by micropillars, whereas 10 μm beads were forced by micropillars and becoming laterally displaced. Fluorescent intensities of 6 μm and 10 μm beads at the end of micropillars area shows Figure 4(d) and Figure 4(e), respectively. Two recovery ports are provided at the destination for separated particle after passing through micropillars. As we observed each particle in the branching point of recovery ports, 80% of 6 μm beads entered the left recovery port, on the other hands, 90% of 10 μm beads entered the right recovery port (Figure 4(f)). So these smooth surface, high aspect ratio micropillars acted in the mechanism of DLD, and successful separation microbeads as pseudo

erythrocytes and leukocytes.

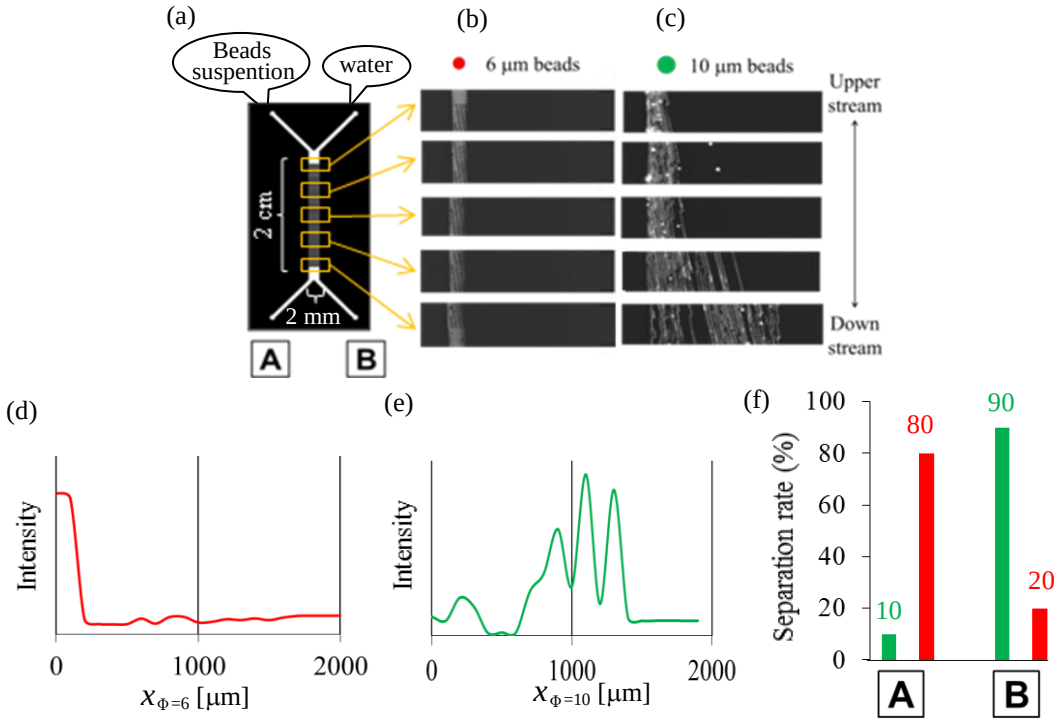

Figure 4. Flow direction was from top to bottom. (a) The micropillars area is 2 cm long and 2 mm wide. Beads suspention flowed from one-side inlet, water flowed from the other inlet to make laminar flow. Fluorescent trajectories of (b) 6 and (c) 10 μm beads were observed at each yellow boxed section. As 10 μm beads flowed to the down stream, they were laterally displaced by the micropillar array. Fluorescent intensities of (d) 6 and (e) 10 μm beads at the 2 cm point from junction. The displacement distance between 6 and 10 μm beads was about 1 mm from this graph. (f) Green, and red bar graph represented separation rate of 10 and 6 μm beads in the branching point. 80% of 6 μm beads in A, 90% of 10 μm beads in B.

CONCLUSIONS

We demonstrated fine fabrication with high aspect ratio, and smooth surface micropillars on PMMA substrates by RIE. The micropillars never realized by conventional hot-embossing fabrication method. The micropillars acted in the mechanism of separation based on mechanism of DLD, and successful separation microbeads as pseudo erythrocytes and leukocytes. The micropillars contribute to the device with high feasibility for early diagnostics, prevention because of the fine structure, disposability and cost and surface treatment.

ACKNOWLEDGEMENT

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