



**HAL**  
open science

## Ferroelectrics for multi-energy harvesting

Matthieu Fricaudet, Maja Koblar, Katarina Žiberna, Samir Salmanov, Sharath Kattemanne Chandrashekar, Delong He, Jens Kreisel, Brahim Dkhil, Tadej Rojac, Mojca Otoničar, et al.

► **To cite this version:**

Matthieu Fricaudet, Maja Koblar, Katarina Žiberna, Samir Salmanov, Sharath Kattemanne Chandrashekar, et al.. Ferroelectrics for multi-energy harvesting. International Symposium on Applications of Ferroelectrics (ISAF), Jun 2022, Tours, France. hal-04089992

**HAL Id: hal-04089992**

**<https://centralesupelec.hal.science/hal-04089992>**

Submitted on 5 May 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



## Context/Introduction

### Available energy in the environment

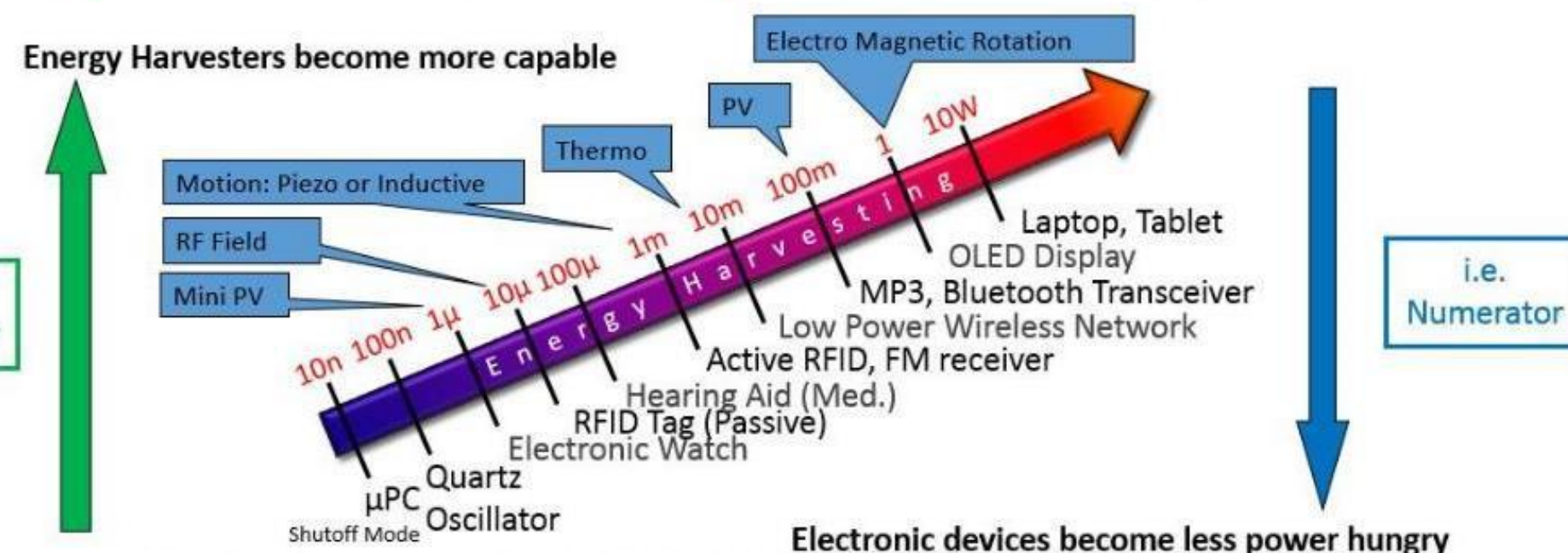


A lot of free energy is available in the environment:

- Wind
- Water flows
- Body heat
- Exhaust heat and vibrations
- Light
- Human movements
- Human and animal heat

### Power generation and consumption<sup>1</sup>

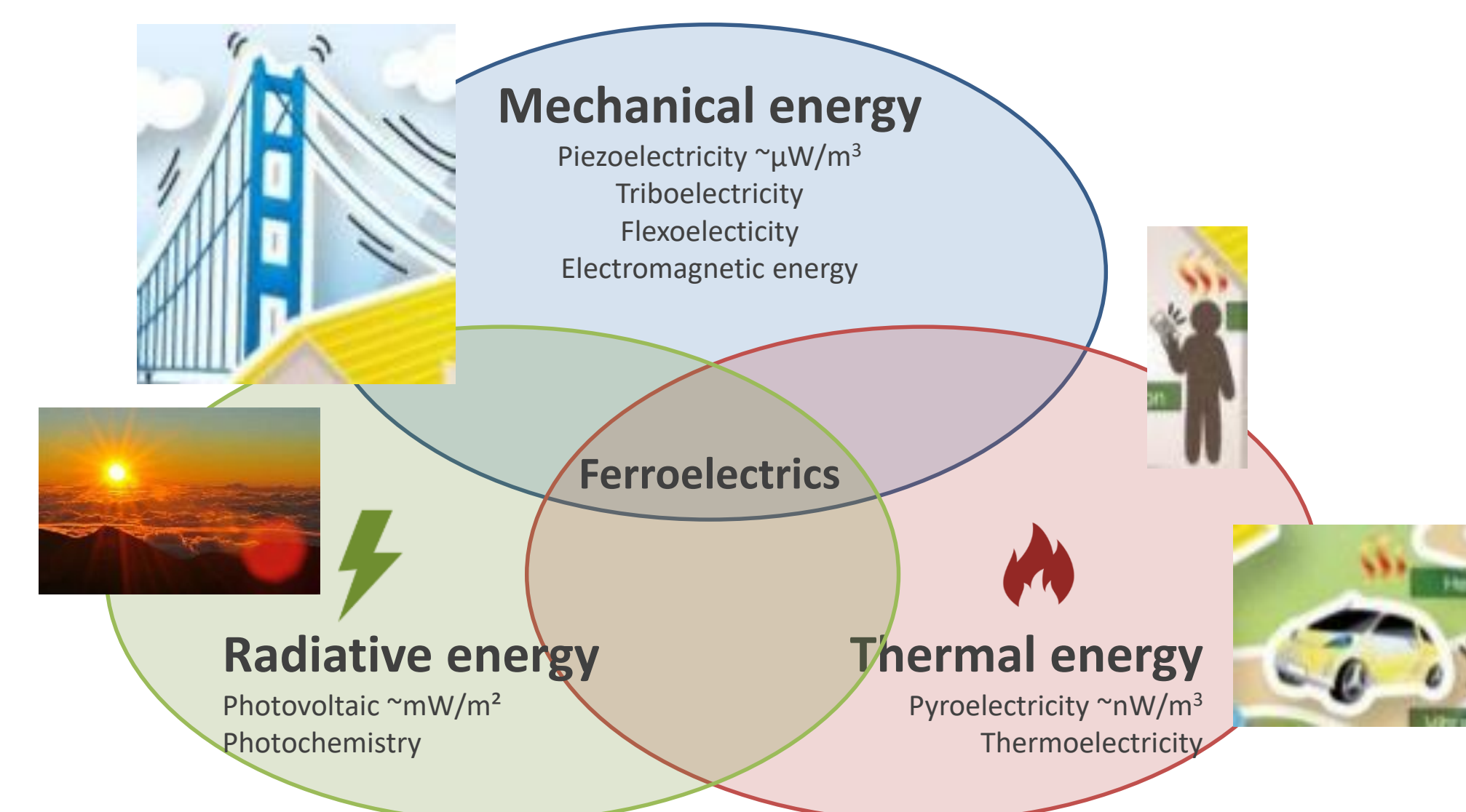
- Typical Energy Harvester Output Power
  - ▶ RF: 0.1μW/cm<sup>2</sup>
  - ▶ Vibration: 1nW/cm<sup>2</sup>
  - ▶ Thermal: 10mW/cm<sup>2</sup>
  - ▶ Photovoltaic: 100mW/cm<sup>2</sup>
- Typical Energy Harvester Voltages
  - ▶ RF: 0.01mV
  - ▶ Vibration: 0.1~0.4 V
  - ▶ Thermal: 0.02~1.0 V
  - ▶ Photovoltaic: 0.5~0.7 V typ./cell



Energy consumption of sensors and small actuators are now in the same range as the energy available through energy harvesting methods.

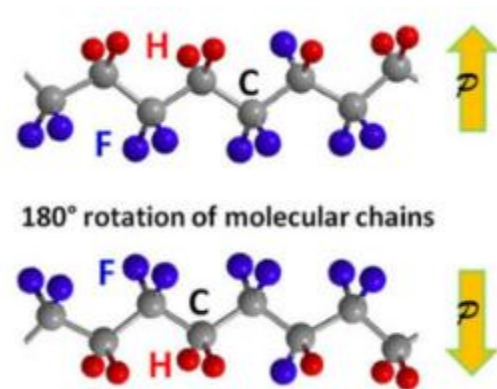
## Interest of ferroelectrics

### Energy conversion methods



## PVDF-based polymers<sup>2</sup>

Polymer -CH<sub>2</sub>-CF<sub>2</sub>- (PVDF)

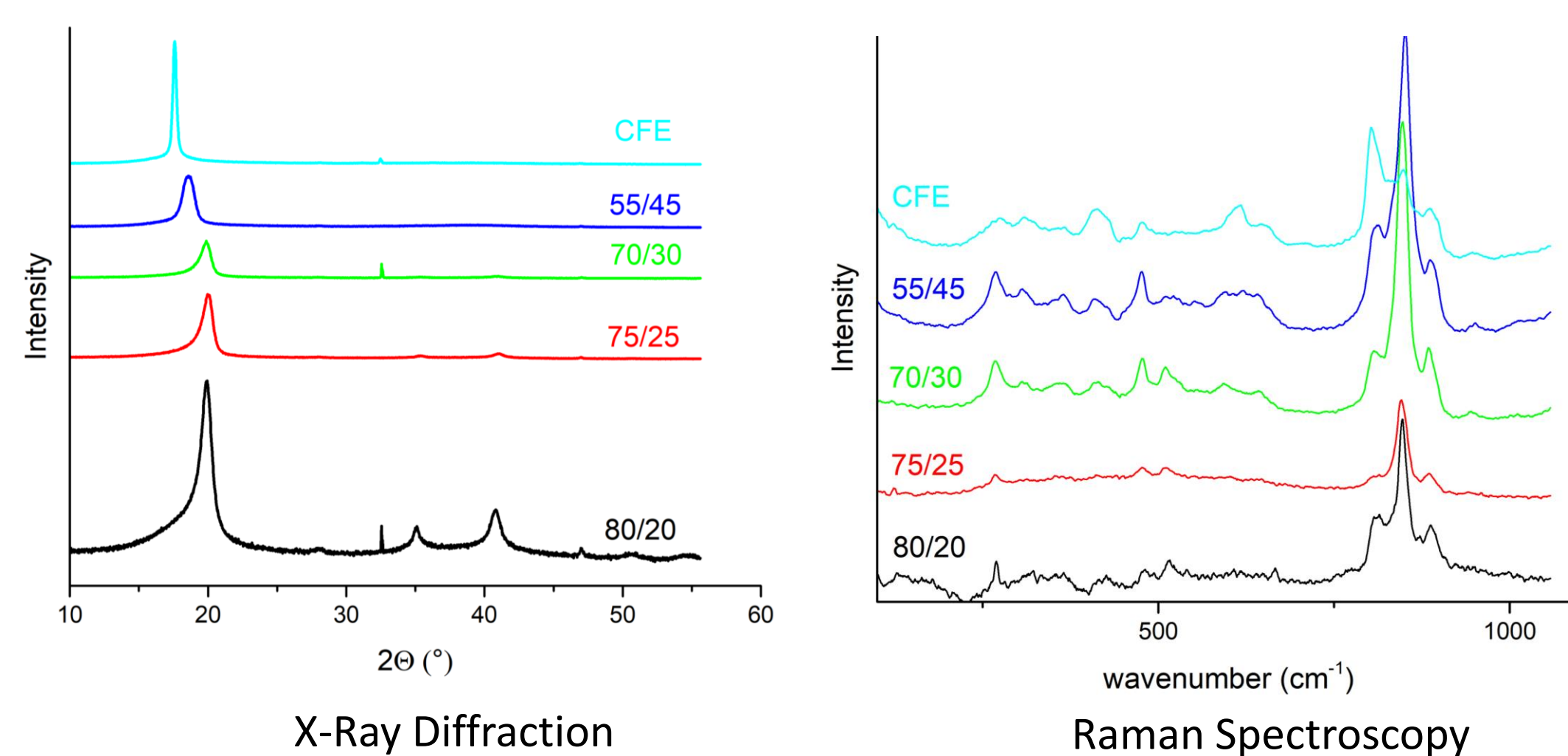


### Compositions

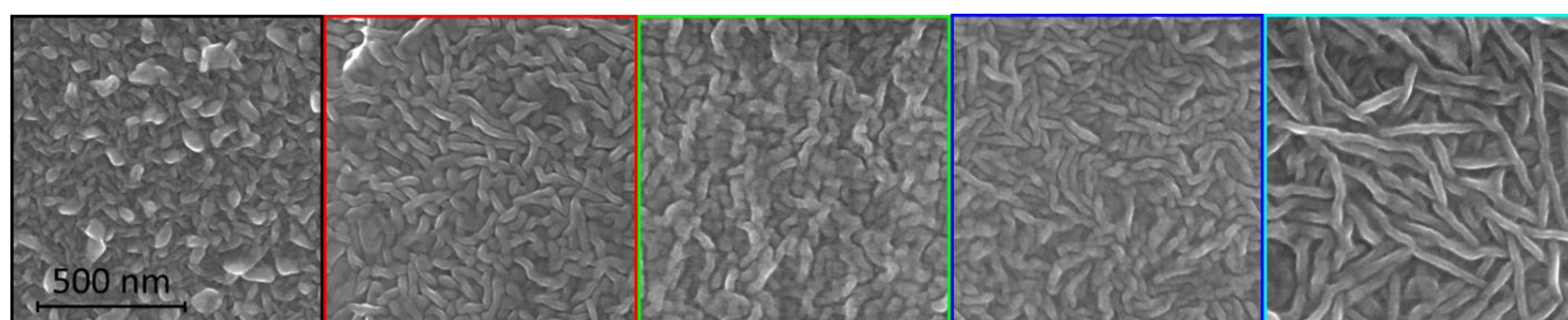
Notation	VDF (wt %)	TrFE (wt %)	CFE (wt %)
80/20	79.6	20.4	/
75/25	75.1	24.9	/
70/30	70	30	/
55/45	54.5	45.5	/
CFE	64.6	26.2	9.2

Poly(Vinylidene Fluoride): PVDF  
TriFluoroEthylene: TrFE  
1,1-ChloroFluoroEthylene: CFE

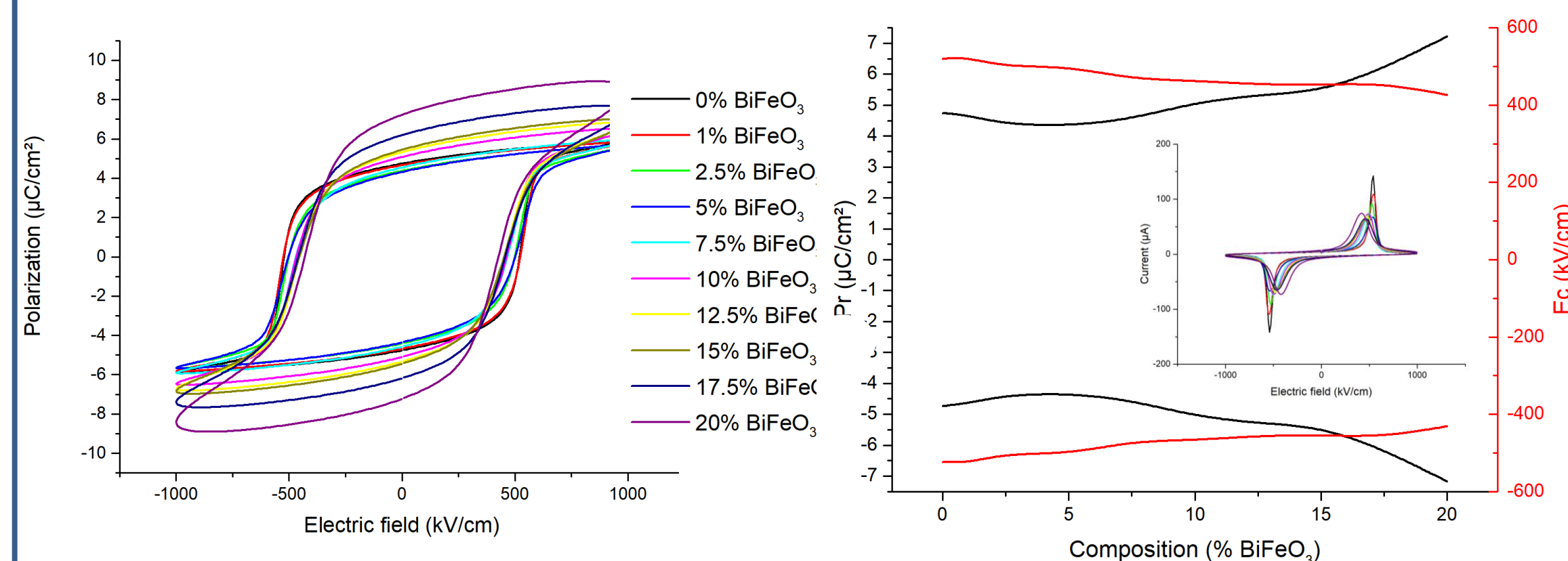
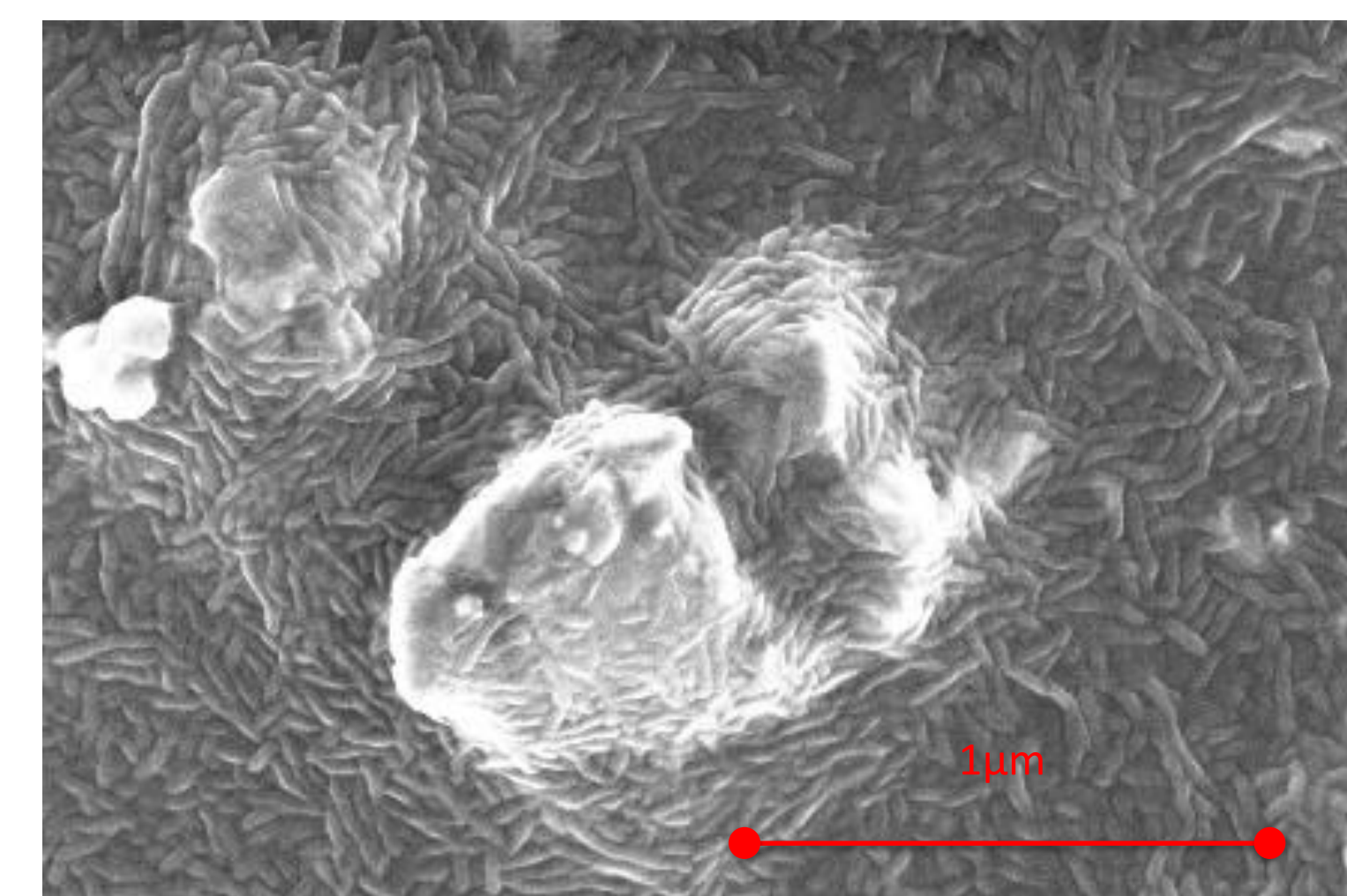
### Structure and microstructure



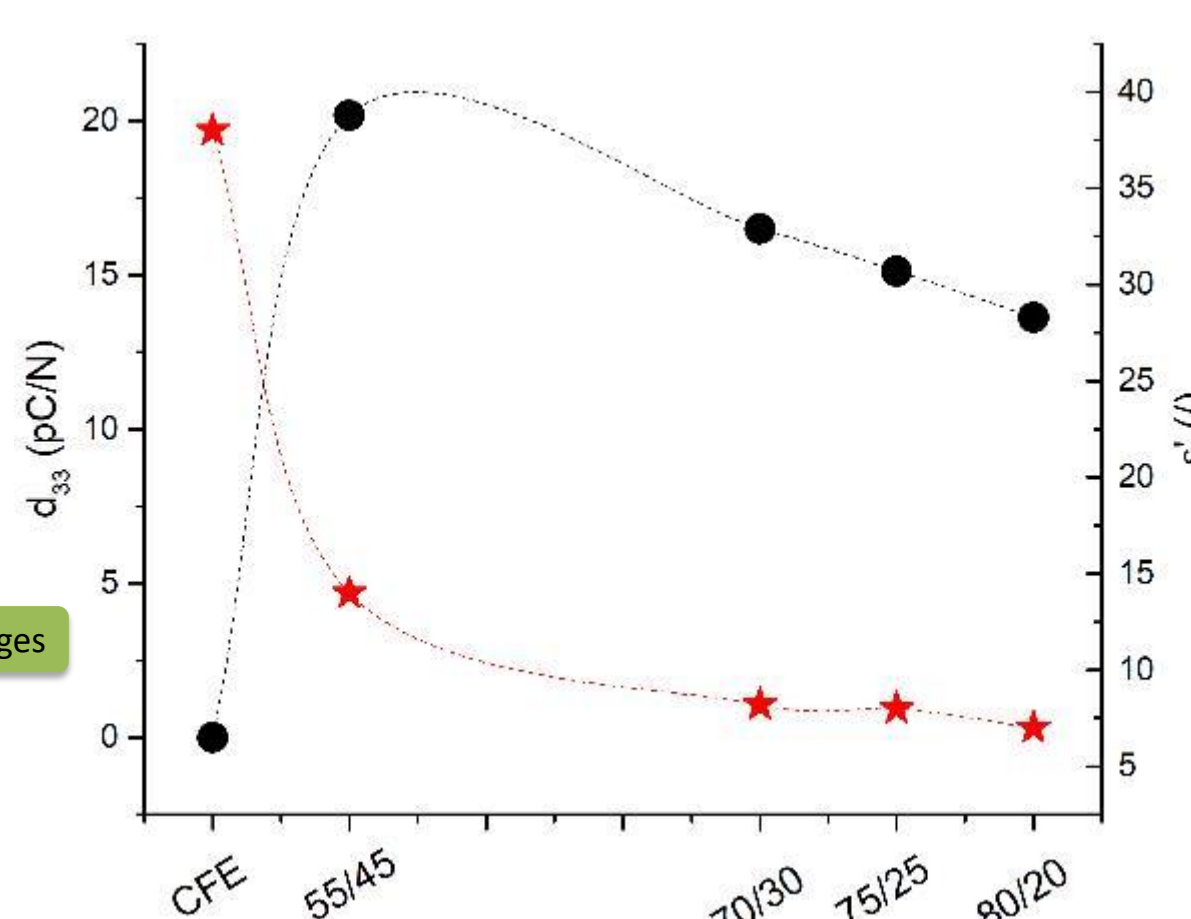
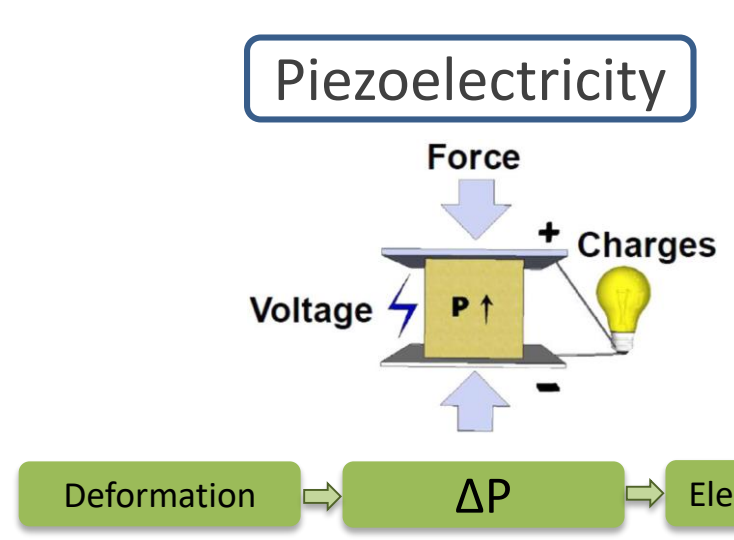
### Scanning Electron Microscopy



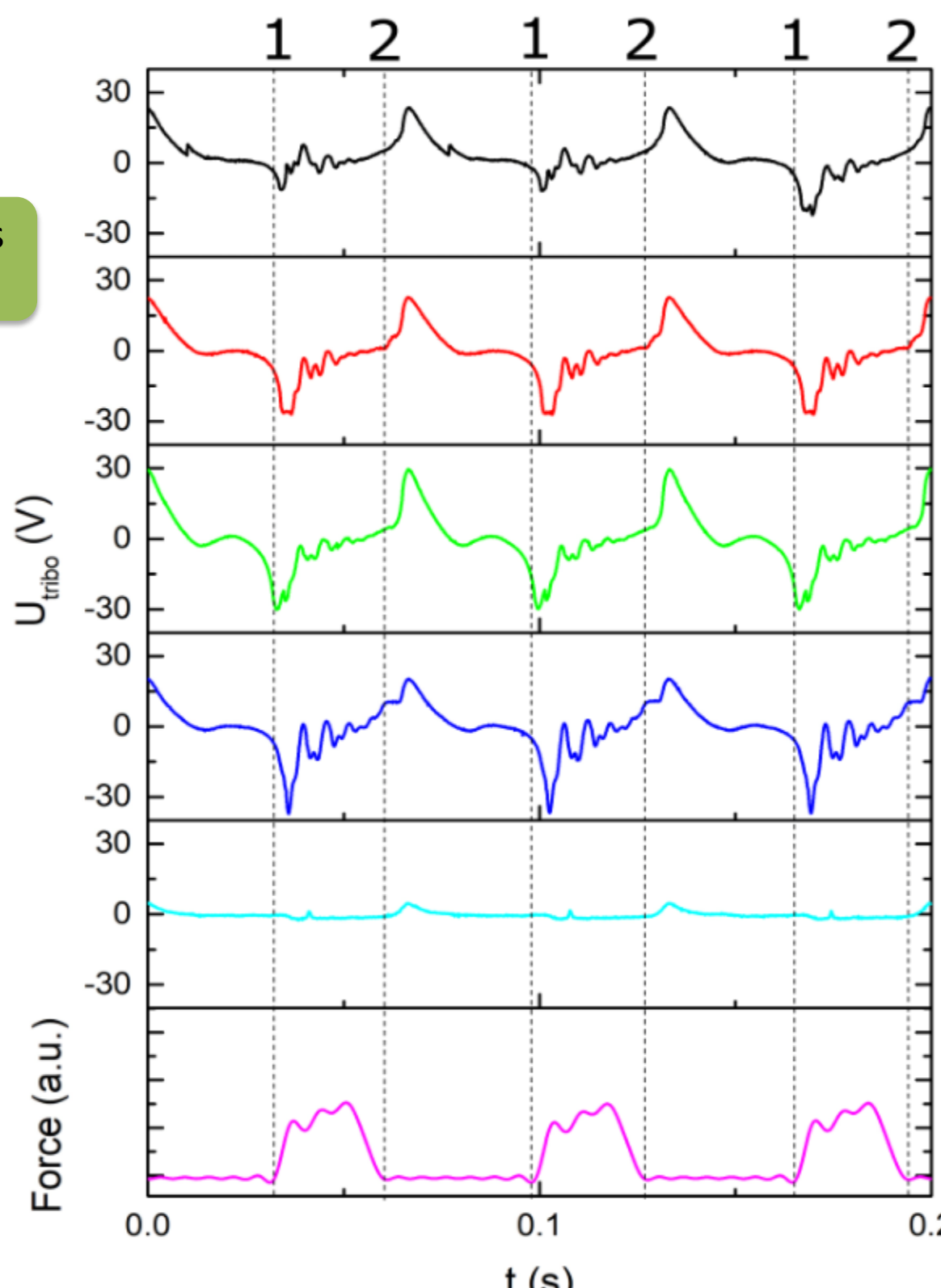
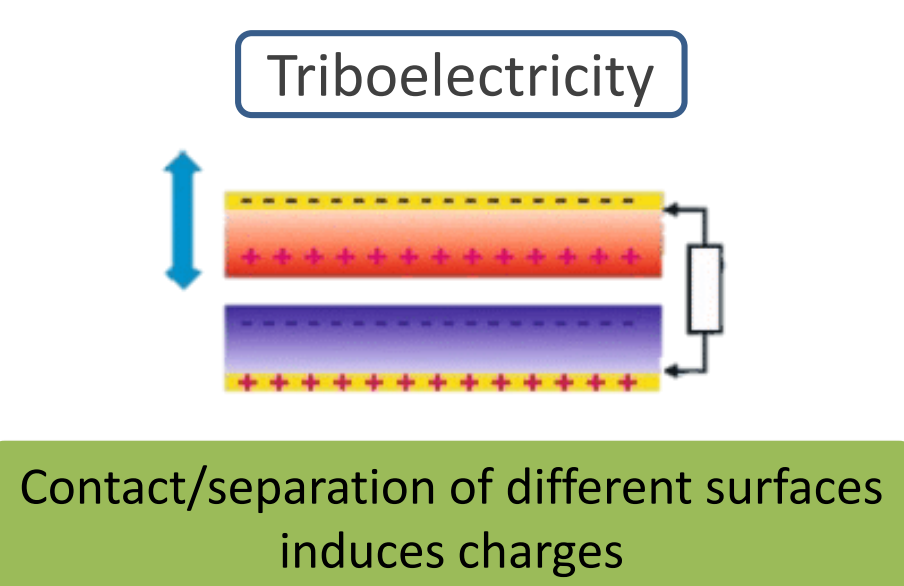
## PVDF-TrFE/BiFeO<sub>3</sub> composites<sup>3</sup>



### Piezoelectric response

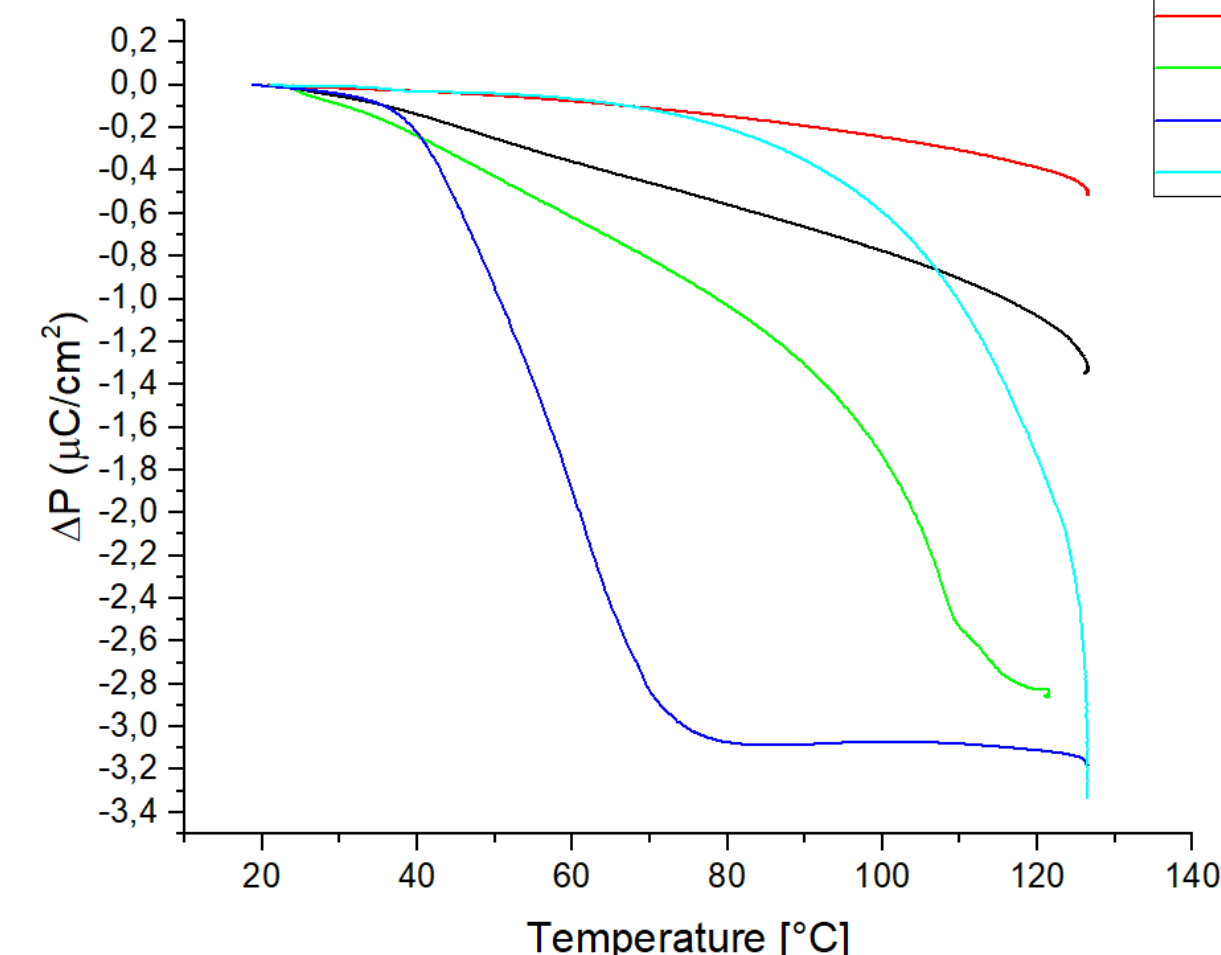
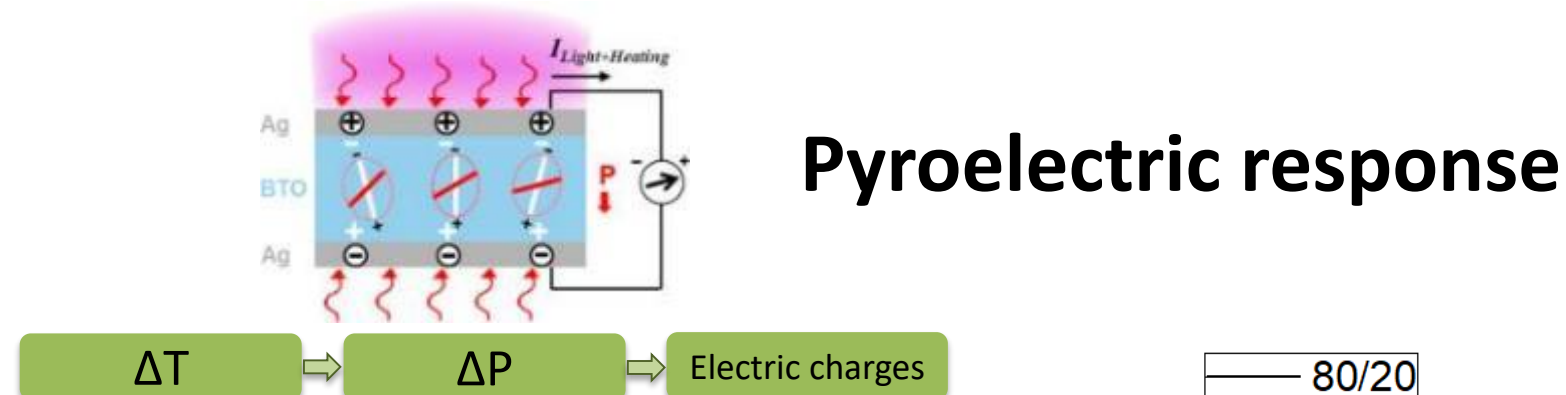


### Triboelectric response

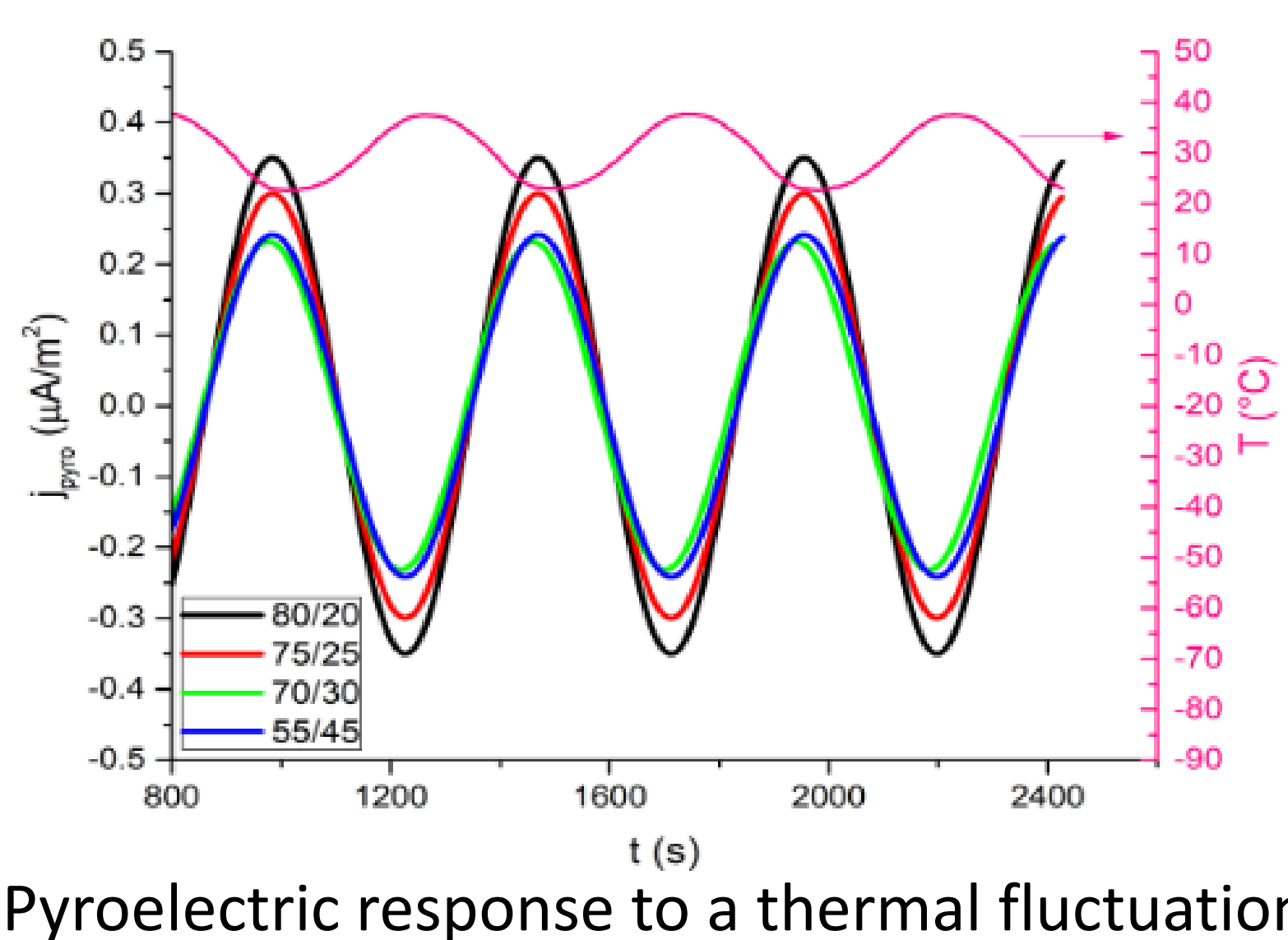


Triboelectrically induced signal excited in contact-separation mode.

### Pyroelectricity

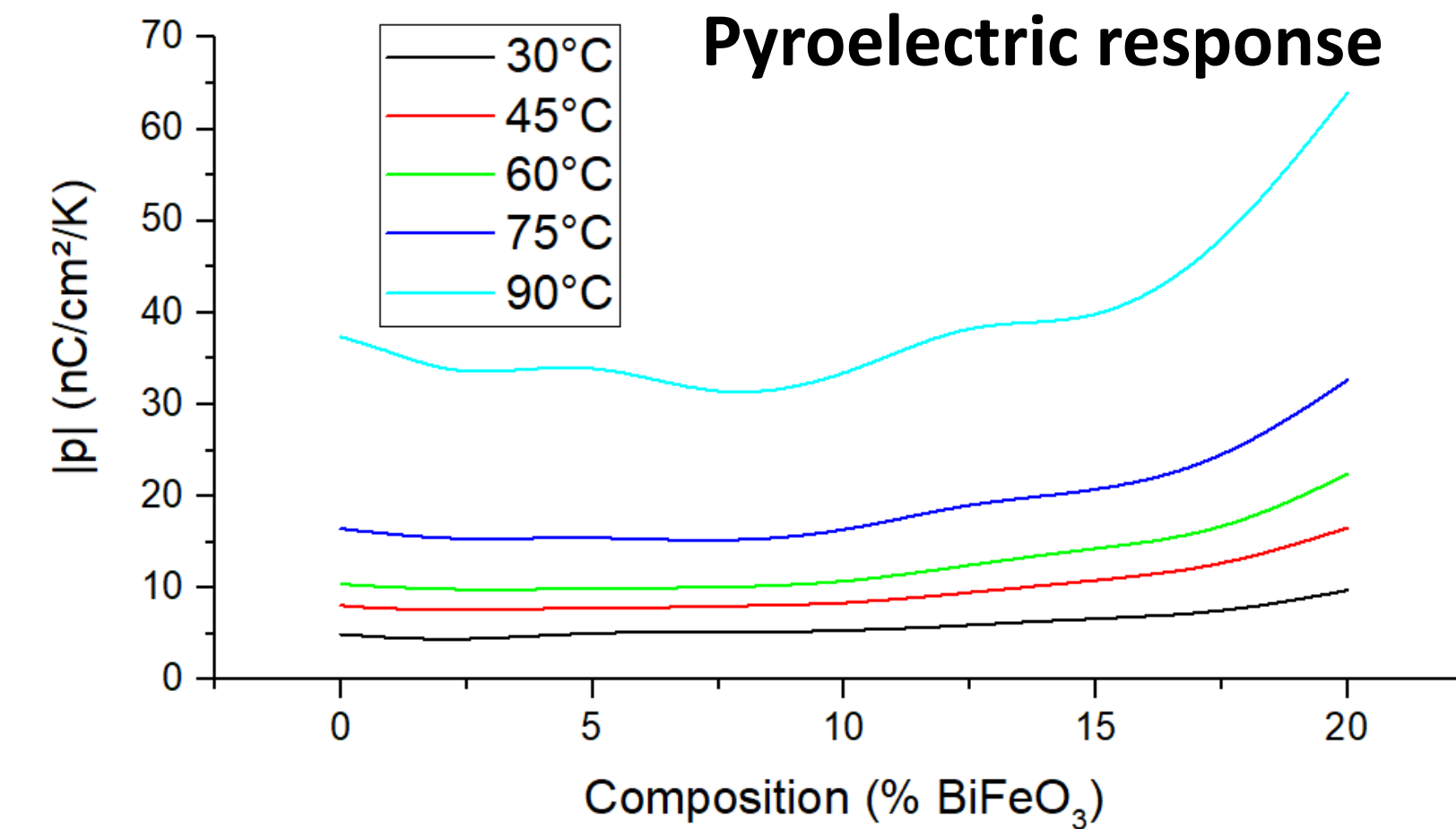


### Temperature dependence of polarization

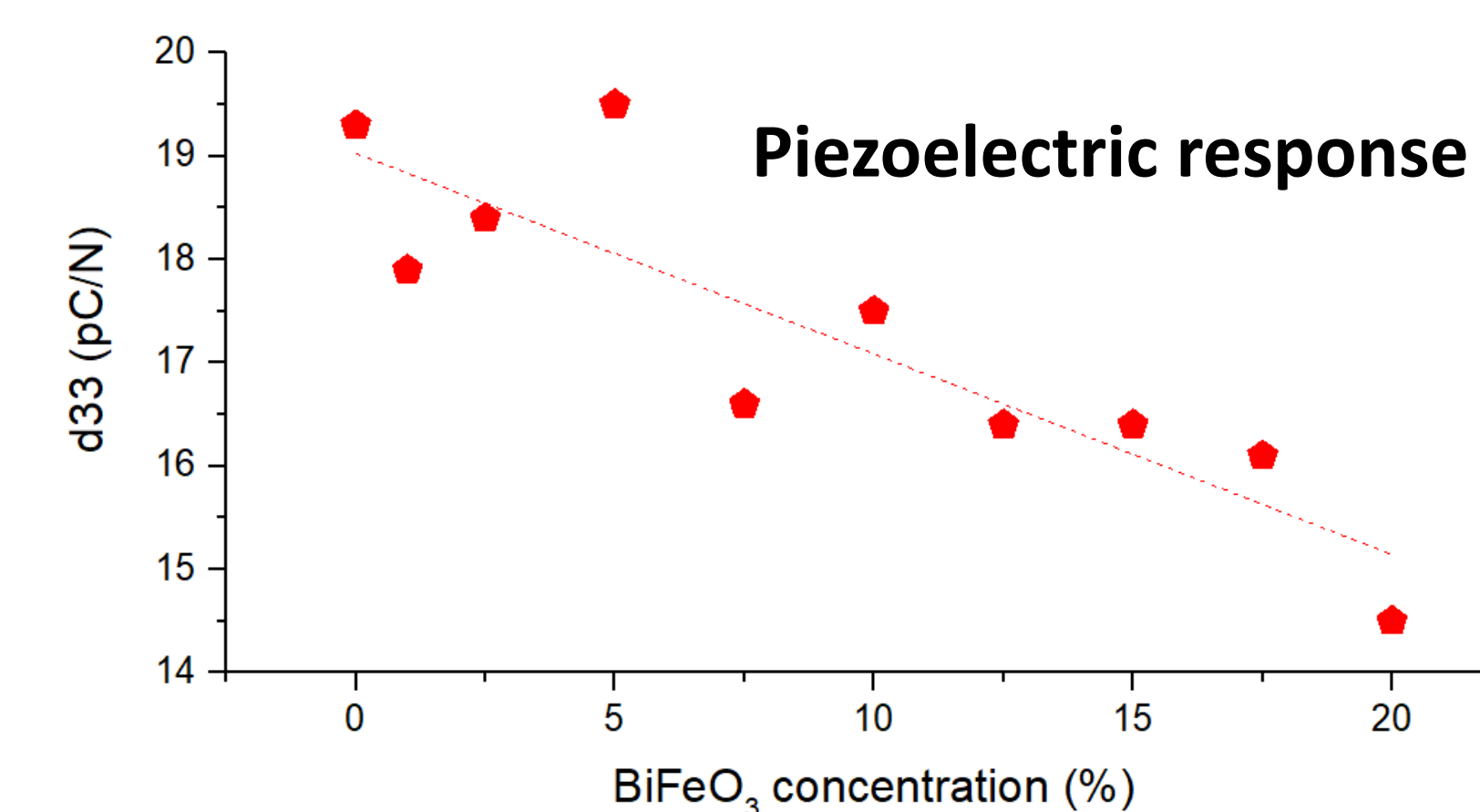


Pyroelectric response to a thermal fluctuations

### Pyroelectric response



### Piezoelectric response



## Work in progress

- We have identified at least three ways we can use sequentially or simultaneously to harvest energy with ferroelectrics: **piezoelectricity, pyroelectricity and triboelectricity.**
- We have fabricated various systems (PVDF-based polymers, oxide-polymer-based composites, etc.) and studied their **functional properties.**

## References

- [1] M. Hayes, "Synergies between energy harvesting and power electronics, Tyndall National Institute, IEEE PELS Young professionals webinar, Oct. 20, 2016
- [2] M. Fricaudet et al., submitted
- [3] M. Fricaudet et al., to be published