A circular multilayer plastic approach for value retention of end-of life multilayers films

D7.4: Scientific and industrial papers report

WP7: Pre-normative studies, dissemination, communication and exploitation

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Executive summary

The results of the CIMPA project, aiming at turning multilayer plastic waste into circular and valuable resources, have been widely disseminated towards the scientific and industrial communities.

As part of Task 7.3, on dissemination activities, CIMPA partners have presented the main findings of the project in several conferences and events, but also through public deliverables and publications, including scientific and industrial papers.

Moreover, public deliverables are available on the projects website and all public data generated within the project is available on Zenodo as well.

In order to protect confidential data and also for emerging protectable results, CIMPA set a Dissemination and Exploitation board and common rules for the examination of publications and communications of results before their release. This has ensured a high-level of quality control prior dissemination.

This deliverable “D7.4: Scientific and industrial papers report” includes the scientific and industrial publications from each partner, with name of journals, audiences targeted, and a summary of each paper.

Sorting results combining NIR and Digital Watermarking technology.

The results obtained within the CIMPA project on sorting for multilayer plastics has been summarized in the white paper "Two automated sorting solutions for multilayer flexible packaging", writted by industrial partners Filigrade and Pellenc ST. The document is available here.

Title: Two automated sorting solutions for multilayer flexible packaging

Authors: Raphael Josselin, Marien De lint, Johan Kerver, Antoine Bourely

CIMPA partners involved: Filigrade, Pellenc ST

Date of publication: March 2024

Audience targeted: industry and scientific community

Abstract

This white paper describes two sorting solutions to enhance the circularity of multilayer plastic films coming from packaging. The first one is "Advanced NIR-based detection with Mistral + Connect –TRL9". This solution is based on the compositional analysis and sorting trials done by Pellenc ST on flexible samples, with the support from all plastic film manufacturing partners and Paprec. It uses Pellenc ST's NIR optical sorter, the Mistral + Connect. Advanced Chemometric algorithms used give accurate detection results for PE/PET and PE/PA structures. The second solution proposed is "Combined NIR + DW prototype –TRL7-8". Digital watermarking is a promising technology for effective sorting of multilayer materials. The technology of FiliGrade has the potential to deliver sorted fractions that meet specific quality standards. Moreover, digital watermarks enable sorting to be triggered by characteristics unrelated to package composition like 'membership' and 'usage' (food versus non-food). The combination of digital watermarking and NIR technologies surpasses the intrinsic limits of NIR detection and permits closed-loop recycling for food grade materials.

“METEOR” compounding and mechanical recycling process

The results obtained within the CIMPA project on mechanical recycling through the METEOR technology are summarized in this article, which also describes the properties of the films obtained from this process.

Title: Morphological, Rheological, mechanical and Barrier Properties of PE/EVOH blends Films Produced via innovative Extensional Flow Mixing technology “METEOR”

Authors (not final): Nour Jaouadi, Céline Chevallier, Skander Mani

CIMPA partners involved: IPC

Journal (not final): Polymer

Date of publication: January 2025

Audience targeted: scientific community

Abstract

In this study, IPC (Technical Industrial Center for Plastics and Composites) introduces an innovative one-step compounding and mechanical recycling process, the extensional flow mixing technology 'METEOR®'. This technology aims to enhance the properties of polymer blends and recycled materials. Its potential for developing materials and blends holds promise for applications in packaging and film recycling. Initially, the study focused on virgin material blends, such as PE/EVOH, selected as representative materials for industrial use. A comprehensive morphological and rheological analysis was performed, followed by evaluations of mechanical and barrier properties. The results highlighted particularly notable elongation-at-break properties for these blends.

Moreover, the degradation study demonstrated that the METEOR® process does not degrade materials compared to single or twin-screw extruders, attributed to the reduction in shear rate. The analysis also revealed a significant reduction in interfacial tension for PE/EVOH blends, emphasizing METEOR®'s efficiency, particularly with low concentrations of OREVAC compatibilizer. This suggests its potential for industrial applications, where the use of compatibilizers could be minimized or even eliminated. The interfacial tension and dispersed phase morphologies are effectively controlled by the extensional flow, offering considerable flexibility in polymer compounding and recycling under low shear rate conditions. This ensures the protection of highly sensitive materials.

MultiNanolayering (MNL) recycling process

The results obtained within the CIMPA project on mechanical recycling through the MNL technology are summarized in this article, which also describes the properties of the films obtained from this process.

Title: Development of Sustainable PE/PA Films with Enhanced Barrier Properties Using Multi-Nanolayer Coextrusion Technology

Authors (not final): Nour Jaouadi, Céline Chevallier, Skander Mani

CIMPA partners involved: IPC

Journal (not final): Polymer

Date of publication: January 2025

Audience targeted: scientific community

Abstract

This study focuses on the production of multi-nanolayered coextruded films using polyethylene (PE) and polyamide (PA) blends, with the objective of demonstrating the efficiency of the MultiNanolayering (MNL) process in recycling multilayer packaging. Specifically, the study compared different numbers and positions of layer multiplying elements (LMEs) within the MNL modules.

Through comprehensive experimentation, the research assessed the impact of these variables on the mechanical and barrier properties of the resulting films. The findings indicate that significant improvements in film properties can be achieved when specific processing techniques are optimized. These enhancements were particularly evident in the mechanical strength, barrier properties, and overall structural integrity of the films.

The results suggest that the MNL process, when finely tuned, offers substantial benefits for the recycling of multilayer packaging materials. The improved properties of the recycled films highlight the potential for this technology to be applied in industrial settings, promoting more efficient and sustainable recycling practices. This study not only advances the understanding of MNL processing but also provides a foundation for future developments in the production of high-performance, recycled films.

Quantifying the quality of recyclates

As part of the work done in WP6 by TNO on life cycle assessment, an article has been submitted on the quantification of the quality of recyclates.

Title: RecyQMeter: application-specific quality of recycled plastics

Authors: Milad Golkaram, Ruben Demets, Jack T.W.E. Vogels, Jan Harm Urbanus, Amalia Christoula, Raphael Elbing, Steven De Meester, and Kim Ragaert*

CIMPA partners involved: TNO

Journal: Waste management Journal

Date of publication: pending (submitted)

Audience targeted: scientific community

Abstract:

Objectively quantifying the quality of recyclates and finding suitable applications for individual products is challenging in plastics recycling. Confronted with ambitious targets for recycled content, industry urgently needs a robust method to understand the quality of recycled plastics. This study describes the RecyQMeter tool, which was developed to address this challenge and help recyclers position their secondary materials in an appropriate market. RecyQMeter benefits from an application-property matrix, a large dataset of application-specific material requirements obtained through data mining, expert interviews, literature searches and modeling. RecyQMeter generates a value between 0 and 1, which refers to the quality of recyclates relative to virgin plastics used in different market applications. Additionally, this tool can be used to automatically estimate substitution ratios in life cycle assessment (LCA) studies. RecyQMeter makes a significant step forward in standardizing plastics recycling and supporting decision makers in achieving higher circularity in the plastics sector with a large database, ease of use, transparent calculations, and a comprehensive approach.

Future recycling of multilayer plastic films

Title: Plant of the future for recycling multilayer films

Authors: Milad Golkaram, Rajesh Mehta, Sami Zakarya , Ilkka Rytöluoto, Lucie Prins, Milena Brouwer-Milovanovic

CIMPA partners involved: TNO

Journal: Nature sustainability

Date of publication: pending (submitted)

Audience targeted: scientific community

Abstract:

The recycling of multilayer films (MLF) has posed a significant challenge to achieving circularity. In response to this issue, a series of pilot-scale initiatives have been implemented, focusing on the processing of multilayer materials. The steps included Near Infrared / Digital water marking (NIR/DW), pretreatment, super critical CO2 decontamination, dissolution, upgrading using in-line rheology control, METEOR and multi-nano layering (MNL). The findings indicated that for PET/PE and metalized PP films in 2050, the use of advanced recycling results in greenhouse gas (GHG) emissions that are 21% and 85% higher than those from landfill incineration, respectively, assuming a recycled content of 10%. In contrast, the results for PE/PA and PE/EVOH demonstrated reductions in GHG emissions of 0.5% and 4%, respectively, when compared to the current best practices. An analysis of films with increased recycled content revealed that elevating the recycled content from 0% to 50% leads to a 36% decrease in GHG emissions. These findings refute the notion that a target of 10% recycled content is advantageous, suggesting that a more ambitious target of over 25% should be established for 2050.

LCA approach and methodology

Some of the CIMPA's results were included in the article "Microplastic ecotoxicological impacts included in Life Cycle Assessment for a consumer film"

Authors: A.E.Schwarz; M. Golkaram; Tom Ligthart; S. Herlaar; Q. Cohen; T. van Emmerik; M. Huijbregts

CIMPA partners involved: TNO

Date of publication: March 2024

Audience targeted: Scientific

Abstract

Although Life Cycle Impact Assessment (LCIA) methods assess a wide range of environmental impacts, ecological impacts of plastic pollution are not commonly included. Here, characterization factors of Polypropylene (PP), Low density polyethylene (LDPE) and Polyethylene Terephthalate (PET) microplastics were assessed. Fate was assessed through the multimedia fate model Simplebox4Plastics. Ecological effects were based on species sensitivity distributions. Macroplastic impacts were included though a conversion fraction. The characterization factors were included in ReCipe2016 method and applied to two consumer packaging films to show the relevance of including plastic pollution in LCAs. Plastic losses were assessed using material flow analysis. The freshwater and marine ecotoxicity midpoint indicators were dominated by plastic pollution impacts, whilst these impacts were limited on ecosystem quality as endpoint. Extending this methodology to additional polymers and additional methodological developments will help to obtain a more complete picture of plastic pollution in LCA and to identify effective mitigation options.

Physical recycling and valorisation routes

Based on the results obtained by TNO and AIMPLAS on the physical (dissolution) recycling of multilayer plastic films and valorisation routes, the article "Recovery and potential use for non-polyolefin materials after physical recycling of complex multilayers" has been accepted for publication in Open Research Europe. Open Research Europe is an open access publishing venue for European Commission-funded researchers across all disciplines, with no author fees. The article is available here.

Title: Recovery and potential use for non-polyolefin materials after physical recycling of complex multilayers

Authors: Gutiérrez V, Mafé M, Prins L and van de Runstraat A.

CIMPA partners involved: AIMPLAS, TNO

Journal: Open Research Europe

Date of publication: 27 November 2024

Audience targeted: scientific community

Abstract

Standard flexible packaging in the market contains many components that differ from polyolefins (PO). These components can include barrier materials (Polyamides (PA), Polyethylene-terephthalate (PET), Ethylene-vinyl alcohol (EVOH), Polyvinyl-alcohol (PVOH), and aluminum), inks, lacquers, adhesives, fillers, and pigments. All these materials are insoluble in the solvents used for the physical, dissolution-based, and recycling of polyolefins, leaving them as a solid residue in the process. Characterization of the residue obtained after physical recycling of printed/metallized polyolefin flexible structures using the TNO Möbius dissolution process was performed to select potential applications, stakeholders, and/or secondary valorization routes. The residue resulted in a heterogeneous material composed of PET (60%), inorganic fraction (28%), and other organic components (12%). The potentially valuable materials from this residue are the PET and aluminum fractions. After a desk study, possible secondary recovery techniques for PET and aluminum were selected.

In-line rheology control for upgrading recyclates

The results from CIMPA WP5 are summarized in this article written by David Eldridge (AMI), based on interviews and reports from AMI Plastics Recycling Expo 2024, where VTT presented an adaptive process control for rheological upgrading of recycled plastics in its advanced mechanical recycling pilot plant. The article is available here (pag. 23-28)

Title: Finding consistency using in-line rheology control

Authors: David Eldridge (AMI), Joonas Mikkonen (VTT)

CIMPA partners involved: VTT

Journal: Plastics Recycling World.

Date of publication: November/December 2024

Audience targeted: industry and scientific community

Abstract

For compounds containing recycled plastics to be used in high-value applications, they need to be as consistent in quality as compounds based entirely on virgin polymers. That is a major challenge for companies reprocessing post-consumer material with all its variability in quality. Usually PCR input material requires additives to be applied during compounding to restore mechanical properties, but with unpredictable quality fluctuations and flow behaviour, the compounder must do time-consuming testing offline and/or rely on estimates for the correct amount of additives to dose. Two organisations are now offering to take the time and guess-work out of dealing with feedstock material variability using rheometers in line with the compounding system and thereby ensure consistently high quality products with recycled content.