# The design, fabrication and test of linkage mechanism of Microelectromechanical Systems process


## Abstract

In this paper, two types of Microelectromechanical Systems (MEMs) process technologies and linkage mechanisms are proposed. The first type of process is a process that integrates reluctance motor rotor and mechanism. In this process, sputtering and electroformed metallic copper were adopted as the structural upper and lower layer gap, meanwhile, CK6020 was used as anti-reflection layer to protect photo resist to be free from the illumination of glow during the sputtering process. In the second type of process, attached metallic aluminum foil was used to replace sputtering metallic copper as the upper and lower layer gap, meanwhile, it can also be used as mask during the exposure. This technology greatly reduces the process step and mask needed.

In the second type of process, attached metallic aluminum foil was adopted to replace sputtering, electroforming and anti-reflection layer. Metallic aluminum foil can provide a gap for the motion of the upper and lower layer structures and a mask for masking the lower layer structure, meanwhile, this technology can greatly reduce process step and time. Finally, the technology was used to prepare a five linkage mechanism, and this mechanism, through two sets of input sources and under different rotational speeds, can generate any path under certain range, meanwhile, when the rotational speed is two times, it can drive five linkage mechanism to generate flapping motion.


## Ⅰ. Introduction

The process of MEMs system, along with the progress in the semiconductor industry, makes such product be able to achieve the characteristics such as miniaturization, compact size, systemization, all-in-one and mass production. Therefore, MEMs system has created a great impact to the traditional machinery industry. The linkage mechanism proposed in this paper has integrated micro reluctance motor, therefore, it should have relatively great potential in the precision machinery field.

In this study, the first type of MEMs thick film photo resist process technology was proposed to prepare micro four linkage double rocking mechanism, in this mechanism, SU-8 100 photo resist was used as the material, after multiple spin coatings and exposure, SU-8 100 photo resist defines the linkage structure, meanwhile, sputtering and electroformed metallic copper was adopted as the sacrificial layer of the moving gap for the upper and lower structure, in the meantime, anti-reflection layer CK6020 was adopted as mask to protect the lower layer structure. Bogdanov et al. [1] have adopted photo-lithography technology using epoxy resin SU-8 negative photo resist as material and investigated the method to control the photo resist thickness, and it was found that under certain after-exposure baking temperature condition, the maximal sensitivity of the photo resist can be obtained, and it was also

proved that the structural aspect ratio of photo resist can be as high as 100: 1 (height: width). Long-Sheng Fan et al. [2] have used two layers of polycrystalline silicon process accompanied with Phosphosilicate Glass (PSG) as sacrificial layer, then they have used HF to etch PSG to prepare micro contact. Fariborz Behi et al. [3] have used LPCVD accompanied with isotropic etching, then they used HF to remove oxide layer (sacrificial layer) to prepare polycrystalline silicon linkage mechanism. Pister[4] has used two structural layers and two sacrificial layers to prepare a micro hinge. In this micro hinge, polyimide or other polymer material was used to prepare the flexible contact so that the micro structure can rotate its planar structure into 3D structure, therefore, the wearing problem caused by the frictional force on the micro structure can be solved when the structure is making dynamic motion. Eiji Iwase et al. [5] have proposed the use of SiO2 deposition with subsequent sputtering of Cr and Ni, next, in the hinging part, they have used micro-lithography process to spin-coat photo resist, meanwhile, in part not covered with photo resist, it was electroformed with permalloy, finally, the bottom silicon structure is partially etched and removed, and photo resist is developed to form micro hinge contact and cantilever structure, then it can be used to lift up plate structure. Tsung-Sheng Chen [6] has proposed an innovative thick film photo resist process to use photo resist as a structure and to apply metallic mask, anti-reflection layer and sacrificial layer technology to prepare successfully micro four linkage double rocking mechanism, which does not need any re-assembly.

Further in this study, a new process was proposed to prepare reluctance motor rotor into micro four linkage crank rocking mechanism to achieve the goal of one-piece forming. In this process, the silicon wafer is drilled and processed first, meanwhile, anti-corrosion tape was pasted on the backside, then after several times of spin-coating and exposure of SU-8 100 photo resists, the linkage structure was defined, then sputtering and electroforming of metallic copper was used as the sacrificial layer of the motion gap between the upper layer and lower layer structure, finally, SU-8 100 is developed, then the sacrificial layer is etched to obtain micro four linkage crank rocking mechanism containing reluctance motor rotor.

Sheng-Lin Yang [7] has proposed the association of reluctance motor rotor and planar four linkage crank rocking mechanism process, in this process, reluctance motor rotor is made into four linkage mechanism crank rocking mechanism to achieve the purpose without the need of extra assembly of the input source.

In this study, second type of MEMs thick film photo resist process technology was proposed to prepare micro four linkage crank rocking mechanism, however, since the size design of this mechanism is shrunk in equal proportion by 55% as compared to that of the previous type, therefore, after preparation, development and etching, it was found that the mechanism cannot move due to the remaining of anti-reflection

residue layer of CK6020 in the gap between the rotational axes, therefore, it was proposed to use the attachment of metallic aluminum foil to replace electroplating and electroforming metallic copper and anti-reflection layer CK6020. In the rotational axis technology of this mechanism, AZ4620 was used to define the connection area of the rotational axis, after the development of AZ4620, $FeCl_3$ solution was used to etch the metallic aluminum foil, meanwhile, SU-8 100 was used to define the structure of the rotational axis, meanwhile, during the process of defining each linkage, it is needed to consider the mutual interference caused between linkages due to the rotational action, therefore, one circular ring structure is proposed to define the linkage to upper layer.

Yi-Ta Tu [8] has used the method of attachment of metallic aluminum foil as sacrificial layer and metallic mask, and this technology has greatly reduced process step and the photo mask needed.

In the last part of this paper, micro five linkage mechanism was proposed to be integrated with micro reluctance motor to become double input sources micro drive system. Through the setup of different rotational ratio between two input sources, any path can be generated within certain range, meanwhile, when the ratio between two input sources is two, flapping motion can be generated, in the future, it should be able to be applied in micro bionic flying device.

Wei-Ting Li [9] has used genetic algorithm (GA), particle swarm optimization (PSO), hybrid particle swarm optimization (HPSO) and differential evolution (DE) to synthesize gear five linkage mechanism dimension scale and hybrid five linkage mechanism dimension scale with path of “8” shape, arc shape and straight line closed loop trace path. T.Nick Pornsin-sirirak et al. [10] have used MEMs process to prepare micro flapping wing mechanism. The flapping wing mechanism is made up of Ti alloy, then under the Ti alloy substrate, HF and HNO3 is used to perform the etching, then it is coated with photo resist, and through exposure, the wing film structure is defined. Ying-Cheng Chen [11] has proposed the integration of micro reluctance motor and micro five linkage mechanism to form double input source micro drive system, then through different rotational ratio between two input sources, motion of any path can be generated within certain range, when two input sources are of rotational ratio of two, it can drive micro five linkage mechanism to generate flapping motion.