EVALUATION OF A LINEAR HYBRID MICRO STEP MOTOR

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Introduction

Today's challenge in designing a linear micro step motor is to minimize its dimensions and to optimize the driving force. Different concepts of micro step motors are known. First a variable reluctance (VR) step motor was fabricated [1]. To improve the driving force, a hybrid micro step motor was developed [2]. In comparison to a VR micro step motor, which only uses soft magnetic materials, a hybrid motor consists of permanent magnets, which increase its driving force [3].

Design

Figure 1 depicts a schematic representation of the linear hybrid micro actuator. The actuator consists of two parts, the stator and the traveler. The layer at the bottom of the stator represents the flux guide. The constitutive layer contains the poles as well as the dual layer spiral coil system. The finishing layer of the stator consists of the pole arms including teeth. Depending on the direction of the current, the magnetization of the teeth on a pole arm can be changed.

The traveler is divided into three adjoining basic elements. Each element consists of two rows of flux guides with teeth. These teeth of a single row are displaced by half of the tooth pitch to teeth of the other. A permanent magnet is located between the flux guides, resulting in magnetic north poles at the one row and south poles at the other row of teeth.

Stator and traveler of the motor were fabricated separately in thin film technology. The final motor assembly consists of a stator, a traveler, and a guide using micro balls.

Fabrication

The fabrication of the stator starts with electroplating of the flux guide (NiFe 81/19). To achieve a smooth surface for the insulation layer, the flux guide was planarized by CMP. After this step an insulating layer (photoresist SU8) was created. The insulation has openings for the poles, which are deposited by electroplating (NiFe 81/19) as well.

The next step was the fabrication of the dual layer excitation coil. The first layer of the coil is deposited by using copper electroplating. A layer of SU8 was utilized to insulate the bottom and the top layer of the excitation coil. This layer contains openings for the contact pads, poles, and for the vias, which connect the two layers of the coil. The vias were filled by electroplating with copper and the openings with NiFe. Next, the top layer of the coil was deposited applying the same technology as for the bottom layer. The top layer of the excitation coil is also insulated by SU8. The layer also contains openings for the poles, which are filled up by electroplating of NiFe. The pole arm structures were deposited through NiFe electroplating. To achieve a smooth surface, the pole arms have to be planarized by a CMP process. The final stator fabrication step was the manufacturing of the teeth by electroplating of NiFe in a permanent SU8 micro mold.

Producing the traveler, hart magnetic material was deposited. This is done by magnetron sputtering of SmCo. An additional layer of Cr was sputtered and patterned by photolithography. This structured layer served as a mask in the following wet chemical etching of the SmCo layer. After being covered by a protective layer of Cr, the structured SmCo was annealed for improving the magnetic properties. The final steps were the fabrication of the flux guides and the teeth by electroplating of NiFe. Both electroplating processes are followed by a CMP planarization process. Subsequent to the wafer dicing, the separated travelers were magnetized.

Experimental Test Results

A measurement of the driving force was carried out using a force measurement system, which is based on the deflection of a cantilever and strain gauges. For the test, the stator was mounted on a plate and the cantilever was brought in contact with the traveler. Energizing one motor phase resulted in a deflection of the cantilever. The forces measured were between 50 µN and 100 µN. It fell substantially short of the driving force predicted by the simulation, which is 1 mN. Friction in the micro guide is the most likely reason for the discrepancy.

Conclusion

The assembly of a linear step motor was accomplished successfully. Beside the fabrication in thin film technology the composition of a hybrid motor was carried out.

Two key challenges in fabricating a hybrid linear micro step motor are to create thick magnetic films with appropriate magnetic properties for the use in soft magnetic flux guides as well as the integration of hard magnetic material in the traveler to maximize the driving force.

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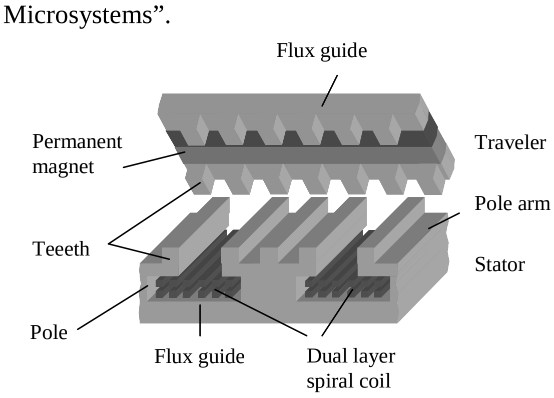

Fig 1: Schematic representation of a micro linear hybrid actuator

References

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