

Study on fabrication of polymer electrostatic comb-drive actuator by X-ray lithography

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Micro electrostatic comb-drive actuators are important components in micro electromechanical systems (MEMS) [1]. Especially, polymer materials like PMMA have been of great interest in the research and development of integrated circuits (IC) and MEMS recently due to their relatively low cost and easy process [2]. In this research, we are trying to fabricate a PMMA-based electrostatic comb-drive actuator by X-ray lithography, which serves for a Micro Conveyor System.

An interdigitated comb-drive actuator is designed in this experiment. Figure 1 illustrates the frame of the comb-drive actuator. As is shown in table 1, the key size of the structure, the finger width is $4\mu\text{m}$ and the gap is $2\mu\text{m}$, with the thickness of $200\mu\text{m}$, which makes an aspect ratio 50:1. For simulation, a three-dimensional model in ANSYS is used. The medium surrounding the fingers is meshed as air with the relative permittivity of 1. This realizes a displacement of $3.6\mu\text{m}$ at a bias voltage of 100V in the simulated result.

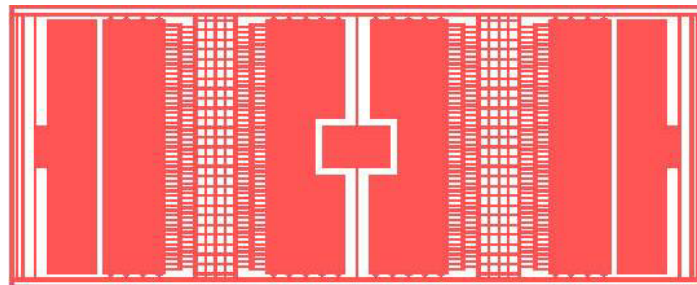


Fig 1. Design of the comb-drive actuator

For fabrication, there are four main steps. First, we designed and fabricated a PMMA holder substrate by Excimer Laser. This part can support the anchors of the actuator and thus make the suspension of the moving fingers available. Then, this substrate was bonded to a $200\mu\text{m}$

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PMMA sheet by spin-coating of the adhesive. After that, we aligned the sheet to the X-ray mask by digital microscope, got X-ray exposure and developed in GG solution. At last, the metallization was implemented by sputtering Au.

Gap	Overlap	Finger width	Finger length	Comb number
2 μm	10 μm	4 μm	30 μm	100

Table 1. Feature size of the comb-drive

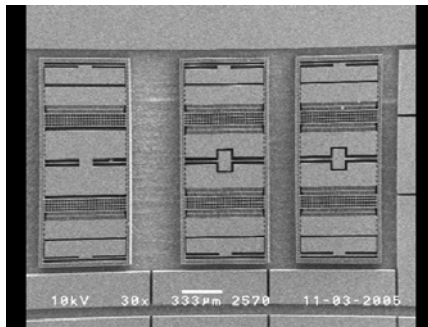


Fig 2. The fabricated structures

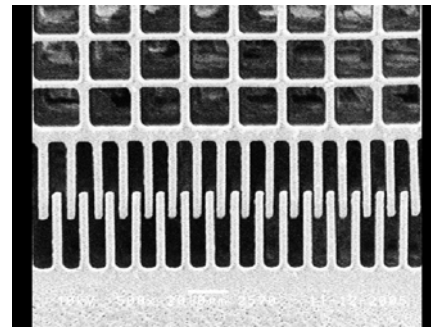


Fig 3. The comb fingers

Figure 2 and figure 3 show the structures and the comb fingers which were fabricated successfully in the experiment. However, because PMMA is much softer than Si (with the Young's modulus of 3GPa, compared to Si with Young's modulus of 190GPa) and the aspect ratio is comparatively high (50:1), the deformation can happen easily. Additionally, when applying voltage, the fingers will be deflected significantly due to the gap-closing driving force between the two fingers. Any perturbation of the central fingers will cause an offset of the force and pull the fingers to one side or the other. In an extreme case, the fingers will be clamped together, resulting in a circuit short and breakdown.

A new approach to fabricate polymer electrostatic comb-drive actuator by X-ray lithography was designed and studied. Most of the fabrication processes have been worked out. Because this work is at an early stage, there is still much room to improve.

References

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