Electrostatic Rotary Stepper Micromotor
for Skew Angle Compensation in Hard Disk Drives

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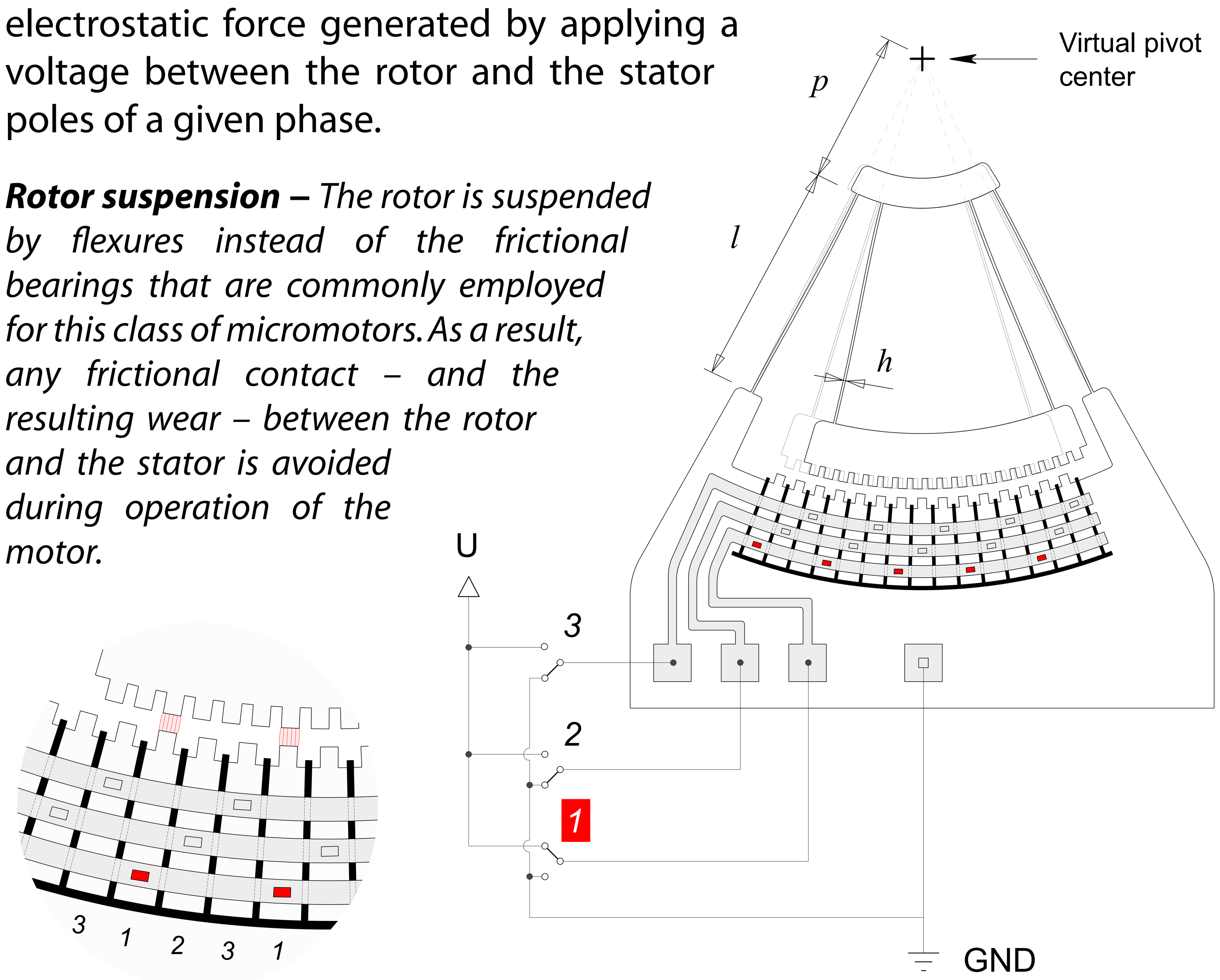
Vertical trench isolation technology was advantageously used to create a monolithic electrostatic rotary stepper micromotor. The motor uses flexure pivots to avoid any frictional contact of the rotor, providing precise, repeatable and reliable bidirectional stepping motion without feedback control.

Working principle

The motor consists of a **rotor with grounded poles** and a **stator with active poles** that are controlled with integrated 3-phase electrical connections. The actuation relies on the electrostatic force generated by applying a voltage between the rotor and the stator poles of a given phase.

Rotor suspension – *The rotor is suspended by flexures instead of the frictional bearings that are commonly employed for this class of micromotors. As a result, any frictional contact – and the resulting wear – between the rotor and the stator is avoided during operation of the motor.*



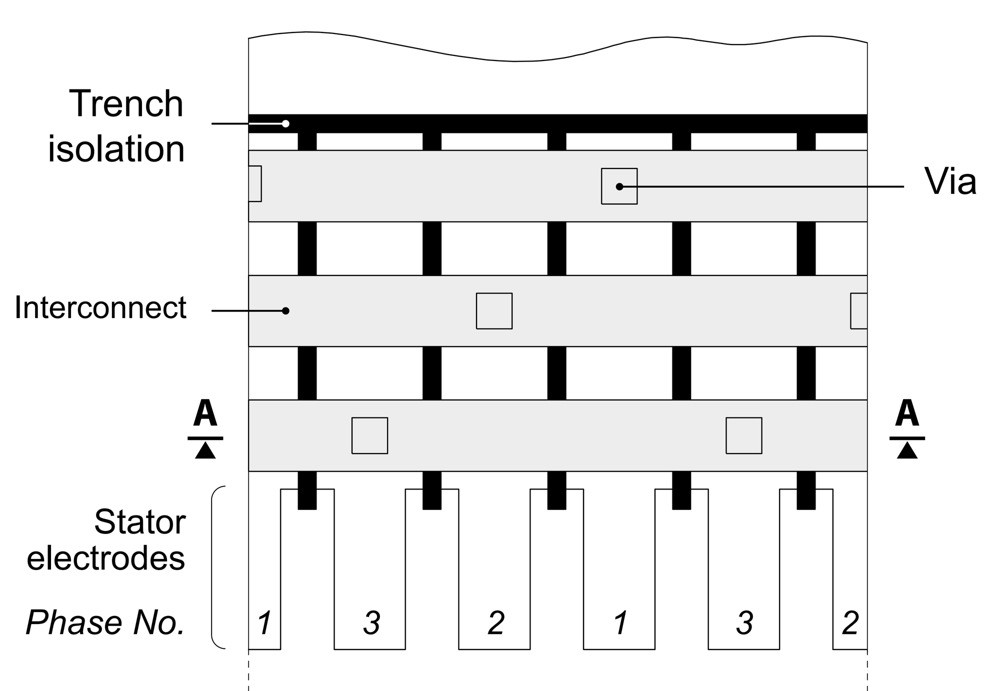
Microfabrication method

The five masks fabrication process is based on vertical trench isolation and polysilicon interconnects.

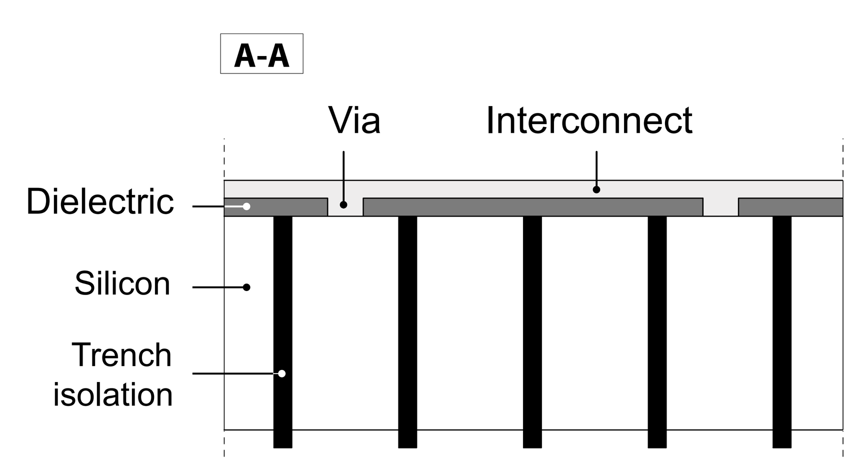
We started from a standard 3" monocrystalline silicon wafer (highly doped) having a thickness of 200 μm.

The insulating trenches (2 μm wide and 40 μm deep) were refilled using a combination of thermally grown silicon oxide and undoped polysilicon.

A 300 nm thick silicon oxide was used as an insulating layer between the phosphorus doped polysilicon interconnects (1 μm thick) and the highly doped silicon substrate.



(a) Top view

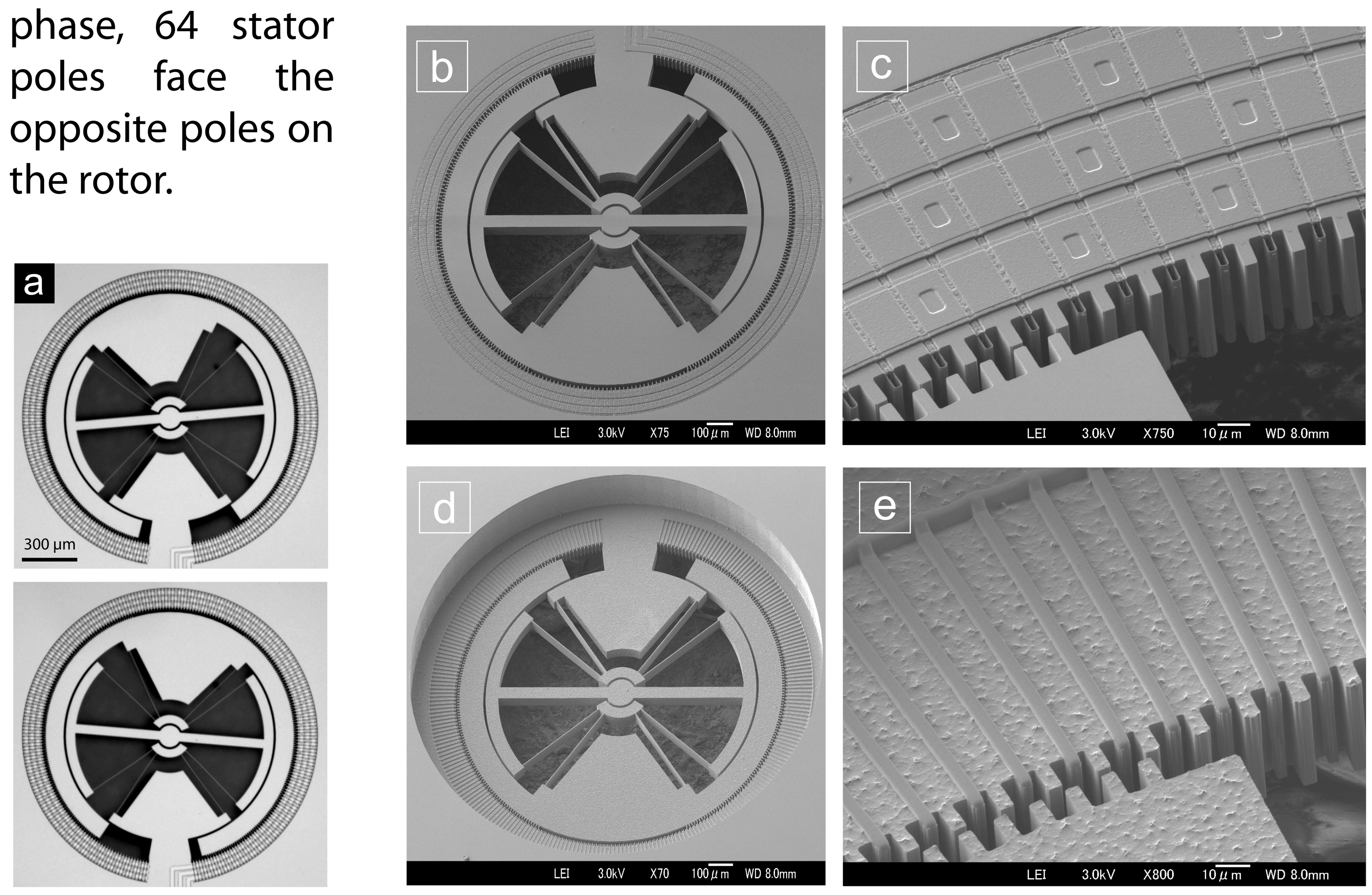


(b) Cross-section view

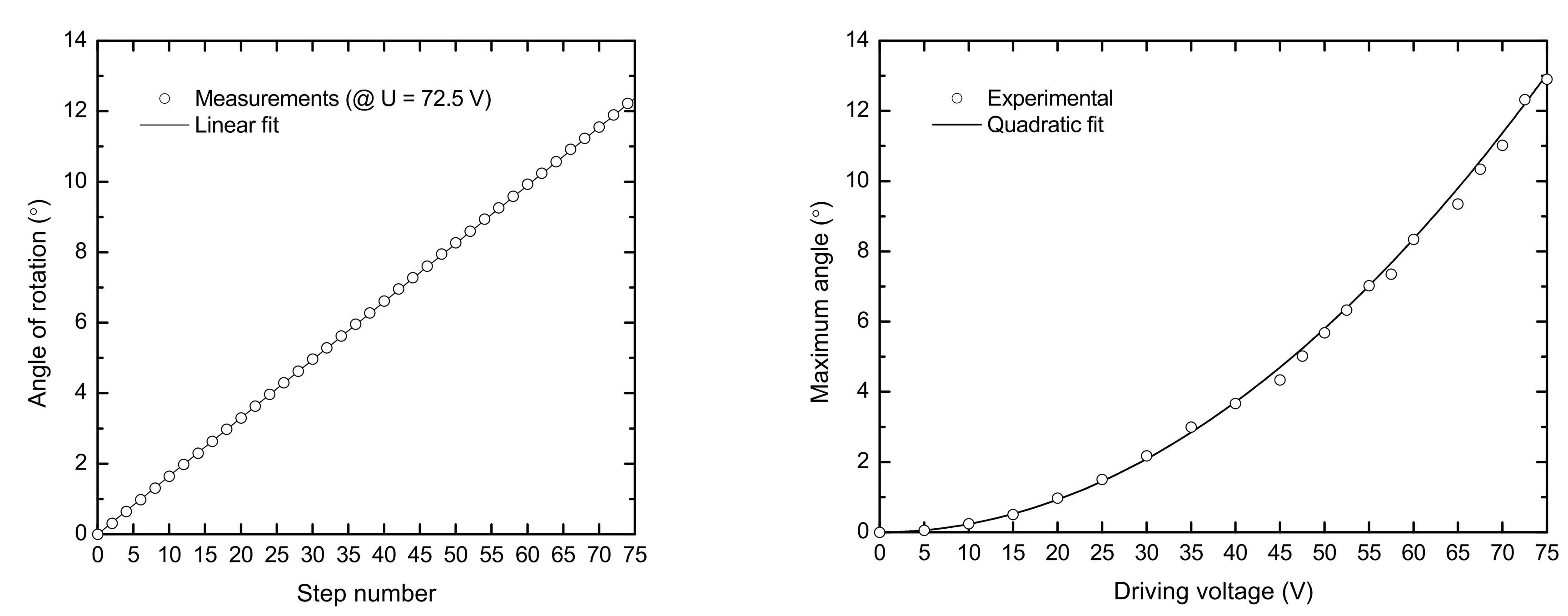
Experimental results

The motor is suspended with a 'butterfly' flexure pivot which consists of 8 flexure beams that are 400 μm long, 3 μm wide and 37 μm high.

Poles on the stator and rotor are 10 μm long, 4 μm wide and are separated by a gap of 1.25 μm. The pitch of the poles is 1° on the rotor and 4/3° on the stator. In each phase, 64 stator poles face the opposite poles on the rotor.



▲ ***(a)*** *Operation of the 3-phase rotary stepper motor: counter-clockwise and clockwise rotation.* ***(b-e)*** *SEM micrographs of the motor* ***(b,c)*** *from the front and* ***(d,e)*** *from the backside.*



▲ ***(left)*** *Rotational motion of the 3-phase rotary stepper motor as a function of the number of steps. The measurements were performed with square voltages of 72.5 V using a half stepping sequence;* ***(right)*** *Maximum angular displacement of the stepper motor as a function of the driving voltage.*

These measurements are for one direction only (the angular range is double).

CONCLUSION & OUTLOOK

We have devised, fabricated and experimentally tested a monolithic silicon rotary stepper micromotor aimed at skew angle compensation in Hard Disk Drives. Our prototype showed a rotational range of 26° (+/– 13°) at 75 V, a resolution of 1/6° in a coarse stepping mode and a maximum speed of 1.67°/ms.

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