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► **To cite this version:**

Raynald Seveno, Thibault Dufay, Benoit Guiffard, Mohammed El Gibari, Julien Le Scornec, et al.. Flexible Electro-Active Materials. World Electronics Forum, Oct 2017, Angers, France. 2017. hal-01714979

**HAL Id: hal-01714979**

**<https://hal.science/hal-01714979>**

Submitted on 22 Feb 2018

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# Flexible Electro-Active Materials

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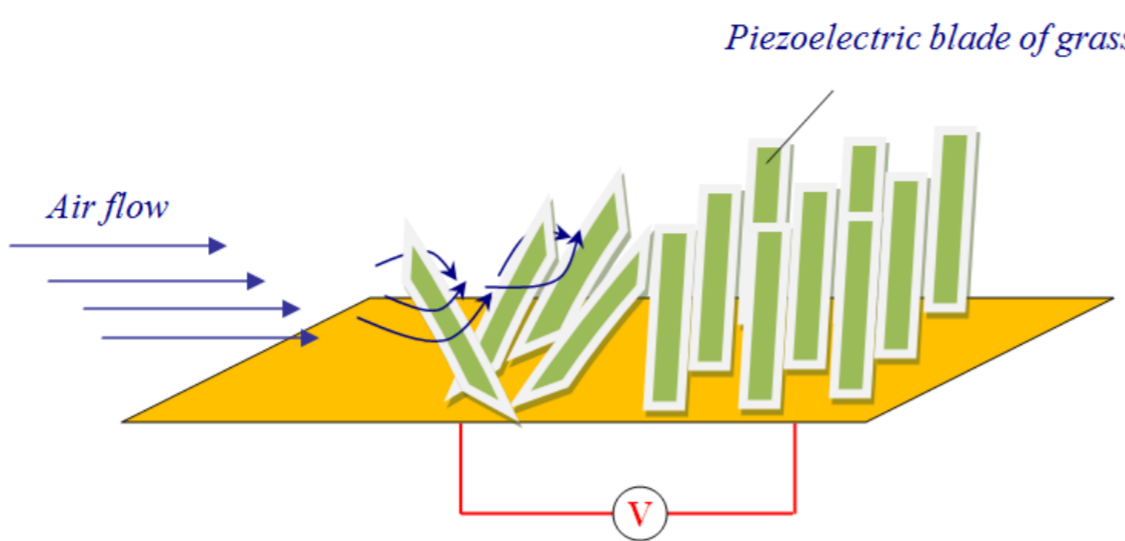
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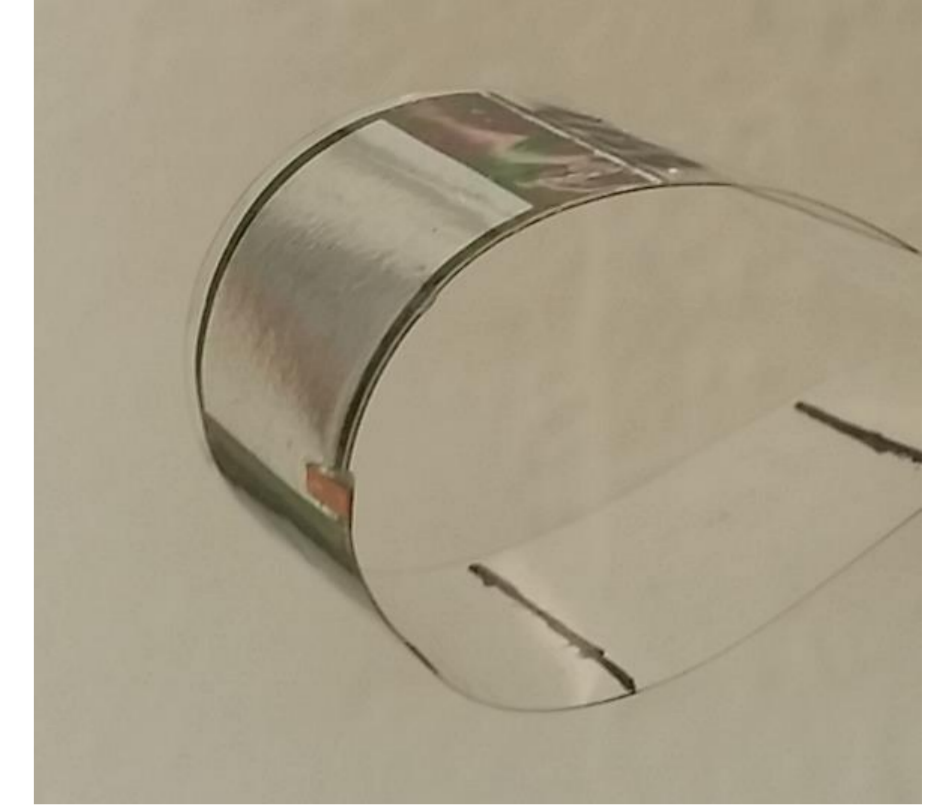
## N-air-J and MIGAC projects

- Aim:** Synthetic blade of grass to convert wind energy into electricity
- Solution:** Use of flexible piezoelectric thin films
- Support:** Financial support provided by the french region Pays de la Loire and RFI WISE



## Others applications

- Energy harvesting from other ambient energy sources (wave energy, body motion)
- Smart sensors (biomedical, buildings, health care, IOT, smart cities)
- Actuators showing high displacements (centimeter range)



## Flexible piezoelectric thin films

### Lead zirconate titanate (PZT) films



PZT on Aluminium



PZT on PET

**Fabrication process easily transferable to industry**

low cost: 280 €/m<sup>2</sup>

0.5 cm × 4 cm beam = 5.6 cents

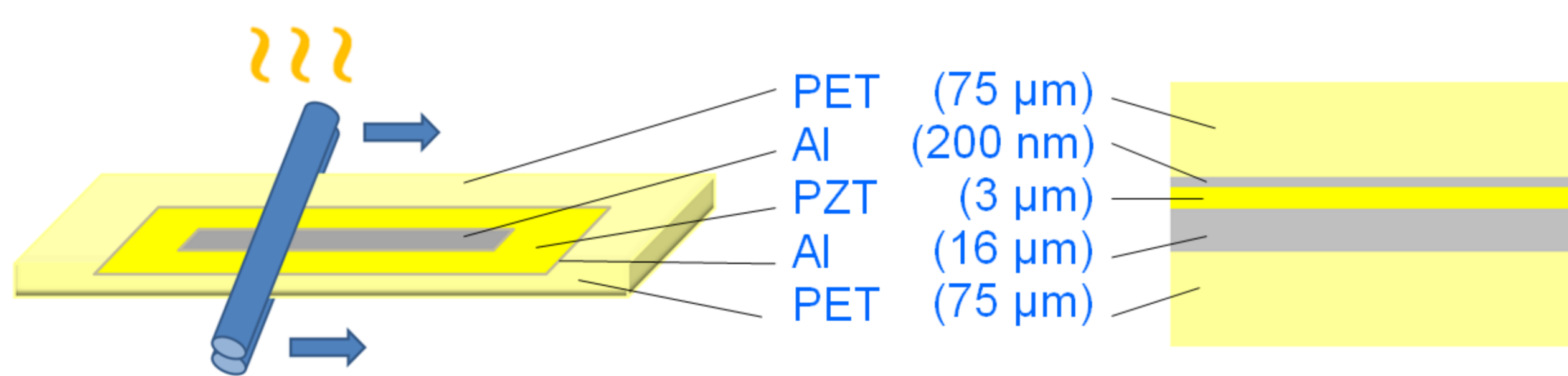


Cut able



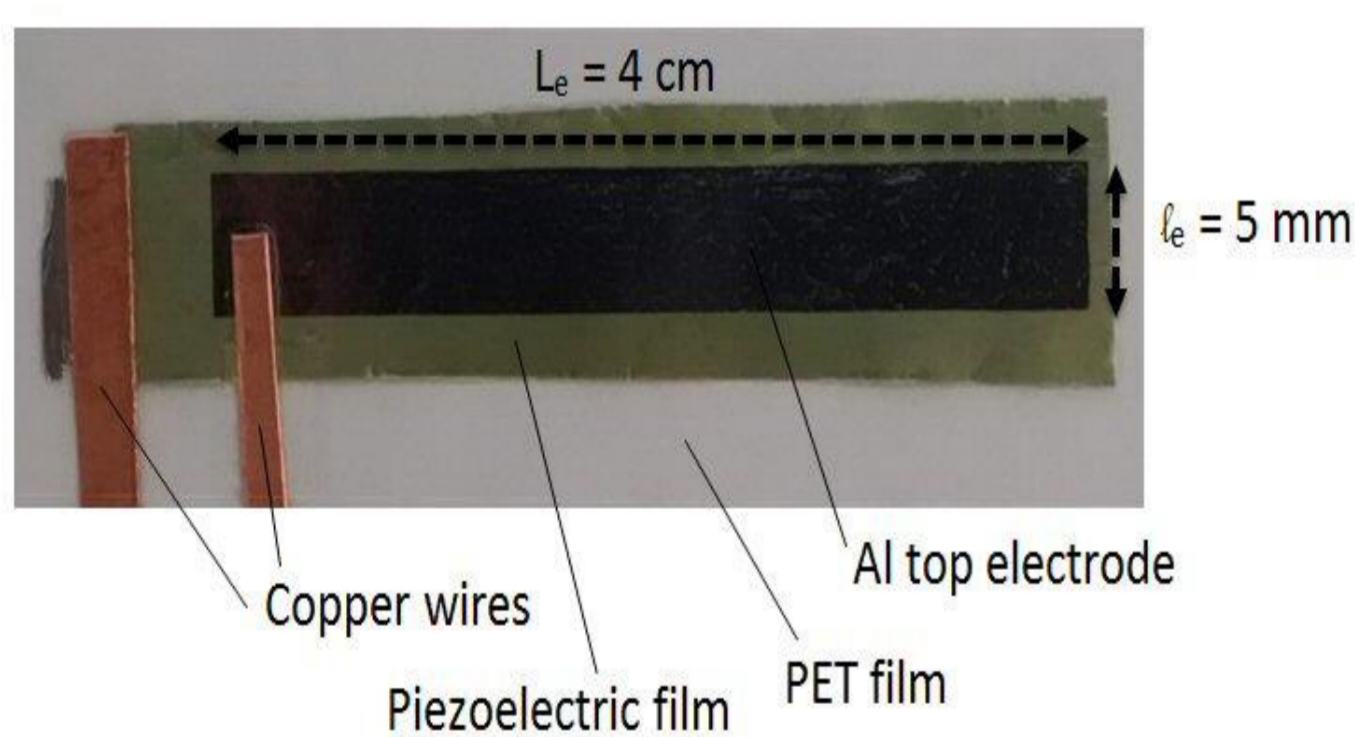
3D shape

**Non conventional shapes**



Preparation of the composite by lamination of the PET

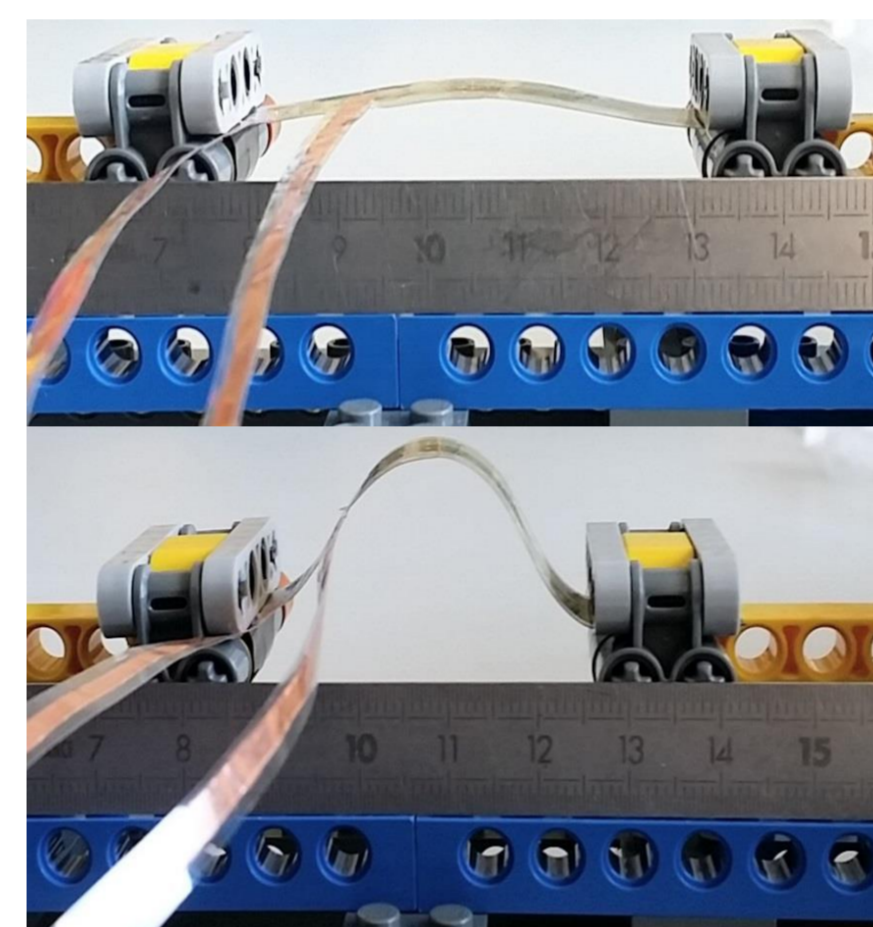
Sectional view of the composite



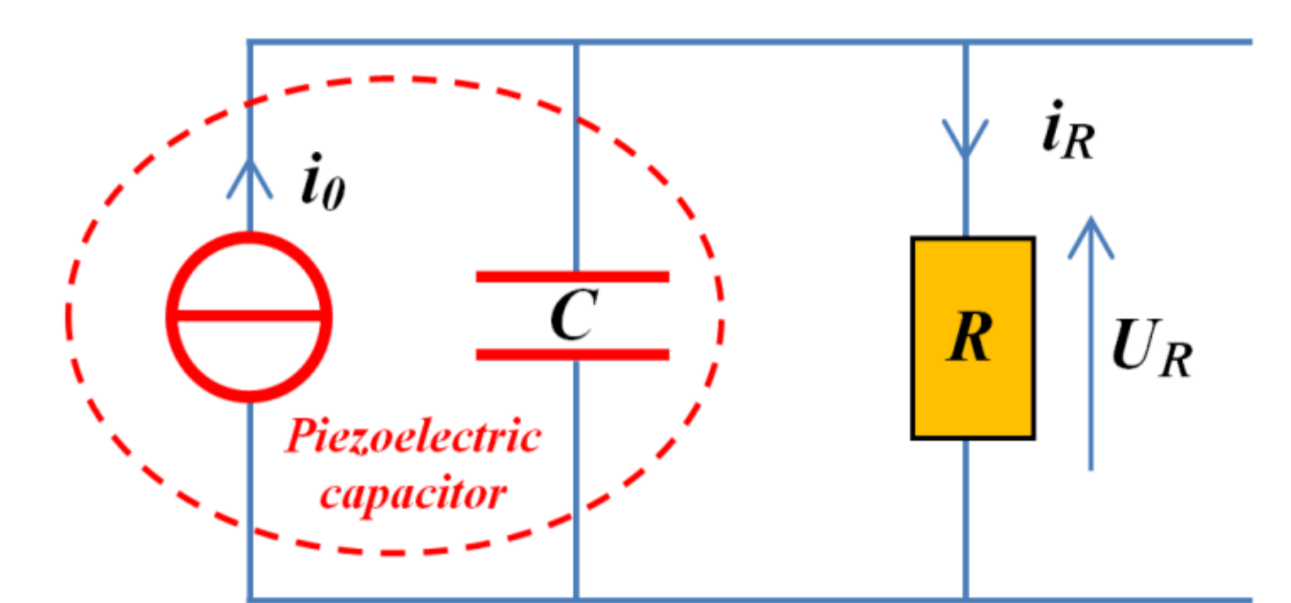
**Flexible and watertight**

## Energy harvesting

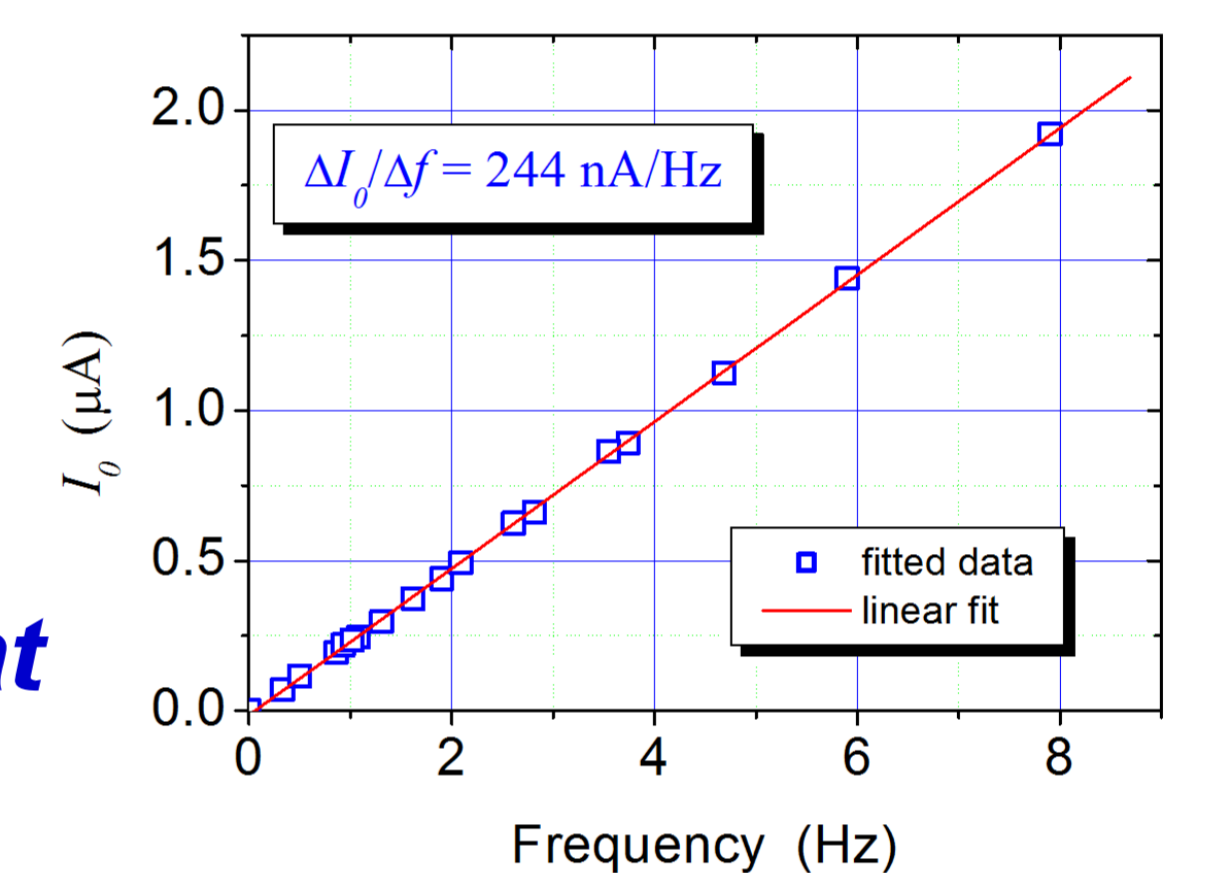
### Mechanical excitation of the piezoelectric blade



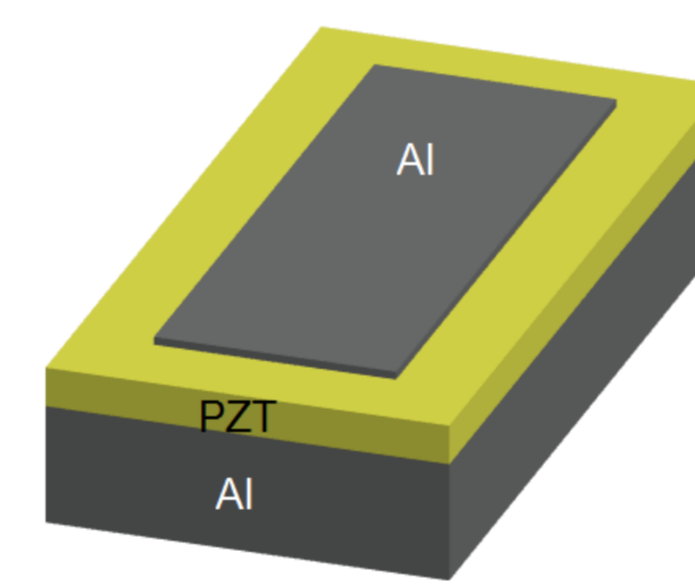
Scheme of the equivalent circuit of the energy harvesting device :



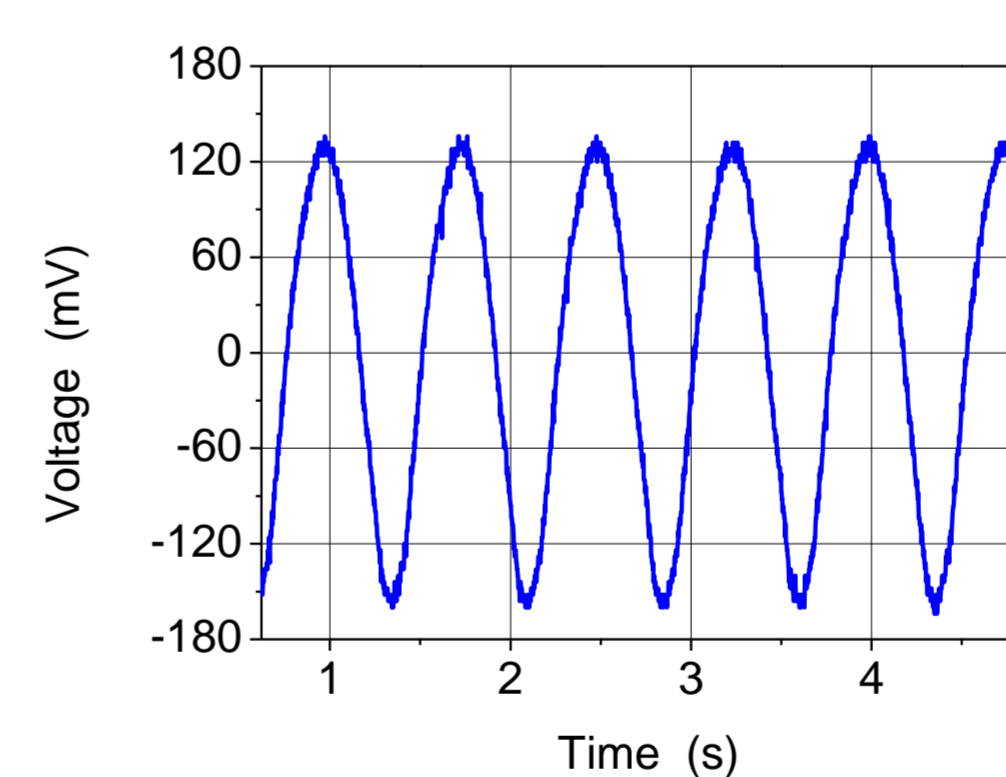
### Piezoelectric current



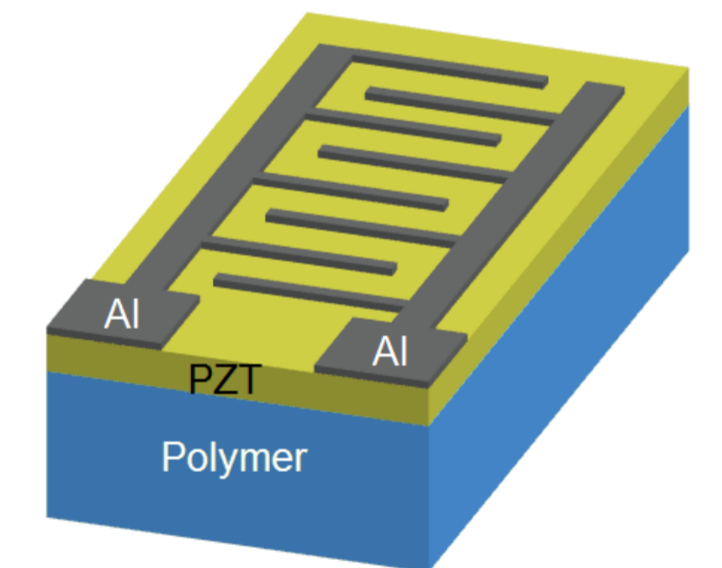
**Harvesting device working at very low frequencies**



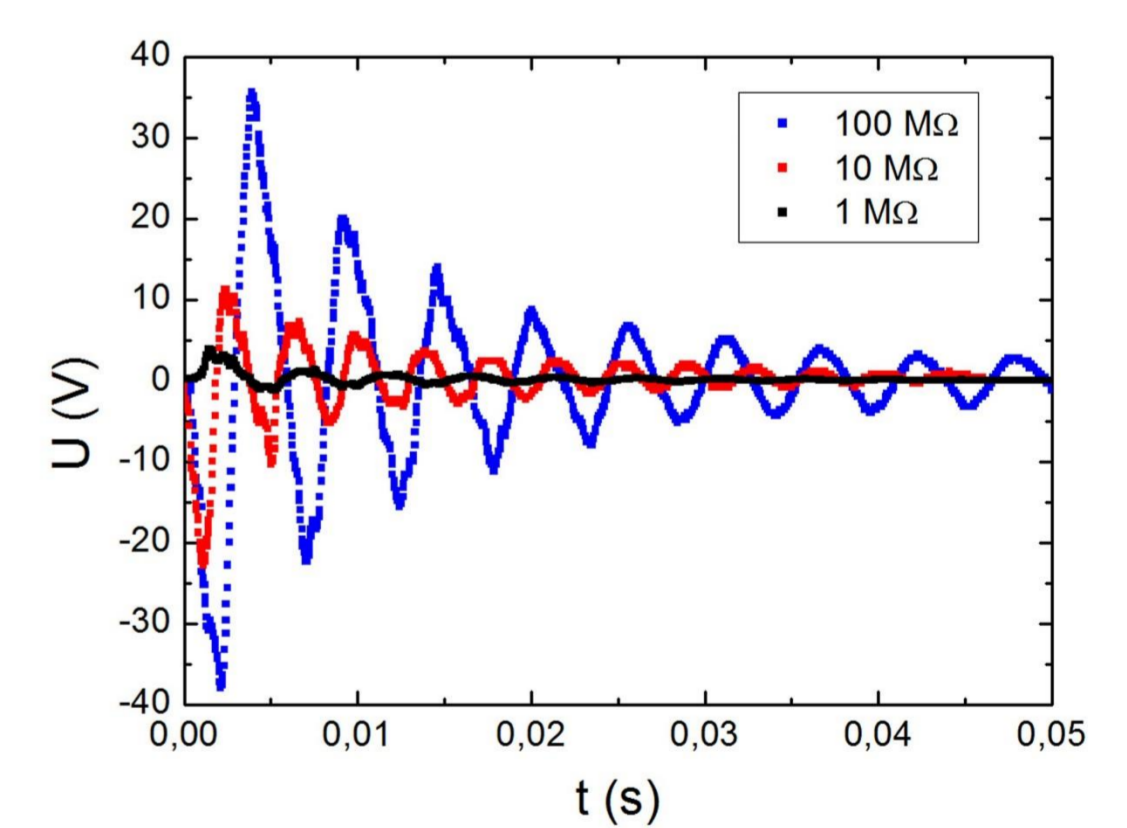
MIM structure



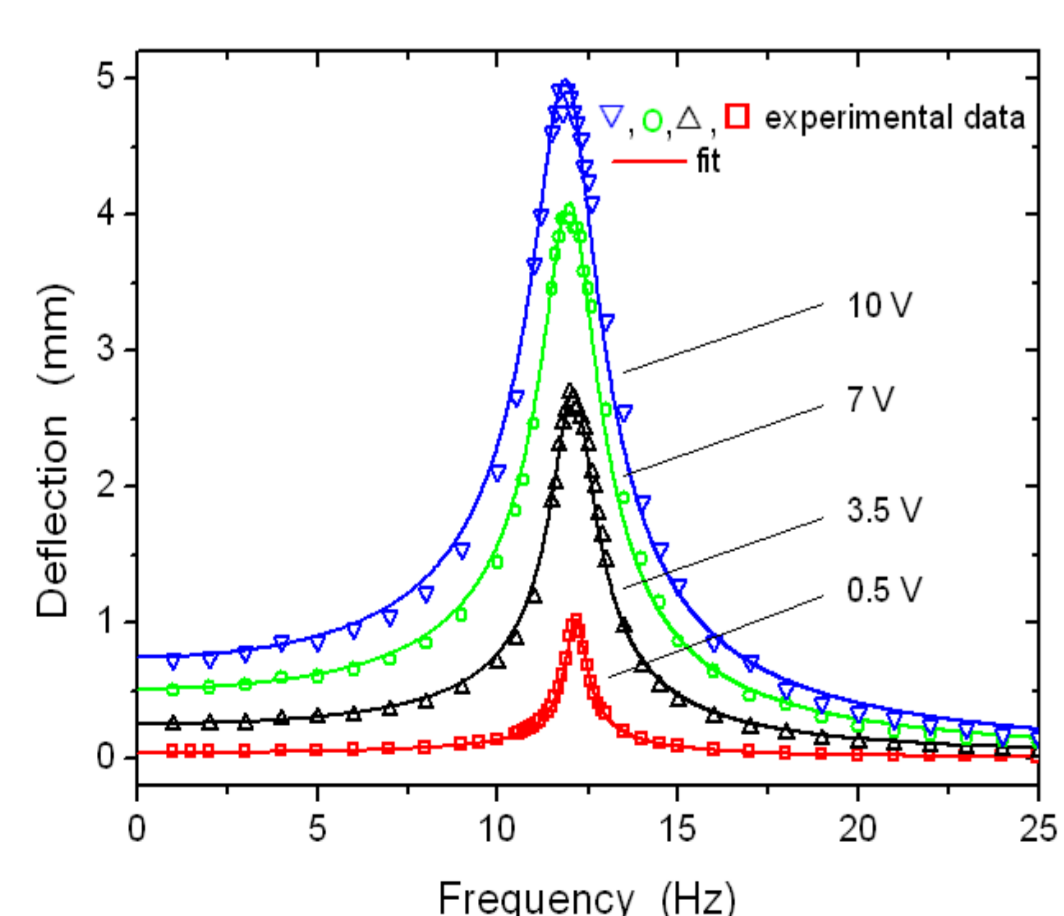
Output voltage X 100



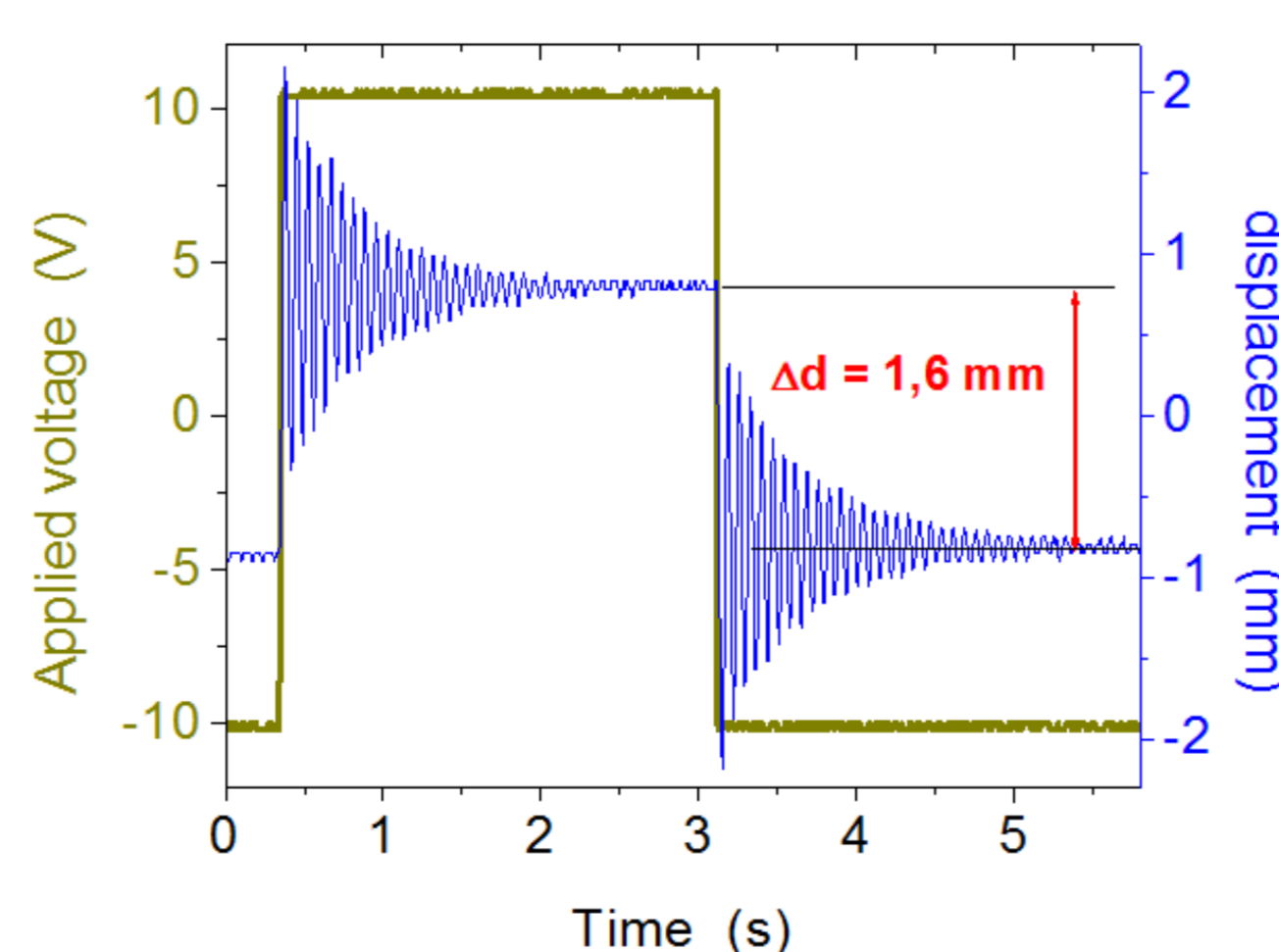
IDE structure



## High bending mode actuation properties



Sinusoidal electrical excitations



ON/OFF " mode

**milimetric deflections at low applied voltages**

## Flexoelectric polymers for large curvature sensing

**Flexoelectricity:** Mechanical-to-electrical coupling between strain gradient (curvature) and electrical polarization  $P_{flex}$  in every solid dielectrics → Flexoelectric effect in soft polymer films may be used for the development of low cost and easy to implement elastomer-based large curvature sensors on highly flexible metallic structures

Strain gradient

Curvature

$$P_{flex} = \mu \left( \frac{\partial S}{\partial x} \right) = \mu C$$

Flexoelectric coefficient  $\mu$



Polyurethane (PU) film

PU thin films ( $e = 6$  μm) deposited onto Al foil /PET flexible cantilever → direct sensing of large curvature ( $80$  m<sup>-1</sup>) = radius of curvature (~ 1 cm)

