Low Power Inchworm Motors

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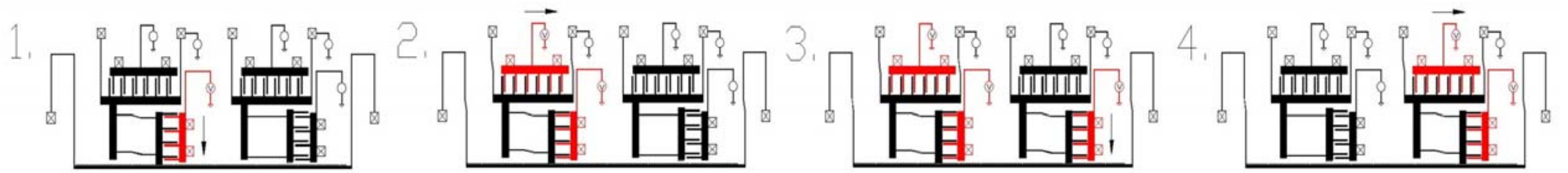
Design and operation of a standard electrostatic inchworm motor



Attractive force:

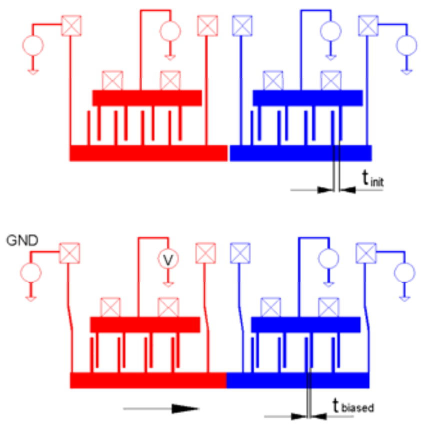
$$F = \frac{1}{2}\varepsilon_0 N V^2 \frac{S}{g^2},$$

where g – is the gap between fingers

Improvements

"Pre-biasing" actuator

"Pre-biasing" actuator decreases the initial gap; therefore, increases the starting pulling force



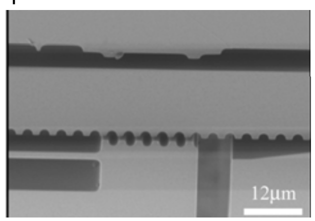
The motor has two operating modes:

The "pre-biased" actuator is

ON	**OFF**
Larger step – smaller starting force	Smaller step – larger starting force

Removing Teeth-to-Teeth Contact

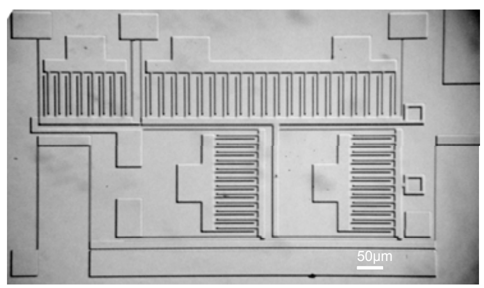
Fabrication of rectangular teeth for teeth-to teeth contact is difficult due to limitations of the photolithography and etching processes.



SEM image of the manufactured teeth-to-teeth contact. The designed layout had square shaped teeth.

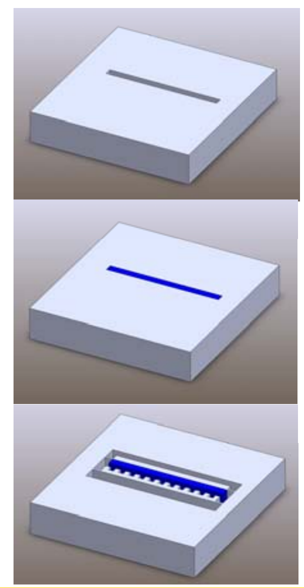
Experiments of the manufactured devices revealed the slipping effect of the shuttle as the result of imperfect teeth profile.

The removal of teeth and one of the driving actuators decreased the total area of the motor.



Using a Soft Elastomer to Improve the Friction Coefficient

We are coating the silicon walls at the place of shuttle-clutch contact in order to increase the friction coefficient.



Etching trenches for the elastomer pattern

Elastomer deposition

Etching trenches for the silicon pattern

Results:

The electrostatic inchworm motors with all these improvements are currently at the stage of testing. According to calculations, they would have the following characteristics:

Occupied area	3.6 mm^2
Pulling force without "pre-biased" actuator, at 200V	0.5 mN
Pulling force with "pre-biased" actuator, at 200V	1.2 mN
Final force density	2.1 μN/(mm^{3}V^2)

The previously manufactured electrostatic inchworm motor had their force density around 1.6 μN/(mm^{3}V^2)