Electrostatic 3-Phase Linear Stepper Motor
Fabricated by Vertical Trench Isolation Technology

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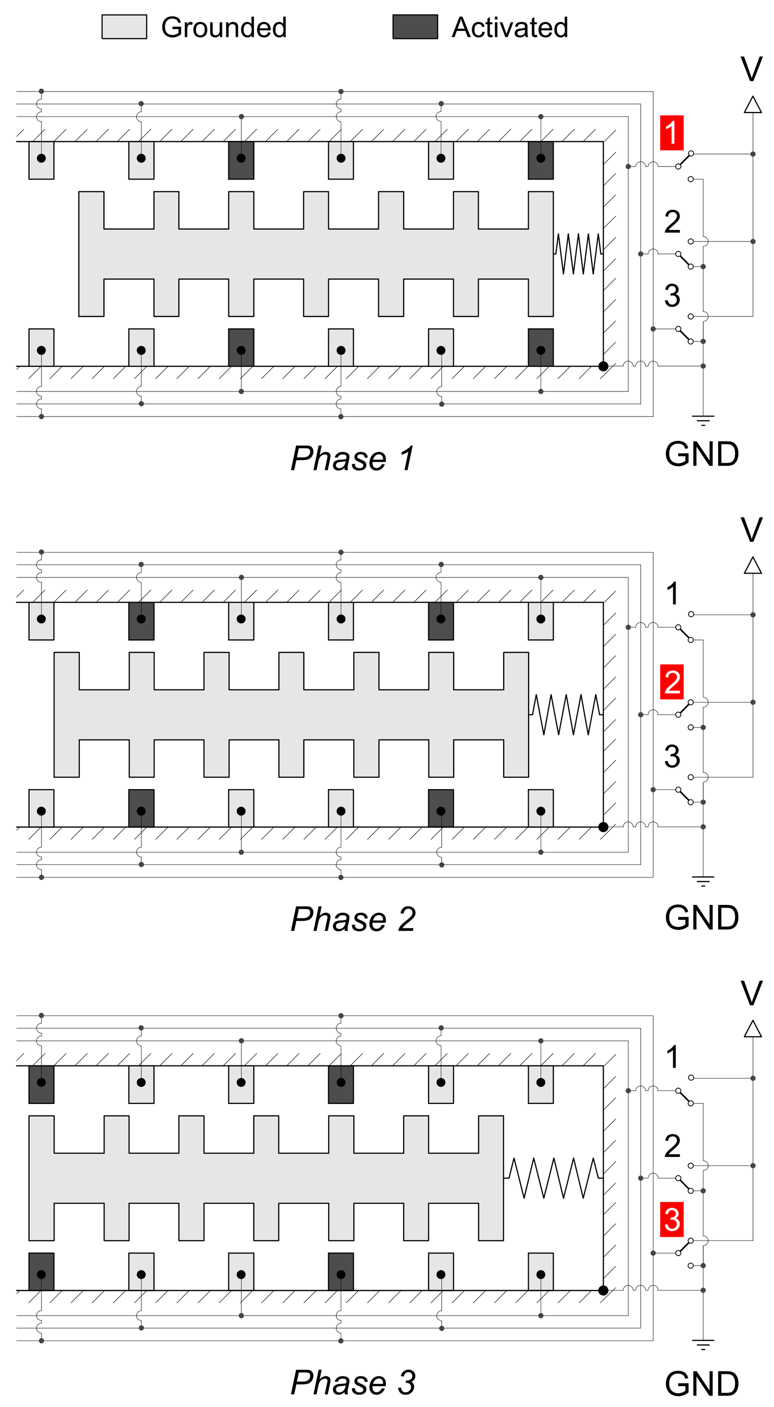
Vertical trench isolation technology was advantageously used to create a monolithic stepper motor with high aspect ratio poles and an integrated 3-phase electrical network in the bulk of a standard silicon wafer.

Working principle

The 3-phase electrostatic linear stepper motor consists of two elements:
(i) a grounded shuttle connected to the chassis by a flexure mechanism;
(ii) a stator with integrated 3-phase electrical connections.

The actuation relies on tangential electrostatic forces that generate a global force realigning the grounded poles with the active stator poles.

In the initial position, the stator poles connected with the first phase are perfectly aligned with the opposite poles on the shuttle, while the stator poles connected with other phases have a certain misalignment.
When a voltage is applied between the misaligned poles on the shuttle and the stator, an electrostatic force is developed.



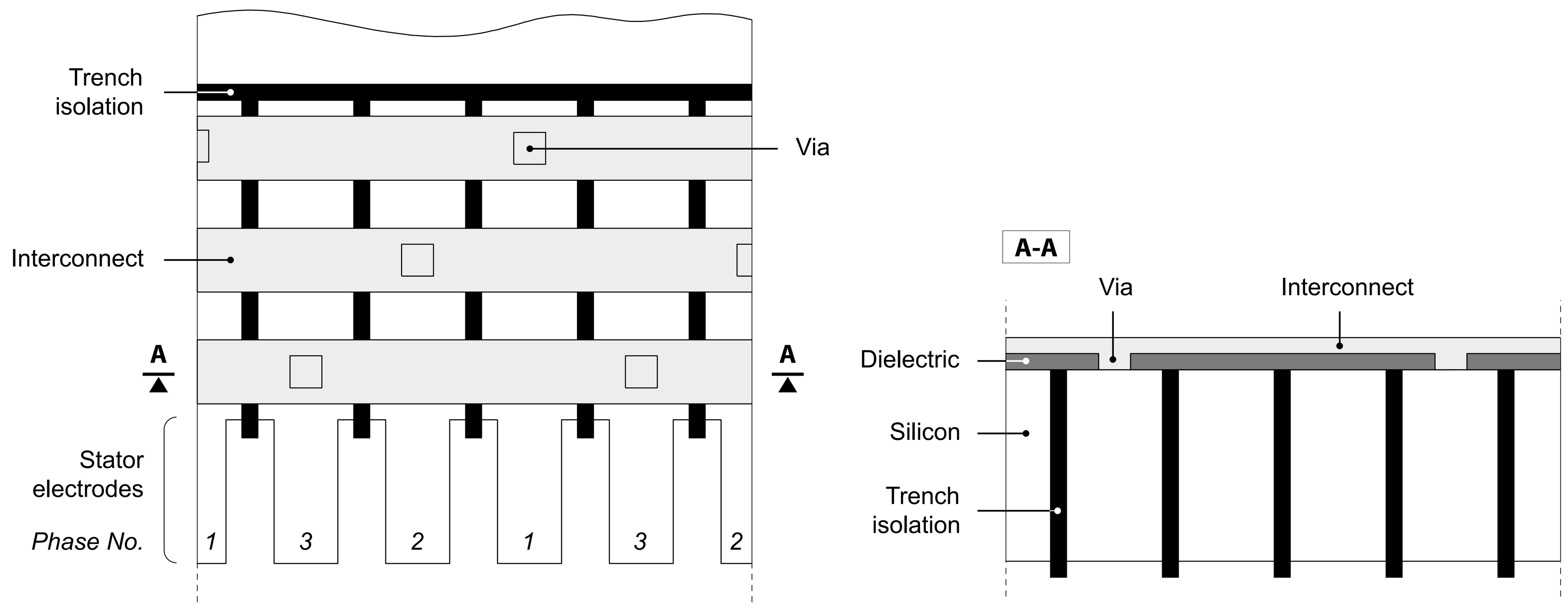
Microfabrication method

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) 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.



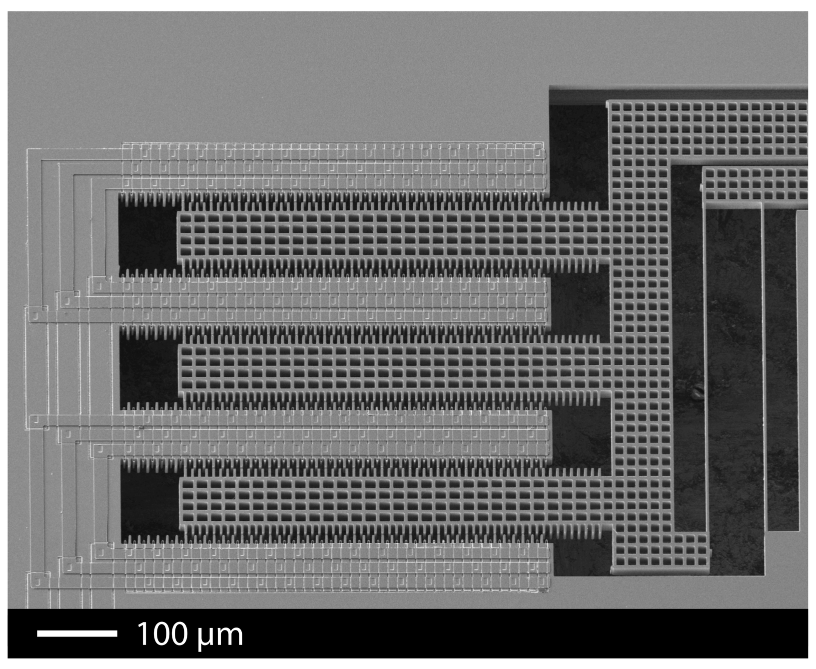
(a) Top view (b) Cross-section view

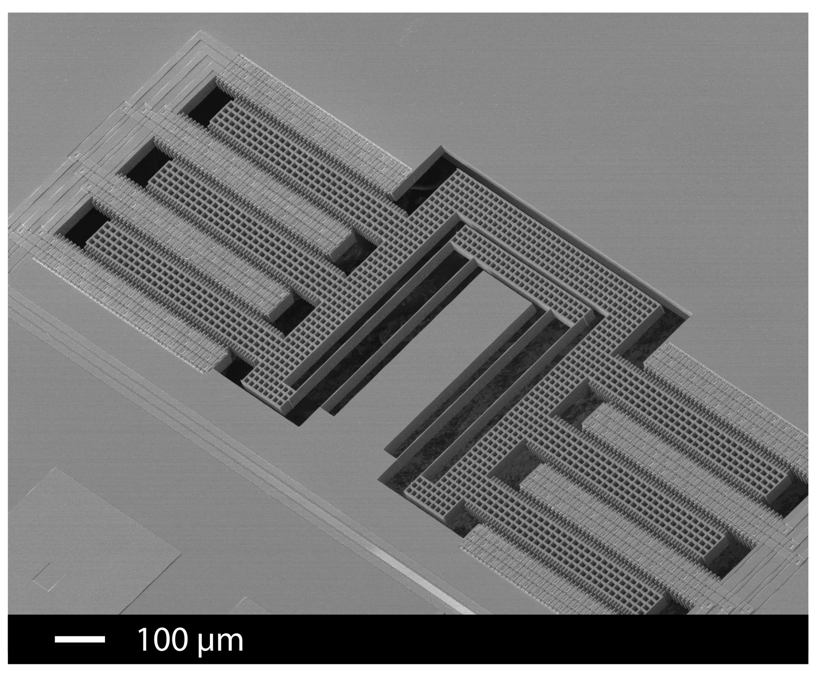
Experimental results

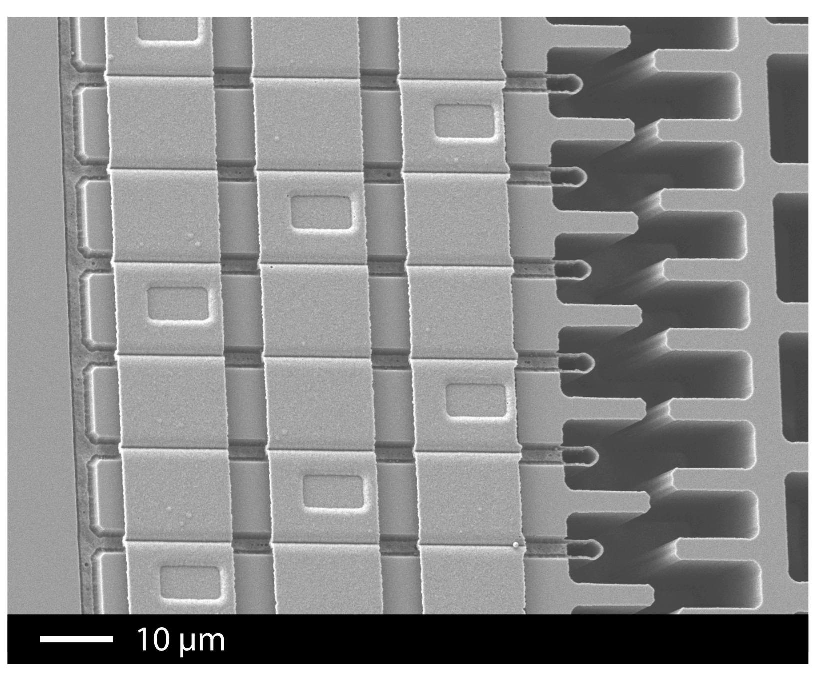
The entire motor fits in an area of 1.9 mm × 700 μm.

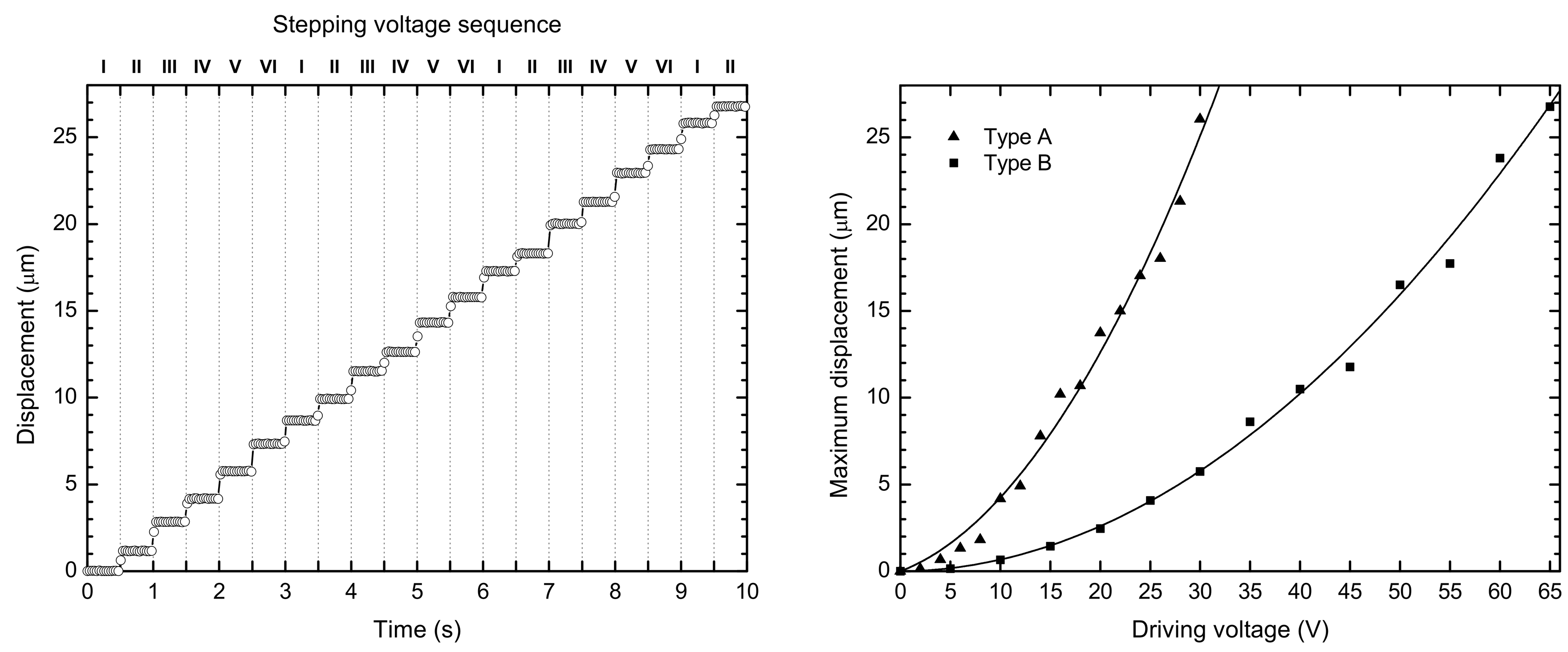
The shuttle is suspended by a double parallelogram flexure guiding. The flexure beams are 445 μm long and 30 μm high. Their width is 2 μm for 'Type A' and 3 μm for 'Type B' motor.

Poles on the stator and the shuttle are 12 μm long, 4 μm wide, and 30 μm high. The total number of poles on the shuttle is 720 and 540 on the stator. In each phase, there are 156 active poles at a time. The pitches between the poles on the shuttle and the stator are 9 μm and 12 μm, respectively.









Displacement measurements performed using image processing. The measurements shown are for one direction only. The displacement range is double.
(left) *Displacement versus stepping showing nearly linear increment (Type A motor);*
(right) *Maximum output displacement of the motors (Type A and B) as a function of the driving voltage.*

CONCLUSION & OUTLOOK

We have designed, fabricated and tested a monolithic linear stepper motor with open-loop operation, large displacement range and high repeatability.
We are currently working on the development of a rotary stepper motor based on the same technology.

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