研 究 速 報

Thin Film of Titanium/Nickel Shape Memory Alloy for Multi-Degree of Freedom Microactuators

Lionel BUCHAILLOT*, Yousuke NAKAMURA*, Shigeo NAKAMURA* and Hiroyuki FUJITA*

1. Introduction

The application of present microactuators is limited because they can only produce small force or displacement. As for a new active material, the Titanium/Nickel Shape Memory Alloy (SMA) provides very attractive characteristics for Micro Electro Mechanical System (MEMS) applications[1]. First of all is the Shape Memory Effect (SME) that can be observed in some bulk alloys as well as in thin film SMA. SME refers to the response of a material deformed at a lower temperature to return to its original shape upon simple heating. High power-weight ratio, large force-displacement product, large recovery stress, operation under low voltage, simple structural design, non-toxicity to human, and long lifetime can also be noticed among the advantages of the TiNi SMA. The lack of the fine patterning process of TiNi thin films has retarded their wide use for microactuators[2]. Therefore, we developed a lift-off and sacrificial etching process for surface micromachining of TiNi SMA films. Film thickness was ≈10μm with patterned widths of 10-30μm. This process was elaborated to obtain powerful microactuators for MEMS applications[3].

2. Fabrication and thermomechanical characterisation of SMA thin films

The process chart is given figure 1. A 150nm thick layer of chromium is evaporated on the silica substrate. Then, a 10μm thick polyimide layer is spin coated in three steps and post baked. The second 150nm thick chromium layer used as a mask during Reactive Ion Etching (RIE) is evaporated onto the polyimide. After classic photolithography and chromium wet etching, the polyimide is patterned. To prevent the sputtered TiNi layer from peeling, polyimide should be carefully removed. So, an additional RIE process may be necessary. Then, the TiNi is sputtered in the resulting polyimide mold layer. The deposition rate is 2.5μm /15 mn.As the desired thickness is 10μm, the sputtering time is set to one hour. We subsequently proceed to the lift off: the polyimide is removed using hot hydroxide potassium (KOH). The releasing is achieved through the side etching of the sacrificial chromium layer. Large areas such as pads used for the power supply remain attached to the substrate while the active part of the microactuators are released. Eventually, the TiNi layer is annealed to crystallize

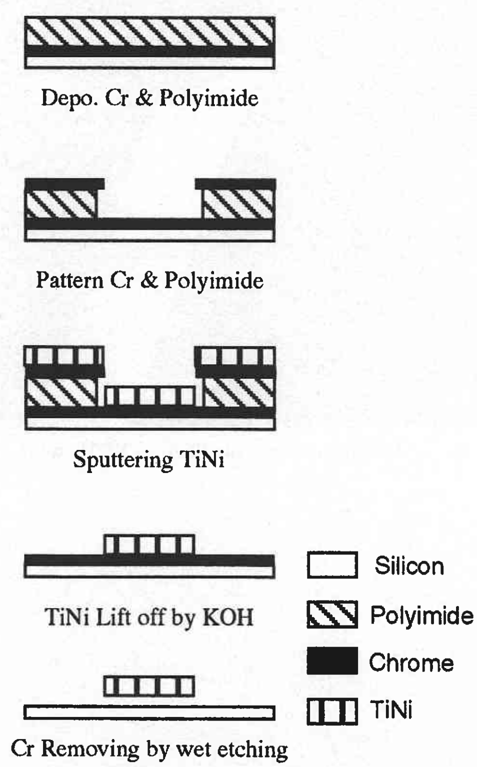

Fig.1 Process chart

*3 rd Department, Institute of Industrial Science, University of Tokyo

for 0.6ks at 1023K, and aged for 21.6ks at 773K. From Differential Scanning Calorimetry measurement, Ms is found to be 287K, and As is 313K (Fig.2). Therefore, the actuator is able to operate without any cooling device at the ambient.

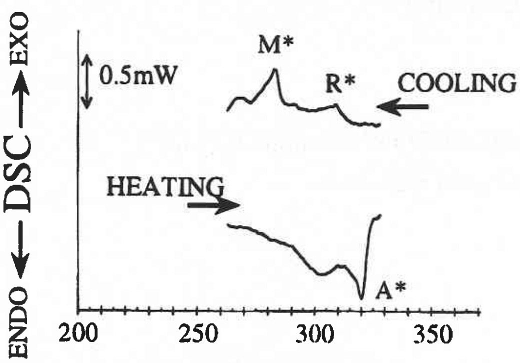

Fig.2　DCS measurement

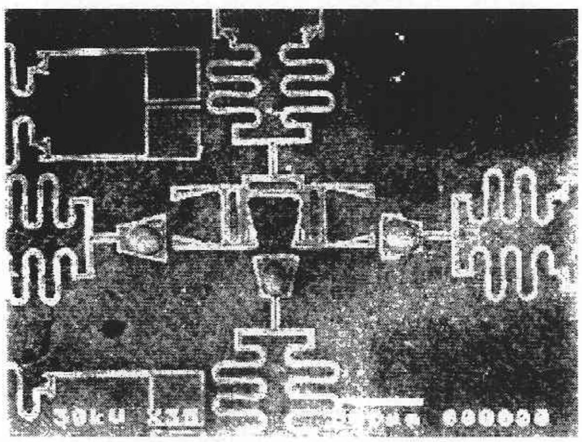

Fig.3　The XY stage

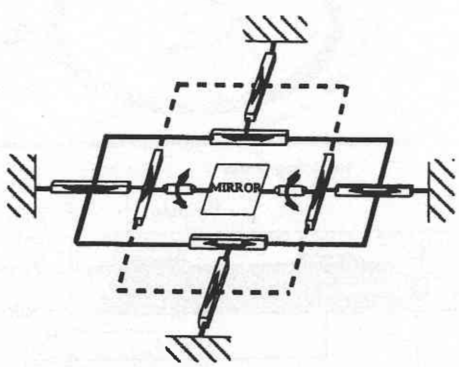

Fig.4　The XYθ stage

3. The XY stage

The XY stage using TiNi SMA thin film as an actuator is made of four actuators operating in the same plane as the substrate. Eaçh actuator is initially stretched to induce the phase transition through the mechanical stress. In the current version of the XY stage, it is linked to the directly opposite actuator as well as the two other right-angled located actuators (Fig. 3). The design was made to allow each actuator to operate separately from the others (distributed elasticity). The next step will be to add a mirror located at the center of the XY stage (Fig. 4). Thus, the XY stage acts as a mobile frame to which the hinges of the mirror are attached. The original aspect of this device lies in the use of torsion stress to induce the phase transition. The mirror and the supporting hinges should be made of another material that the TiNi SMA. Then, as the mirror itself is protected, the hinges are twisted and clamped in that position during the TiNi sputtering, crystallization and annealing. afterwards, the structure is released and the hinges act as torsion return spring to recover their original shape - in the plane of the substrate - inducing the phase transition of the TiNi SMA coated film from the parent phase to the martensite phase. Upon heating, the TiNi SMA phase transition occurs from the martensite phase, to the parent phase. This results in a macroscopic displacement. Since the mirror can rotate, a new degree of freedom (θ) is added to the XY stage.

4. Conclusion

The thermomechanical properties of the TiNi SMA that is used to actuate our microdevices have been significantly improved. It is now possible to operate our SMA microactuators at the room temperature. The SMA XY stage is characterized. Range of displacement as well as precision are to be determined.

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Reference

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3) Y. Nakamura, S. Nakamura, L. Buchaillot, H. Fujita Proc of MEMS 97, p262, 1997.