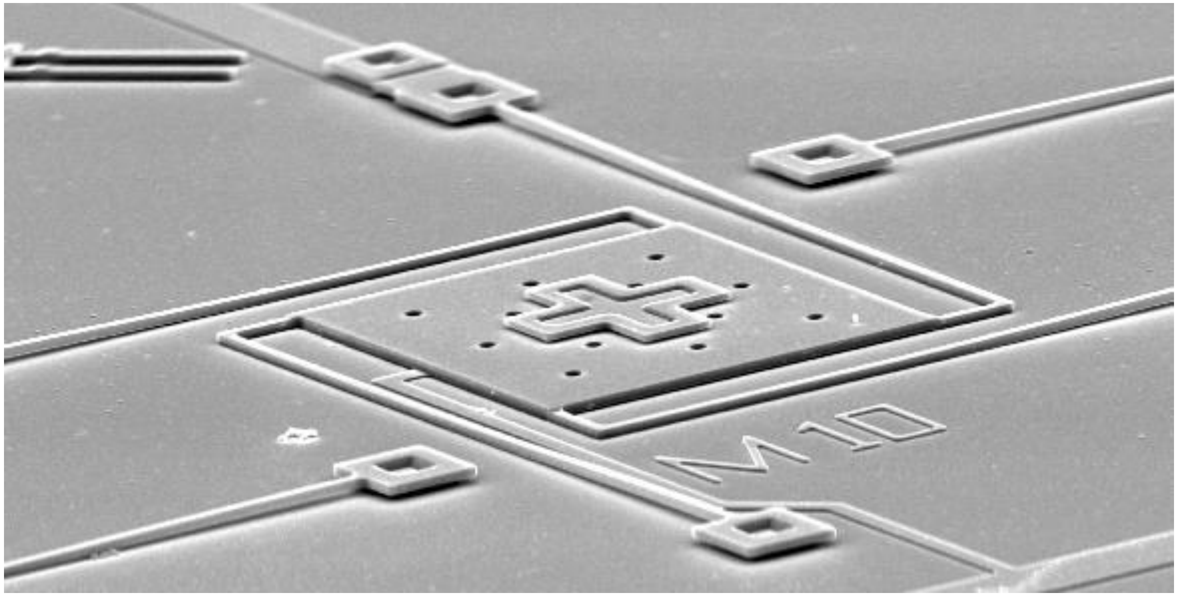
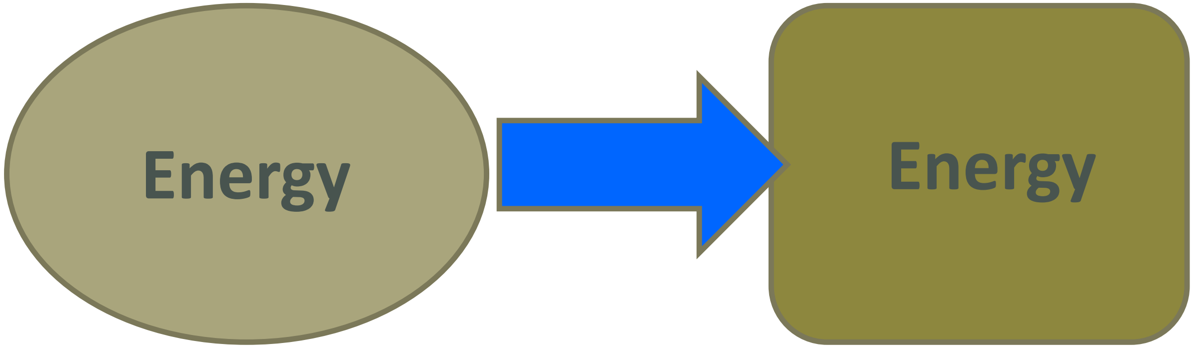
MEMS Parallel Plate Electrostatic Microactuator: How it is fabricated and how it works.



Group #1: Elena Chong, David, InJoo, Olivia, Sunny, Wendy.
Intro to MEMS Summer 2013
Dr. McInerney

What is micro-actuator?

Convert an energy type to another.



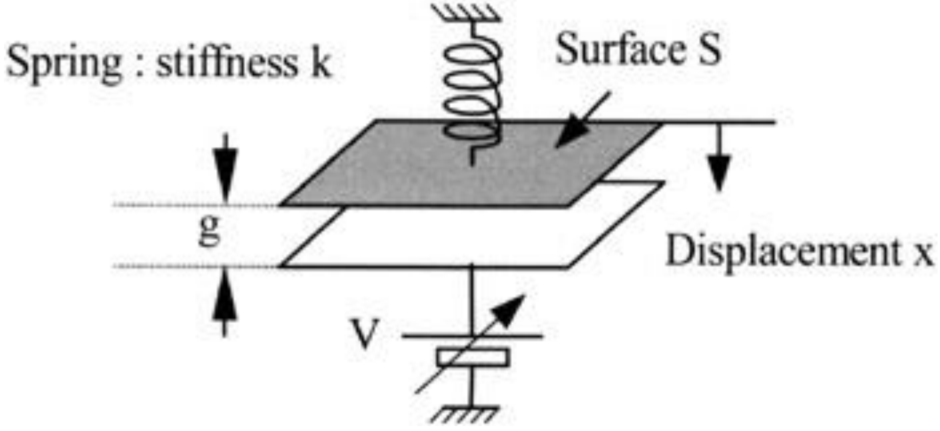
Category for microactuator

Optical	Magnetic
Thermal	Chemical

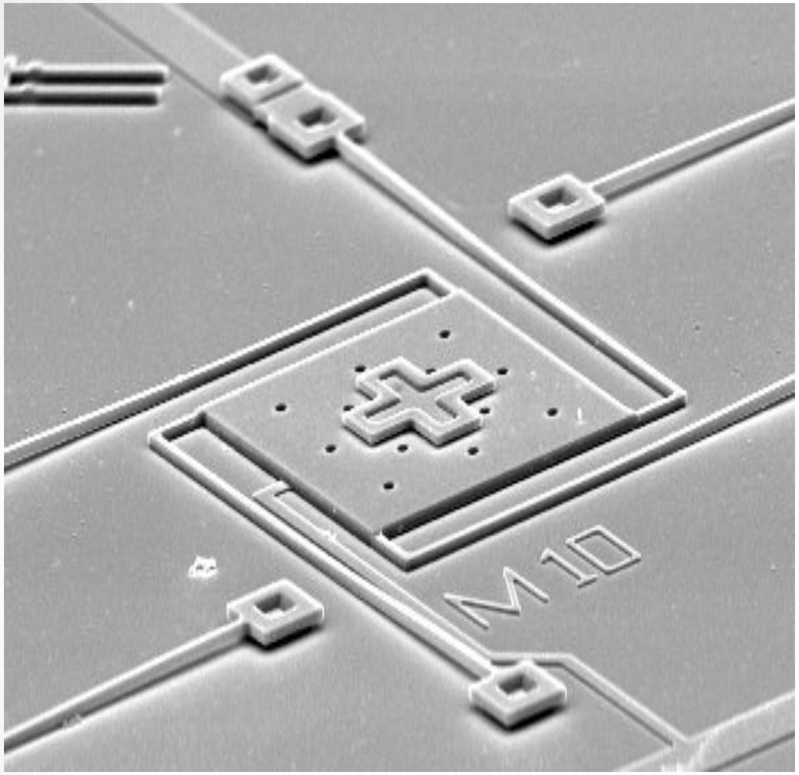
Electrostatic

How does it work?

- Principle of coulombic attraction
- Generate small force and displacement

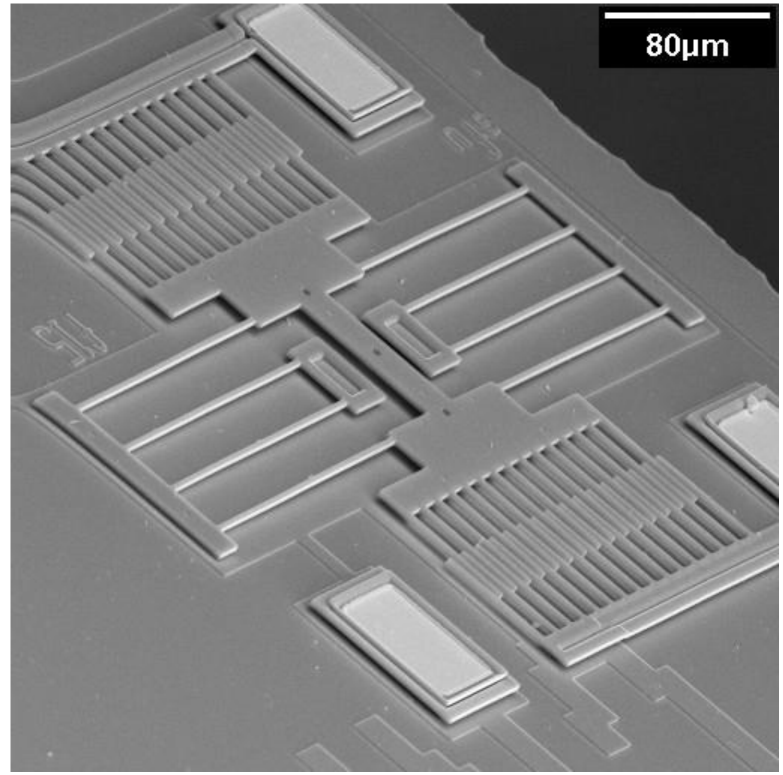


The two most commonly known electrostatic actuators:



Parallel Plate Actuator

Generate a large non-linear force that gives a limited displacement.



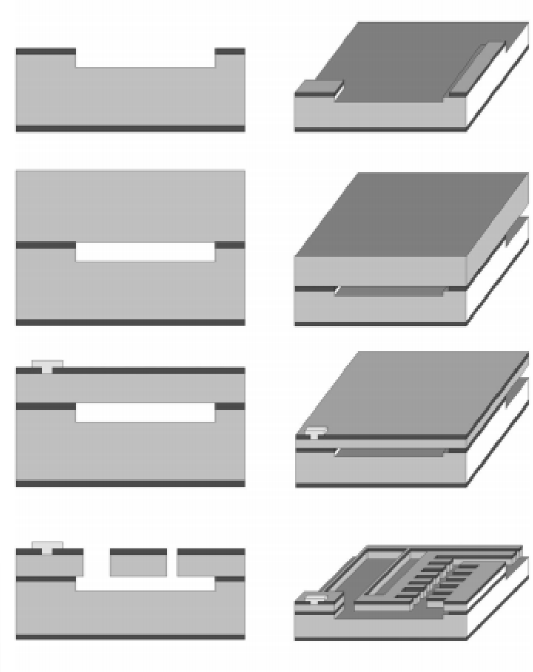
Linear Comb Drive

Generate a small force that gives a linear displacement, but need larger voltages.

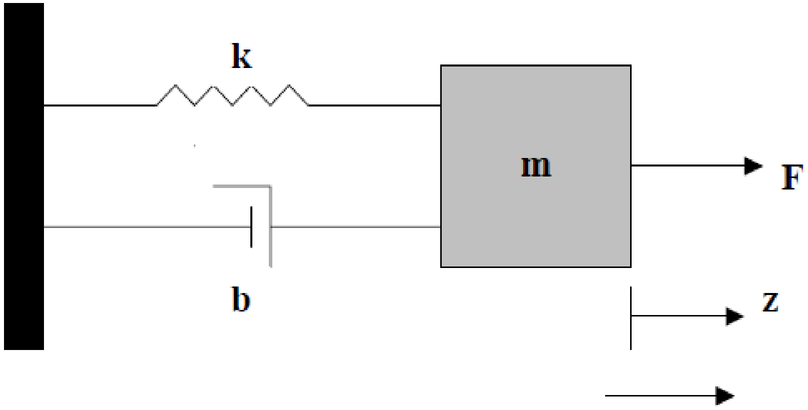
The two most commonly used electrostatic actuators are parallel-plate actuators and comb drive actuators.

Let's understand better how a parallel plate actuator works.

How to fabricate a parallel-plate actuator?



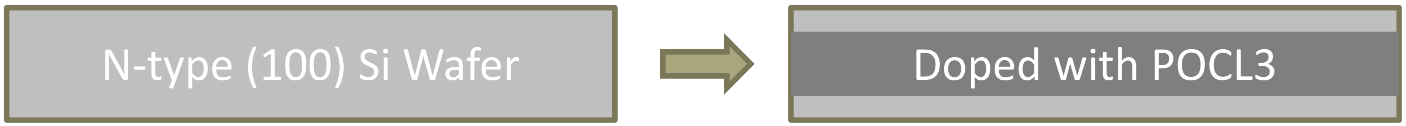
How a parallel-plate actuator works?



MultiUser MEMS Process is used for the fabrication process.

Starts with a 100mm silicon wafer doped heavily with phosphorus using POCL3 as a dopant source.

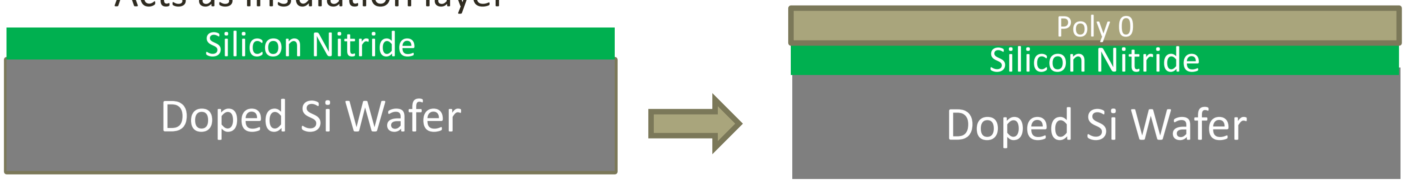
Diffusion furnace



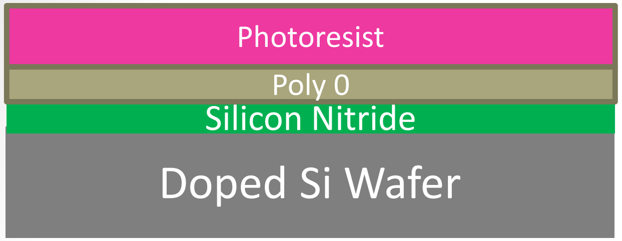
Doping will prevent charge going from devices on the surface to the substrate.

Low Pressure Chemical Vapor Deposition (LPCVD)

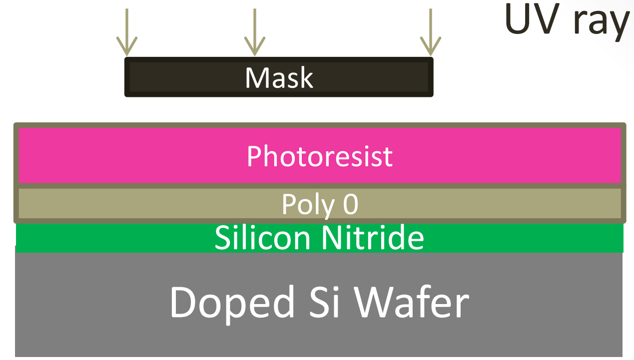
Acts as insulation layer



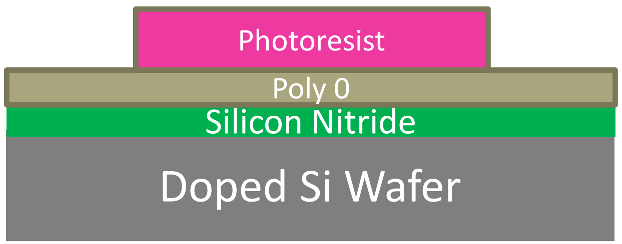
Deposit Silicon Nitride layer



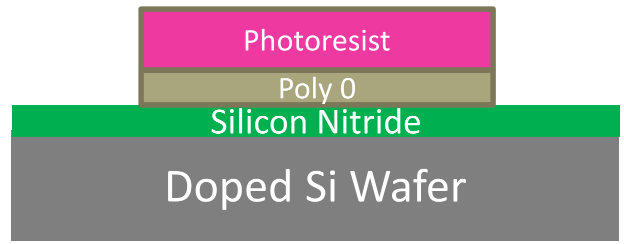
Deposit photoresist by spinning



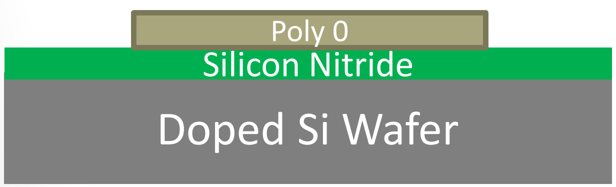
Expose with UV ray



Develop photoresist



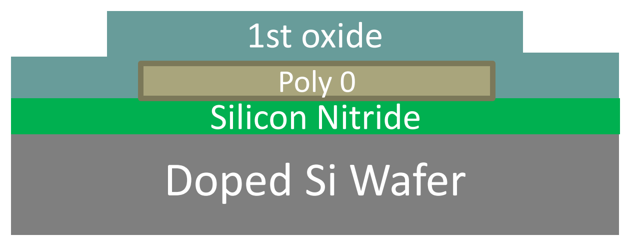
Etch poly 0 by Reactive Ion Etching



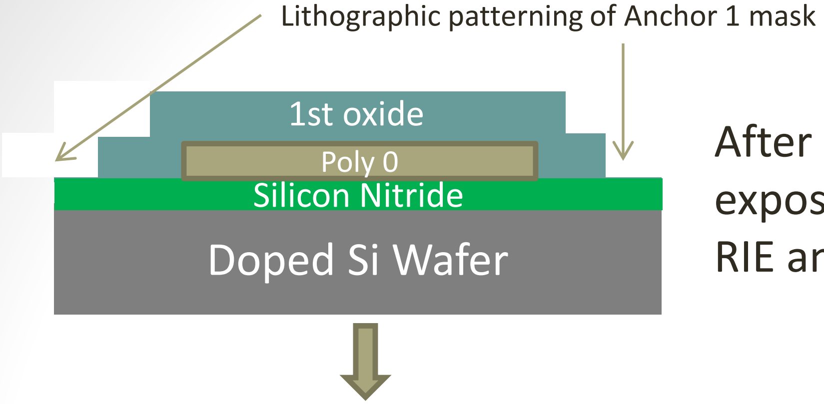
Strip photoresist in solvent bath

LPCVD

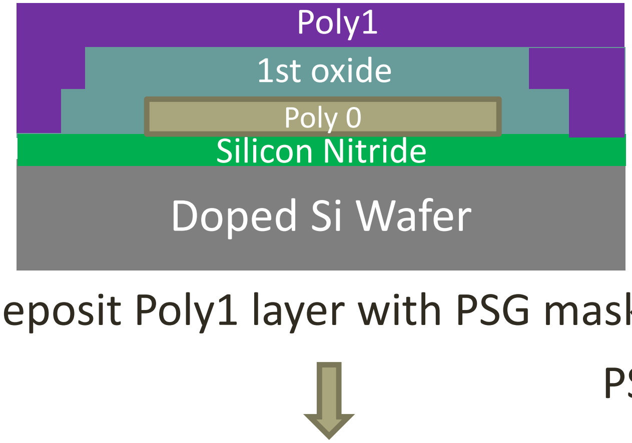
1050°C



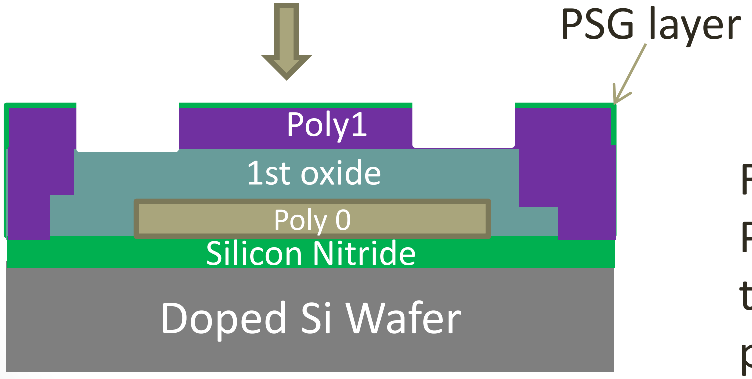
Deposit PSG (Phosphosilicate Glass) layer. 1st oxide layer used as sacrificial layer



After coating again with photoresist, the wafer is exposed with Anchor 1 mask and then etched by RIE and then the photoresist is stripped.

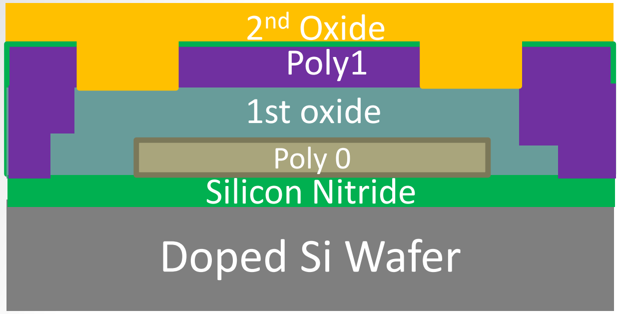


Deposit Poly1 layer with PSG mask



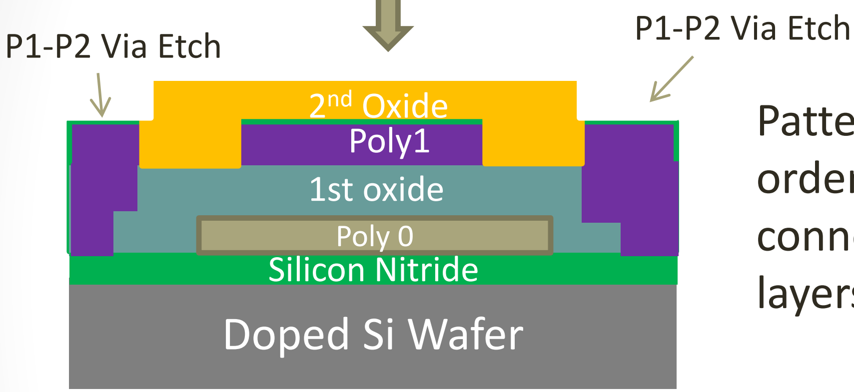
Etch poly1 layer after the patterning.

Recoat wafer with photoresist and pattern Poly1. Etch PSG to make a hard mask and then etch poly1 by RIE after etching photoresist. Remove PSG mask.

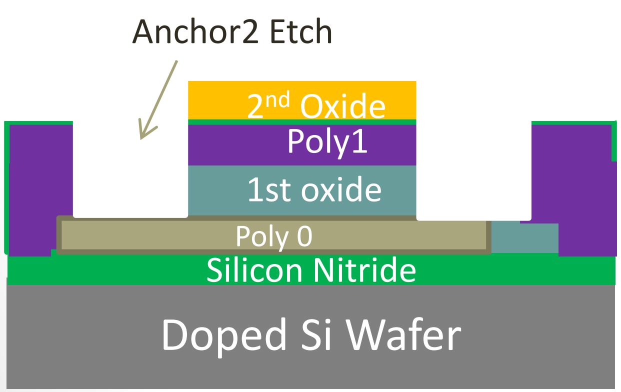


This layer is patterned twice the to allow contact to both poly1 and substrate layers.

Deposit 2nd oxide layer.

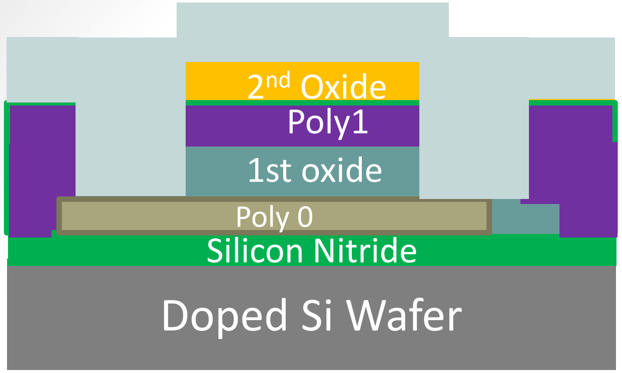


Pattern the oxide using Poly1_Poly2_Via in order to provide mechanical and electrical connection between Poly 1 and Poly2 layers

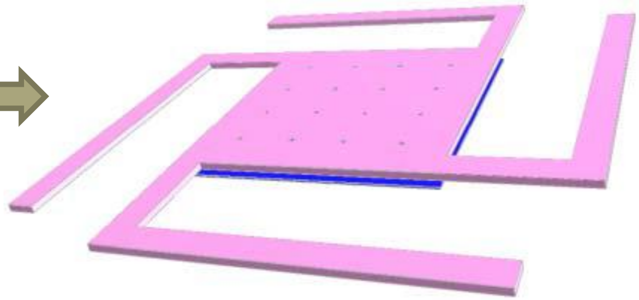


Wafer is coated with photoresist and anchor2 is lithographically patterned. Second and first oxide are etched in RIE stopping on either poly0 or nitride and photoresist is stripped.

back

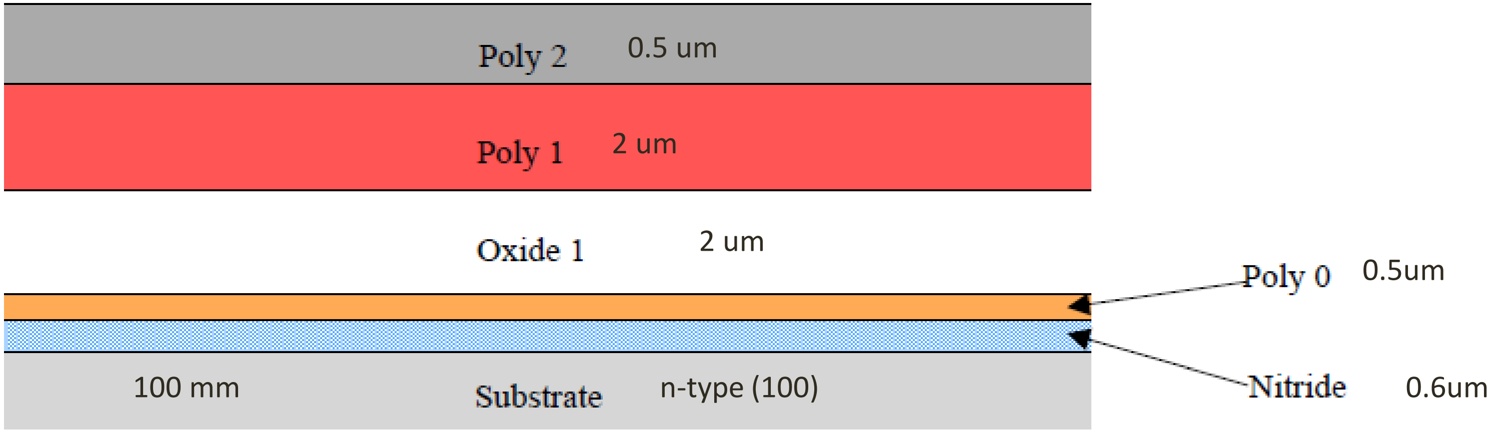


Deposit Poly2 layer

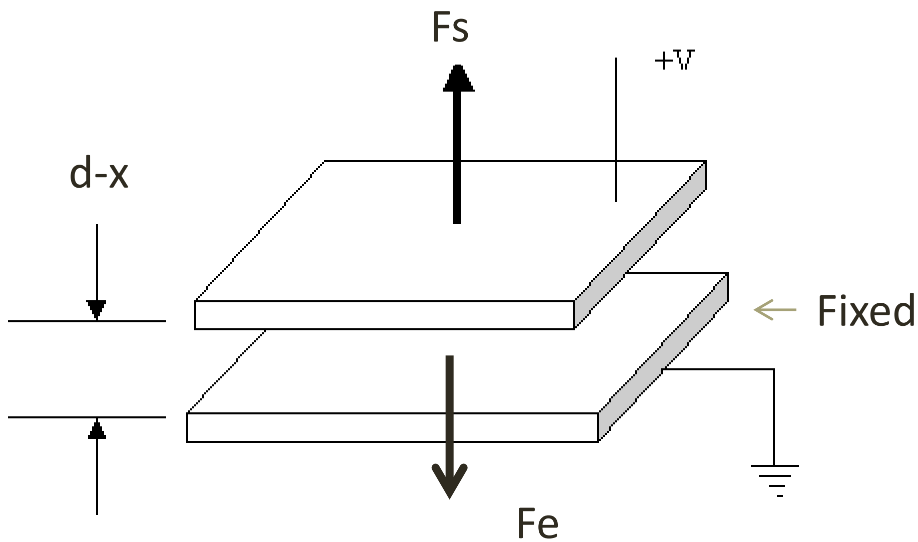


Resulting device: 150x150 micron parallel plate actuator

Thickness of different layers of the fabrication process



The parallel plate actuator works on the principle of change of capacitance between two conductive parallel plates.



$$U_{field} = \frac{1}{2} C V^2$$

Potential energy stored

$$C = \frac{K \epsilon_0 A}{d-x}$$

Capacitance of parallel plate capacitor

$$F_u = \frac{1}{2} V^2 \frac{dC}{dx}$$

Force related to potential energy

Pull-In effect occurs when the critical voltage is applied to get the critical distance.

$$kx = \frac{1}{2}\frac{\varepsilon A_{el}}{(d-x)^2}U^2$$

Forces at equilibrium F= 0.

$$\frac{\partial F}{\partial x} = \frac{\varepsilon A_{el}}{(d-x)^3}U^2 - k$$

Expression for the pull-in point.

Unstable point is given by $\frac{\partial F}{\partial x} = 0$ Giving the critical distance $x = \frac{1}{3}d.$ Beyond this point the two plates will join.

Pull-in voltage at which the system becomes unstable:

$$U_P = \sqrt{\frac{8}{27}\frac{kd^3}{\varepsilon A_{el}}}$$

References

[1] Gandhi, S. P. MEMS: Fabrication. Retrieved from: http://www.me.iitb.ac.in/~gandhi/me645/05L10_polymumps.pdf

[2] Medipalli R. R., MEMS Parallel-Plate Electrostatic Actuator: Modeling, Simulation and Characterization.

[3] Kaajakari, V. *MEMS Tutorial: Pull-in voltage in electrostatic microactuators* Retrieved from: http://www.kaajakari.net/~ville/research/tutorials/pull_in_tutorial.pdf