The design and fabrication of a movable O-shape micro-clamper

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ABSTRACT

With the demanding of handling micro objects, the development of micro-clamper has emerged. Here an electro-thermally driven micro-clamper with adjustable vertical position is proposed. This micro-clamper is consisted of an adjusting unit and a clamping unit. The adjusting unit formed by four bimorph beams in the longitudinal direction can move the clamping unit vertically. The clamping unit formed by a pair of bimorph beams at the end of the adjusting unit is in the transversal direction. Due to the residual stress difference in the bimorph beams, at initial state, the adjusting unit in the longitudinal direction will bend upward, and the other two bimorph beams will also curl up to become a clamper. When the adjusting unit is heated, the whole device will move downwards. When the clamper unit is heated, two sides of the clamping unit will open up to a waiting state. It is hoped that the capability of adjusting the clamper in vertical position will provide larger operating range for the micro-clamper. The micro-clamper proposed here is batch-fabricated by surface micromachining. The testing results show that the adjusting unit can produce 8 μm downward displacement at input voltage of 2V and the clamping unit can be fully flattened around 5 V.

Keyword: Electro-thermal, bimorph, micro-clamper

1.INTRODUCTION

The devices and components fabricated by MEMS are becoming more versatile and complex. Positioning, inspection, and assembly of micro objects are also required with the development of MEMS. Therefore the device to handle micro objects is desired. A wide variety of micro grippers have been proposed that are generally based on a grip method by two or more fingers to grip micro objects [1,2,3,4]. Because the contact area between the micro gripper and micro objects is very small, the gripping could be quite unstable. Clamping mechanism may be another choice. Kim [5] has constructed a micro cage by multi-fingers to enclose the entire micro object. However this device can only control the clamping fingers to open or close, lacking the capability to chase the micro objects. Here an electro-thermally driven micro-clamper movable in vertical position is proposed by several sets of bimorph beams. It is hoped that the capability of adjusting the clamper in vertical position will provide larger operating range for a micro clamper. This device has not been reported before. The design, fabrication, and testing of such micro-clamper are presented below.

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2.CONCEPT DESIGN

A schematic view of the proposed micro-clamper is shown in Figure 1. This micro-clamper comprised of two major units. One is the adjusting unit formed by four 100 μm x 10 μm x 4.5 μm bimorph beams in the longitude direction. Another is the clamping unit, which is in the transversal direction. At two sides of the clamping unit, bimorph structures are about 400 μm x 50 μm x 4.5 μm. The whole clamping unit, including the connection area with the adjusting unit is about 900 μm x 50 μm x 4.5 μm. At initial state, the bimorph beams in the longitude direction will bend upwards due to the residual stress difference in two layers of bimorph beams. When these bimorph beams are heated, the whole device will bend downwards to achieve a vertical-adjustable motion. For clamping function, it is obtained by heating the clamping unit. Like the adjusting unit, the clamping unit curls up at first, and it will become more and more flatten with the increasing of input voltage. Then the vertical-adjustable motion and clamping motion can be achieved by controlling the input voltages at two units.

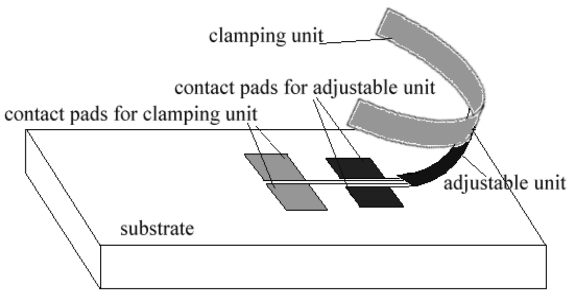

Figure1: Schematic view of the proposed micro-clamper movable in vertical position.

3.FABRICATION

The micro-clamper proposed here is batch-fabricated by surface micromachining. The four-mask fabrication process is outlined in Figure 2. First, the 1 μm Al sacrificial layer is deposited by vacuum evaporation. Then it is patterned to form the anchor (mask 1, Figure 2(a)). A 3 μm of polyimide with lower thermal expansion coefficient is spin coated and cured as the lower layer of the bimorph structure. Heater is constructed as a three-layer structure (Cr(40 Å)/Au(1000 Å)/Cr(40 Å)) by lift-off process(mask 2, Figure 2(b)) where the Cr layer is used to enhance the adhesion between the Au and polyimide. After that, a 1000 Å Ni is deposited and patterned (mask 3) to protect the heater of the adjusting unit (Figure 2(c)). On top of them, an 1.5 μm polyimide with higher thermal expansion coefficient is then spin coated and cured with patterned 1000 Å nickel as a mask layer (mask 4, Figure 2(d)). Finally, two polyimide layers are patterned by oxygen R.I.E..

The releasing process is performed by immersing the chip in Al etchant, then several minutes in DI water and 30 minutes in alcohol to reduce stiction effect, following is at least 10 minutes in an oven at 110℃.

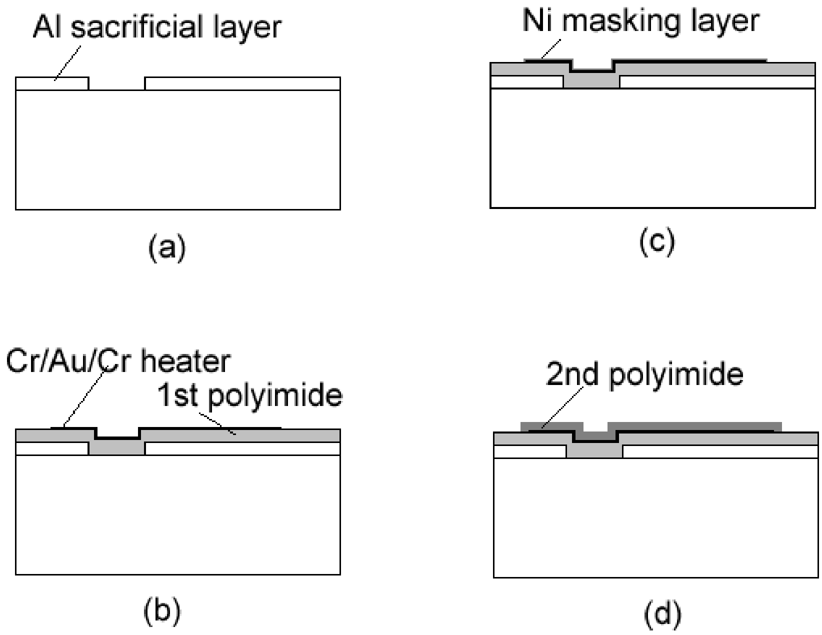

Figure2: Fabrication process.

4.RESULTS AND DISCUSSION

The top view of the fabricated result is shown in Figure 3. The SEM of the end side of this micro-clamper is shown in Figure 4. In testing, various dc voltages are applied to different contact pads to generate different motion modes. The downward displacements are determined by focus/defocus method under the optical microscope, which gives the measurement error about 1 μm.

In the initial state, it is observed that the end of the adjusting unit curls up about 8 μm from the substrate, 4.6 degrees in angular displacement, due to the residual stress in bimorph beams. Figure 5 plots the testing results of the adjusting unit under various input voltages. The downward displacement up to 8 μm can be achieved at input voltage above 2 V. Also, the testing results of the clamping unit is shown in Figure 6, where 18 μm downward displacement is achieved at 5 V before touching the substrate. These testing results demonstrate the clamping principle and the capability of providing vertical movement by the proposed micro-clamper.

5.CONCLUSIONS

Here an electro-thermally driven micro-clamper movable in vertical position is designed, fabricated and tested here. Some features of this micro-clamper are summarized below. (Ⅰ)Using the residual stress difference in two layers of bimorph beams to produce the first out-of-plane motion and clamping mechanism. It is undesired to have the residual stress in the IC fabrication. But we use this effect to have initial vertical displacement and curl up the clamping unit. (Ⅱ) The fabrication of this micro-clamper is compatible with IC processes. This makes the micro-clamper suitable to be integrated with other IC components on the same chip. (Ⅲ) The vertical position of this micro-clamper is shown to be adjustable, and this capability may provide larger operating range for the micro-clamper, or be used for more complex work in MEMS. (Ⅳ)This micro-clamper is self assembled and does not need any locking structures or external manipulation.

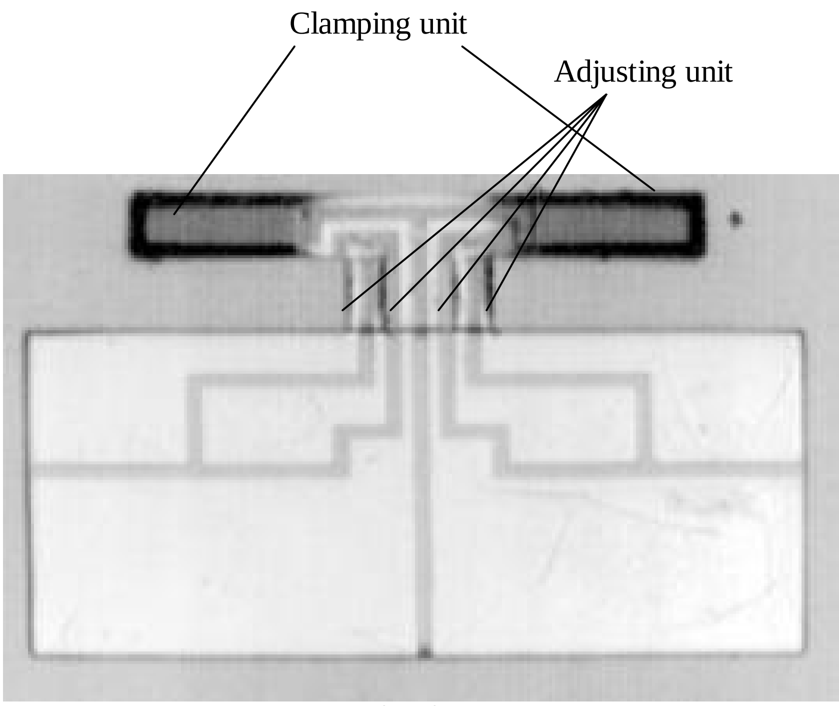

Figure3: The top view of the fabricated micro-clamper.

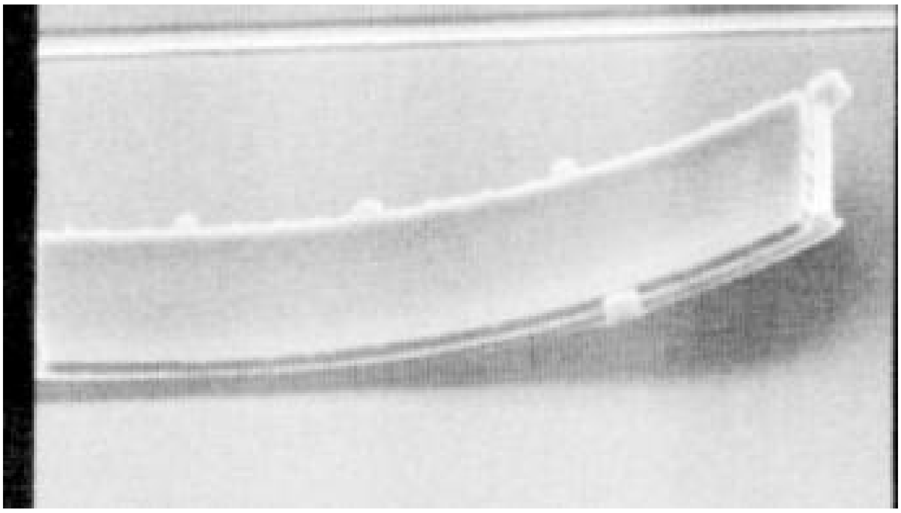
Figure4: The SEM at the one end of the clamping unit.

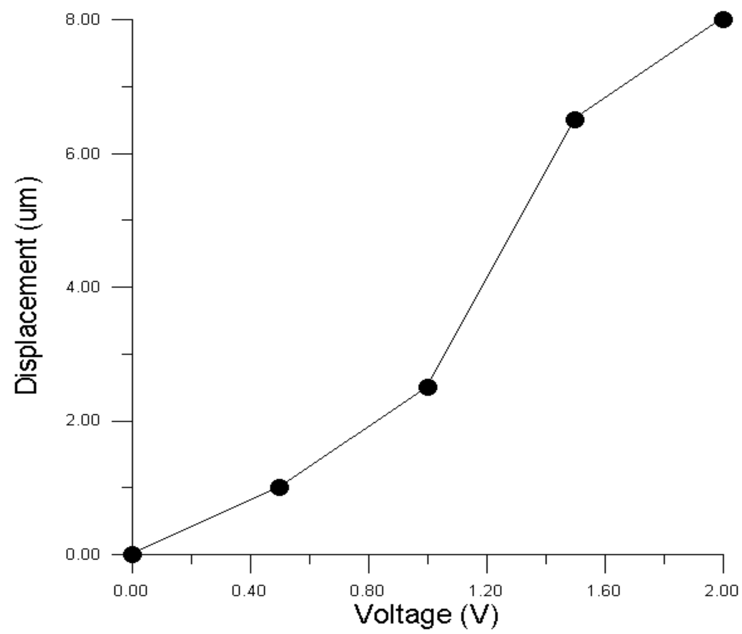

Figure5: The calibrated downward displacements of the adjusting unit under different input voltages.

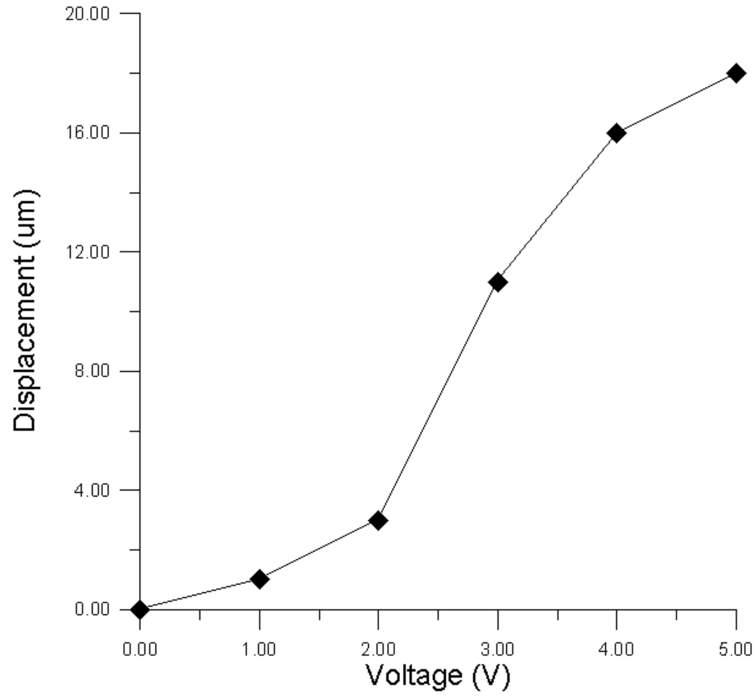

Figure6: The calibrated downward displacements at the end of the clamping unit under different input voltages.

6.ACKNOWLEDGEMENTS

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7.REFERENCES

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