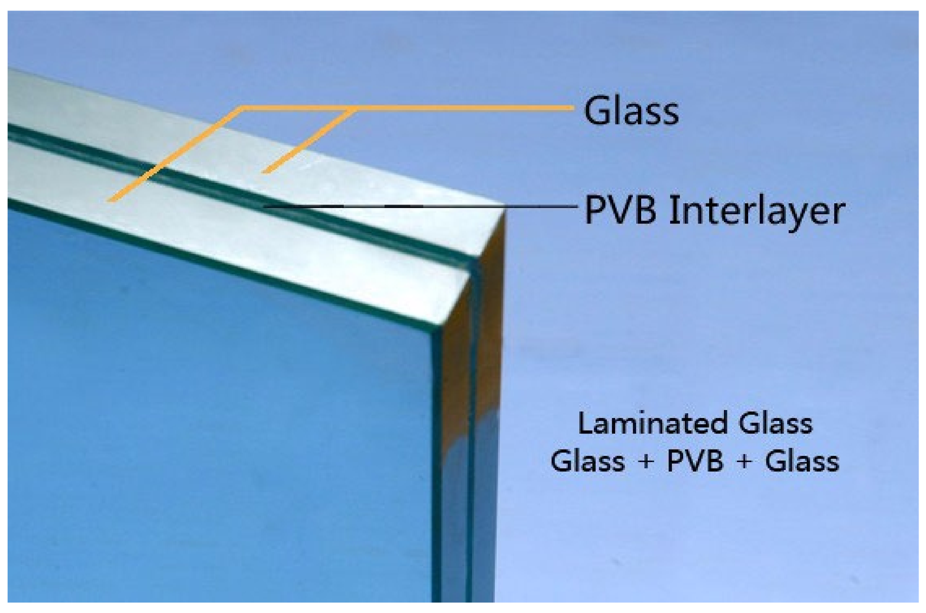
Benchmarking practices for the recycling of PVB interlayer film in laminated glass applications

Vasilis Nikitakos [1], Athanasios D. Porfyris [1], Konstantinos Beltsios [1], Constantine D. Papaspyrides [1]

[1]Laboratory of Polymer Technology, School of Chemical Engineering, Zographou Campus, National Technical University of Athens, 15780 Athens, Greece

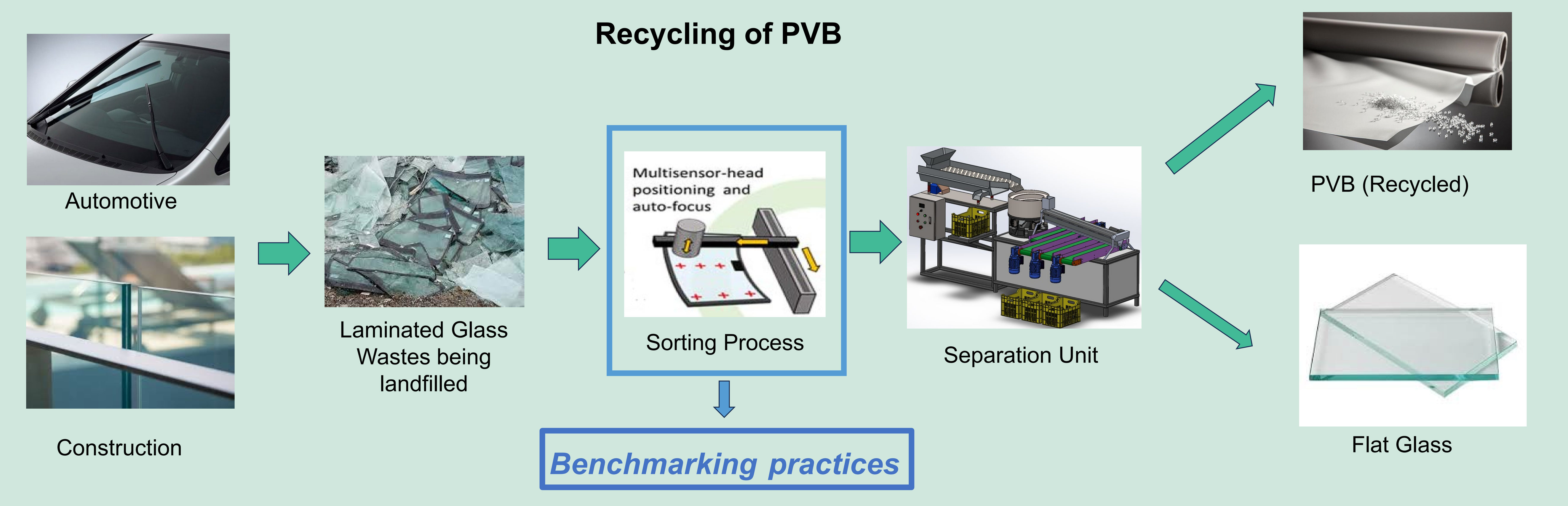
Abstract

Laminated glass is obtained by bonding two glass layers using a polymeric interlayer (PVB) and it is mainly applied in car windshields, construction, photovoltaic. Its use is constantly growing with a total amount of PVB sheet produced by automotive and architectural industry estimated around 120 million kg per year, therefore its end-of-life should be addressed [1]. In addition, PVB has a high value with an average price of 5,24 €/kg and it is usually mixed with ca. 30% w/w plasticizer, which is also valuable, and currently it is being landfilled after the end of life of the vehicle. In this work it was attempted to create a recycling strategy by determining the critical parameters for sorting PVB such as molecular weight, plasticizer type and plasticizer content. The characterization methods include FTIR, MFR, DSV, TGA, DSC and plasticizer extraction processes aiming at establishing a protocol for the recycling process [2,4]. In overall, this benchmarking strategy aims at the development of a multi-sensor sorting tool for categorizing different PVB waste streams as appropriate materials for reuse as interlayer film.



Laminated Glass = Glass + PVB + Glass

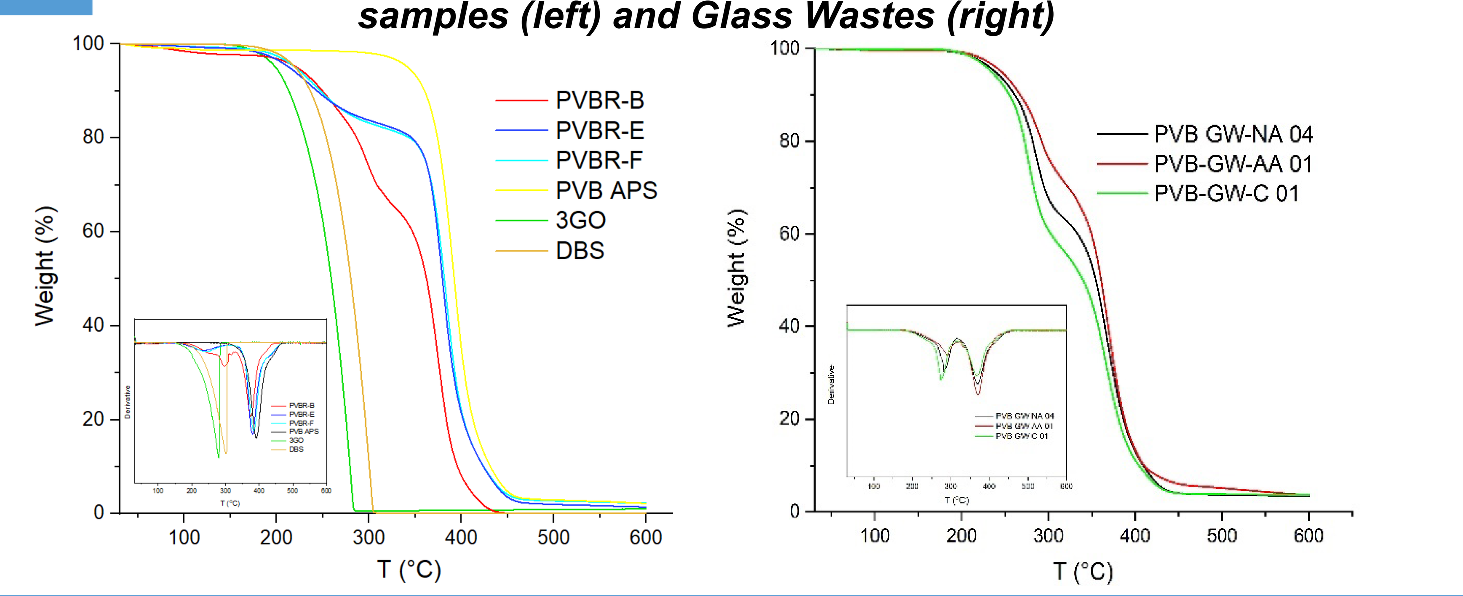
PVB interlayer= PVB neat + Plasticizer



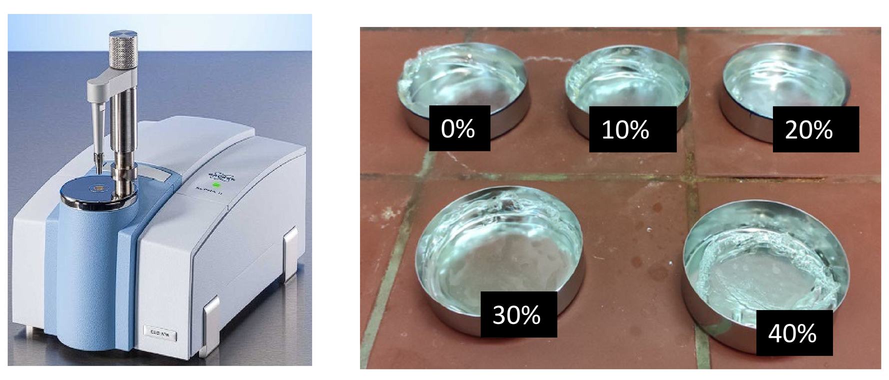
Samples	Plasticizer	Manufacturer (Commercial Name)	Plasticizer Content (% w/w) by TGA	[η] (dL/g)
PVB APS	Unplasticized	American Polymer Standards Corporation	0	1.75 ± 0.01
PVBR-B	Triethylene glycol bis(2-ethylhexanoate) (3GO)	Eastman (Saflex RB41)	30.7 ± 1.0	1.51 ± 0.09
PVBR-E	Dihexyl adipate (DHA)	Eastman (Saflex AG)	21.7 ± 2.7	1.90 ± 0.01
PVBR-F	Dibutyl sebacate (DBS)	Eastman (Saflex DB)	18.5 ± 0.6	1.86 ± 0.11
PVB-GW-NA 04	unknown: can be determined by NMR	Waste from automotive	36.6 ± 0.0	1.89 ± 0.09
PVB-GW-AA 01			28.1 ± 1.1	1.50 ± 0.10
PVB GW – C 01		Waste from construction	40.8 ± 2.5	2.02 ± 0.05

TGA

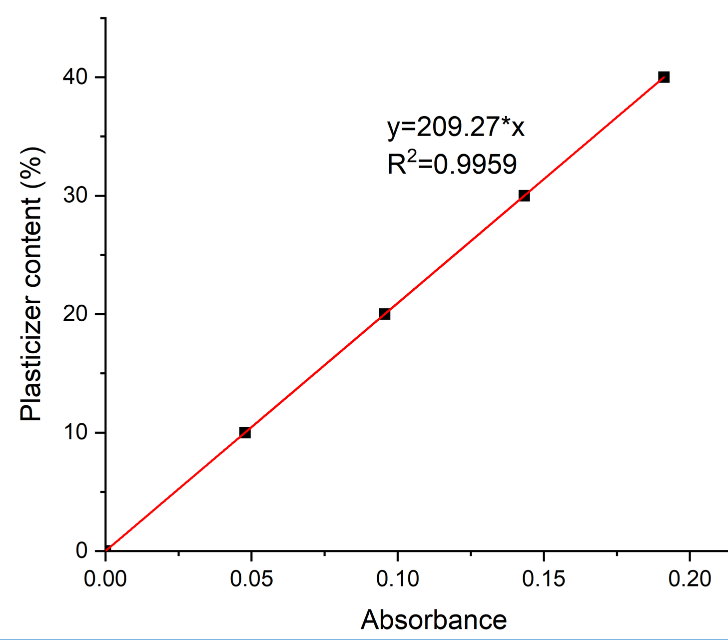
tool for calculating the plasticizer content in Reference samples (left) and Glass Wastes (right)



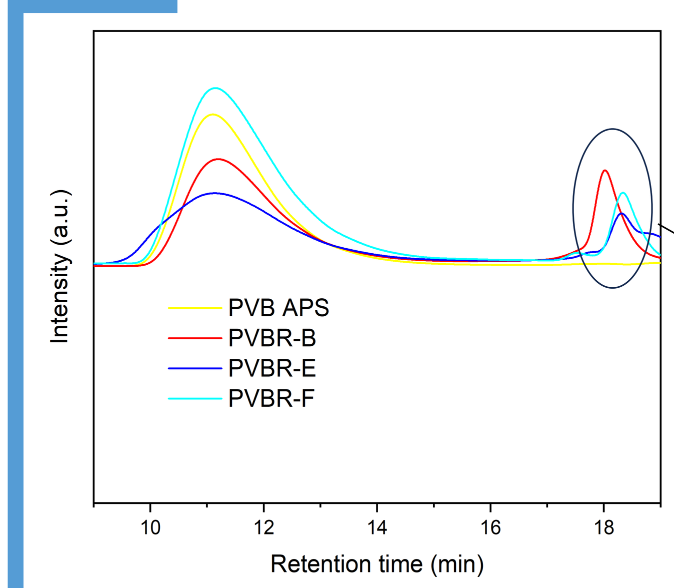
ATR-FTIR



Fast non-destructive ATR-FTIR master-curve for the estimation of plasticizer content based on the intensity of 1740 cm⁻¹ peak (C=O) (characteristic peak for plasticizer)



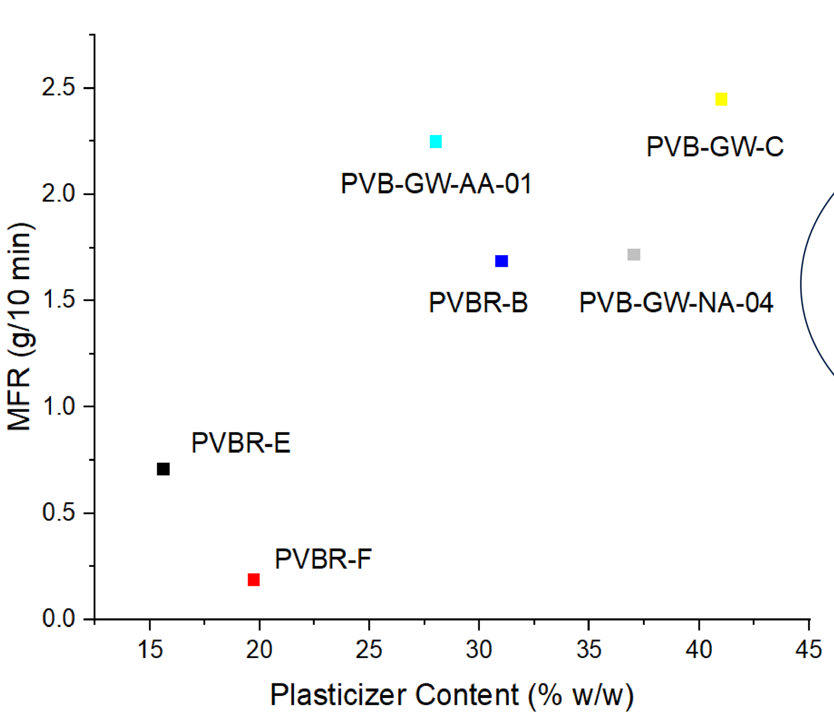
GPC



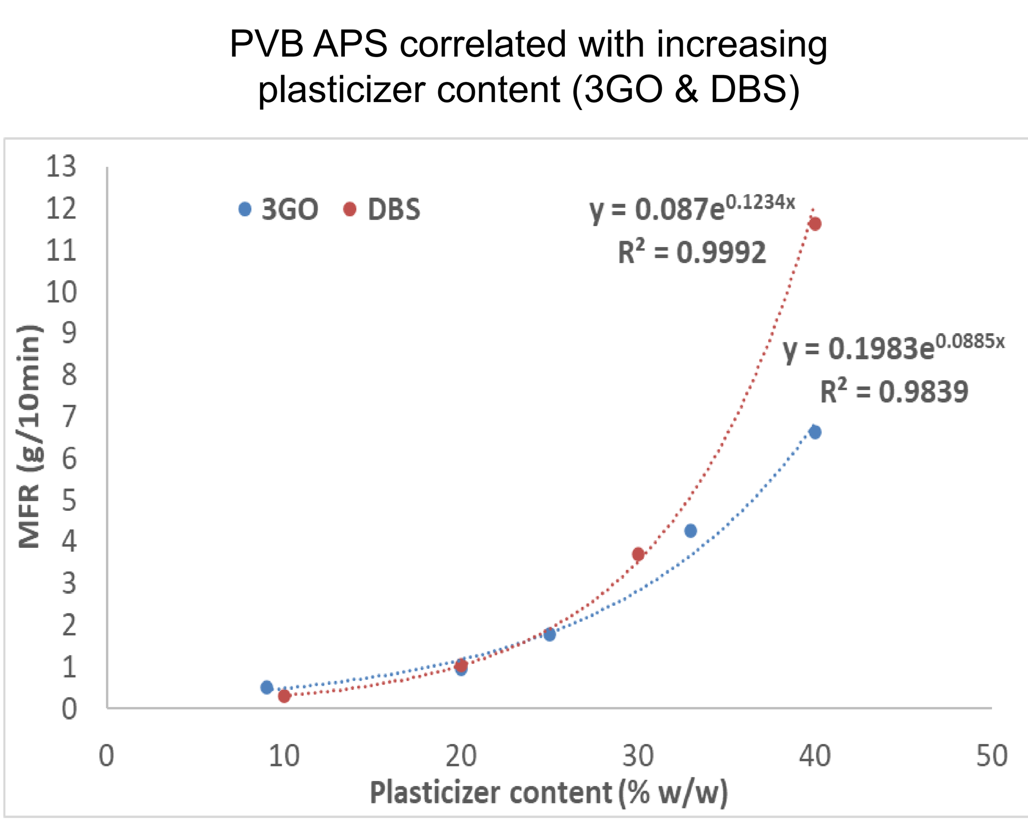
Different retention times correspond to different plasticizers

Peaks for the plasticizer part of PVB interlayers

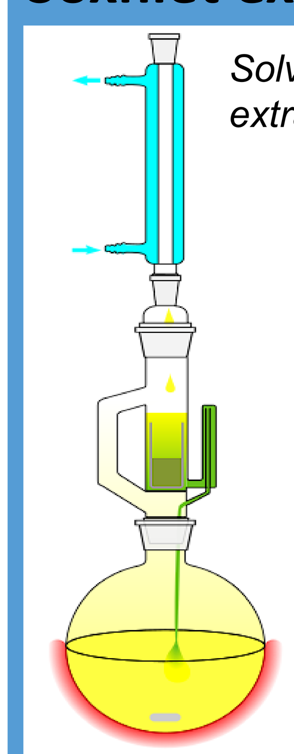
MFR



MFR depends on MW of PVB neat, type of plasticizer and plasticizer content



Soxhlet extraction (SE)



Solvent: hexane, extraction duration =12h

Hexane favors the full extraction of DHA and DBS in comparison to 3GO

Samples	Plasticizer content by TGA (% w/w)	
	Before SE	After SE
PVBR-B (3GO)	30.7	12.0
PVBR-E (DHA)	21.7	0
PVBR-F (DBS)	18.5	0

Acknowledgement

The results of this scientific Poster were generated in the SUNRISE project that has received funding from the European Union's Horizon 2020 Research and Innovation Program under grant agreement No 958243. We acknowledge Eastman Chemical Company in their support generously providing us samples for the study

This project has received funding from the European Union's Horizon 2020 research and innovation programm under grant agreement No 958243".

Conclusions

In this work a characterization strategy for PVB was developed aiming at benchmarking the key properties of raw grades appropriate for interlayer use, which will be further exploited in sorting post-consumed PVB grades. Accordingly, analytical techniques, such as TGA, FT-IR, were applied so as to study the plasticizer content, molecular size and rheological behavior of PVB interlayer. TGA provides an accurate estimation of the plasticizer content, but cannot give an insight into the type of plasticizer. Via the development of a FT-IR master-curve, a faster non-destructive but maybe less accurate determination of plasticizer content is feasible, GPC provides accurate information of the molecular weight of PVB, but also can give qualitative information about the plasticizer content and type. Finally, MFR values correlate quite well to the determined plasticizer content, but cannot give additional info regarding potential ageing suffered in the waste samples. Finally, Soxhlet extraction can be a useful tool for the extraction of the plasticizer and consequently the direct estimation of plasticizer content. Isolation of and identification of the plasticizer is also feasible. Summarizing, this work constitutes a good practice for the in-depth analysis of the interlayers of the laminated glasses and proposes an industrial friendly methodology for the off-line classification of the different PVB interlayers in waste laminated glasses for wise and sustainable recycling. Critical data are herein obtained that can be further exploited in the development and calibration of an on-line sorting sensor of PVB wastes.

References

1. Carrot, C et al. *Handbook of Thermoplastics, 2nd ed*; Olabisi, O., Adewale, K., Eds.; Plastics Engineering; CRC Press, 2015
2. Corroyer, E. et al. *Int. J. Polym. Anal. Charact.* **2013**, *18*, 346–357
3. Dhaliwal, A.K.; Hay, J.N. *Thermochim. Acta* **2002**, *391*, 245–255
4. Šooš, Ľ et al. *Recycling* **2021**, 6, 26,
5. El-Din and N.M.S *Polym. Degrad. Stab.* **1995**, *47*, 283–288
6. Wang, C. et al. *J. Macromol. Sci. Part B* **2022**, *61*, 92–110
7. Valera, T.S.; Demarquette, N.R. *Eur. Polym. J.* **2008**, *44*, 755–768

14th Hellenic Polymer Society Conference, 22-25 November 2023, Thessaloniki, Greece