Maastricht University

Circular Plastics
Making it happen

Structural Characterization of Recycled Polyolefins

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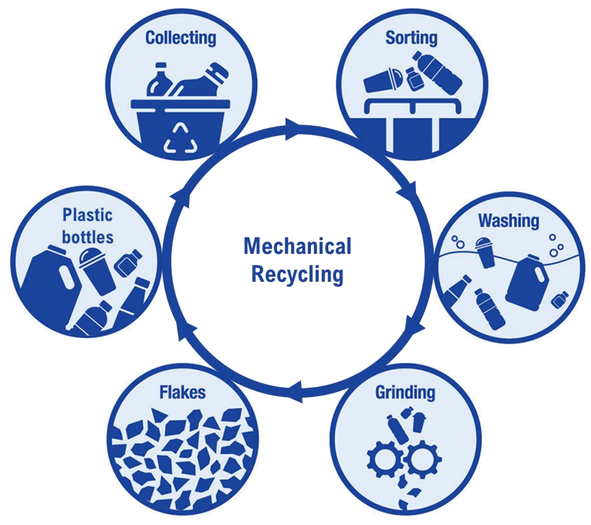
INTRODUCTION

Commercial grades of polyolefins are inherently complex materials regarding their molecular weight and distribution, degree of crystallinity, macromolecular constituents, and presence of a myriad of additives. PE/PP components from waste streams present an uncertain composition associated with unknown additives, contaminants, degradation occurred during their first life cycle and, therefore, recycled PE, PP, and their blends are often depicted as inferior materials, which challenge proper characterization and subsequent use.

In *Circular Plastics*, polyolefins model blends and real recyclates are investigated as closed-loop packaging candidates. Common techniques, especially thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), infrared (IR) and nuclear magnetic resonance (NMR) spectroscopies, are combined to study the materials composition and to determine optimal modifications to reach target properties. Additionally, scanning electron microscopy (SEM), atomic force microscopy (AFM), and dynamic mechanical analysis (DMA) are applied to unravel the polyolefin micro- and nano-scale morphologies, to gain deeper insight into the recyclates' structure and their effect on the final properties of these blends. Relevant findings have been obtained regarding the impact of the composition of discarded polyolefins on their recyclability and physical properties, such as environmental stress crack resistance in HDPE rigid bottles.



CASE STUDY: polyethylene rigid bottles

Post-consumer rigid polyolefins make up 70% of European plastic packaging waste.

HDPE: extrusion blow-molded bottles

PP: injection-molded caps (2-10 wt.%)

BOTTLENECK

Low environmental stress cracking resistance (ESCR) in recycled HDPE

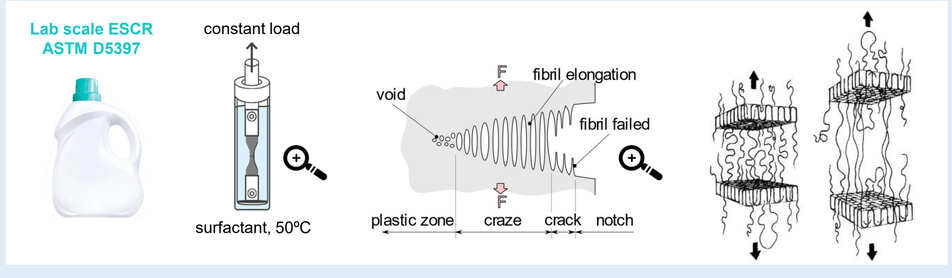
Low post-consumer recyclates (PCR) uptake in the new bottles

Environmental stress cracking

Molecular weight and short chain branching

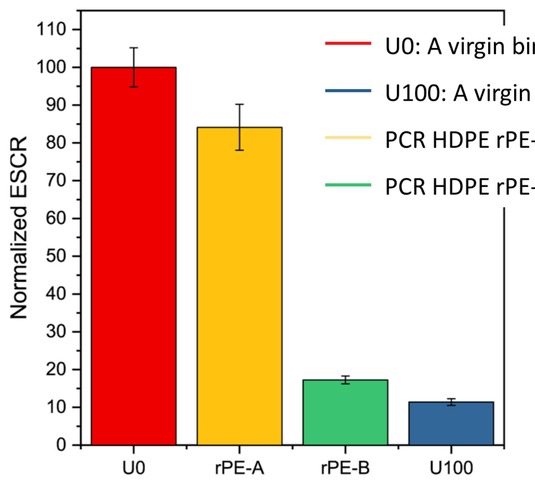
Interlamellar links: tie-molecules and chains entanglements

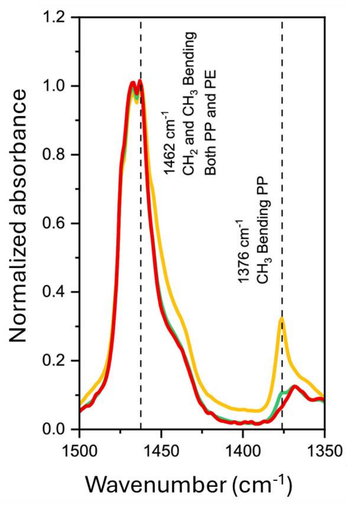
Load-bearing molecular bonds in the amorphous phase

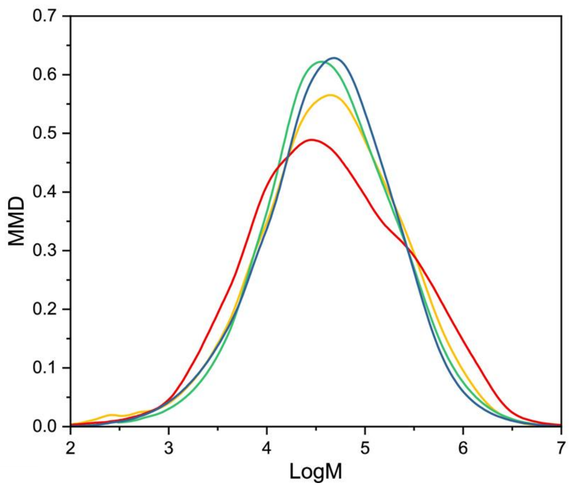


Root causes of PCR HDPE failing in new bottles

Resources, Conservation & Recycling 209 (2024) 107776

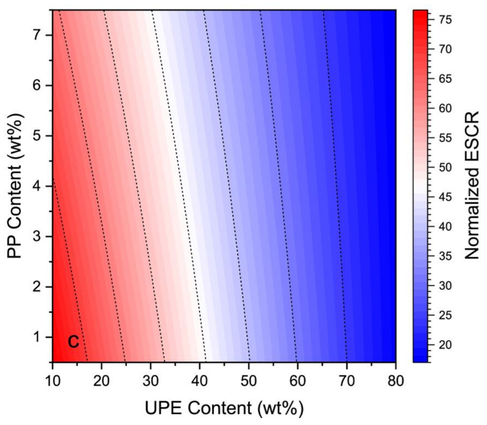






Lower ESCR despite having lower PP contamination content

HDPE grade plays a crucial role in the ESCR, rather than PP contamination

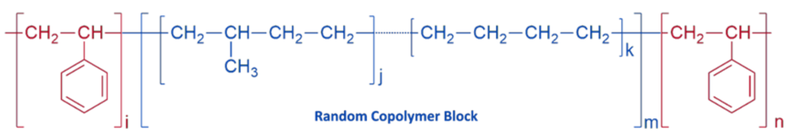


Anchoring ties: improving ESCR in HDPE

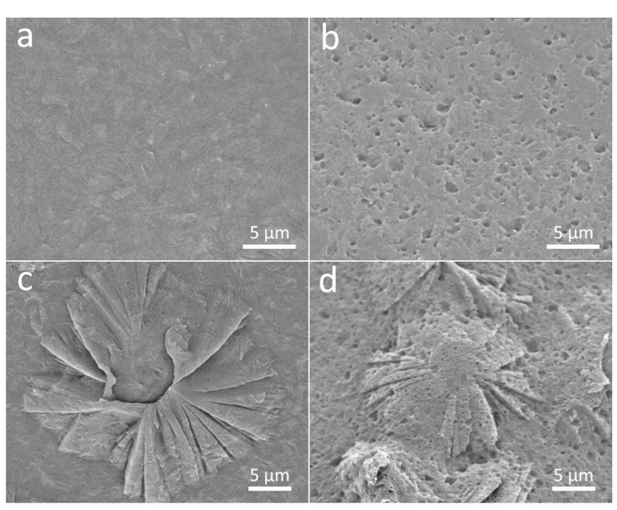
ACS Appl. Polym. Mater. 2024, 6, 23, 14283–14289

U50: A 50:50 wt% blend of U0 & U100

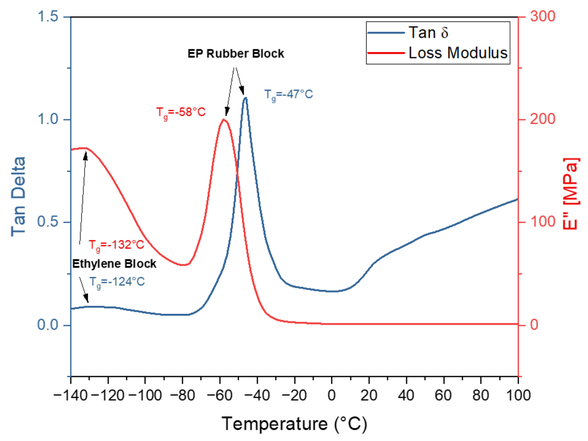
SEEPS: A styrene-b-ethylene-b-ethylene/propylene-b-styrene triblock copolymer



A styrenic triblock copolymer increased the ECSR of virgin and recycled HDPE to 130%

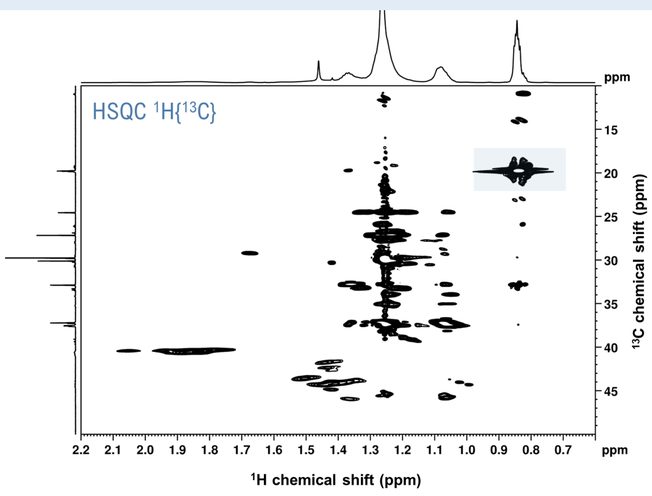


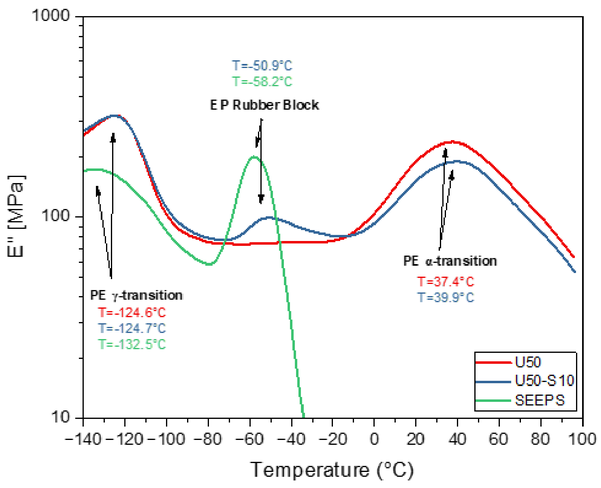
Cross-section SEM images of etched samples with 50:50 H_2SO_4/H3PO_4 + $KMnO_4$

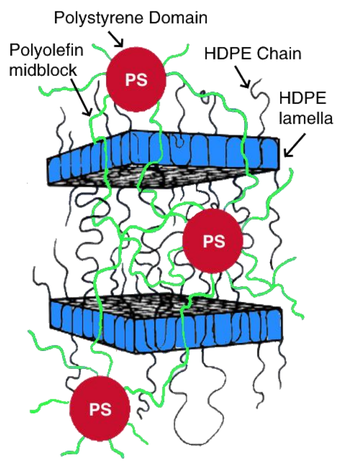


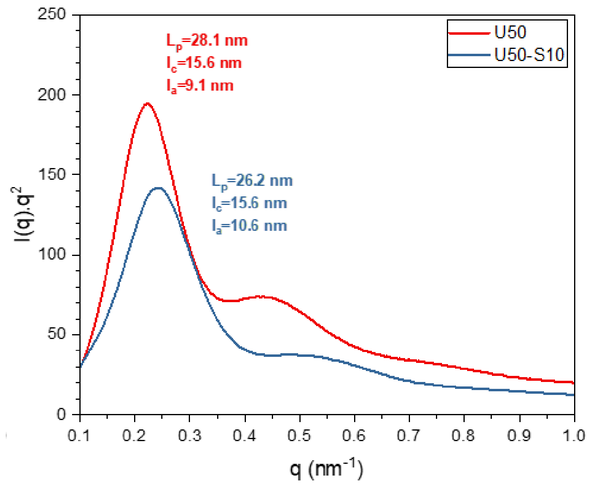
Methyl protons of the hydrogenated 1,4-addition isoprene units

PE segment representing 46 wt.% of the EEP middle block









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