Polyurethanes as low cost and efficient encapsulant materials for (flexible) Perovskite Solar Cells

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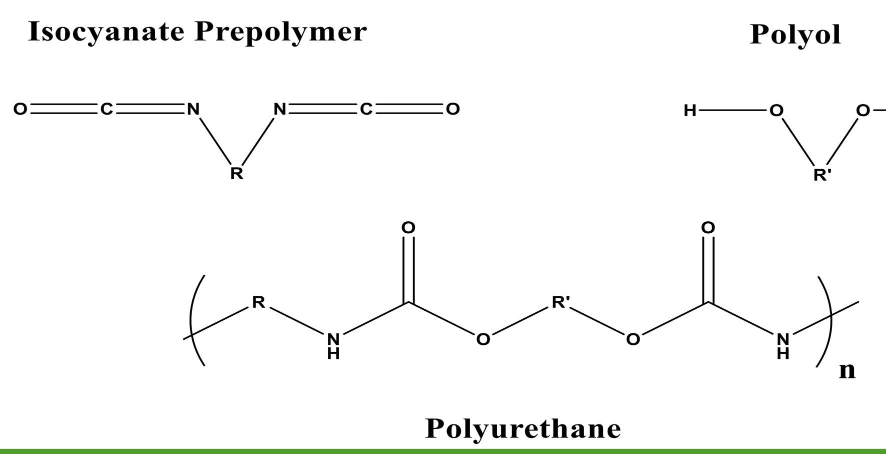
Introduction

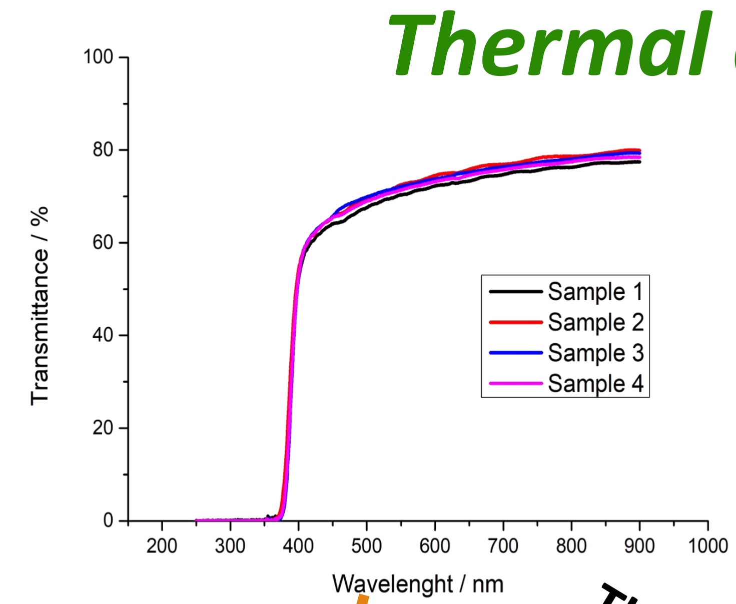
Long-term stability of Perovskite Solar Cells (PSCs) is the main issue to be solved for a forthcoming commercialization of this technology [1]. The stability of PSCs mainly suffers for water and oxygen infiltration as well as prolonged exposition to UV radiation. Straightforwardly, encapsulation of devices is a mandatory to achieve good long-term stability. Up to now, best encapsulant properties have been reached by the employment of nanometric film of metal oxides deposited by ALD [2]. Nevertheless, the latter approach inadequately fits the requirement of flexibility. Among the feasible matrixes to be used as encapsulant film, we resolved to polyurethanes (PU) that are polymers build up by the condensation between diisocyanate and polyol moieties [3].

Aim of the work

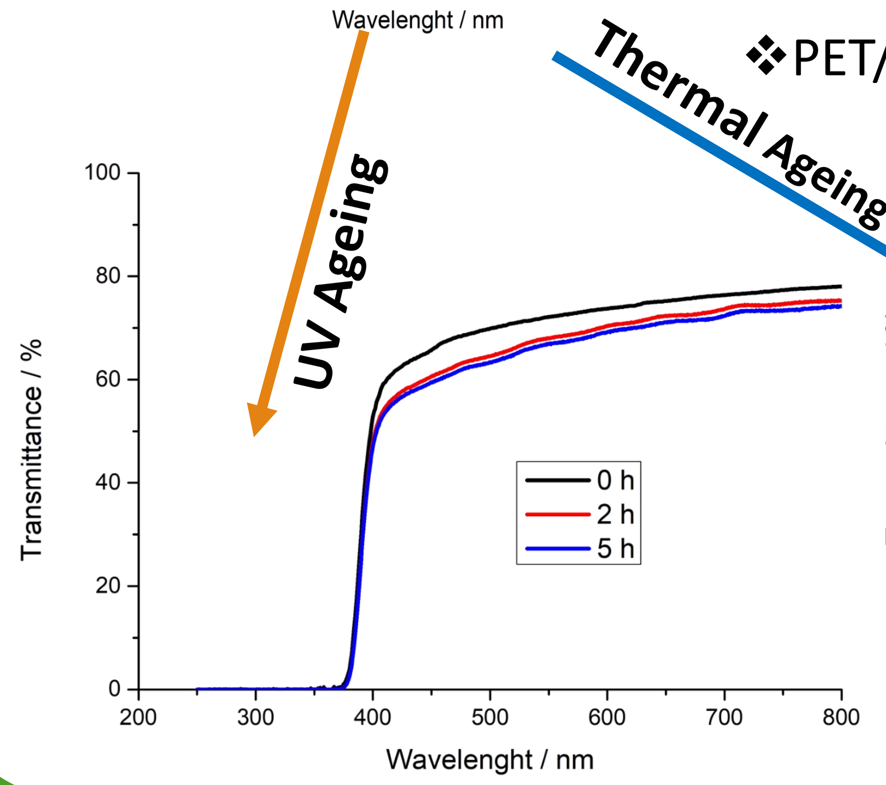
The present work aims to verify the compatibility of Polyurethanes matrixes as encapsulating materials for emerging PhotoVoltaics (PVs). PUs were deposited onto a flexible substrate (i.e. PET) and their properties have been carefully evaluated in terms of transparency, resistance to thermal and UV stress and water and oxygen barrier properties.

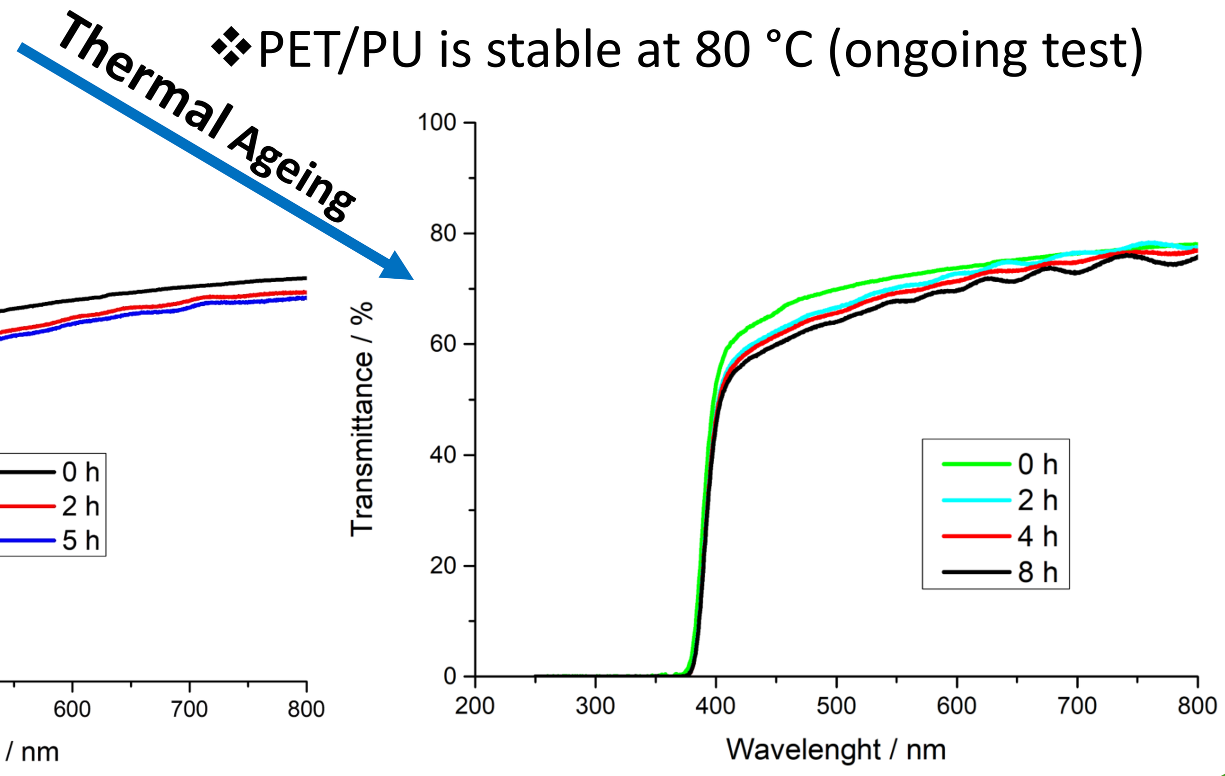


Thermal and UV Stress



- ❖ The addition of PU onto PET does not negatively influence the optical properties
- ❖ Several formulation with UV adsorbers showed similar transmittance
- ❖ UV ageing caused a slight decrease in the transmittance of the composite
- ❖ PET/PU is stable at 80 °C (ongoing test)



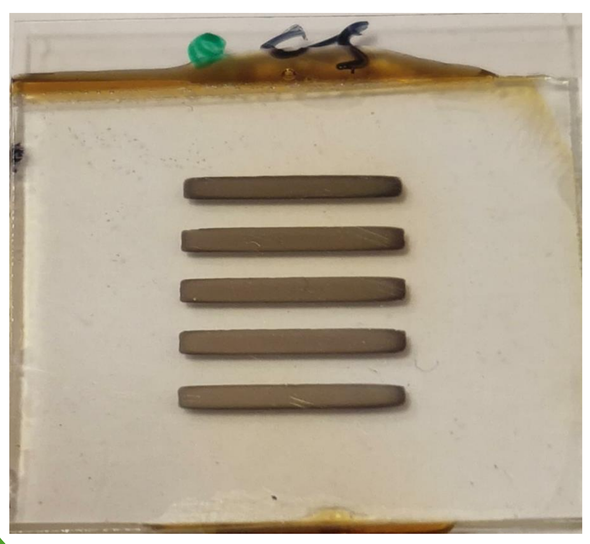


Why Polyurethanes?

- ➢ They fulfil the requirements for a good encapsulant material in terms of transparency (up to 90%), chemical inertness and UV and thermal stability
- ➢ They are relatively cheap
- ➢ They could be easily obtained
- ➢ They do not require high temperature or UV treatment during the polymerization process
- ➢ Their mechanical and optical properties are tunable by changing the precursor or by adding some filler/additives

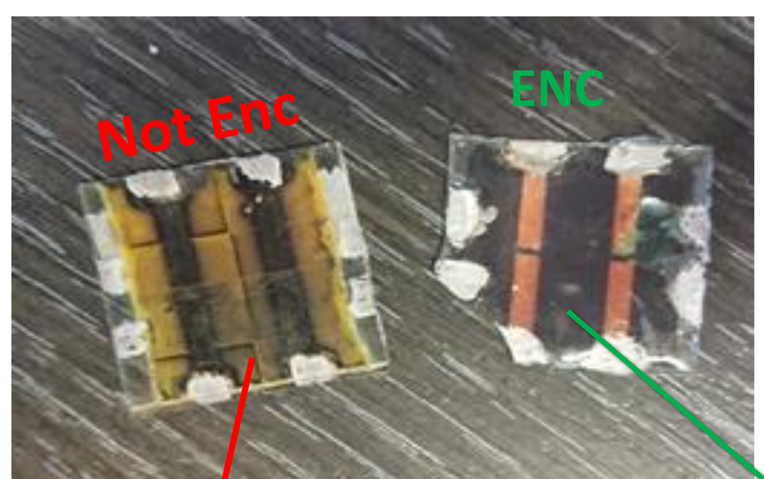
Calcium Test: barrier properties

- ❑ Calcium (300 nm) was evaporated on glass in a GloveBox
- ❑ PET/PU were attached onto glass by an epoxic resin
- ❑ Calcium degrades in contact with H_2O and O_2. It oxidizes to CaO becoming transparent
- ❑ The degradation could be monitored by transmittance (optical method)
- ❑ WVTR (Water Vapor Transmission Rate) $10^{-2}/10^{-3}$ $g*m^{-2}*d^{-1}$
- ❑ WVTR values were averaged on 10 samples for each formulation



Sample	WVTR / $g*m^{-2}*d^{-1}$
1	$6.76*10^{-3} \pm 4.16*10^{-4}$
2	$3.35*10^{-3} \pm 1.61*10^{-4}$
3	$1.17*10^{-2} \pm 9.23*10^{-4}$
4	$1.23*10^{-2} \pm 1.33*10^{-3}$

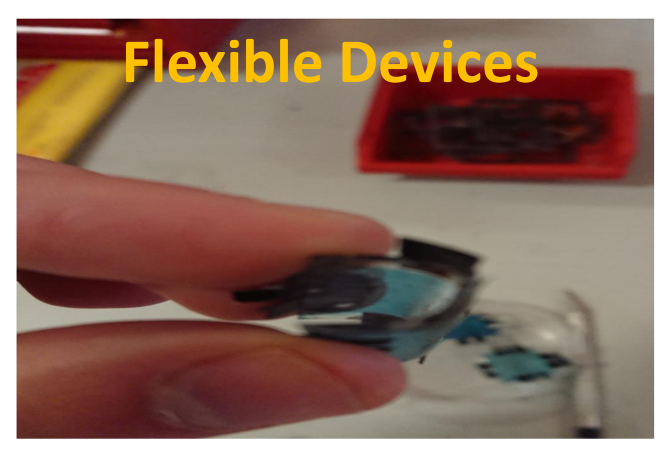
Compatibility with Flexible Substrates and Photovoltaic Materials



- ➢ Encapsualtion was perfomed by drop casting
- ➢ Polimerization process depends on temperature, time and formulation
- ➢ Deposition method fits well with different substrates (glass, ITO, FTO, PET…)

Yellowing of the perovskyte layer after a couple of days due to O_2 and H_2O

Encapsulated device preserved their brownish colour



Conclusions

Polyurethanes, implemented onto a PET substrate, was proved to assure a high flexibility of the composite coupled with high transparency and good resistance to thermal and optical stress. Additionally, WVTR value close to 10^{-3} lead to relatively good barrier properties [4]. More interestingly, when deposited onto PSC, PU prevent the latter from degradation.

Acknowledgments

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References

[1] Wang, D.; Wright, M.; Elumalai, N.K.; Uddin, A. Stability of Perovskite Solar Cells Solar Energy Materials and Solar Cells, 2016, 147, 255-275. [2] Choi, E.Y.; Kim, J.; Lim, S.; Han, E.; Ho-Baillie, A.W.Y.; Park, N. Solar Cells Solar Energy Materials and Solar Cells, 2018, 188, 37-45. [3] Søndergaard, Roar R., et al. Solar Energy Materials and Solar Cells 99 (2012): 292-300. [4] S. Castro-Hermosa, M. Top, J. Dagar, J. Falteich, T. M. Brown. Quantifying Performance Of Permeation Barrier Encapsulation Systems For Flexible And Glass-based Electronics And Their Application To Perovskite Solar Cells. Adv. Elec. Mater. 2019. Under revision.