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UV-A TREATMENT OF P(VDF-TRFE-CFE): A ROUTE TO EFFICIENT SOLID-STATE COOLING SOLUTIONS

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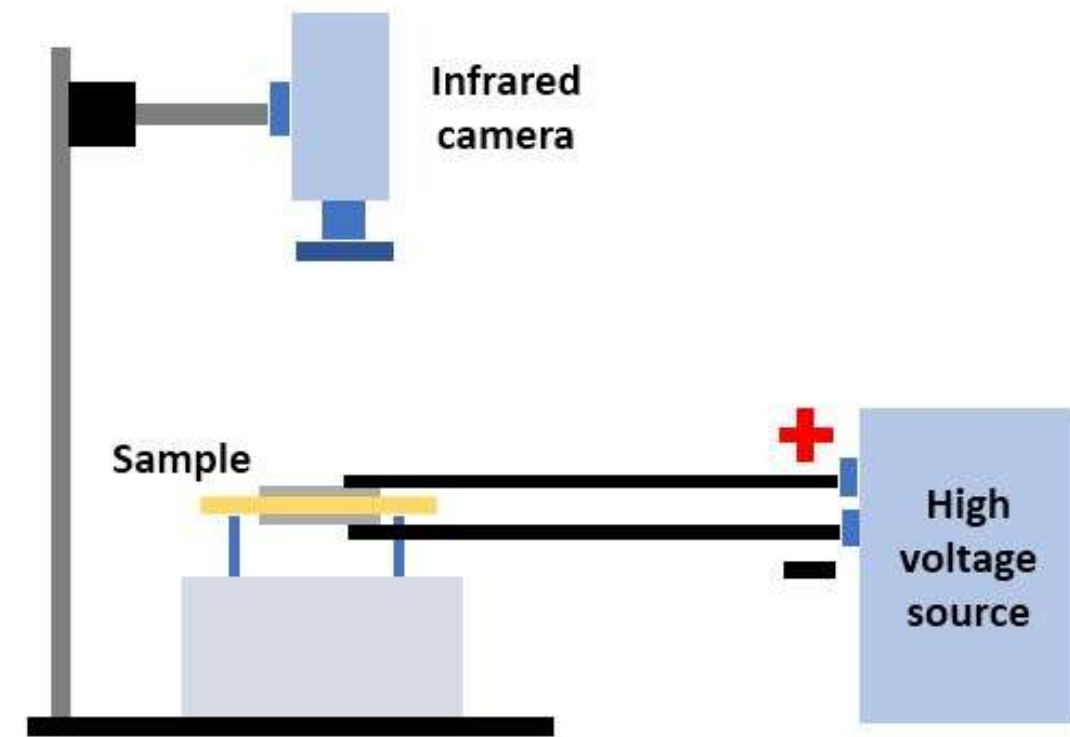
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Abstract

Electrocaloric (EC) materials are gaining significant attention as eco-friendly alternatives to traditional gas refrigerants in next-generation cooling technologies due to their outstanding caloric properties and compact design [1]. The EC effect, which is characterized by isothermal entropy change (ΔS) and adiabatic temperature change (ΔT_{adia}) under an applied electric field, has already been demonstrated in several cooling devices [2]. Among the promising candidates, the P(VDF-TrFE-CFE) terpolymer stands out for its large ΔT_{adia} and ease of processing into thin films via solvent casting. However, solvent-cast films typically exhibit insufficient EC responses (1.5°C at $50\text{ V}/\mu\text{m}$) and high dielectric losses, limiting their potential in practical applications [3]. In this work, we present a straightforward post-processing method using low-energy UV-A irradiation to enhance the EC effect and minimize dielectric losses in P(VDF-TrFE-CFE) films. After irradiation, the material exhibits new functional groups, thicker crystalline lamellae, and a denser structure. X-ray diffraction under an electric field reveals the appearance of a defective ferroelectric phase alongside the ferroelectric (FE) phase, with the latter occurring at a lower electric field post-irradiation, indicating that UV-induced modifications favor the polar phase. These changes result in a significant improvement in EC performance, with an increase in ΔT_{adia} from 1.76°C to 2.88°C at $60\text{ V}/\mu\text{m}$ and reduced dielectric losses. This work highlights a simple yet effective strategy to enhance the performance of P(VDF-TrFE-CFE) terpolymer films, making them more suitable for solid-state refrigeration applications[4].

Setup for ECE measurement

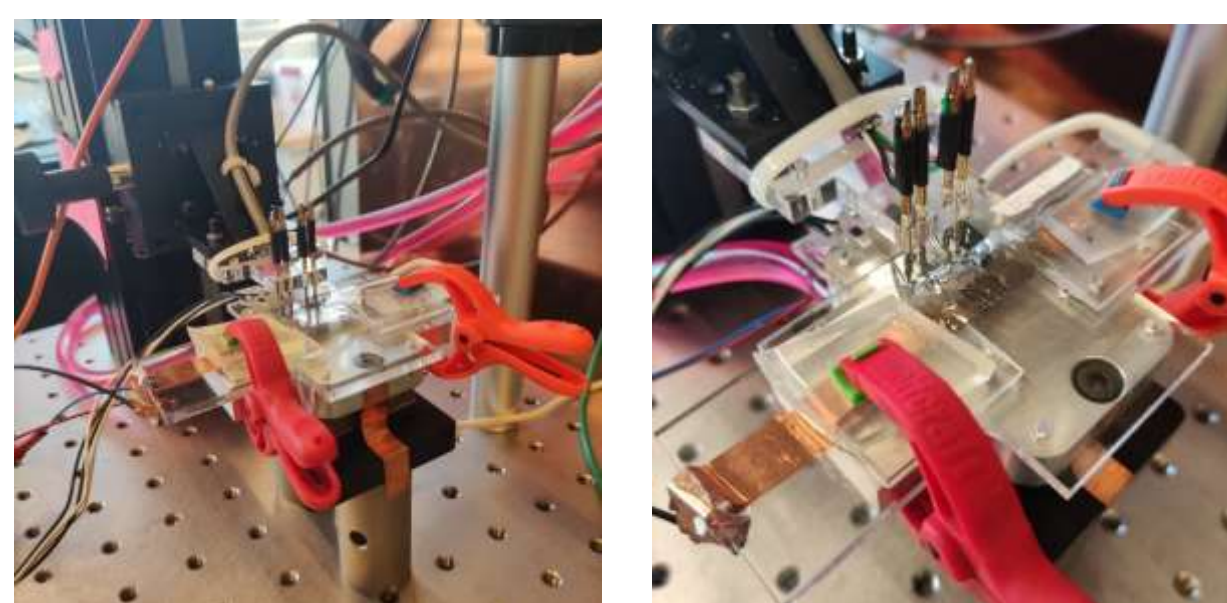
Direct temperature measurement by infrared technique



Why this technique is not easy perform ?

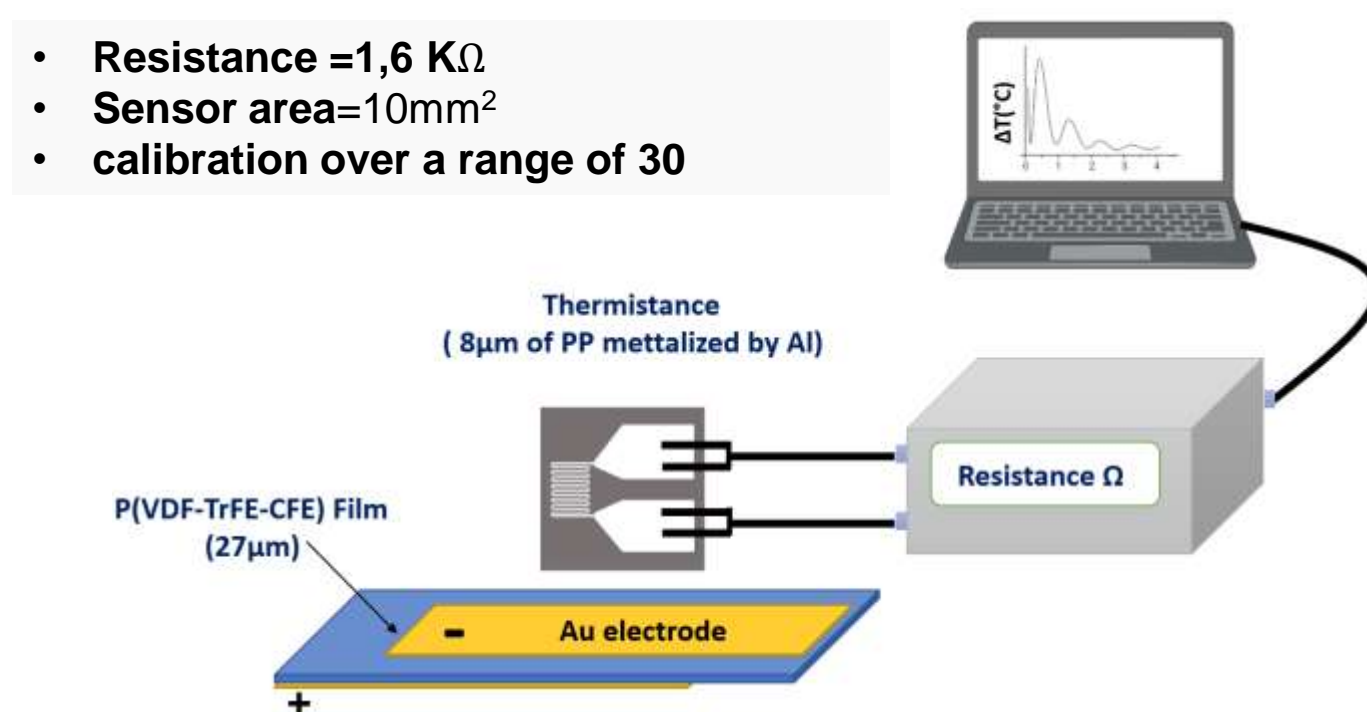
- Emissivity based technique which strongly depend on surface conditions
- Heat exchange with environnement must be limited and this can be done only by applying rapid variation of Electric field

Setup for ECE measurement



Thermistance for measuring the EC effect

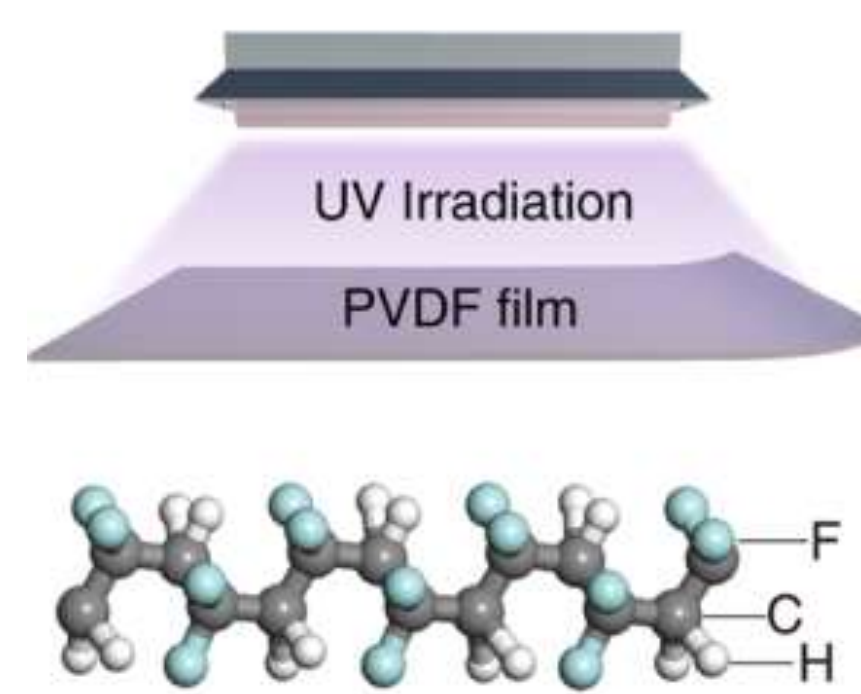
- Resistance = $1,6\text{ K}\Omega$
- Sensor area = 10mm^2
- calibration over a range of 30



Enhancement of electrocaloric properties

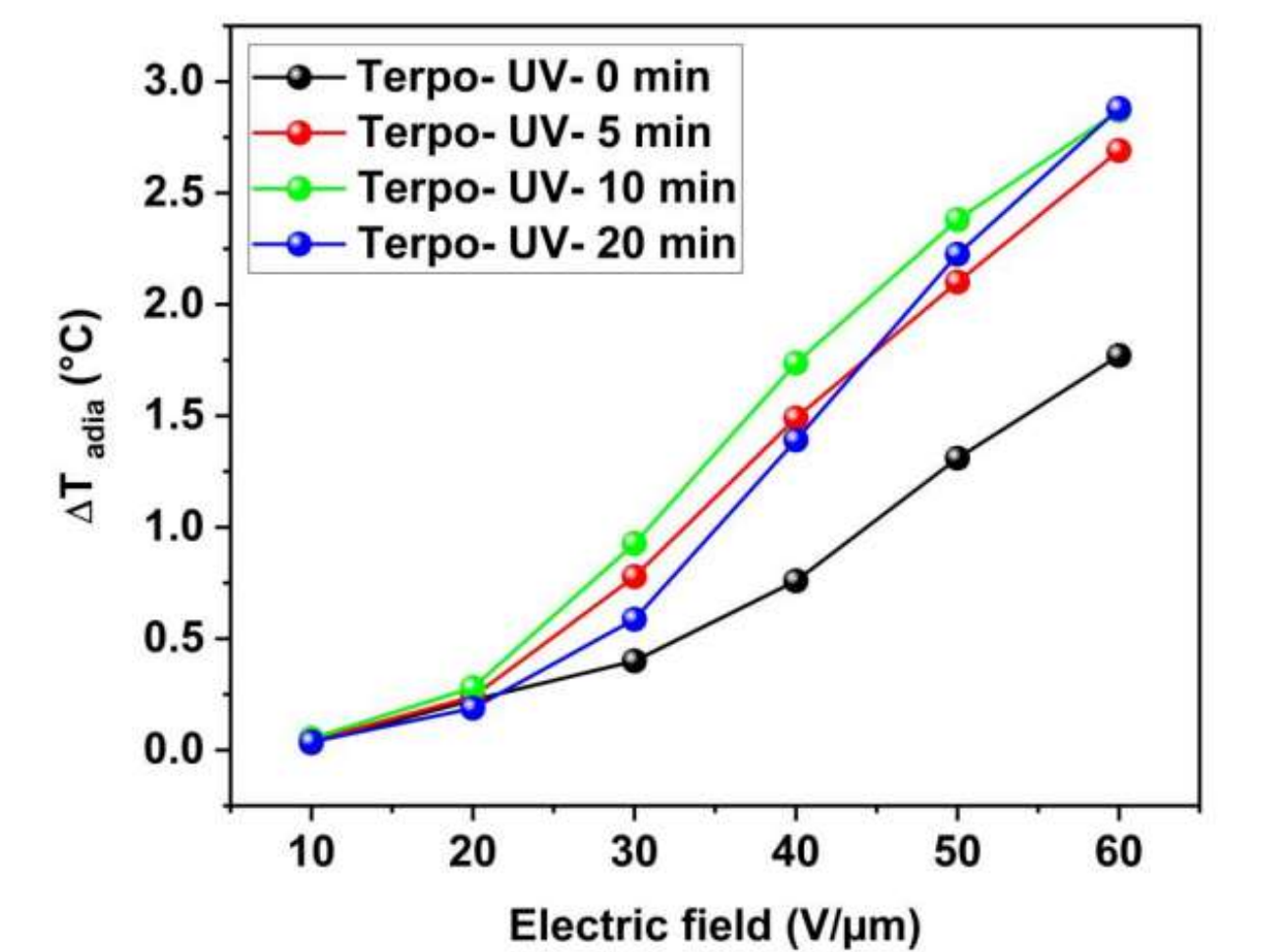
We first established that poling is crucial for minimizing losses [3]. Furthermore, UV irradiation significantly enhances the ΔT_{adia} resulting in improved overall performance.

UV-Irradiation effect



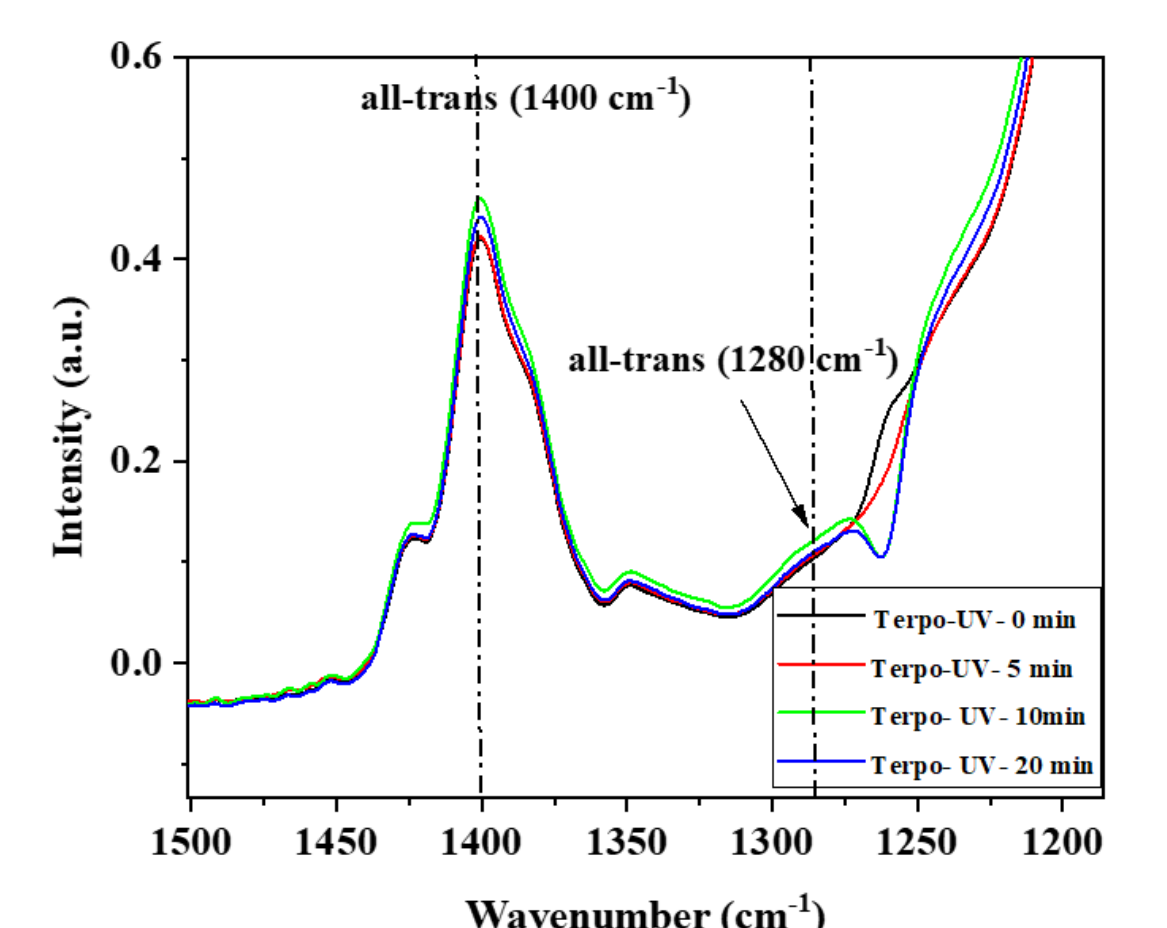
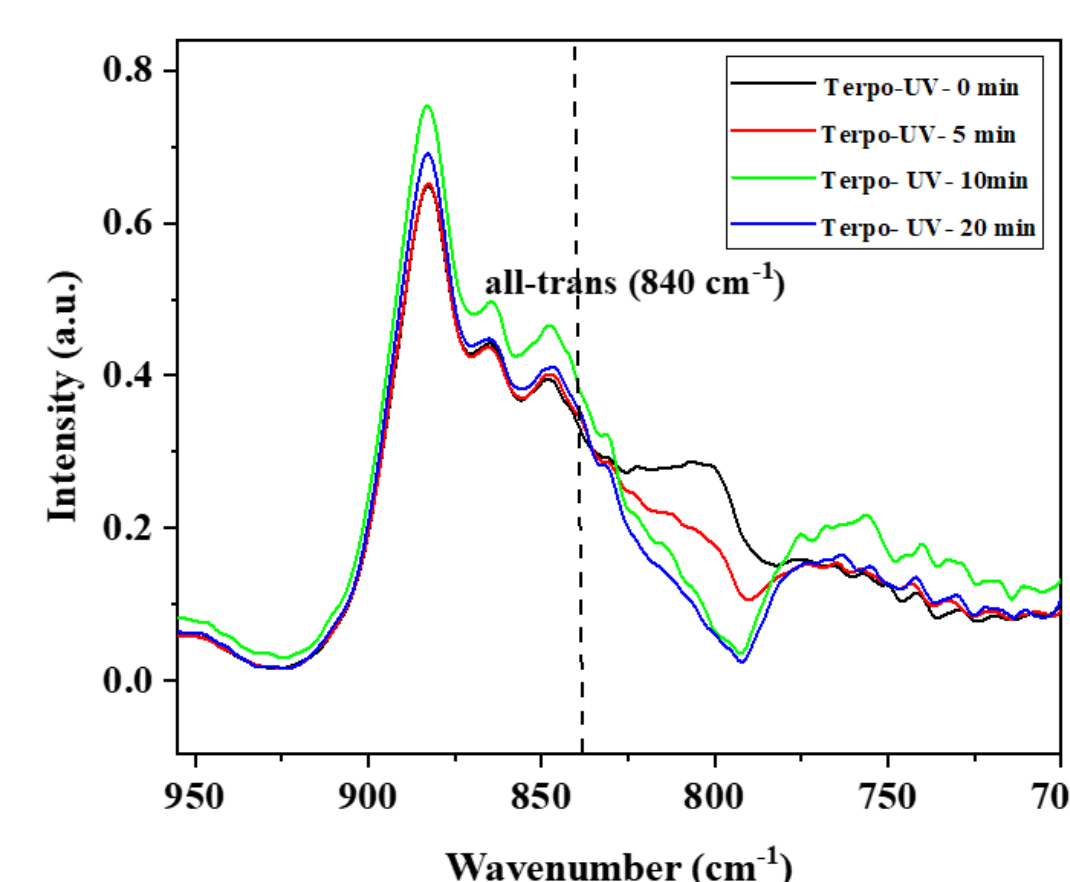
- Each side of the Terpo films was exposed to UV irradiation at room temperature, for 5-20 minutes with an of $20\text{ mW}/\text{cm}^2$. UV irradiation was performed using lamp of 385 nm

ECE



- At $60\text{ V}/\mu\text{m}$ the ΔT_{adia} increases by 1.76°C up to 2.88°C at 20 min of exposure. This is equivalent to an 81% increase

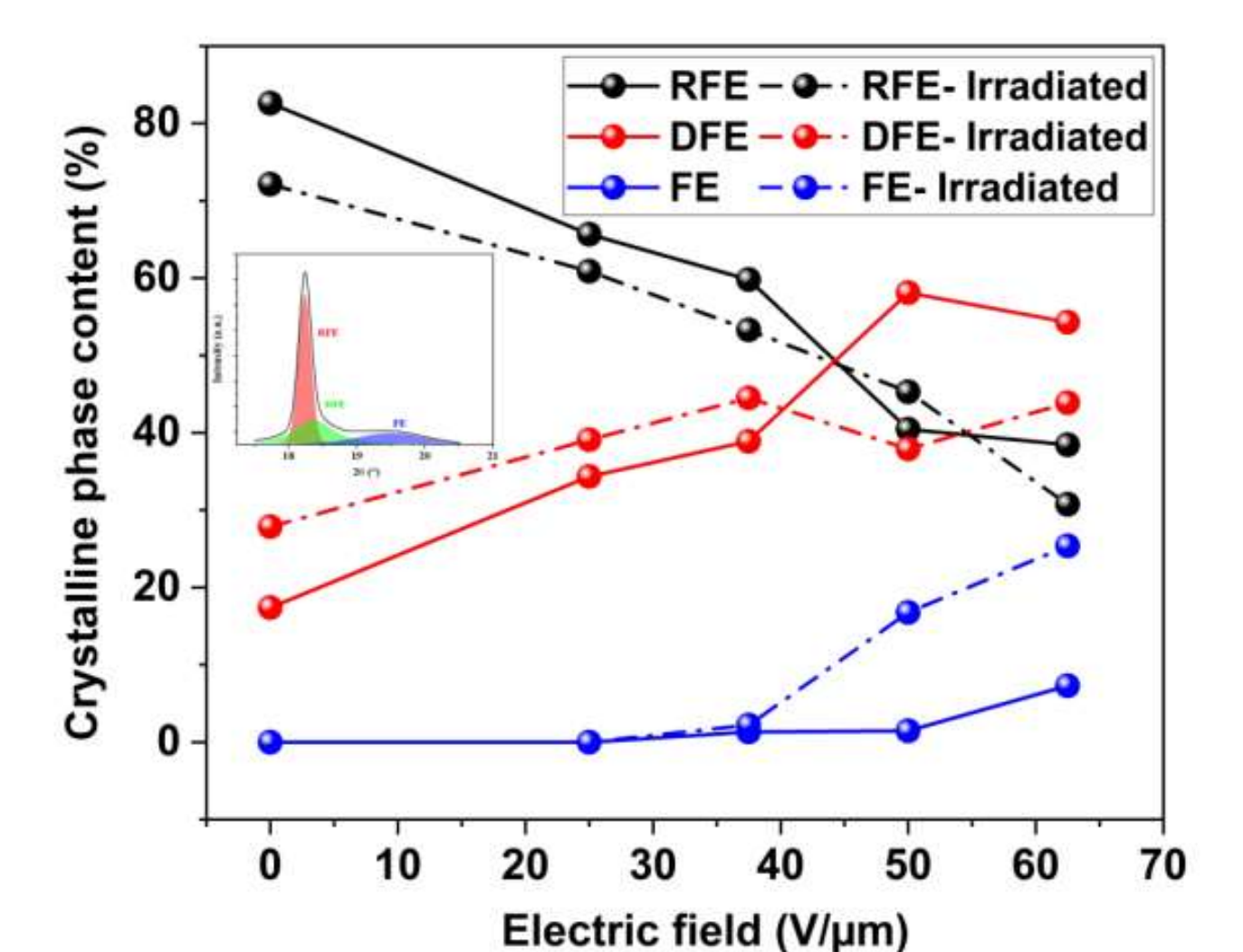
FTIR



- irradiation, The amount of all-trans conformations gradually increases 1400 cm^{-1} , 1280 cm^{-1} and 840 cm^{-1} . At the same time the tg conformation drastically decreases at 800 cm^{-1}

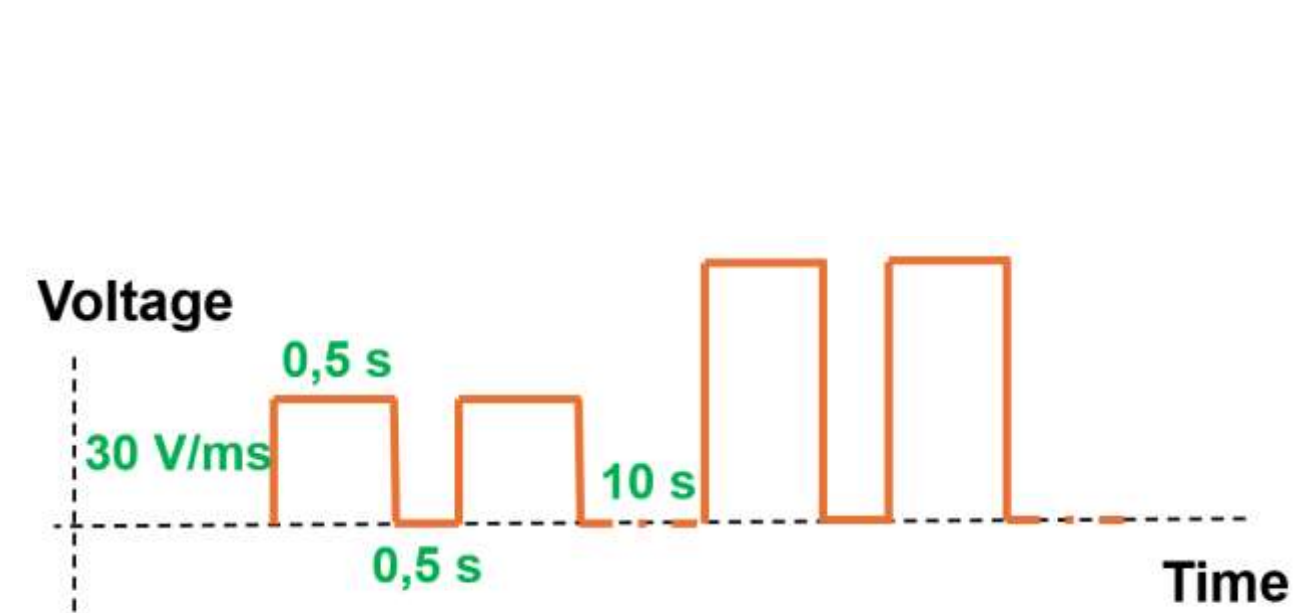
XRD under electric field

- ΔT_{adia} increases with the growth of DFE or FE phases
- In irradiated films, the electric field triggers the FE phase earlier, leading to a higher ΔT_{adia} response compared to non-irradiated films.



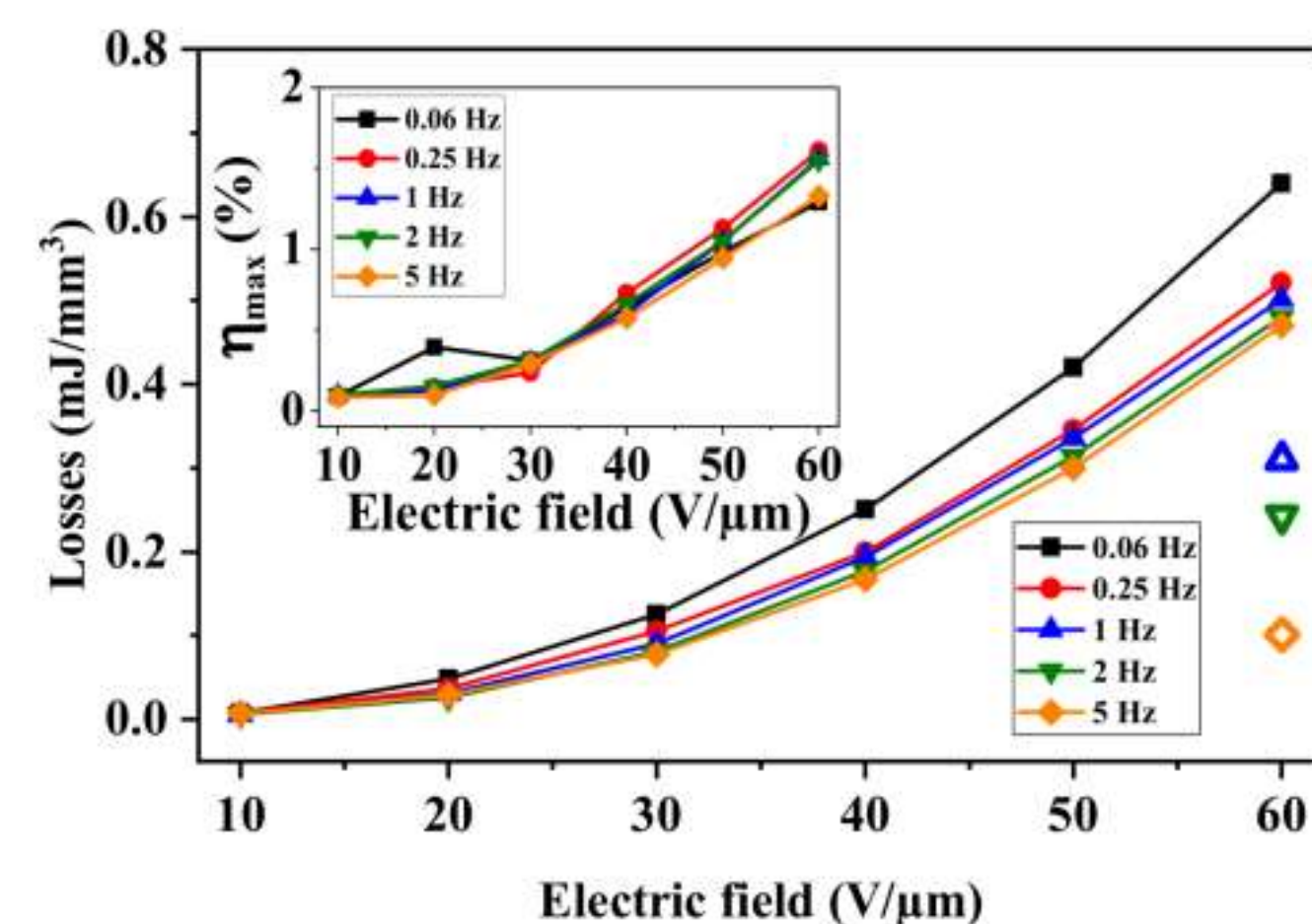
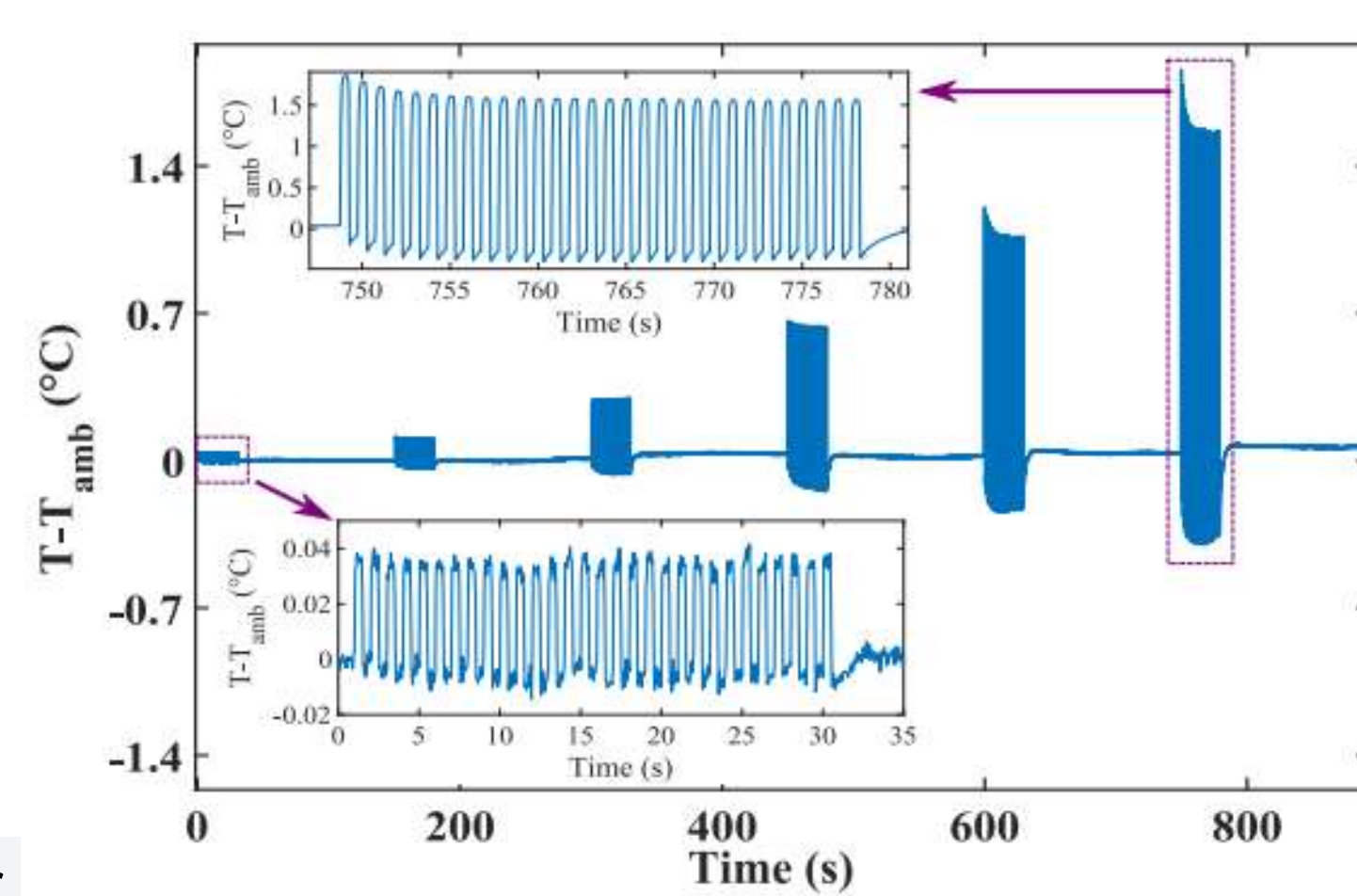
Measurement of the adiabatic temperature change

EC measurement



- The curve shows the voltage profile for ΔT measurement: a $30\text{ V}/\text{ms}$ rise, $0,5\text{ s}$ at constant field, and $0,5\text{ s}$ rest, designed for precise ΔT evaluation.

- Le delta T adia augmente avec le champ electric ainsi que les pertes



Conclusion

- Electrocaloric effect in P(VDF-TrFE-CFE) film supported on a polymer substrate was directly measured using thermistor
- UV-A irradiation significantly improves the electrocaloric effect of P(VDF-TrFE-CFE), increasing the adiabatic temperature change from 1.76°C to 2.88°C at $60\text{ V}/\mu\text{m}$
- XRD analysis under electric fields reveals changes in the interplay of RFE, DFE, and FE phases

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