SHORT COMMUNICATION

Self-assembly of micro parts on normal glass substrate*

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Abstract Fluidic self-assembly is an approach by which micro parts less than one millimeter in size can be driven by the capillary force of a certain adhesive liquid and be fixed onto the desired sites on some substrates. Normal glass with the composition of $Na_2SiO_3CaSiO_34SiO_2$ has been widely used in fluidic microelectromechanical systems (MEMS) and bio-MEMS devices. We investigate the MEMS self-assembly experiment on normal glass substrate. The results of scanning electron microscopy (SEM) show that micro-parts of 400 μm × 400 μm squares can be precisely assembled in the expected area of the normal glass substrate.

Keywords: self-assembly, microelectromechanical systems (MEMS), capillary force, normal glass substrate.

The goal of microelectromechanical systems (MEMS) technology is to develop a micro system that can be batch-fabricated. Approaches to assembling micro scale electrical, fluidic and optical device are highly desired, but confront some special difficulties. The following facts must be considered: Firstly, at micro scale the forces depending on the surface of the device such as the van der Waals force, surface tension and electrostatic attraction become dominant. These forces prevent the handling of the micro devices[1, 2]. Secondly, requirement of the assembly precision is higher than that of macro scale. Thirdly, it is difficult to use conventional technology to assemble devices made of different material such as Si, Si_3N_4, glass, metal, and polymer.

The existent assembly technologies in MEMS can be classified as serial microassembly and parallel microassembly. Serial microassembly can operate micro device 10 μm in size. Parallel microassembly includes deterministic and stochastic parallel micro assembly. So far parallel micro assembly is mainly wafer to wafer assembly. Various soldering and bonding technologies are also the MEMS assembly technologies. All the above self-assembly methods have their disadvantages, such as material and fabricating process incompatibility, small assembly quantity and low precision.

Fluidic self-assembly is an important MEMS assembly technology, which is schematically shown in Fig. 1, and will be discussed in detail in this paper. Fluidic self-assemblies on LPCVD Si_3N_4 substrate have been accomplished[3]. Normal glass with the composition of $Na_2SiO_3CaSiO_34SiO_2$ has been used widely in various bio-MEMS devices. In this paper we develop the fluidic self-assembly on normal glass substrate, and investigate its principle and process.

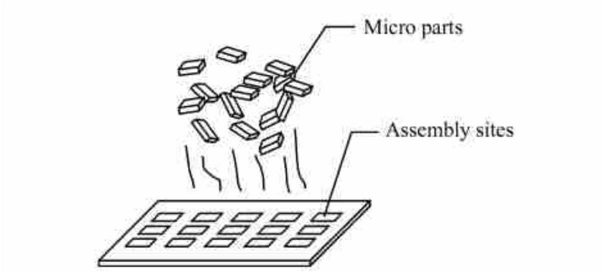

Fig. 1. Schematic of the MEMS self-assembly.

1 Principle of self-assembly in MEMS

Self-assembly is the autonomous organization of components into patterns or structures without human intervention[4]. Activated by the research of molecular self-assembly, self-assembly has attracted much attention in the research field such as biological science, chemical science, nano-physics, surface physics and so on. Fluidic self-assembly is one type of self-assembly. The operating objects of fluidic self-assembly are the micro devices in size ranging from tens of micrometers to hundreds of micrometers. The

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driving force in fluidic self-assembly is the capillary force arising from the meniscus of the adhesive liquid[5]. There are two concepts of self-assembly in fluidic self-assembly: the self assembly monolayer (SAM) and the fluidic self-assembly of micro part. The former self-assembly is the prerequisite of the latter one.

The chemical and physical properties of self-assembly monolayer are distinguished. The strong hydrophobic property of the self-assembly monolayer formed by the reaction between gold and thiol is applied in fluidic self-assembly. The mechanism of the reaction between gold and thiol is[6]

$$2Au + 2RSH \longrightarrow 2Au-SR + H_2$$
$$2Au + 2RSH + O_2 \longrightarrow 2Au-SR + H_2O_2,$$

where R is the terminal group of thiol, and SH is the head group of thiol. The key in the formation of thiol self-assembly monolayer is that the bond energy of Au-S is very high (184 kJ/mol). If R is alkanes, the thiol self-assembly monolayer will have strong hydrophobic property.

In our fluidic self-assembly research, both the micro parts and the desired assembly sites on the substrate have SAM. When the substrate coated with certain hydrophobic methacrylate adhesive is placed under the water, the methacrylate adhesive will selectively adhere to the areas with SAM. Surface tension powered capillary force of the methacrylate adhesive can attract the micro parts in the water, thus causing the combination of the substrate and the micro parts. Since the free energy of methacrylate adhesive-water and SAM-water interface tends to its minimum, shape match effect will occur. It means that the SAM of micro parts and the substrate will be strictly uniform. This shape match effect ensures that the assembly precision is within 0.2 micrometer[3]. Methacrylate adhesive is the key part in fluidic self-assembly, with three functions: Firstly, it is a kind of lubricant that enables the micro parts and substrate to adjust the position to the shape match state. Secondly, it is a kind of hydrophobic adhesive that has the surface tension powered capillary force to attract micro parts in the water. Thirdly, it is a solidifiable material that enables the micro parts to stick to the substrate permanently under certain bonding condition.

Since silicon is frequently used in the fabrication of MEMS, MEMS self-assembly technologies are mainly applied on silicon substrate. With the rapid progress in MEMS, other materials such as glasses and polymers are widely used especially in bio-MEMS. We try to use the fluidic self-assembly technology to assemble the micro parts on the normal glass substrate in this paper.

2 Experimental process

2.1 Formation of SAM

The micro parts were fabricated with the structure of 15 μmSi-0.5 μmSi_3N_4-500 ÅCr-1500 ÅAu, of 400 μm × 400 μm in size. The normal glass was coated with 500 ÅCr-1500 ÅAu by thermal evaporation, and then some squares were formed on the surface of normal glass with the structure of 500 ÅCr-1500 ÅAu and 400 μm × 400 μm in size by photolithography and etching technology.

The micro parts and substrate were rinsed by pure water and ethanol, and then they were immersed in the SAM solution (1 mM 1-octadecanethiol in absolute ethanol) for twenty hours. After these procedures the self-assembly monolayers on the micro parts and substrate were formed.

2.2 Fluidic self-assembly

After the micro parts were rinsed and the normal glass had been immersed in the SAM solution for twenty hours, a certain methacrylate adhesive was coated on the surface of normal glass, and then it was placed in the water. Because of the strong hydrophobic property of the SAM on the normal glass substrate, the methacrylate adhesive was selectively located in the SAM area on the substrate in the water automatically. Then, a number of micro parts were placed into the water. According to the mechanism of fluidic self-assembly described above, the micro parts combine with the substrate in the desired area. By heating the methacrylate adhesive in certain condition, the methacrylate adhesive can be solidified and the micro parts can be assembled on the normal glass permanently.

The process of the fluidic self-assembly is schematically shown in Fig. 2.

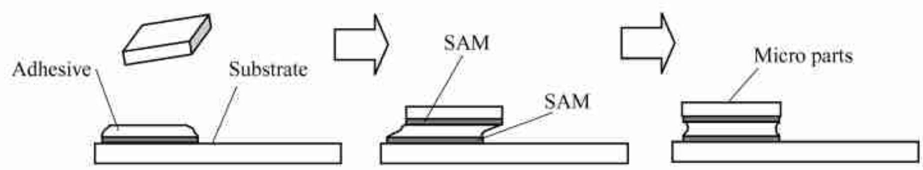

Fig. 2. Schematic of the MEMS fluidic self-assembly experimental process.

3 Experimental results

Scanning electron microscopy (SEM) pictures of the experimental results are shown in Fig. 3. As both the micro part and desired assembly site on the substrate have the same size, the smooth gold surface of assembly site on the substrate cannot be seen from Fig. 3 (a), and the edges of micro part and assembly site are parallel and uniform, the micro-parts have been assembled in the desired area on the normal glass substrate with high precision.

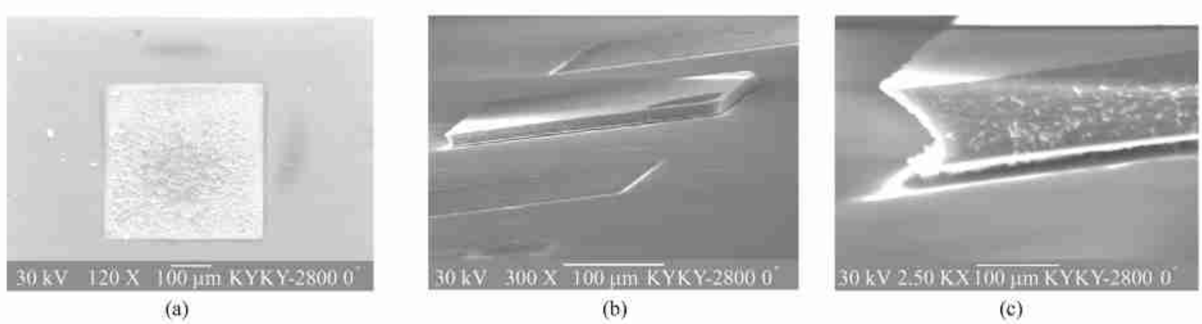

Fig. 3. Micro parts self-assembly on normal glass substrate. (a) An micro part self-assembled on the normal glass substrate; (b) the lateral figure of micro part self-assembled on the normal glass substrate; (c) a corner of self-assembled normal glass substrate.

4 Conclusion

We have used the fluidic self-assembly driven by capillary force to assemble the micro parts ($400\mu m \times 400\mu m$) on the normal glass ($Na_2SiO_3CaSiO_34SiO_2$) substrate which has been widely applied in bio-MEMS. The SEM pictures of experimental results show that the micro-parts have been assembled in the desired areas of the normal glass substrate with high precision. Experimental results indicate that this kind of self-assembly technology is a promising one for micro device, having the advantages of wide material compatibility, large assembly quantities and high assembly precision.

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