Micro Polymer Capsule Constructed with Micro Pillars Formed by Multi Laminating Method

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A micro polymer capsule of 6.5mm length and 4.0mm diameter is fabricated by multi laminating method. The micro polymer capsule has 56 micro pillars for generating a turbulent liquid flow in the inside of capsule. As a fabrication process, the SU-8 resist film based on epoxy resin is coated on a glass substrate. A ring shape image is exposed on the resist film. After pattern development, the ring patterns are peeled from the glass substrate by dipping into HF aqueous solution. The SU-8 ring patterns are stacked in 18 layers by using the micro tweezers under the alignment accuracy of ±0.3mm. In order to adhere the SU-8 ring layers each other, an i-line resist material is pasted into SU-8 ring patterns, then baked on a hotplate at 200°C for 10min. These functional capsule structures can contribute to develop various biological and medical MEMS (Micro Mechanical electronic system) devices.

Keywords: micro polymer capsule, micro pillar, stacked structure, adhesion, MEMS, SU-8 resist

1. Introduction

In recent years, a three dimensional (3D) fabrication process has been recognized as one important key technology in MEMS (micro electro mechanical systems).[1-5] For example, micro stereolithography was employed for a hybrid structure fabrication of a micro turbine or cogs.[1] However, in order to fabricate the micro capsule structures, it is necessary to employ expensive equipments for exclusive use. Moreover micro structure fabrication for 1 to 5mm is not suitable by the optical lithography systems. In this paper, we focus on a simple method for fabricating a 3D structure, that is, stacking of micro resist patterns. The stack method requires no expensive equipment as a stepping exposure system or a computer controlled pattern generator system. As the results, the micro polymer capsule is developed for fluid flow control by micro pillars.

2. Experiment

2.1 Device structure design

Figure 1 shows a schematic of a micro capsule structure in a cross sectional view, which is used for a photo mask design. The micro capsule size was designed in 6.5mm length and 4.0mm in maximum diameter. The wall thickness of capsule was about 1.0mm. The inlet and outlet of 0.8mm diameter are formed at the top and bottom of the capsule.

![Fig. 1 Schematic of the micro capsule structure.](image-url)
The 56 micro pillars were formed at inside of the ring stack structure. They were positioned at the period of 450 µm. Figure 2 shows a precise design position of the ring and pillars in the cross section. The micro capsule structure can be formed by stacking 18 ring layers. The ring pattern layer was made by resist of 450 µm thickness. An upper half reason of capsule is constructed by the ring with micro pillars. The size of the pillars is from 360 to 650 µm length, 150 µm width, and 50 µm thickness. By using the pillars, turbulent flow is generated in the micro polymer capsule. As the resist material, negative type SU-8 resist (SU-8 3050) made by Nippon Kayaku Co., Ltd. was used. The SU-8 resist indicates high contrast and epoxy base photoresist designed for micromachining and micro electronic application.

2.2 Micro capsule fabrication

Figure 3 shows the fabrication flow of micro capsule. Table 1, the process condition of the micro capsule is summarized. At first, the SU-8 resist film was coated on a glass substrate (18 mm × 18 mm × 120 µm) in 450 µm thickness by the spin method. Then the resist film was baked on a hotplate at 65 °C for 5 min and 95 °C for 30 min. A photomask was contacted on the resist film and exposure to UV light of 365 nm for 8 sec. Figure 4 shows photographs of photo mask plates which were used for the pattern exposure of the ring shape. At the vicinity of photo mask, alignment marks of cross shape are positioned. Next, the SU-8 patterns were processed in post exposure bake (PEB) after the development of the SU-8 patterns in the developer. Figure 5 shows the photograph of the ring resist.
The pattern on the glass substrate. The ring patterns were connected each other by the short line. In third step, in order to separate the micro pattern, the glass substrate was removed by dipping into 5wt% HF aqueous solution for 6 hours. As shown in Figure 6, the SU-8 micro pillars formed at ring inside can be observed. Figure 7 shows a photograph of series of the SU-8 ring patterns. The patterns in Fig.7 are arranged in series of stacking process. The each pattern was cut off from the connected line patterns by the cutter knife and tweezers. In fourth step, the SU-8 ring patterns were stacked each other. Then, the SU-8 ring patterns were baked in a glass case on a hotplate at 200°C for 10min in order to improve the pattern adhesion. Moreover, in order to ensure the success of adhesion of the SU-8 ring pattern, the patterns were baked with i-line resist as adhesive material. Figure 8 shows the photograph of adhesion baked process. Each parts of the micro capsule is constructed in 3 to 5 layer of the SU-8 ring pattern.

Figure 9a shows the photograph of micro capsules. The rugby ball shaped micro capsule size is 6.5mm height and 4.0mm width(maximum). Figure 9b shows the X-ray photograph of transparent observation of the micro capsule. As can be seen from the Fig.9b, micro capsule has a hollow space for liquid control as designed. Each ring patterns can be stacked in the alignment accuracy of ±0.3mm. The micro capsule has 56 micro pillars for generating a turbulent liquid flow in the inside of capsule. In addition, it is possible to vibrate the micro pillars by applying ultrasonic wave. Figure 10 shows the photograph of cross section of micro capsule after separation. As shown in Fig.10 it is clearly observed that the micro pillars are aligned as the design of micro capsule. Figure 11 shows the cross sectional view of X-ray CT image by using the X-ray CT analyzer. As can be seen, it can be confirmed that the micro capsule structure is fabricated by multi laminating method.
It is not easy to fabricate a 3 dimensional structure of 1 to 5 mm size by a recent lithography technology. The multi laminating method in this study could apply the convenient fabrication technology of 3D structure. These structures can contribute to development of various biological and medical MEMS (Micro Mechanical electronic systems).

3. Conclusion

The micro capsule made of the SU-8 resist combined with micro pillars is constructed. By the multi-laminating techniques makes it possible to fabricate a micro capsule structure of maximum efficiency of liquid flow within the available space. The fabrication of micro capsule technique has a high and intelligent potential on micro fabrication. In the future, we will be fabricated a micro pomp or liquid mixture chamber system by using multi-laminating techniques.

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References