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High curvature sensors based on flexoelectric effect in soft semi-conducting polymer films

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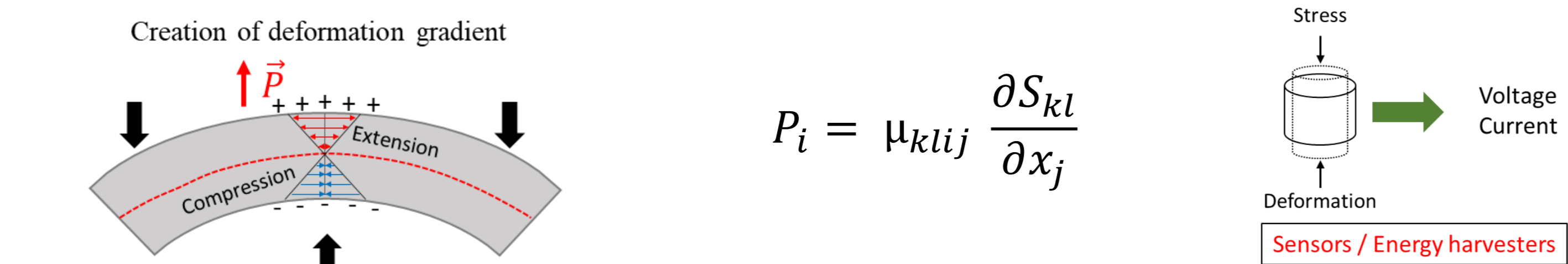
Context

- Objective** : To obtain a high-curvature sensor based on flexoelectric effect
- Solution** : PEDOT:PSS free standing thin film
- Lines of research** :
 - Optimize the flexoelectric sensor

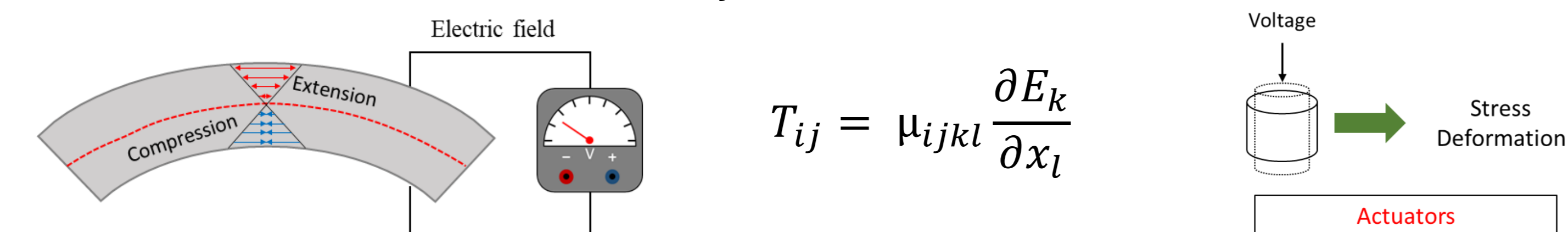


Flexoelectricity ? (direct and reverse effect)

Direct effect : electrical polarization P_i is induced by a deformation gradient



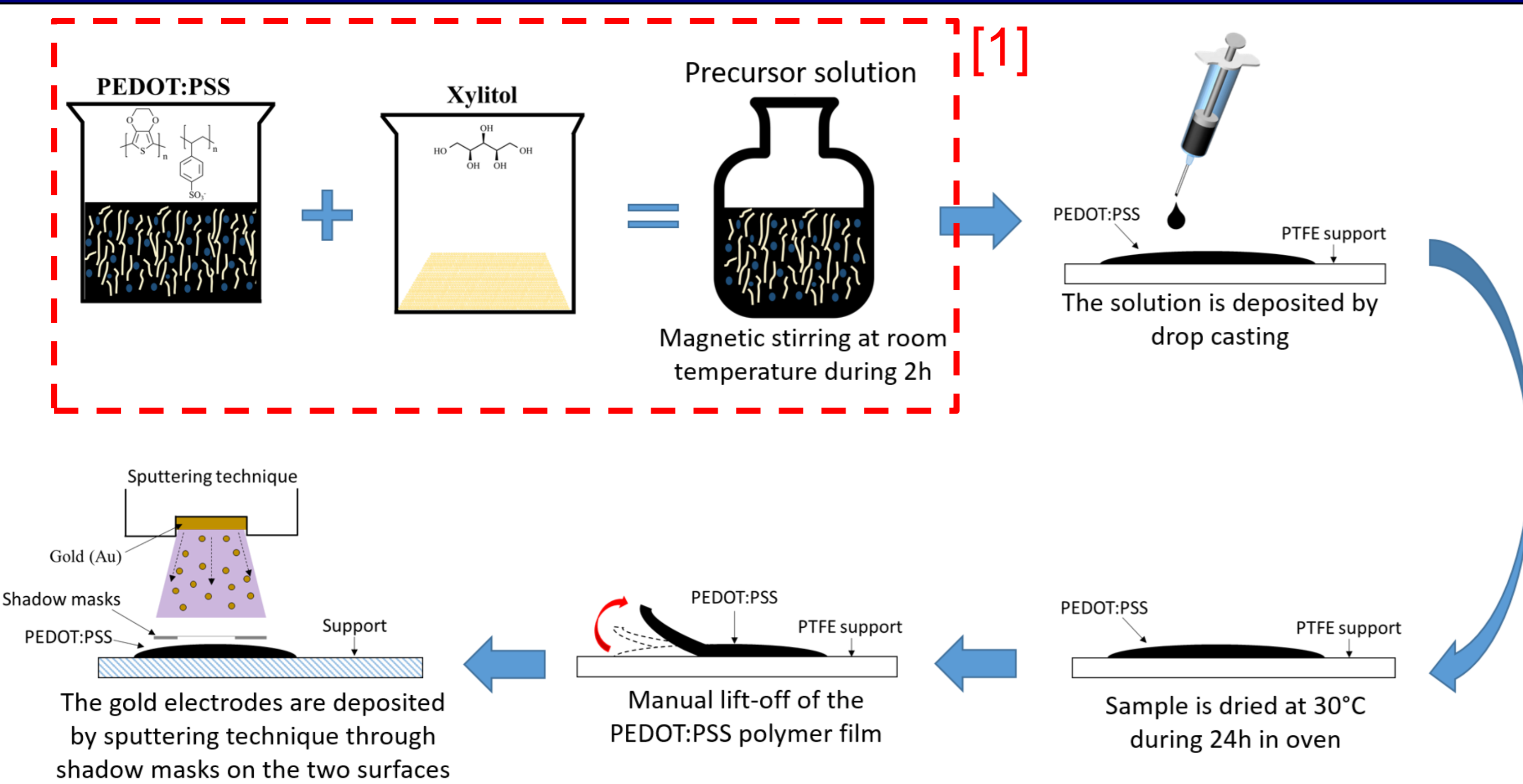
Reverse effect : Mechanical stress T_{ij} induced by an electric field gradient (E_K)



Piezoelectricity vs Flexoelectricity

| Piezoelectricity | Flexoelectricity |
|--|---|
| $P_{piezo} = e \cdot S$ <small>S = deformation</small> | $P_{flexo} = \mu \left(\frac{\partial S}{\partial x} \right) = \mu \cdot C$ <small>C = curvature</small> |
| No centrosymmetric materials | Universal coupling |
| Electric field polarization : YES | NO |
| Piezoelectric coefficient $e \approx 10 \text{ C/m}^2$ | Flexoelectric coefficient $\mu \approx 10^{-4} \text{ C/m}$ |
| Effet de vieillissement | Pas de vieillissement |
| Deformation $S \sim 1\%$ <small>S depends on the position of the sensor relative to the neutral axis!</small> | Curvature $C = \frac{\partial S}{\partial x} \text{ to } 10^6 \text{ m}^{-1}$ <small>C is constant throughout the thickness!</small> |
| $S = y/R = y \cdot C$ | Curvature varies inversely with thickness and mechanical rigidity Flexible films |

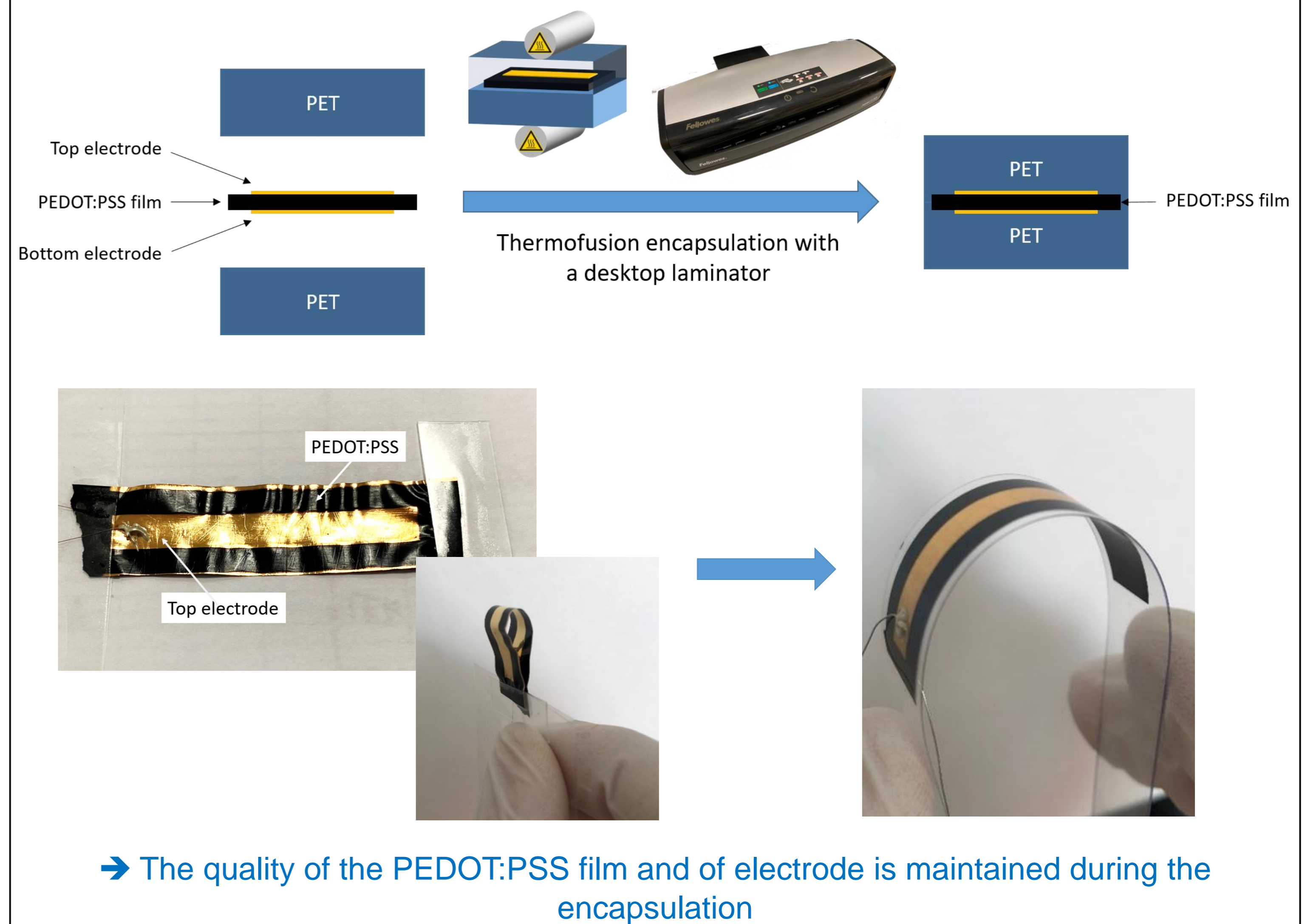
PEDOT:PSS thin film preparation



Research prospects

- Optimization of curvature sensor
- Realize a circuit for sensor management
- Making a green curvature sensor
 - biopolymer or biodegradable polymer
 - eco-friendly manufacturing process

Preparation of the flexoelectric sensors



Experiments

Schematic of experimental setup

$$\mu'_{12} = \frac{i}{2\pi f b l C}$$

Initial State / Release → **Bend**

Schematic of experimental setup

$$C = \frac{i}{2\pi f b l \mu'_{12}(f)}$$

High-curvature sensor based on flexoelectric effect

REFERENCE :

[1] Saadeh, M., Frère, P., and Guiffard, B. (2020). Revealing the flexoelectric-like response of poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) thin films. *Polymers for Advanced Technologies* 31, 2632–2639. 10.1002/pat.4989.