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Bender Typed Piezoelectric Multilayer Actuator

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ABSTRACT

A Bender typed Multilayer Actuator(BMA) for decreasing the depolarization effect was designed and fabricated. Unlike bimorph and multimorph actuators in which depolarization occurred, the BMA did not generate depolarization because the polarization and the electric field directions are the same. The simulated results indicate that higher displacement of the BMA can be achieved by increasing input voltage. Compared with the multimorph actuator, the proposed actuator is expected to extend a life time as well as acceptable voltage range.

Key words : Bender typed multilayer actuator, Bimorph, Multimorph, Depolarization

1. Introduction

An actuator is defined as the device of conversion of electric energy into mechanical energy. The piezoelectric actuators had several advantages such as simple structure, compact size, precise positioning, quick response, and large generative force so that it has been used widely in applications such as micropositioners, miniature ultrasonic motors, and adaptive mechanical dampers.[1] Especially, bender actuators were applied in fluid control device, tracking control system[2] and swing CCD mechanism.[3]

The bender actuators are classified into unimorph, bimorph, and multimorph[4] actuator according to the structure. The conventional bimorph actuator is operated by two poled piezoelectric elements stacked on top of each other. Driving each element to extend or contract causes the bimorph actuator to bend when the electric field applied.[5] In this case, depolarization occurs in one element driven by opposite electric field with polarization direction and it decreases the characteristics of piezoelectric element. And the driving method of multimorph actuator is the same as that of the bimorph actuator.

The purpose of this paper is to suggest a bender typed multilayer actuator for depolarization free.

2. Design and Simulation

The basic configuration of the multimorph actuator for upper bending is shown in Fig. 1. The multimorph actuator is composed of even numbers of piezoelectric elements. When the electric field is applied across the top and bottom part of the multimorph actuator, contraction and extension occur respectively. As stated above, however, the bottom part driven by electric field with reverse polarity direction can be depolarized if the electric field is close to E_C.

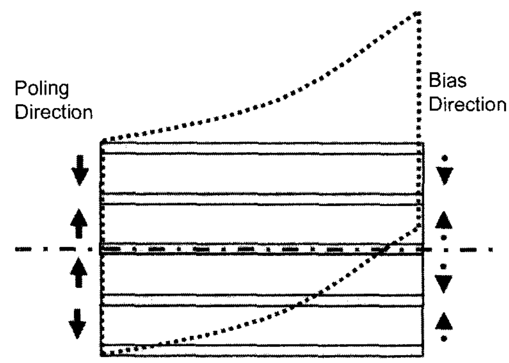

Fig. 1. Basic configuration of multimorph actuator.

In Fig. 2, the Bender typed Multilayer Actuator (BMA) consists of multiple elements and it can make a bi-directional bending by applying only electric field with the same polarity.

Shown in Fig. 2(a) is the upper bending of the BMA of which polarization directions are mutually alternative. When the voltage is applied in the only upper part with the same polarity, the BMA is bent up. And when it is applied in the only bottom part, the BMA is bent down.

To make continuously the bi-directional bending, first, let the upper bending occur and then apply higher voltage to the lower part of the BMA than that to the upper part. As

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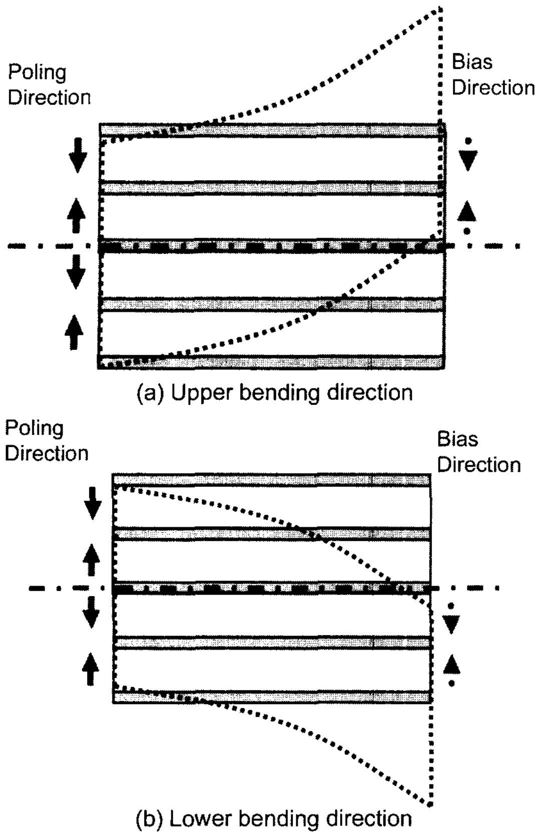

Fig. 2. Bending configuration of BMA.

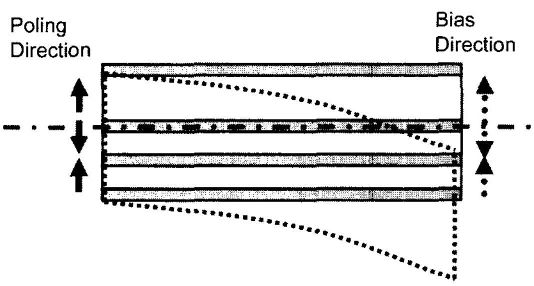

Fig. 3. Bending configuration of advanced BMA for the lower direction.

shown in Fig. 2(b), it leads to the movement of the BMA from up to down. In this case, two voltage sources with different amplitude are necessary to drive the BMA. If it can be driven by two voltage sources with same amplitude, a driving circuit will be small and simple.

In Fig. 3, an advanced BMA consists of multiple elements with two kinds of thickness. Its moving principle is the same as the BMA. The element thickness of the upper part is twice that of the bottom part. When the constant voltage is applied in both parts with the same polarity, the advanced BMA is bent down because the electric field of the bottom part is twice that of the upper part.

Figs. 4 and 5 show the simulation results of the BMA and the advanced BMA. The dimensions of the BMA and the advanced BMA are 40 mm(W) × 10 mm(L). And its thicknesses are 100/100 and 100/(50+50) μm respectively. These are fixed at left side, and the amplitude of displacement is detected at the other.

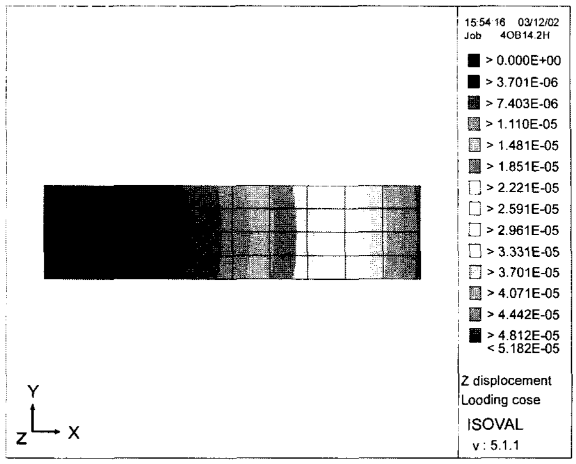

Fig. 4. Displacement distribution in the length direction of BMA.

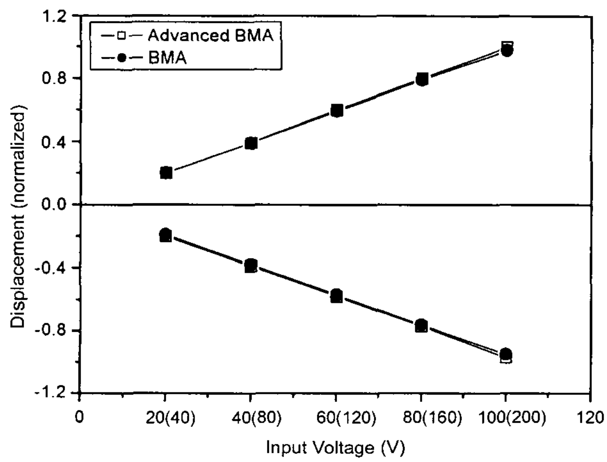

Fig. 5. Simulated results of BMA and advanced BMA.

Shown in Fig. 4 is the displacement distribution in the length direction. The displacement distributions of the BMA and the advanced BMA were showed the highest at the opposite of the fixed side.

In Fig. 5, the normalized results indicate that the amplitude of bi-directional bending is symmetric and the displacement of the BMA and the advanced BMA are almost same.

3. Fabrication and Results

The fabrication process of the advanced BMA is shown Fig. 6. The advanced BMA with different multilayer structure was made of PZT powder (KyungWon Co. KPZ12-TR4030, $d_{31} = -105 \times 10^{-12}$ C/N). The ratio of solid content and mixed solvent (Ferro, B73210) was 63 : 37 wt% which ensures the high green density of the sheet. Tape casting

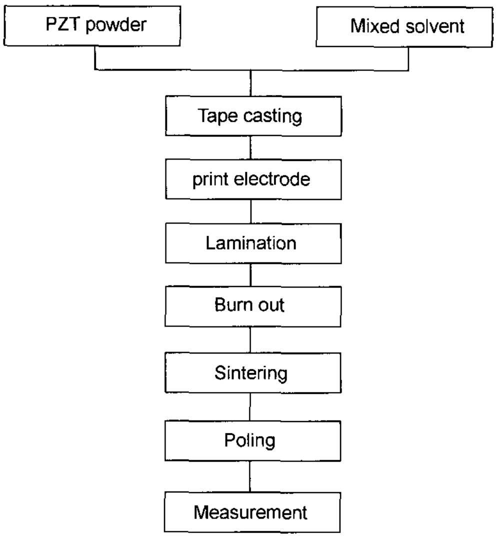

Fig. 6. Fabrication process of BMA.

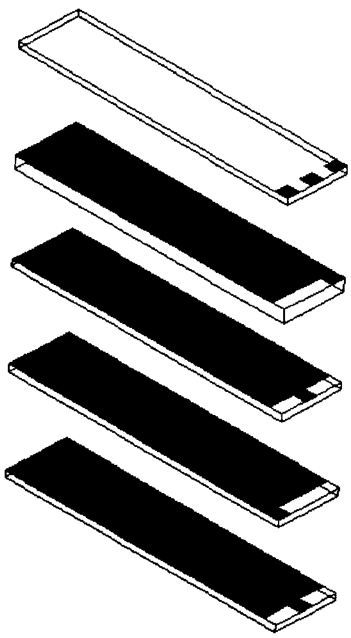

Fig. 7. Basic structure and electrode patterns.

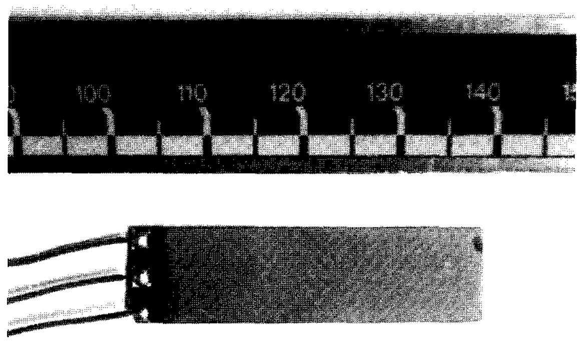

Fig. 8. Photograph of advanced BMA.

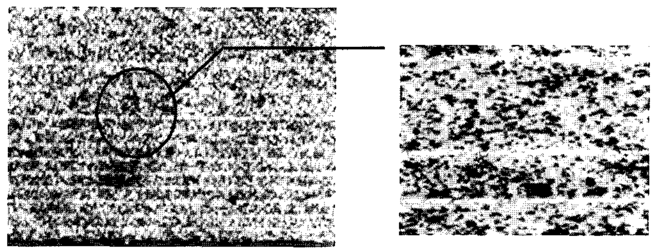

Fig. 9. Cross section of advanced BMA.

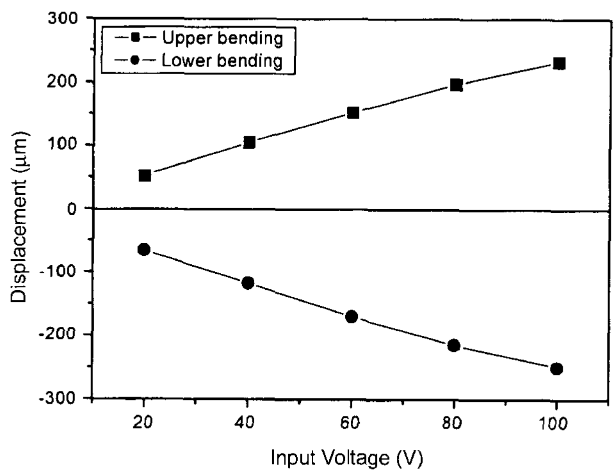

Fig. 10. Measured results of advanced BMA.

was carried out in the system with a doctor blade. The blade speed was 1 cm/s. Square layers of 100 × 115 mm were cut from sheet and electroded by screen printing with Ag/Pd paste (70/30, DaeJoo Co.) as shown in Fig. 7. The advanced BMA was composed of 14 layers. The thickness of 8 layers stacked on bottom part were 50 μm and that of 4 layers stacked on upper part were 100 μm. Two layers with thickness of 50 μm were added to both ends for insulation.

The stacks were laminated at 45°C with a pressure of 140 kgf/cm^2 and then were cut by 48 × 12 mm. The laminated samples were burned out at 600°C for 3 h and sintered at 1100°C for 15 min. The sintered samples were alternatively poled in the direction of thickness under 3.5 kV/mm at 120°C. The dimension of the fabricated actuators are 40 × 10 × 0.73 mm^3 (Fig. 8), but the free length is 35 mm because of fixing. The displacement of the advanced BMA was measured using MTI 2000 Fotonic Sensor (MTI Instruments).

Fig. 9 shows the cross section of the advanced BMA. The thicknesses of ceramic layers are uniform and their thicknesses are 40 and 80 μm respectively.

The displacement of bi-directional bending was measured in Fig. 10 with 20-100V under no load. The amplitude of bi-directional bending was nearly symmetric and its measured values are about ±240 μm at 100 V.

4. Conclusions

We have proposed the advanced bender typed multilayer actuator. This actuator did not depolarize because a bi-directional bending is occurred by applying only electric field with the same polarity. For that reason, the advanced BMA is able to extend a life time as well as acceptable voltage range. And the driving circuit of the advanced BMA is smaller and simpler than that of the BMA because it is driven by two voltage sources with same amplitude.

Acknowledgement

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