Surface Micromachining on Three-Dimensional Bulk Si Structures

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1. Introduction

In order to develop devices for micro-optics applications, elements of the device is often required to have 3D structures so as to form a space for the optical path that is decided by the laws of optics, such as the law of reflection. Few optical systems can be integrated on the surface of a single substrate. Strategies for arranging devices three-dimensionally often have problems in assembly that reduce productivity. Such problems can be alleviated by prealigning the microactuator with the micro-optical bench using an alignment guide. We developed an optical device having a thin film construction layer on a three-dimensional bulk Si structure.

2. Optical Scanner

We prepared a micro-mirror on a Si(111) surface obtained by anisotropic etching and fabricated an optical scanner incorporated with a temperature-driven actuator. We applied a 3D photolithography technique capable of forming a SiN mask and forming patterns in the wall surfaces. Figs. 1(a) and 1(b) show the structure of the optical scanner and an actual photo of the fabricated scanner, respectively. The left side of the structure shows a laser diode (LD) chip mounted on a terrace, which serves as a 3D micro-optical bench. The right side of the structure is a V-shaped cantilever microactuator constructed with SiN sandwiched between a doped poly-Si heater layer and Al. When heated by electricity, the structure arches upward as the Al layer on the bottom expands. As the structure bends, the mirror rotates to a position reflecting light emitted from the LD away from the surface of the wafer. A photodiode (PD) provided on the Si substrate makes the structure applicable for barcode readers. The LD, mirror, and PD can be aligned linearly. The ribs are prepared around the periphery of the scanning mirror to strengthen the thin film mirror and make it resistant to warping. The operations of the LD chip were confirmed after mounting the LD chip on the terrace, wherein a laser scanning angle of 30° was obtained at 120 mW. The cutoff frequency was 100 Hz, close to the required value for a barcode reader.

3. Variable Optical Attenuator

For optical communications, we fabricated a bridge-type device shown in Fig. 2(a) that functions on an optical fiber. An optical fiber fixed in a V groove is polished down near its core, and a surface micromachined structure is prepared on the polished surface. When a SiN film having a high refractive index (~ 2) is brought near the optical fiber core, some coupling loss of the propagating light inside the fiber occurs. The transmittance varies according to the position of the bridge. Fig. 2(b) shows one end of the device, wherein the bridge is 0.25 x 3 mm, and the gap between the bridge and the optical fiber is 3μm. The bridge is aligned precisely in relation to the optical fiber core. Since the position of the optical fiber is set by the V groove, the mask can be aligned to achieve an accurate bridge position. The resulting attenuation was about 1 dB. This small variation is attributed not only to a problem of particles, but also the difficulty of positioning the entire long bridge uniformly near the optical fiber.

4. Conclusion

Two types of devices were successfully constructed by combining thin film microactuator and been aligned on the bulk optical base having three-dimensional structures.

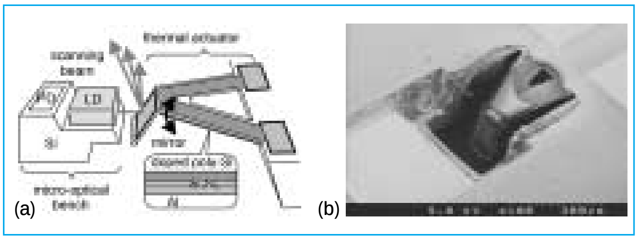

Fig. 1 Optical scanner formed on a 3D micro-optical bench

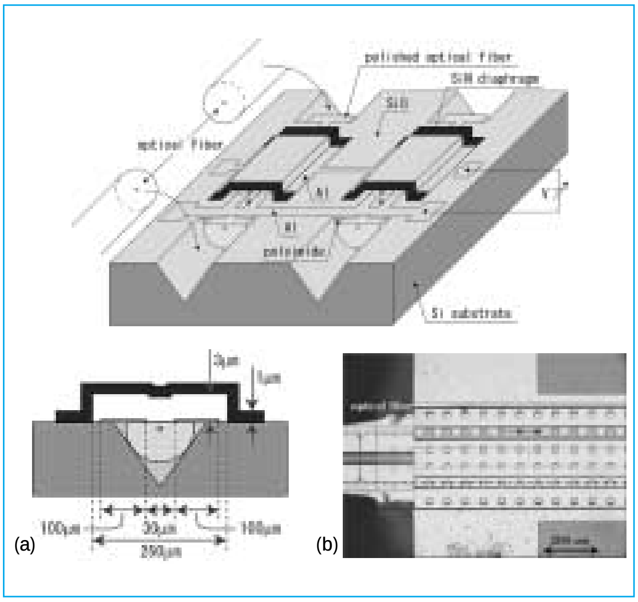

Fig. 2 Movable bridge-type variable attenuator prepared on the polished surface of an optical fiber

Basic Study for Microactuators Controled by Wetting and Driven by Capilary Force between Liquid-Liquid-Gas Interface

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1. Introduction

In fluid phenomena, the effects of wettability and surface tension become dominant as the scale becomes smaller. Since these forces become dominant in a microgravitational field, this study was focused on the similarities between microscale systems and a microgravitational field. We attempted to control a fluid by actively controlling the wettability and surface tension.

2. Fluid Handling by Wettability

Next, we will give an example of fluid handling through wettability distribution. A metal plate in the shape of a letter was placed on top of a Peltier element for cooling, and a culture dish coated with the temperature-responsive polymer IPAAm was placed over the letter-shaped plate. Since the bottom surface of the dish had been coated with the IPAAm, only the cooled parts showed good wettability. Hence, water droplets only adhered to areas with good wettability, forming a path in the shape of the letter on the coated dish, as shown in Fig. 1.

3. Liquid-Liquid-Gas Marangoni Convection

It was discovered that a spontaneous flow occurs when a drop of silicon oil is placed on a layer of fluorinert, as shown in Fig. 2. This flow is attributed to evaporation, since the flow stops when the system is accommodated in a hermetically sealed vessel. The thickness of the silicon oil drop is thought to be about 1 mm. As can be seen from the velocity distribution in Fig. 3, the driving force of this flow appears to originate at the point of intersection between a gas and two liquids. An experimental device that applies this driving force was manufactured in order to produce rotational force. The impeller of this device distributes wettability. When the impeller was floated on the fluorinert and when a silicon droplet dyed red with a syringe was adhered only to one blade of the impeller, as shown in Fig. 4, the impeller began to rotate spontaneously.

4. Conclusion

Developing a microscale system for handling fluids is easy, since fluids are treated without mechanical structures in this study. Future studies will attempt to elucidate the mechanisms of the spontaneous flow and produce linear motion, while developing driving forces that work effectively on a microscale.

Fig. 1 The path of flow is formed by wettability distribution

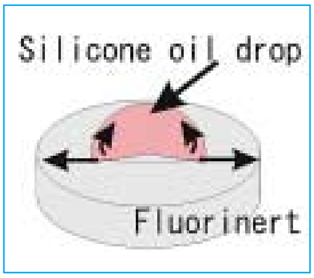

Fig. 2 Liquid-liquid-gas Marangoni convection

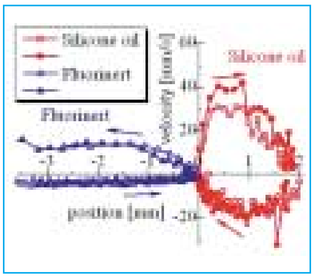

Fig. 3 Velocity distribution in liquid-liquid-gas Marangoni convection

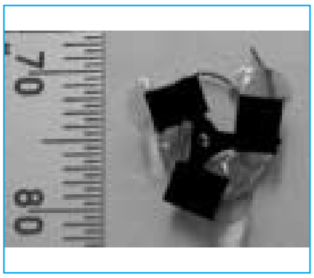

Fig. 4 Impeller employing liquid-liquid-gas Marangoni convection