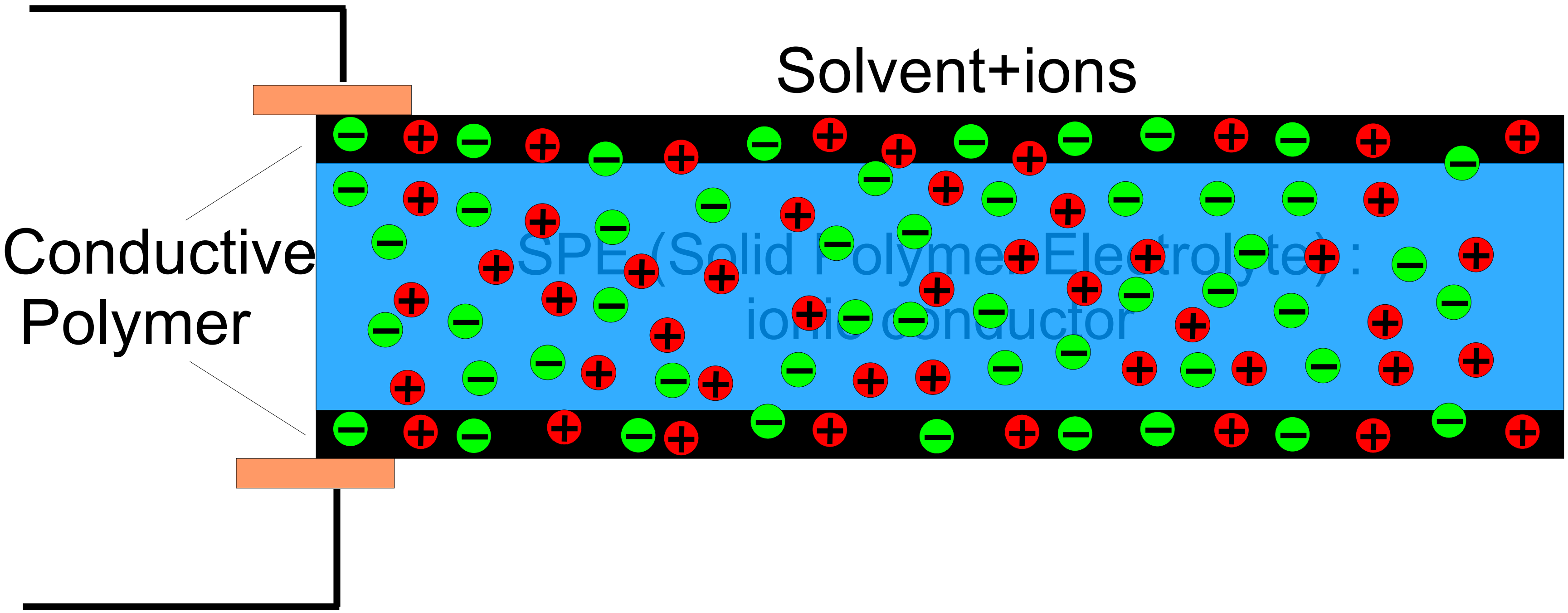
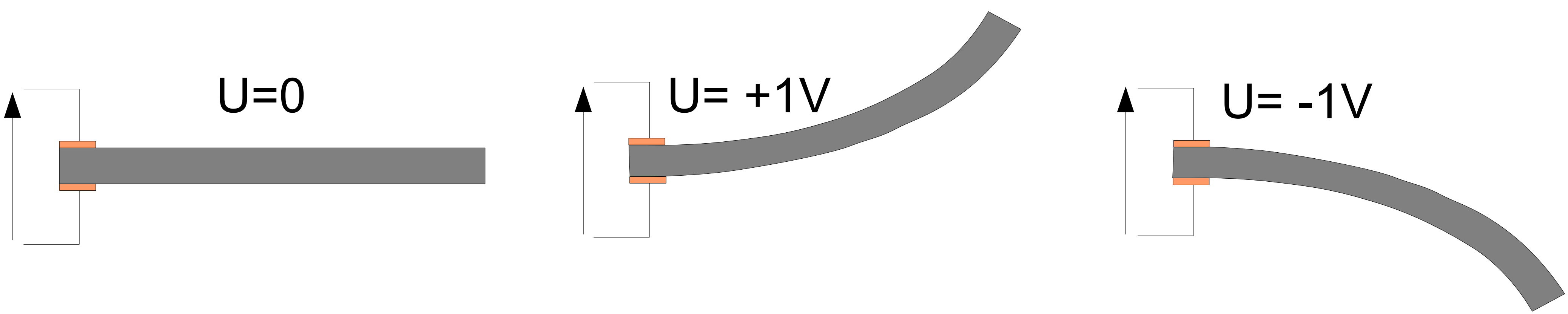
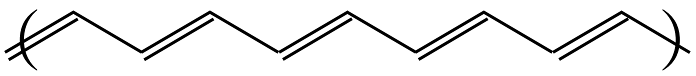
Conductive polymer actuators and Improvements by using Interpenetrated Networks of Conductive Polymers (IPN-CP)

Conductive Polymer Actuators

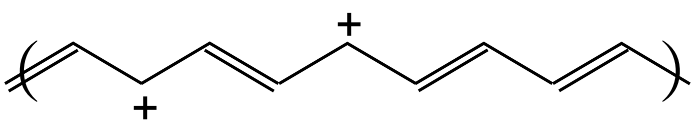




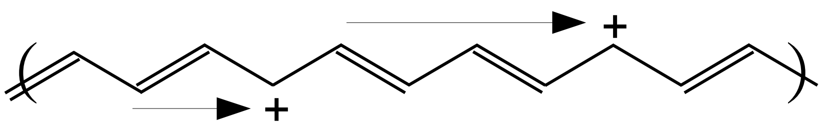
Conductive Polymer Structure



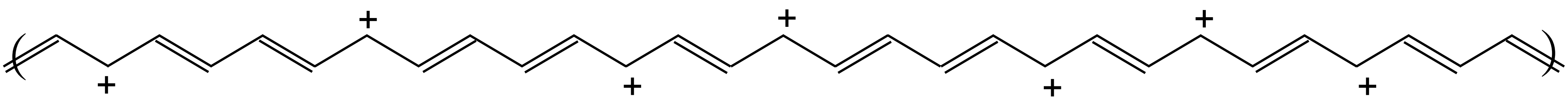
Delocalized π-bondings
on long polymer chains



holes

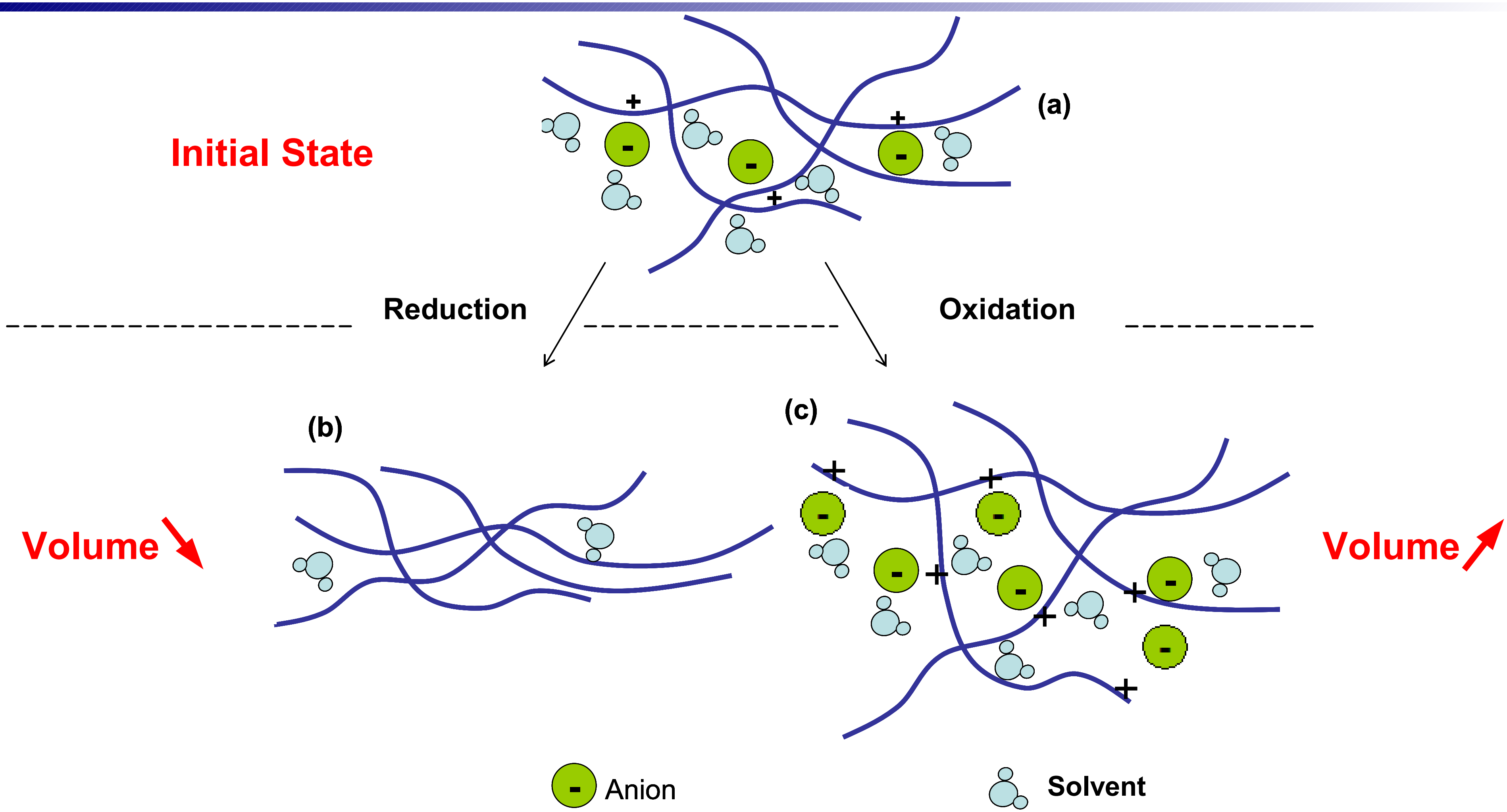


High hole mobility due to π delocalization :
the polymer is conductive



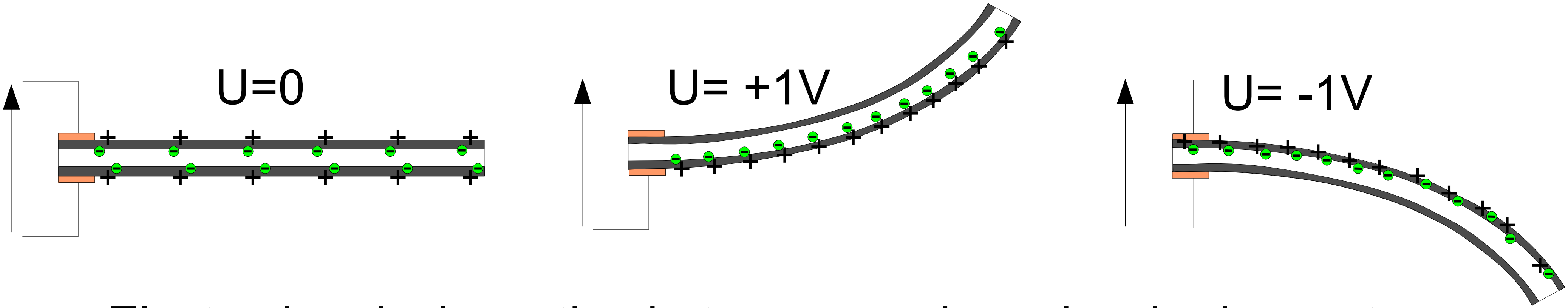
Creation of holes (oxidation) during the fabrication : doping

Actuation Mechanism (1)

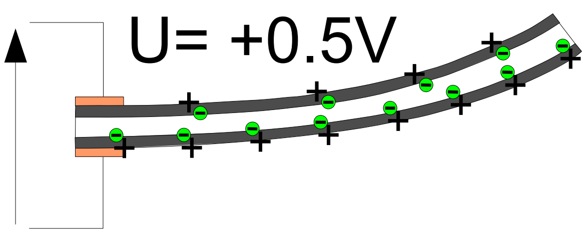


Anion movements can trigger volume changes if the mobility of cations is poor.

Actuation Mechanism (2)

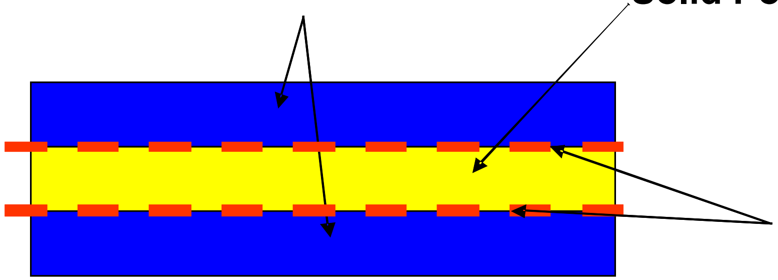


Electrochemical reaction between anode and cathode creates holes on one side; removes holes from the other side.

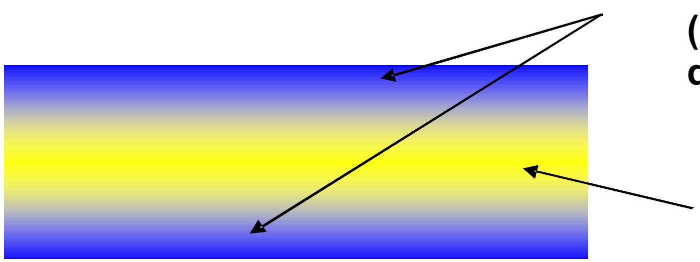


Smaller Voltages induce partial electrochemical reaction swith smaller movements

Our System : Interpenetrated Network of Conductive Polymers



Trilayer Actuator (Classic Design)

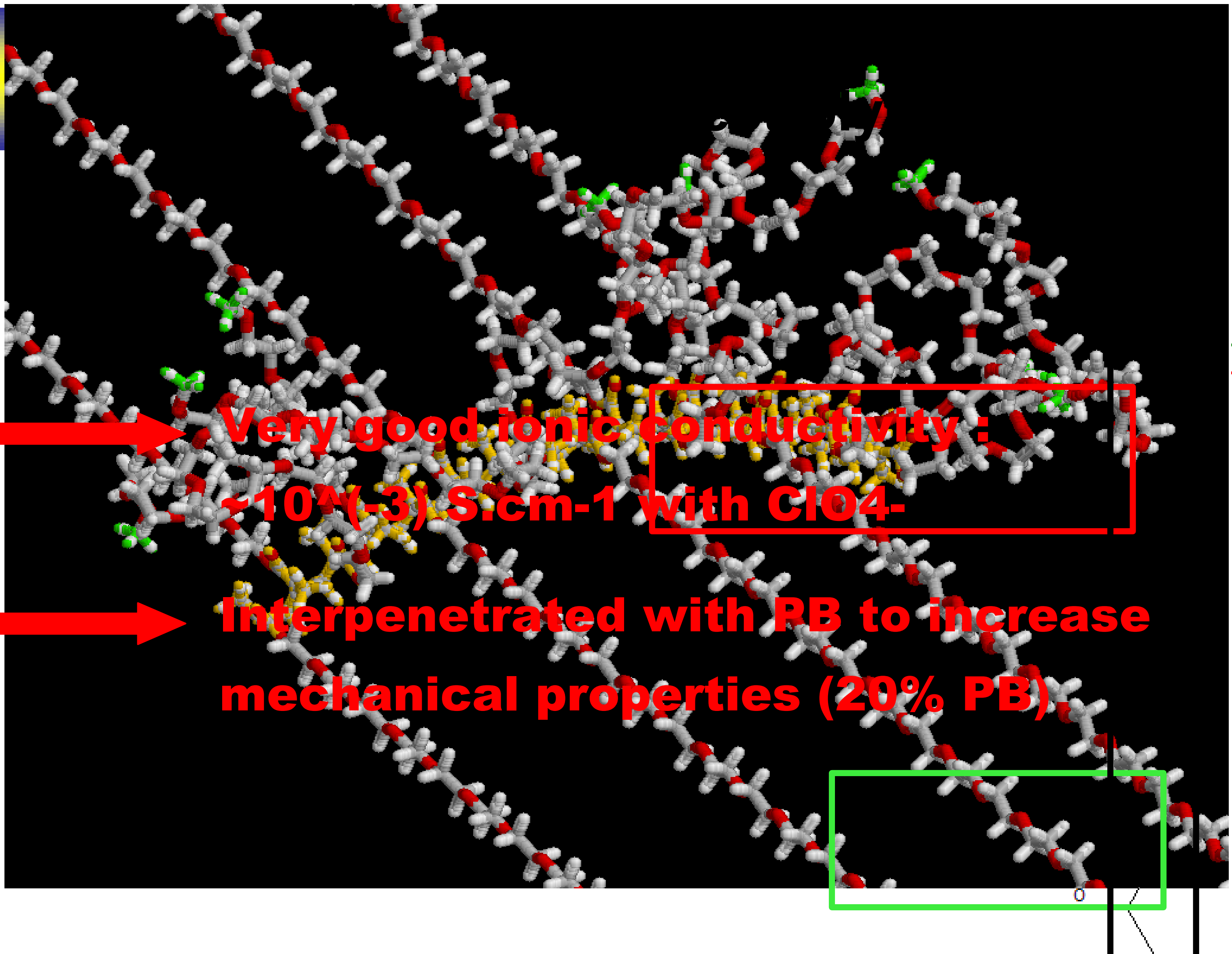


Gradual Interpenetrated Actuator

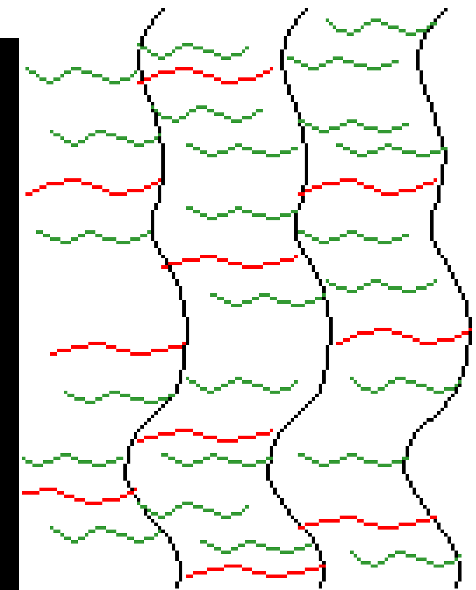
Advantages :

- **Better mechanical resistance (no delamination)**
- **Better ionic conductivity inside CP**

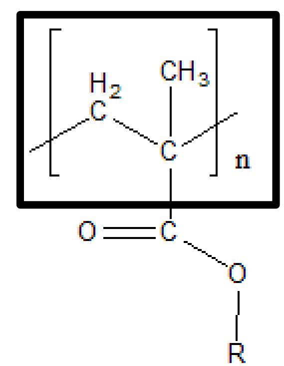
Materials (1)



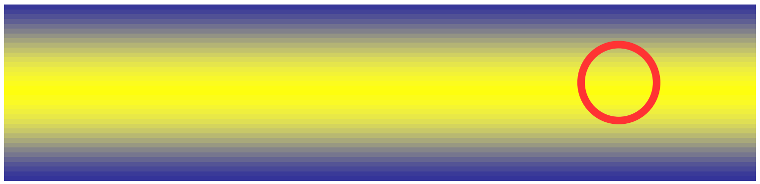
- Very good ionic conductivity : ~10^(-3) S.cm-1 with ClO4-
- Interpenetrated with PB to increase mechanical properties (20% PB)



PMMA-PEO



Materials (2)

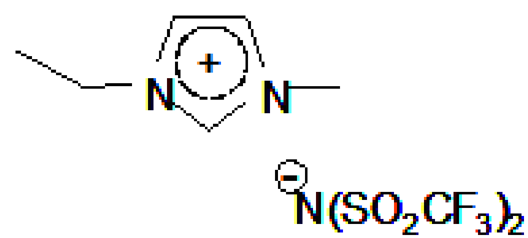


Solution :

- Li+ClO4- ions in Propylene Carbonate
- EmImTFSI Ionic Liquid

Solvent :

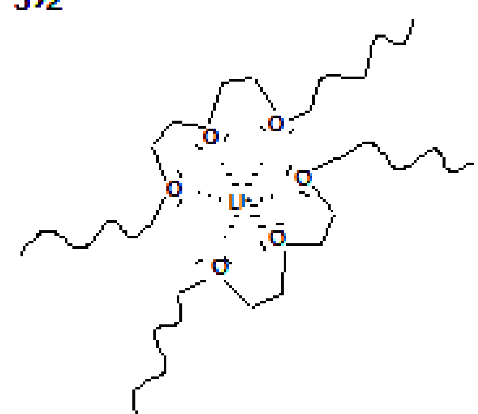
- **Li+ClO4- (1M) in PC :** very slow evaporation (several hours before performances drop)
- **EmImTFSI :** no evaporation



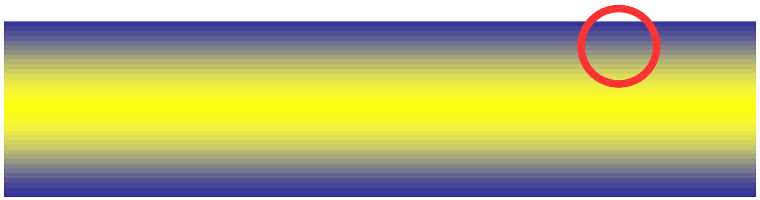
Use in open air

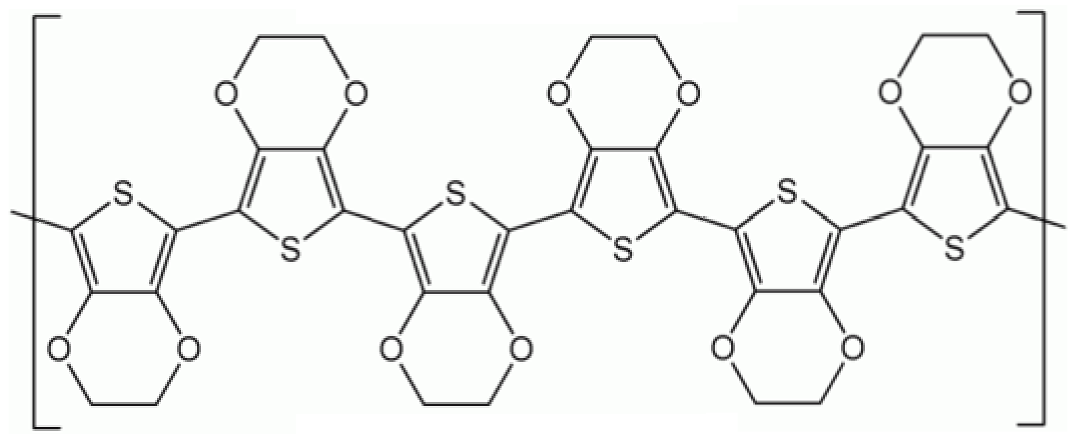
Ions : • **ClO4- :** good compromise between size / mobility

• **Li+ :** complexed by PEO



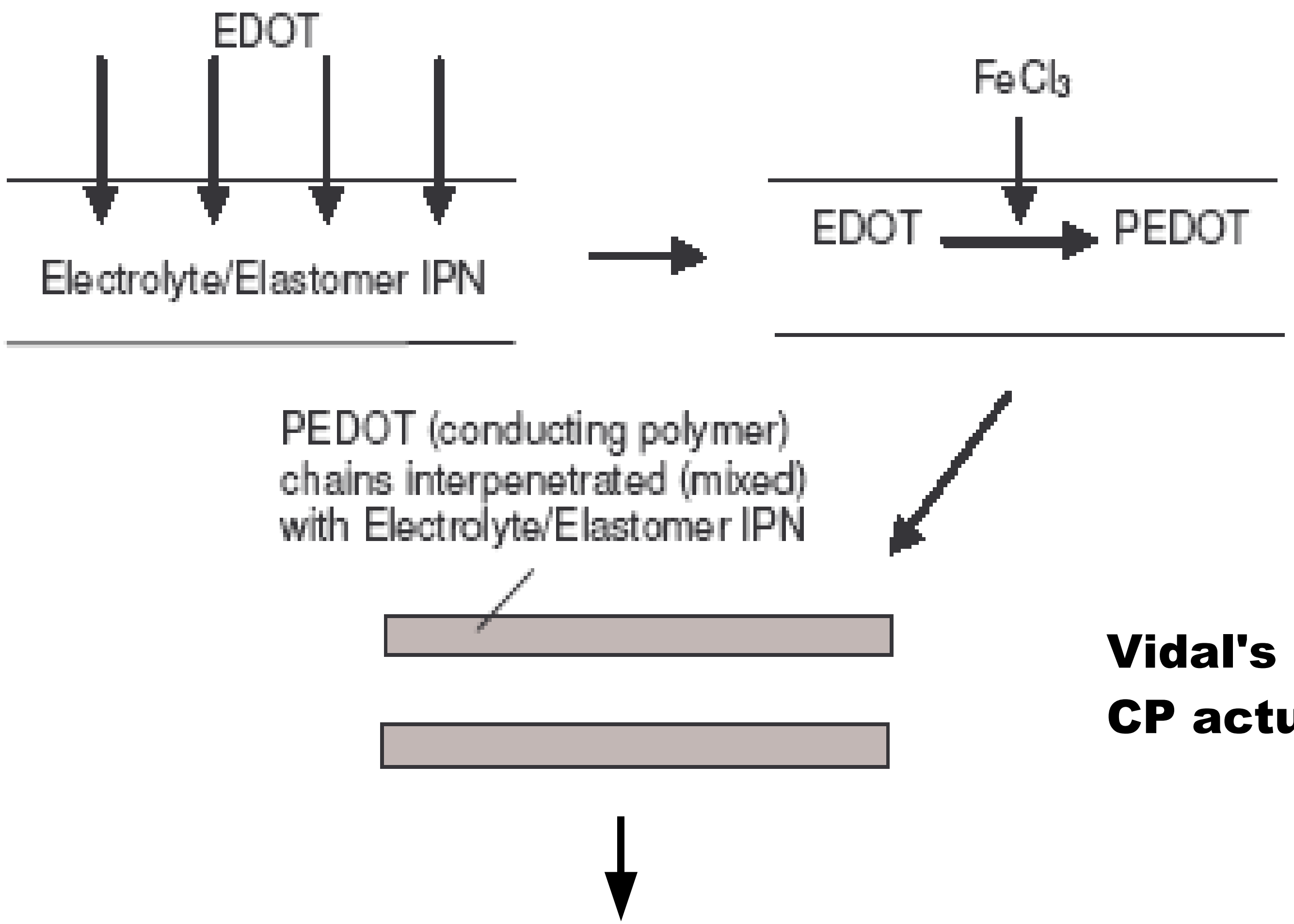
Materials (3)





Conductive Polymer : PEDOT
Conductivity : ~1S/cm
very stable
linear chains
ratio : between 0 – 70% in
the gradient zone

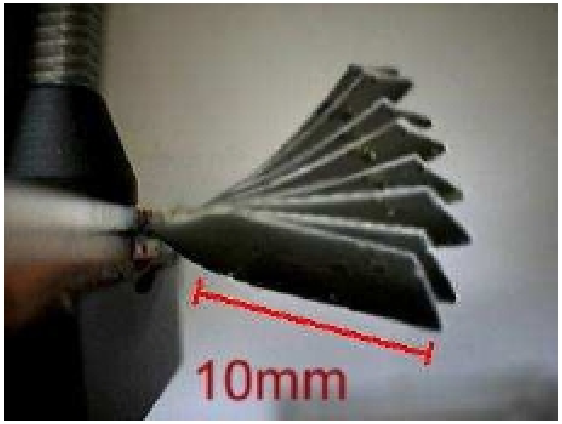
Fabrication



Vidal's procedure for IPN-CP actuators fabrication

Washed, swollen in the finale solution

Performances

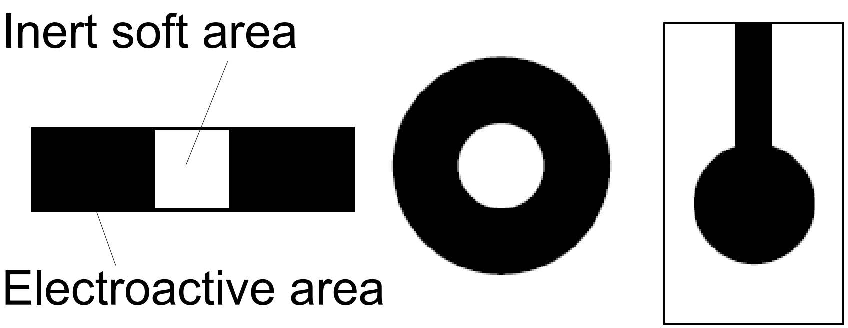


Response time: 1 second
Bandwidth: 1Hz
Force: 80 mN (at 1mm)
displacement: 2-2.5 mm for 5mm beams

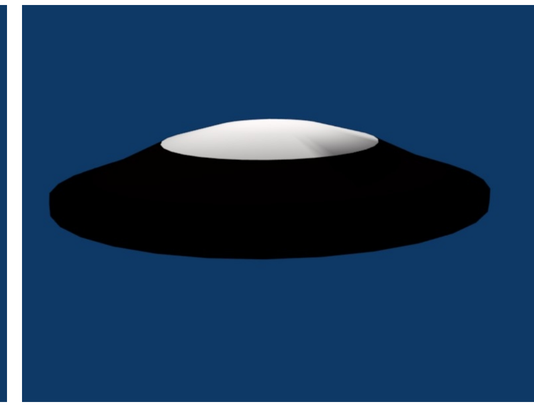
Main problems: bending movements only ; slow ; integration issues

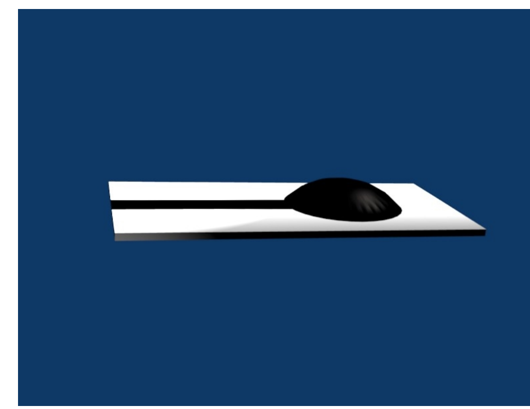
Goal: obtain quicker one piece actuators with intrinsic linear movement and integrated wiring

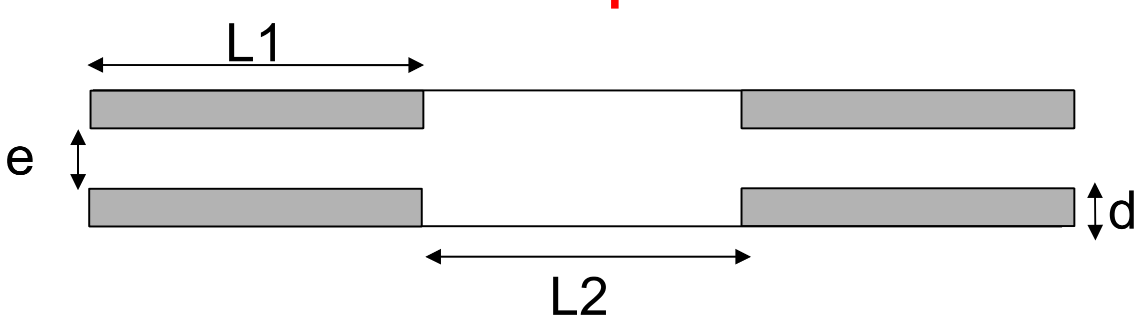
Linear Actuation



Principle: polymerized / not polymerized zones





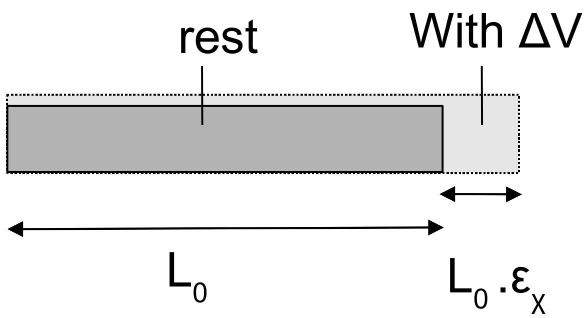


Parameters to be optimized

A simulation is necessary

Simulation: principe

Ionic actuators



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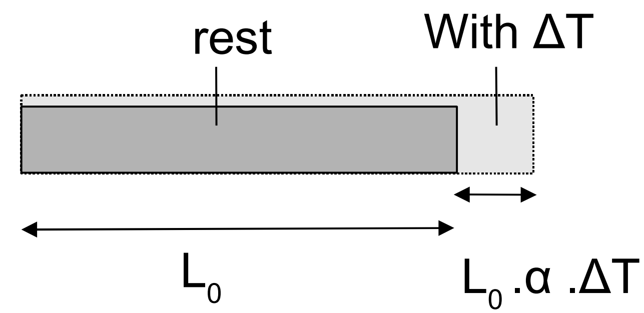
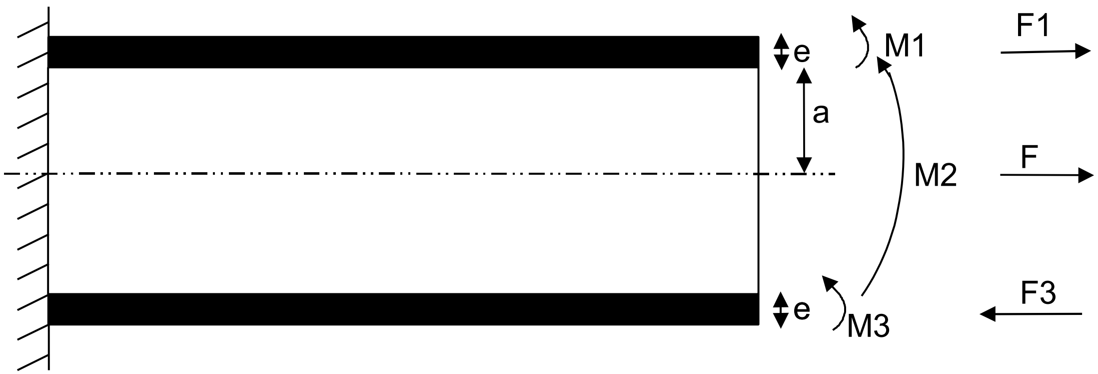
Thermal expansion



→ **Finite element simulations with thermal analogy**

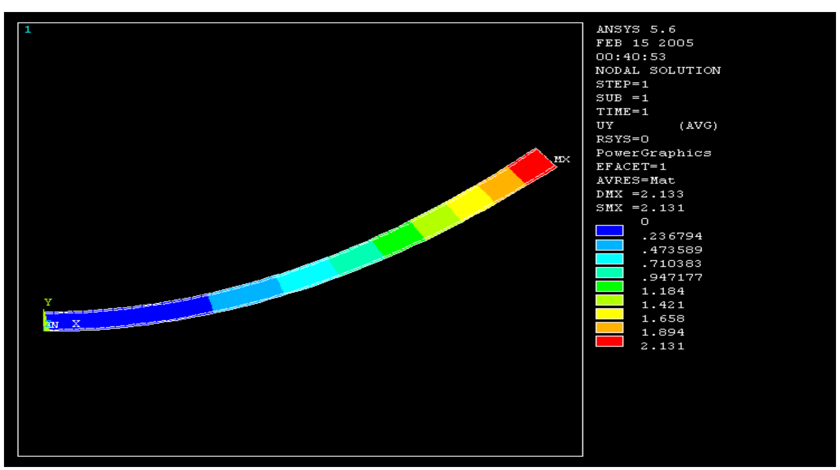
Simulation: validation

- **Theorical calculations**

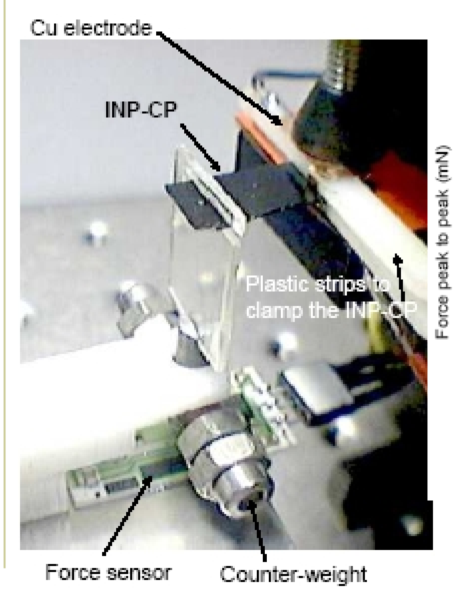


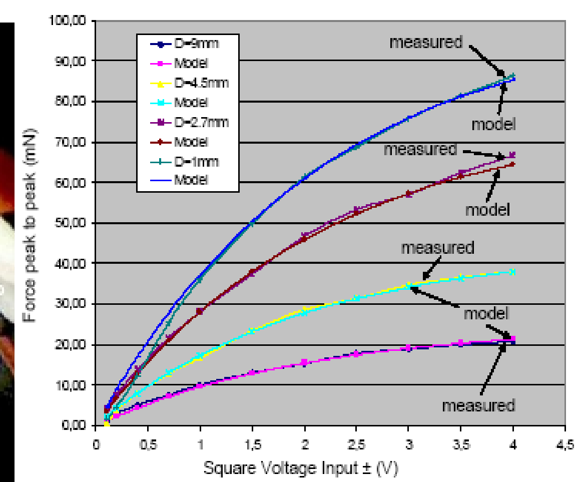
$$\delta = \frac{L^2 \varepsilon_x}{2a+e + \frac{8E_2 a^3 + 2E_1 e^3}{6(2a+e)(E_1 e)}}$$

- **simulations**



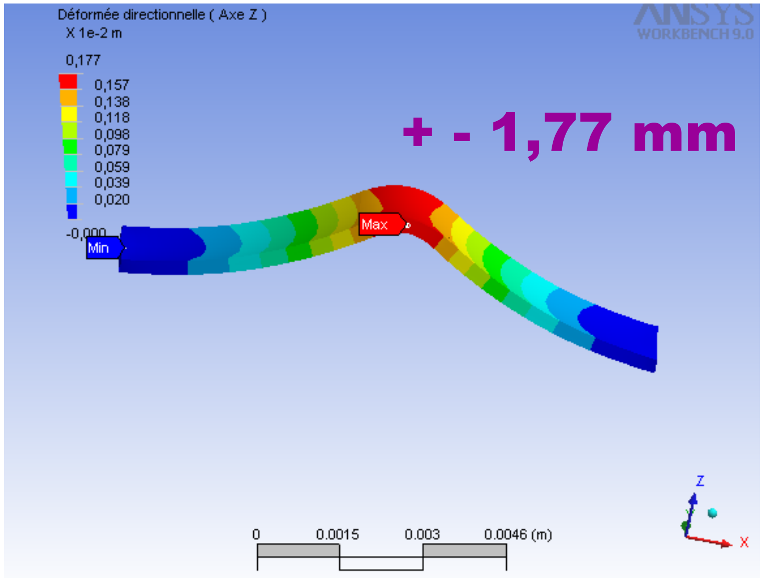
- **experimental measures**

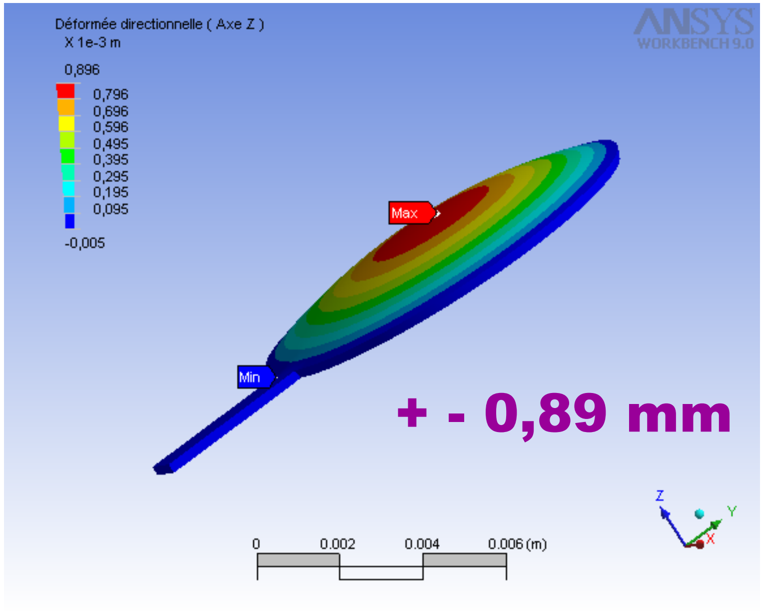


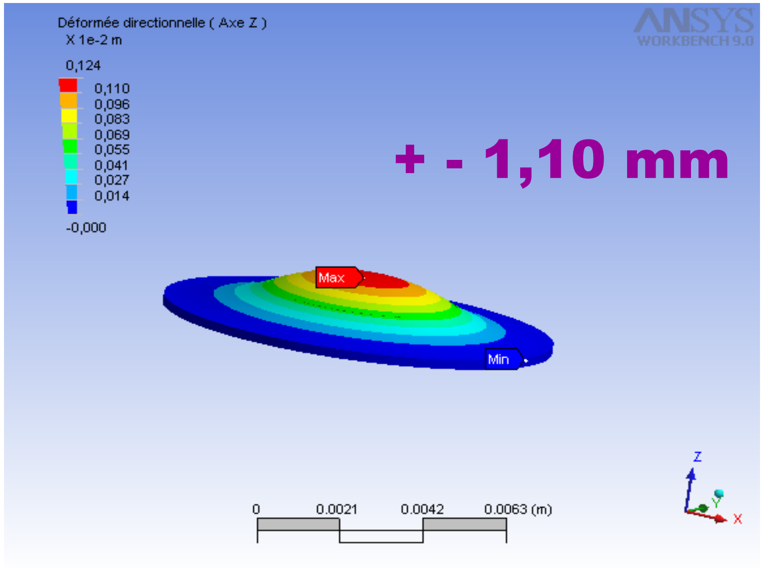


Same results in each case

Simulations: results

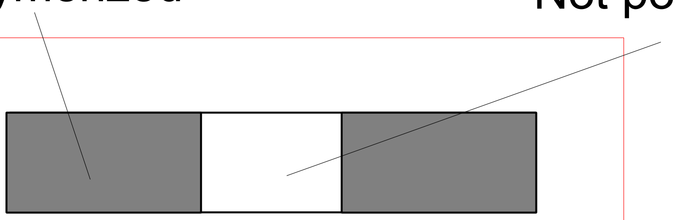






polymerized

Not polymerized

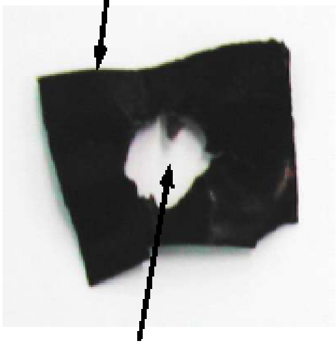


Most efficient shape

Fabrication: using of masks

- **classical rigid masks**

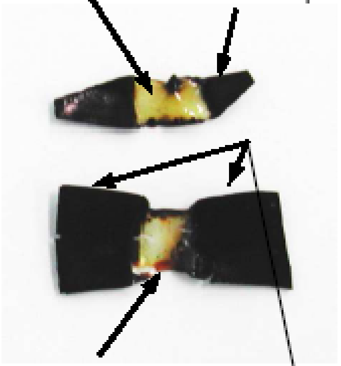
Conductive part



The not-conductive part
was cut out of the actuator
due to mechanical failure

Not-conductive part

Conductive part



Cracks due to
mechanical
failure

Increase of the
conductive
parts volume

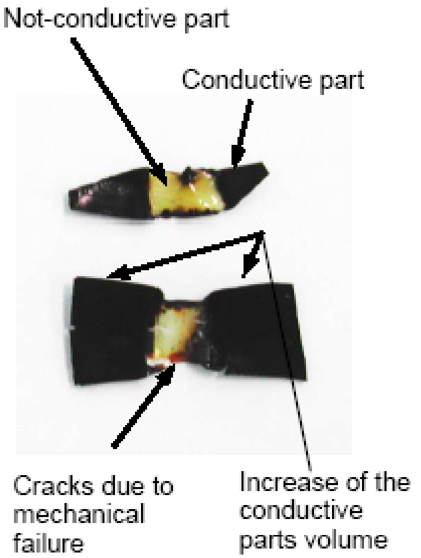
Solutions :

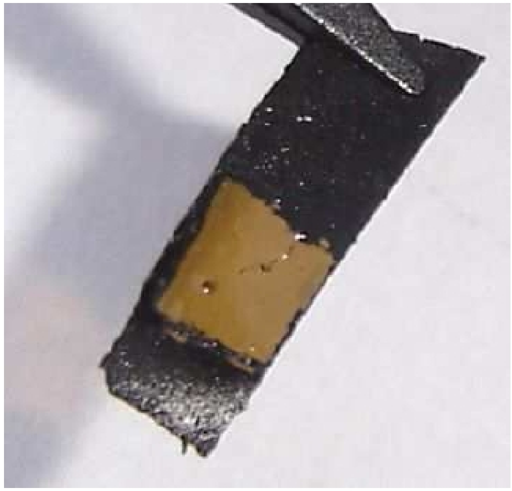
- **Soft masks using**
- **Surface treatment / washing**
- **Evaporation preventing**
- **USING OF MICROWAVES**

Microwaves using

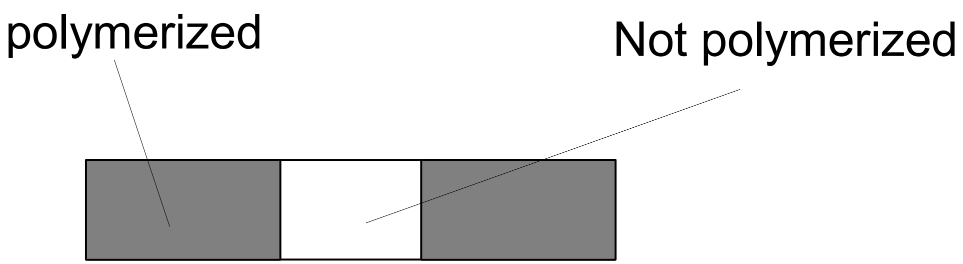
- **Better reproducibility**
- **Better Surface aspect**
- **Much quicker (16h → 6')**
- **Much less mechanical failure**

Fabrication: results

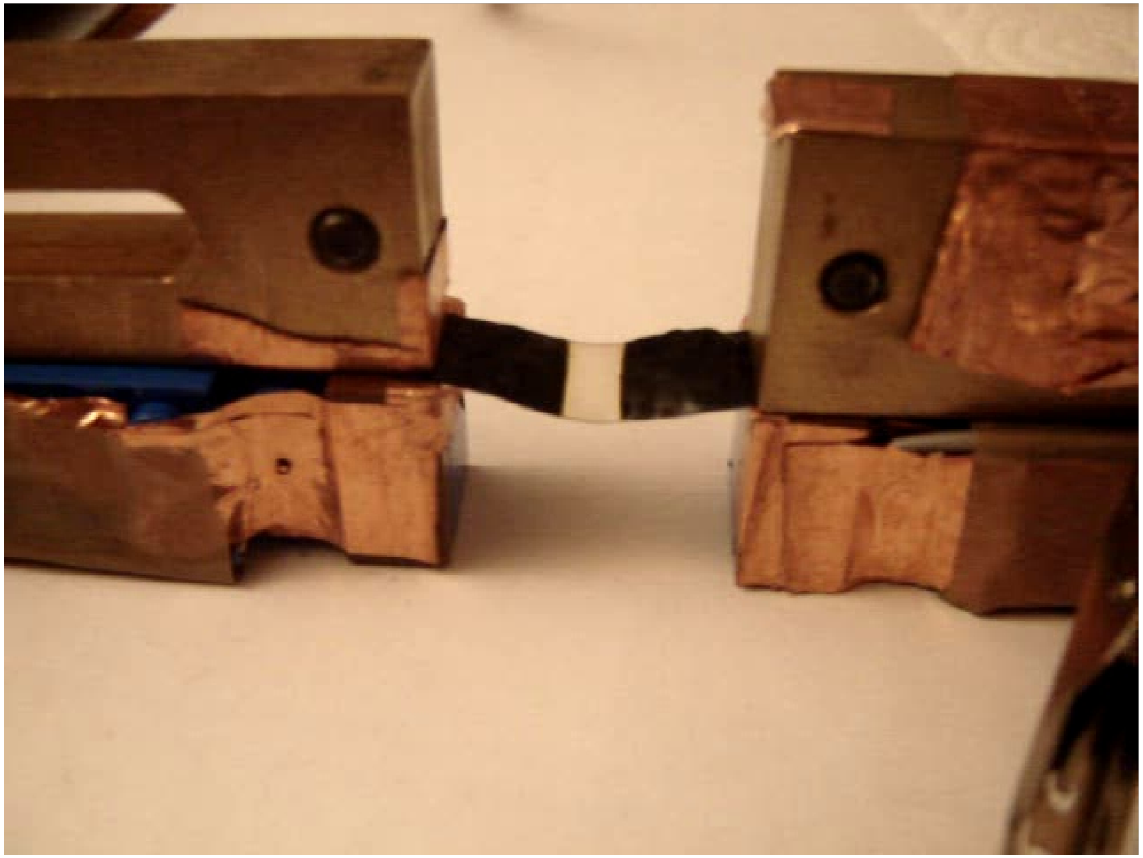




Precise shaping



Actuation tests

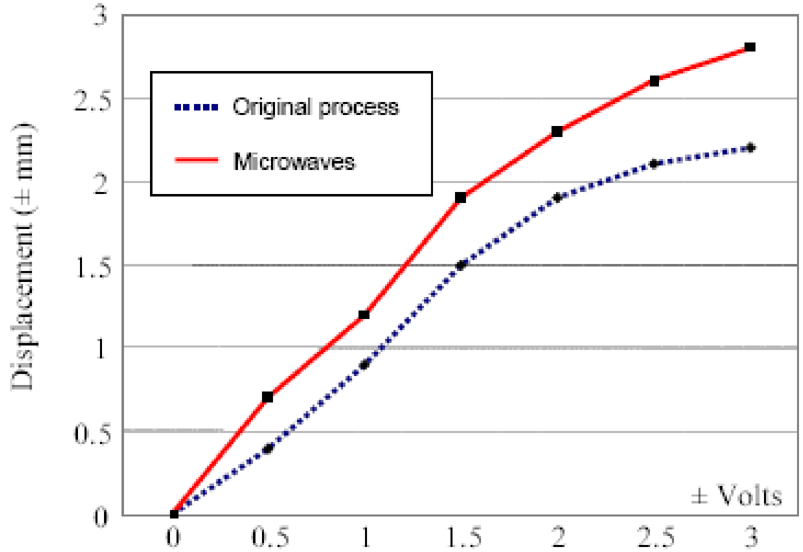


→ **Linear displacement**

Actuation tests

Performances

- high amplitude deformation
- Linear behaviour



Other improvements

- Higher bandwidth (*2 - *3)
- Higher force and displacement (depending on the length, typically * 2-3)
- New integration method – without clamping : “chemical wires” without side-actuation
- Elimination of deformations loss due to length